Australian Government
Australian Radiation Protection and Nuclear Safety Agency

RECOMMENDATIONS

Intervention in Emergency Situations Involving Radiation Exposure

Radiation Protection Series Publication No. ??

Draft Version 12: 5 May 2004

Radiation Protection Series

The ***Radiation Protection Series*** is published by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) to promote practices which protect human health and the environment from the possible harmful effects of radiation. ARPANSA is assisted in this task by its Radiation Health and Safety Advisory Council, which reviews the publication program for the ***Series*** and endorses documents for publication, and by its Radiation Health Committee, which oversees the preparation of draft documents and recommends publication.

There are four categories of publication in the ***Series***:

Radiation Protection Standards set fundamental requirements for safety. They are prescriptive in style and may be referenced by regulatory instruments in State, Territory or Commonwealth jurisdictions. They may contain key procedural requirements regarded as essential for best international practice in radiation protection, and fundamental quantitative requirements, such as exposure limits.

Codes of Practice are also prescriptive in style and may be referenced by regulations or conditions of licence. They contain practice-specific requirements that must be satisfied to ensure an acceptable level of safety in dealings involving exposure to radiation. Requirements are expressed in 'must' statements.

Recommendations provide guidance on fundamental principles for radiation protection. They are written in an explanatory and non-regulatory style and describe the basic concepts and objectives of best international practice. Where there are related **Radiation Protection Standards** and **Codes of Practice,** they are based on the fundamental principles in the **Recommendations**.

Safety Guides provide practice-specific guidance on achieving the requirements set out in **Radiation Protection Standards** and **Codes of Practice**. They are non-prescriptive in style, but may recommend good practices. Guidance is expressed in 'should' statements, indicating that the measures recommended, or equivalent alternatives, are normally necessary in order to comply with the requirements of the **Radiation Protection Standards** and **Codes of Practice**.

In many cases, for practical convenience, prescriptive and guidance documents which are related to each other may be published together. A **Code of Practice** and a corresponding **Safety Guide** may be published within a single set of covers.

All publications in the ***Radiation Protection Series*** are informed by public comment during drafting, and **Radiation Protection Standards** and **Codes of Practice**, which may serve a regulatory function, are subject to a process of regulatory review. Further information on these consultation processes may be obtained by contacting ARPANSA.

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These Recommendations were approved by the Radiation Health Committee on dd mmmm yyyy. On dd mmmm yyyy, the Radiation Health & Safety Advisory Council advised the CEO to adopt the Recommendations.

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The mission of ARPANSA is to provide the scientific expertise and infrastructure necessary to support the objective of the ARPANS Act — to protect the health and safety of people, and to protect the environment, from the harmful effects of radiation.

Published by the Chief Executive Officer of ARPANSA in [month yyyy]

Foreword

These *Recommendations* have been issued by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and replace the document Radiation Health Series No 32, entitled *Intervention in emergency situations involving radiation exposure* (1990) and Radiation Health Series No 26, entitled *Policy on stable iodine prophylaxis following nuclear reactor accidents* (1989), published by the National Health and Medical Research Council. The revised Recommendations have been prepared by a Working Group of the Radiation Health Committee.

ARPANSA is a Commonwealth Government agency within the Health portfolio charged with responsibility for protecting the health and safety of people and the environment from the harmful effects of radiation. Under the *Australian Radiation Protection and Nuclear Safety Act 1998* (the ARPANS Act), the CEO of ARPANSA has, among other functions, a responsibility for promoting uniformity of radiation protection and nuclear safety policy and practices across jurisdictions of the Commonwealth, the States and the Territories, and for providing advice on radiation protection and nuclear safety matters.

The Radiation Health Committee, established under the ARPANS Act, has responsibilities inter alia to advise the CEO of ARPANSA and to develop policies and prepare draft publications, including codes and standards, related to radiation protection. Radiation Health Committee members include radiation control officers from each State and Territory, independent experts and a person to represent the interests of the general public.

These *Recommendations* update existing guidance on the application of protective measures in planning for and responding to emergency situations in Australia involving radiation exposure. These *Recommendations* will be most useful for appropriately qualified radiation protection experts assisting in this process**.**

These recommendations are based on current guidance from International Commission for Radiological Protection (ICRP), the International Atomic Energy Agency (IAEA), the World Health Organisation (WHO) and other relevant international organisations. They represent current best practice for ensuring the health and safety of both emergency personnel and members of the public in the event of an emergency involving radiation exposure.

On xx xxxxxx 2004 the Radiation Health and Safety Advisory Council advised me that I might consider adopting these *Recommendations*, following approval of draft *Recommendations* by the Radiation Health Committee on xx xxxxxx 2004. Accordingly, I adopt these *Recommendations* and commend the *Recommendations* to relevant Australian authorities and regulatory bodies for adoption through their legal processes.

[signature]

John Loy
CEO of ARPANSA

Contents

1. Introduction

1.1 Background

During the past 50 years, activities involving ionizing radiation have increased markedly. Most of these activities have been of considerable benefit to mankind, but some, if not kept under strict control, could be very detrimental. In the development of these activities, high standards of safety have been implemented with the result that, under normal circumstances, the risks to human health are very low. However, no human enterprise is entirely risk-free: accidents happen, and appropriate action has to be taken when a radiation source is out of control.

In the event of an emergency involving exposure to radiation, the effectiveness of measures taken to protect members of the public or workers will depend upon the adequacy of emergency plans prepared in advance. In these emergency plans, criteria are specified for taking particular prompt actions. After the immediate emergency, predefined criteria for longer-term actions provide a means of minimising the public health impact. Such criteria for protective measures are based primarily on radiological protection principles and are under continuous review. These Recommendations reflect current international best practice and are in conformity with the requirements of the IAEA Safety Standard GS-R-2 *Preparedness and Response for a Nuclear or Radiological Emergency* (IAEA 2002).

1.2 Purpose

The purpose of these *Recommendations* is to provide guidance on radiation protection criteria for use in mitigating the consequences of emergencies involving radiation exposure. The application of this guidance is intended to ensure that suitable actions are taken to reduce any adverse health effects, by preventing serious deterministic effects and minimising the stochastic risk to both members of the public and workers.

The purpose of these Recommendations is to provide guidance on radiation protection criteria for use in mitigating the consequences of emergencies involving radiation exposure. The application of this guidance is intended to ensure that suitable actions are taken to reduce any adverse health effects, by preventing serious deterministic effects and minimising the stochastic risk to both members of the public and workers.

1.3 Scope

These *Recommendations* update existing guidance on the application of protective measures in planning for and responding to emergency situations in Australia involving radiation exposure. These *Recommendations* will be most useful for appropriately qualified radiation protection experts assisting in this process. Implementation of emergency plans is the responsibility of Australian Government, State and local authorities and are not within the scope of these *Recommendations*.

They do not cover the medical care of exposed individuals, nor do they cover psychological problems arising from the emergency. These psychological problems do not arise from the radiation exposure as such, but from anxiety about possible late effects of radiation exposure and from any actions implemented to reduce exposure. Even though radiation exposure levels may be low and insignificant, these issues must be taken into account in determining any action to be implemented to reduce radiation exposure.

Any emergencies involving radiation exposure not specified in Section 2 may be dealt with by using the general principles outlined in these recommendations. Electrically generated radiation sources are not included, as the intervention would take place at the time of exposure by removing the power to the machine.

2. Considerations for Emergencies Involving Radiation Exposure

2.1 EMERGENCY SCENARIOS

Radioactive materials are used for a wide variety of purposes in industry, medicine, research and teaching as well as in a number of consumer products on sale to the general public. These sources vary enormously in their physical and chemical forms, the magnitude of their activity and the type of radiation, which could include gamma, alpha, beta or neutron sources. Emergencies happen when there is a failure of the radiation safety controls in place.

Emergencies involving uncontrolled sources of radiation can be divided into two main categories; those involving sealed sources and those involving dispersed sources. The potential radiation hazard from a sealed source is from the external exposure. For a dispersed source there is also the potential for intake of radioactive material through inhalation, ingestion or wounds. International recommendations generally agree that the development of emergency response plans should be based on consideration of a range of scenarios.

Scenarios that are relevant in the Australian context include:

- Uncontrolled, high hazard radiation sources including lost, missing, or stolen
- Loss or destruction of shielding for a high activity radiation source
- Accident in an industrial facility or a laboratory involving radioactive material
- The destruction of a high activity sealed source and the subsequent dispersion of contaminants in the immediate neighbourhood, the environment generally or into products used by the public
- Uncontrolled releases from unsealed radioactive materials
- Malevolent use of conventional explosives or other mechanisms to disperse radioactive or nuclear material with wide spread radiological consequences
- Transport accidents involving radioactive material
- Uncontrolled releases of radioactive contaminants from a nuclear research reactor, with dispersion of the contaminants over a region downwind from the reactor
- Uncontrolled releases from the nuclear reactor on a visiting ship, with dispersion of the contaminants over a region downwind from the ship and into the harbour
- 'Burn-up' of a nuclear reactor in a satellite out of control in re-entry to the earth's atmosphere, where radioactive contaminants might be distributed over a long, narrow region of a few thousand square kilometres.

2.2 EXPOSURE PATHWAYS

Following an emergency involving radiation exposure, radiation doses received by individuals and the public could result from:

(a) External Exposure:

- from localised radiation sources; or
- due to radioactive contaminants in the air or deposited on the ground, buildings, equipment, the body, or other surfaces;

(b) Internal Exposure:

- due to inhalation of radioactive contaminants in the air;
- due to ingestion of radioactive material ;
- due to ingestion of contaminated water or foodstuffs grown in the affected areas, with special concern with certain foods, such as crustaceans and molluscs, which can concentrate contaminants; or
- due to incorporation of radioactive material via wounds or skin absorption.

Radiation emergencies involving uncontrolled radiation sources can result in external exposure with the possibility of local contamination. Some scenarios could result in dispersion of radioactive contaminants in the environment. The greatest potential for serious injury arising from these sources comes principally from an unshielded high activity source. Consequences can be very serious, in some cases death, especially if the source is handled by persons who are not familiar with the hazard of radiation, or who do not know that the source is radioactive.

Appropriate protective actions should be considered to address radiation exposure from all potential pathways, to ensure that deterministic effects are avoided and that any stochastic risks are minimised. These radiation effects are discussed in Section 3.

2.3 TIMESCALES

The progression of an emergency involving radiation and the resultant response to the consequences can cover a wide range of timescales from hours to years. Some emergencies involving radiation are identified very rapidly and can require urgent response within hours to protect both workers and the public. Emergencies involving from uncontrolled sources of radioactive material can take days or weeks to identify, and months or years to rectify. For emergency planning purposes it is usual to apply a temporal classification for the emergency response.

Emergencies involving radiation can be categorised into three sequential time phases, namely the early, intermediate and late (or recovery) phases. Such categorisation provides a useful framework for decision making, since the information available and the exposure pathways may differ in each phase. These differences may require the introduction of different sets of actions, usually in the form of protective measures, enacted by public health authorities with the primary objective of restricting or minimizing exposure of people.

The early phase involves the period following the detection of a significant potential exposure to radiation or of a significant release of radiation and extends into the first few hours following this event. Emergency response decisions incorporate many elements, including assumptions about the nature of the emergency, specific site conditions and meteorological conditions at the time. There will be limited environmental monitoring information available during the initial part of this phase to aid decisions on the introduction of protective measures.

The intermediate phase may extend from the first few hours to a few days or weeks after commencement of the emergency, depending on the nature of the emergency. There will be more comprehensive environmental monitoring information available during this phase to aid decisions on the introduction of protective measures. For extensive environmental contamination situations, temporal extension of this phase involves protective measures at greater distances and for larger populations.

The late (or recovery) phase may extend for a considerable period beyond the intermediate phase and depends on the specific characteristics of the released material. In this phase, decisions are made on the return to normal living conditions. It is expected that decisions on the withdrawal of protective measures would be made on the basis of environmental and food monitoring information and on cost-benefit analysis.

2.4 TYPES OF PROTECTIVE MEASURES

There are several types of protective measures designed to ensure that the radiation doses to individuals or to a collective population are minimised. The effectiveness of these measures is largely dependent on the time taken to implement them. Protective measures that are available in the event of an emergency involving radiation exposure that have been shown to be effective are summarised in Table 1. Protective measures for some of the Australian scenarios, based on historical world-wide experience, are listed in Table 2.

Protective actions for emergencies involving radiation exposure can be categorised into “urgent” and “longer term”:

(a) Urgent protective actions are those which must be taken within hours of an accident to be effective. The principal urgent protective actions are:

(i) *Evacuation*

Evacuation is the urgent removal of the population from the affected area and can be implemented at various stages of an accident. It is most effective in avoiding any radiation exposure when used as a precautionary measure before there has been a significant release of radiation, particularly an airborne release.

Evacuation, after the end of a release and after its dispersion, might be initiated to avoid external dose from deposited material and internal dose from resuspended material. Evacuation and accommodation in emergency facilities is not recommended for a period exceeding 7 days (IAEA 1994a).

On a smaller scale, this is referred to as isolation of, and removal of people from, an area. This is an effective measure for limiting exposure to a localised source (for example, an unshielded high activity industrial radiography source).

(ii) *Shelter in Place*

Shelter in place involves keeping members of the population indoors, in suitable buildings, to reduce radiation exposure from airborne radioactivity and from 'ground shine'. Shelter in place is not recommended for a period exceeding 48 hours (IAEA 1994a). This period may be significantly less depending on climatic conditions.

During the early stages of a release of radioactive material, 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 a factor of ten for brick or large buildings. The reduction in the efficacy of this countermeasure increases over time. Lightweight or open buildings provide less protection.

(iii) Administration of Stable Iodine

This is a method of reducing the uptake of inhaled and/or ingested radioactive iodine by the thyroid. 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 at the time of exposure to radioactive iodine can avert about 90% of the dose. The effectiveness of the protective measure decreases with delay in administration. Guidelines for Iodine Prophylaxis are provided in Annex A.

(iv) *Other urgent secondary protective actions*

These actions supplement the primary protective measures, and include:

- *Control of access and egress.* This could involve the establishment of road blocks and may be used as a prelude to other protective actions, such as distribution of iodine prophylaxis.

- *Respiratory protection*. This is a means of preventing or reducing the inhalation of gaseous and particulate radioactive material from the air for emergency responders.
- *Use of personal protective clothing*. This is the wearing of additional, suitable external clothing to prevent any contamination from radioactive material reaching the wearer's skin.
- *Showering, bathing, changing clothing or mass decontamination*. These protective measures assist in removing radioactive material from a person's clothing or skin, thus reducing their exposure to radiation.
- *Shielding of localised sources where appropriate*. This is the placing of a physical barrier of appropriate material (e.g. steel, lead, masonry) between a source and people.

(b) Longer-term protective actions, which may need to be adopted in a matter of days following an accident. These include:

(i) *Removal of contaminated material*. This is the physical removal of contaminated items, suitably packaged to avoid further spread of contamination, to a storage area pending decay or appropriate disposal.

(ii) *Control of foodstuffs*. This is the withdrawal and substitution of foodstuffs.

(iii) *Relocation*. This is the movement of people from their homes (or from emergency evacuation centres) to live in (temporary) accommodation for a period of several months or more.

2.5 SPATIAL ASPECTS

For purposes of emergency planning, it is convenient to define a series of emergency zones around the radiological emergency. These emergency zones are defined by the type of radiological emergency, the magnitude of risk and the nature of the response.

For radiation accidents involving a localised radiation source or the dispersal of radioactive material, managing the emergency response requires the control of access to the accident scene and the establishment of cordoned areas.

For accident types involving the release of radioactive material from a facility the emergency response may take place over two distinct areas:

(a) On-site area

This is the area surrounding the facility within the security perimeter, fence or other designed property marker. It can also be the controlled area around a radiography source or contaminated area. This is the area under the immediate control of the responsible person for the facility or user and they will therefore have the authority to carry out the actions required by the appropriate zone definition. For transportation accidents on public roads or territories, there is in effect no on-site area.

(b) Off-site area

This is the area beyond that under the control of the facility or user and the actions required by the appropriate zone definition will need to be implemented by the local emergency combat agencies. However, the responsible person or user may still be required to provide technical assistance and advice to allow these agencies to determine the protective measures to be taken. The pre-prepared emergency plans of the facility operators, users, and the combat agencies should consider these requirements.

The definition and application of emergency planning zones is discussed in Section 4.3 for an emergency involving radiation exposure and in Section 4.4 for emergencies at a radiation facility.

3. Basis for Intervention

3.1 SYSTEM FOR RADIATION PROTECTION

The internationally accepted system for radiation protection, as recommended in international publications (ICRP 1991; ICRP 1993; IAEA 1996) and adopted in Australia (ARPANSA/NOHSC 2002), recognises two distinct situations.

(a) Practices

In normal circumstances, radiation exposures from man-made sources such as those in industry, medicine or nuclear reactors, are controlled. Exposures of the public from these sources are low, generally comparable with variations in natural background radiation. In this situation, "practice", controls are placed on the radiation so that the public is free from restrictions.

(b) Interventions

In the event of an accident, the source is no longer under control and some radiation may enter the environment in an uncontrolled manner. Exposure of people may be reduced only by requiring the individuals to take protective action. These protective actions, termed interventions, all impose restrictions on people's activities. Typical interventions include sheltering, prophylactic use of stable iodine, evacuation and restrictions on the consumption of food and water, as described in Section 2.4.

These protective actions may themselves introduce risks. The levels at which the interventions are introduced must therefore take into account the effects of introducing the interventions, such as restrictions on people and any associated risks.

Thus, the systems of radiation protection for normal and for accident situations are different.

3.1.1 Radiation Health Effects

Both practices and interventions are designed to reduce any adverse health effects from exposure to radiation. These adverse health effects may be deterministic, occurring soon after exposure, or stochastic, occurring some time, often many years, after exposure. These effects are described in detail in the literature (eg. ICRP 1984, ICRP 1991) and discussed in Annex B.

(a) Deterministic Effects

Deterministic effects are caused by exposure to high levels of radiation that cause large numbers of cells to die or lose their ability to replicate. Organs containing these cells then fail to function correctly. Such effects include nausea (radiation sickness), reddening of the skin, cataracts, sterility and bone marrow failure.

Each effect becomes apparent only above a threshold level and the severity of the effect depends on the level of exposure above its threshold. Below the threshold, the body can cope with the level of cell death and no explicit damage is seen. Table 3 provides a summary of the thresholds for deterministic effects.

(b) Stochastic Effects

Stochastic effects are believed to result from damaged cells not dying but surviving in a modified form. These modified cells may, after a prolonged process, develop into a cancer. These stochastic effects usually appear many years after the exposure and, although they do not occur in every exposed individual, for radiation protection purposes it is assumed that there is no threshold below which they will not occur. Rather, the likelihood of a cancer or hereditary effect occurring after exposure is assumed to be proportional to the level of exposure.

If the modified cell is a germ cell, then the damage may be passed on to that person's future descendants. Then, hereditary effects may be observed in these descendants. However, as the risk of serious stochastic effects to the individual is higher than that of hereditary effects to the individual descendents, if the individual is suitably protected the risk to the descendents will be minimised.

3.1.2 Principles for Intervention

In an emergency involving radiation exposure, the practical goals of emergency response, as stated in IAEA Safety Standards Series No. GS-R-2 (IAEA 2002), are:

(a) To regain control of the situation.

(b) To prevent or mitigate consequences at the scene.

(c) To prevent the occurrence of deterministic health effects in workers and the public.

(d) To render first aid and to manage the treatment of radiation injuries.

(e) To prevent, to the extent practicable, the occurrence of stochastic health effects in the population (including workers and public).

(f) To prevent, to the extent practicable, the occurrence of non-radiological effects on individuals and among the population.

(g) To protect, to the extent practicable, property and the environment.

(h) To prepare, to the extent practicable, for the resumption of normal social and economic activity.

These *Recommendations* do not address all of these goals but specifically apply to achieving goals (c) and (e). Taking measures towards achieving these goals (undertaking interventions) is governed at all times by the principles established in the internationally accepted system of radiological protection that has evolved to reduce adverse health effects in an accident situation (IAEA 2002). This system may be summarised by three principles (ICRP 1991, ICRP 1993, IAEA 1994):

(1) **Prevention of deterministic effects.** Intervention to prevent serious deterministic effects should be carried out as a first priority;

(2) **Justification of Intervention** Protective actions to avoid stochastic health effects should be initiated when they will be justified – that is, when they will produce more good than harm in the affected population; and

(3) **Optimisation of Intervention.** The levels at which these actions are introduced and withdrawn should be optimised, that is, they should produce a maximum net benefit to the population.

These basic principles underlie the criteria for planning protective measures in case of an accident.

3.2 APPLICATION OF PRINCIPLES

Protective actions should be carried out applying the three principles outlined in Section 3.1.2 above.

Principles (1) and (2) imply that the level of individual dose is of primary importance in deciding upon the introduction of protective measures. Protective measures derived on the basis of limitation of individual risk are intended to be applicable to the most highly exposed individuals, generally within a short time of the release and within a relatively short distance from the source.

Principle (1) requires the implementation of protective measures to avoid high levels of dose. Principle (2) requires implementation below these dose levels, to establish an intervention level appropriate for protection of the individual from stochastic effects. Justification of the protective action is accomplished by comparing the reduction in individual dose, and therefore individual risk, that would follow the introduction of a protective measure with the increase in individual risk resulting from the introduction of that protective measure (ICRP 1991).

Principle (3) states that detriment to the population (or collective detriment) is an important consideration in emergency response, but that it is primarily to be applied to using cost-benefit considerations at the stage of withdrawal of protective measures. Any risks associated with implementation and withdrawal of protective measures should be weighed against the advantage of the dose that is saved. The source-related assessment inherent to principle (3) may be implemented by cost-benefit analysis techniques and would be similar to a process of optimisation in that the social cost of a decrease in the health detriment in the affected population is balanced against the cost of further protective measures. (IAEA 1994a, ICRP 1991)

3.2.1 Intervention Level and Action Level

International guidance (IAEA 1994a, IAEA 1996) recommends the use of intervention levels and action levels to assist in the planning for implementing protective actions. These intervention levels take account of potential risks associated with the implementation of the protective action. The principles behind the selection of such levels are that the protective actions should be invoked at levels that would do more good than harm; that is, the radiation risk reduction of taking the action will be greater than the penalties incurred.

The **Intervention Level** is the level of avertable dose to an individual at which a specific protective action or remedial action is justified for an emergency exposure or chronic exposure situation.

Intervention levels for each protective action can be assessed for all potential emergencies involving radiation exposure and for specific population groups and social conditions. Intervention cannot reduce the dose already received and therefore this existing dose is not relevant when justifying a protective action.

The **Action Level** is applied to foodstuffs and is the level of activity concentration in a foodstuff above which remedial actions or protective actions (for example withdrawal of the foodstuff from distribution) should be carried out.

Avertable dose is the term used to express the dose that may be prevented by the implementation of a protective action, thus reducing the risk of stochastic effects. If a protective action is introduced and then removed after some period of time, the averted dose is the integrated dose that would have been received over that period of time had there been no protective action. Only the avertable doses that can be influenced by the protective measures should normally be taken into account when judging whether to take the protective action or not.

3.2.2 Generic Intervention Levels (GIL) and Generic Action Levels (GAL)

To facilitate emergency planning, international guidance defines a series of "generic" intervention and action levels optimised for a range of typical radiation emergency scenarios for normal population groups (IAEA 1994a). The use of these generic intervention levels underlies the implementation of protective measures to reduce the potential radiation doses arising from an emergency involving radiation exposure.

Generic Intervention Levels (GIL) are the **optimised levels** at which urgent and longer term protective actions should be implemented. 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, and Generic Action Levels (GAL) are the optimised levels at which control should be placed on foodstuffs, water and crops.

The decision to use a particular protective measure should be based on an estimate of the averted dose and the use of Generic Intervention Levels or Generic Action Levels. For planning purposes the avertable dose can be derived from the projected dose assuming that the protective measures are implemented promptly.

In an emergency involving radiation exposure, the **projected dose** is the radiation dose likely to be received via all pathways without protective actions and is usually limited to the dose received in a biologically significant time period, determined by the organ exposed (IAEA 1994a).

When deciding on a given protective measure, the dose to be compared with the relevant intervention level is the total dose which can be averted by that protective measure, including the contribution from all the related exposure pathways. For evacuation, for example, the total dose from all exposure pathways (inhalation, cloud gamma, deposited gamma) is modified by the evacuation. Recommended values for Generic Intervention Levels for urgent and for longer term protective actions are given in Table 4. The recommended Generic Action Levels for restricting foodstuffs are given in Table 5.

These levels were selected so that the protective actions would do more good than harm. That is, the risk avoided by averting a dose will be greater than the penalty incurred by applying the protective action. Notably this also means that taking protective actions at considerably lower or higher values could increase the overall risk to the public or workers. Urgent protective measures should ensure that deterministic effects would be avoided; that the interventions would be justified; and that the levels would be optimised. IAEA Safety Series No. 109 (SS109) (IAEA 1994a), provides a methodology for calculating justified and optimised levels in a generic sense and provides some example calculations for highly developed countries. Australia has no particular anomalies that would render any of the assumptions and data used in SS109 (IAEA 1994a) invalid. Thus, the generic intervention levels developed by the IAEA are adopted for use in Australia.

The dose to be compared with action level for controls on food consumption varies according to the situation. If one nuclide in one food or food type is dominant (e.g. I-131 in milk), the only dose to be compared with the action level for action on that food is the dose due to ingestion of that food and that nuclide. However, if the contribution from one nuclide or group of nuclides is not significantly different in a group of different foods (e.g. Cs-137 in meat, vegetables and dairy products), then the dose to be compared with the action level is the dose for the group of foods rather than for its component foods.

4. Application of Intervention Levels

4.1 INTRODUCTION

The implementation of protective measures in the early and intermediate phases following an emergency involving radiation exposure depends on the potential exposure pathways and on the results of environmental measurements. Some of these protective measures may also be applied in the far field and in the late phase e.g. decontamination of land and property, food and water controls.

The protective measures to be taken in emergency situations apply in two situations:

(a) Where individuals must enter high radiation areas for rescue purposes or to initiate action to bring a situation under control; and

(b) Where a large number of people may be exposed to unacceptably high levels of radiation.

4.2 EMERGENCY RESPONSE PLANS

Radiation emergency response plans should be prepared by the responsible person as part of the authorisation process for the transport or use of radioactive materials or the operation of a nuclear facility. Emergency planning dealing with uncontrolled sources, radiation transport accidents, terrorist use of radiation and other possible emergencies involving radiation exposure should be undertaken by the appropriate Agencies. The plans should be prepared in advance of any foreseeable nuclear accident or radiological emergency.

These plans should ensure that, in the event of an emergency with radioactive material or at a nuclear facility, members of the public, workers and the emergency personnel are protected from unnecessary or excessive radiation exposure. Consideration should be given to the provision of properly equipped and trained radiation monitoring teams and the radiation expert responsible for advising the incident controller on the implementation of protective measures should be designated.

Wherever possible the emergency planning and the agencies involved for nuclear or radiological emergency response should be consistent with the emergency response to “conventional” emergencies. This will ensure the agency with the expertise best suited to particular tasks in the plan will be used, for example, carrying out evacuations, search and rescue, and fire fighting. The standing operating procedures required for these actions will therefore be based on the agency’s expertise in dealing with the “conventional” hazard.

As a minimum the emergency response plans should cover the following topics:

- Pre-designation of emergency planning zones

- Actions required to prevent deterministic effects and reduce the stochastic risk to workers and members of the public, with particular emphasis to vulnerable groups
- Actions required by the response organisations to categorise and contain the emergency
- Protective measures required to prevent deterministic effects and reduce the stochastic risk to emergency response personnel
- Follow-up remediation of the site including any on-going monitoring and protective action to further reduce exposures to workers and members of the public
- Record keeping and reporting to the relevant regulatory authority (see Annex E).

4.3 PLANNING FOR EMERGENCIES INVOLVING RADIATION EXPOSURE

In the event of an emergency involving radiation exposure it is possible that initially there will be little or no knowledge of what radiation levels might be encountered. However, experience in previous emergency situations should give some indication if the hazards are likely to arise from inhalation or active deposit on the ground, buildings etc., or both. Table 2 provides some guidance to types of hazards likely in various emergencies.

Early response in an emergency will necessitate radiation monitoring to evaluate the strength of the radiation field prior to implementing any protective measures. From this monitoring, preliminary action can be planned. More detailed monitoring should be undertaken as quickly as possible and should include measurement of dose rate levels 1 metre above the ground and radionuclide concentrations in air, with identification of the major radionuclides present.

For the radiation emergency response to a terrorist Radiological Dispersive Device (RDD) additional planning and multi-agency coordination is required. It is necessary to first identify that a terrorist incident involves radiation. It is recommended that a dose rate of 10 μSv/h be used to indicate that an emergency involving radiation exposure has occurred and that the relevant response plan should be implemented. This value is consistent with existing practices, and although lower than that used overseas, will reduce the likelihood of significant exposures while still also reducing the likelihood of false alarms. If first responders have radiation dosemeters with alarms then the alarm threshold should be set to this value. Any explosive device must be dealt with and neutralised before detailed radiation monitoring can commence. Before and after any explosion, the location constitutes a crime scene, and care must be taken to preserve forensic evidence, without compromising the safety of the emergency responders or members of the public.

For radiation accidents involving a localised radiation source or the dispersal of radioactive material, managing the emergency response requires the control of access to the accident scene. These accidents can occur on-site or off-site of a facility. The best method to control access and egress is to use physical barriers. The placement of the barriers will need to take account of local conditions and the extent to which exposures can be reduced. Access to and egress from the cordoned-off area should be made through established checkpoint(s). The checkpoint(s) should serve as an assembly point for emergency personnel, as well as a radiological control station(s). Figure 1 illustrates an example of a layout of safety and security perimeter. Table 6 provides guidance on safe distances for a range of accident scenarios.

Although this document is not concerned with the medical management of individuals who have had large radiation exposures as a consequence of the emergency, attention is drawn to the need to remove them from the source of exposure as quickly as possible and to implement prompt medical intervention if necessary. If heavily contaminated, initial decontamination should be carried out on site, if safe to do so, or they should be transported to an accident/emergency department of a nominated hospital, care being taken not to contaminate other people or equipment in the process. If persons have received large radiation doses that require specialized treatment, they should be transferred to a designated medical centre, with as much information as possible relating to their likely radiation doses.

FIG. 1. Example of a idealised layout of safety and securityfor radiological incident perimeter .

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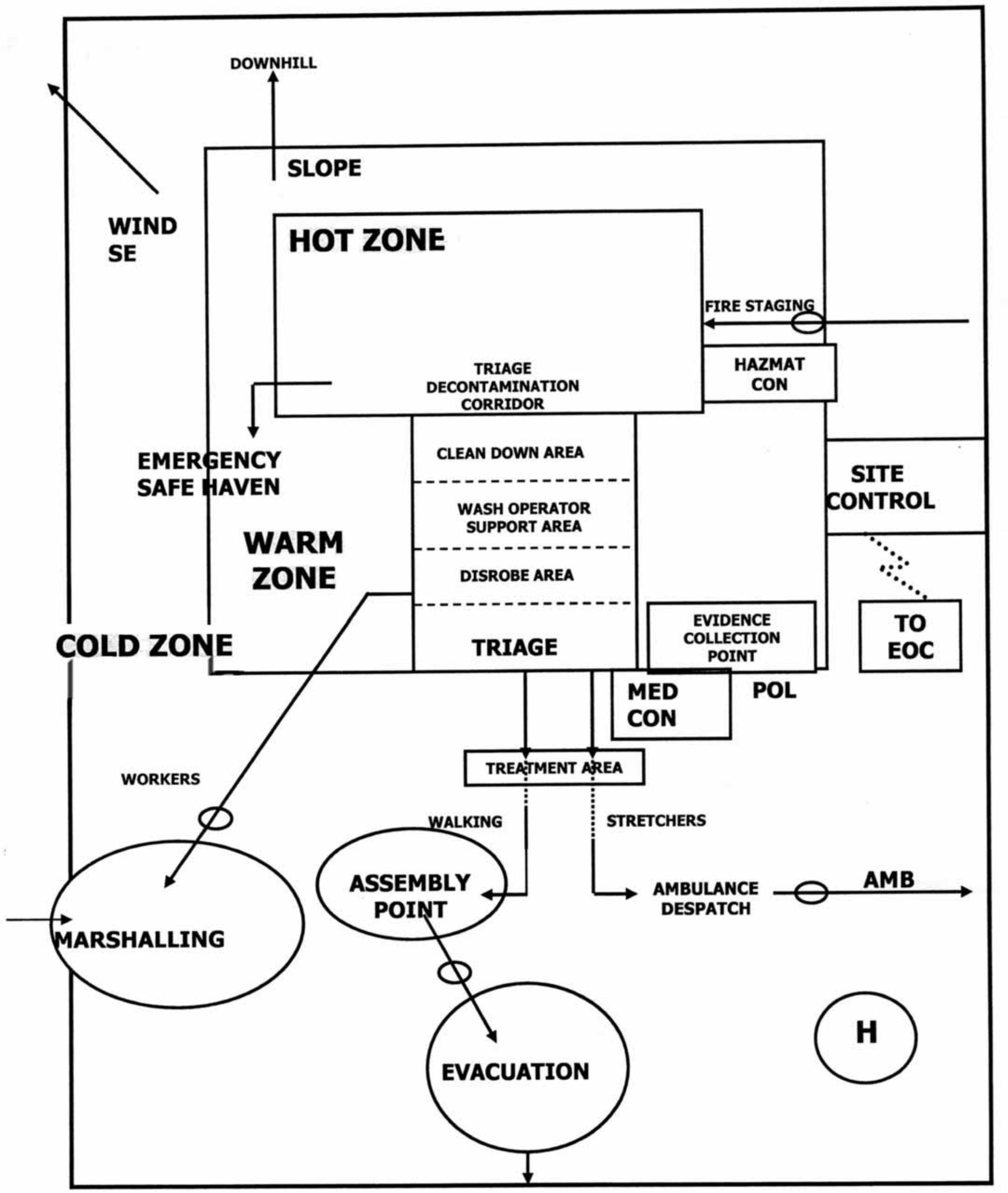


4.4 PLANNING FOR FACILITY-BASED EMERGENCIES

In the planning for radiological emergencies at a facility, three emergency planning zones are defined. These are the Precautionary Action Zone, the Urgent Protective Action Zone and the Long Term Protective Action Zone. These are illustrated in Figure 2.

(a) Precautionary Action Zone (PAZ)

The PAZ is a predesignated area around a facility where urgent protective actions have been preplanned and will be implemented immediately upon declaration of a general emergency. The goal is to substantially reduce the risk of deterministic health effects by taking protective action *before* a release.

The size of the precautionary action zone is based on a best estimate of the consequences in the case of a worst accident. Protective actions should be implemented for the whole zone whenever the conditions for a severe accident develop.

The PAZ is the area where preparations should be made to quickly alert the public and workers (e.g., siren systems) and instruct them on the urgent protective action to take. Protective actions such as substantial sheltering, evacuation and distribution of thyroid blocking agents should be recommended immediately when severe conditions are detected in the facility without waiting for monitoring.

(b) Urgent Protective Action Zone (UPZ)

The UPZ is a predesignated area around a facility where preparations are made to promptly implement urgent protective measures based on environmental monitoring.

The choice of the size of the protective action planning zones represents a judgement on the extent of detailed planning which must be performed in order to ensure effective response. In a particular emergency, protective actions might well be restricted to a small part of the planning zones. On the other hand, for the worst possible events, protective actions might need to be taken beyond the planning zones.

The UPZ is the area where preparations are made to promptly perform environmental monitoring and implement urgent protective measures based on the results. Plans and capabilities should be developed to implement sheltering or evacuation and distribute thyroid blocking agents (if appropriate). They should also reflect the fact that evacuation could be required up to the boundary of the zone (e.g. reception centres for evacuees should be sited outside this zone). If there is likely to be a significant delay in the provision of the initial environmental monitoring data, then it may be appropriate to plan to implement shelter in place in the down wind sectors of the UPZ on notification of a release. The continuation of this initial shelter in place or the implementation of further protective measures should be contingent on the results of the environmental monitoring.

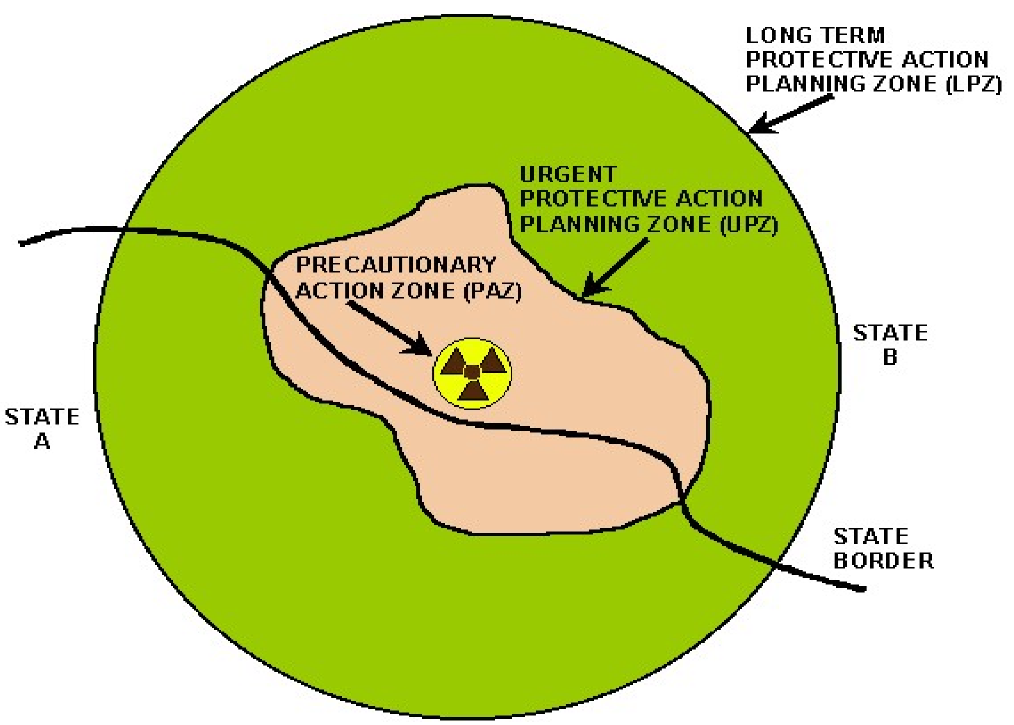
(c) Long Term Protective Action Zone (LPZ)

The LPZ is a predesignated area around a facility furthest from the facility and including the urgent protective action planning zone.

It is the area where preparations for effective implementation of protective actions to reduce the risk of deterministic and stochastic health effects from long term exposure to deposition and ingestion of locally grown food should be developed in advance. More time will be available to take effective action within this zone. In general, protective actions such as relocation, food restrictions and agricultural countermeasures will be based on environmental monitoring and food sampling.

In the initial planning, these zones should be roughly circular areas around the facility or accident. However, during an actual incident only part of the zone may be affected, such as the downwind quadrant where airborne radioactivity has been generated. The size of the zones can be determined by an analysis of the potential consequences. The boundaries of the zones should be defined by local landmarks (e.g., roads or rivers) to allow easy identification during a response. It is important to note that the zones do not stop at State or Territory borders.

FIG. 2. Concept of emergency planning zones for facility emergency.



4.5 OPERATIONAL INTERVENTION LEVELS

GILs and GALs provide a means of ensuring a consistent approach to the implementation of a particular countermeasure. They are specified in terms of organ dose or effective dose for GIL and activity per unit mass for GAL. These parameters cannot be promptly measured in the field during an emergency and do not address facility conditions.

However, they can be used to develop, as part of planning for emergencies involving radiation exposure, *operational intervention levels* (OIL). Operational Intervention Levels are derived from GILs and GALs applied to specific scenarios and assumptions. They are specified in terms of operational parameters that can easily be measured during an emergency, such as, ambient dose rate in plume or from deposition, marker radionuclide concentration in deposition or foodstuffs. OILs relate direct field measurements to the need to implement protective actions. OILs are a useful tool, especially early in the release, when little is known about the nature of the hazard but there is a need for prompt decision-making.

Operational Intervention Levels or OILs, are not significantly different in principle from "derived response levels" or "derived intervention levels". They are based on the generic intervention levels and/or generic action levels and on assumptions such as the source term isotopic composition, the duration of the release, and the decay profile of ground and food contamination. Operational Intervention Levels can be derived for each protective action.

When using default values the user should be aware of assumptions under which these values were calculated. As more detailed isotopic information becomes available during an accident, the assumptions used to derive the OIL values 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 methods for reassessing OIL values are detailed in Annex C.

(a) Emergencies Involving Radiation Exposure

For radiation emergencies involving uncontrolled sources modelling should be used for planning purposes and this should be supplemented by field measurements, where available, to refine the response. Operational Intervention Levels can be used to assess the need for immediate protective actions (e.g. evacuation) for the public. The Operational Intervention Levels (OILs) for radiological emergencies based on ambient dose rate measurements from gamma-emitting radionuclides are listed in Table 7.

In the event of the accident involving either a large beta or a neutron source, an appropriate set of OILs should be calculated as part of the emergency planning. These OIL values should take account of the beta + bremsstrahlung or neutron + gamma dose rates to ensure that the dose rate readings properly reflect the relevant GIL. For a large damaged alpha source the pre-planned response must specify OILs for the potential alpha airborne concentrations which might lead to a GIL being reached.

(b) Reactor Emergencies

For emergencies involving nuclear reactors, four types of OILs are calculated:

(i) 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 is calculated for an unsheltered person in the plume taking into account the mixture of fission products for a core melt accident; and

- OIL2 is the operational intervention level for thyroid blocking and sheltering expressed as the ambient dose rate in the plume for an unsheltered person. An additional OIL2c has been calculated for thyroid blocking for children.

(ii) Ambient dose rate from deposition [mSv/h]

- OIL3 is an operational intervention level for evacuation or substantial sheltering;

- OIL4 is an operational intervention level for temporary relocation; and

- OIL5 is an operational intervention level for precautionary restriction of food and milk.

(iii) Deposition concentration of marker radionuclide(s) [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; andOIL7 has the same function as OIL6 except that the marker radionuclide is Cs-137.

(iv) Marker radionuclide(s) concentration in food, milk and water [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 like OIL6 but measured in food and milk or water, rather than ground deposition; and

- OIL9 is an operational intervention level above which restrictions for food and milk or water are recommended. It is based on Cs-137 (marker radionuclide) activity concentration measured in food and milk or water.

Values for the Operational Intervention Levels for a reactor-based accident are listed in Table 8 together with the assumptions under which default values 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.

In a severe reactor accident (core melt accident) dominant radionuclides that can be easily measured and assessed are most likely to be 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. The I-131 marker concentrations in a plume, corresponding to the Generic Intervention Levels for iodine prophylaxis, are listed in Table 8.

4.6 IMPLEMENTING PROTECTIVE MEASURES

The initial response to an emergency involving a release of radiation should be based on the emergency response plan. For a facility emergency, this plan should designate the boundaries for the emergency planning zones, derived from the modelling of potential accident scenarios. Since the GIL cannot be measured directly during a radiological emergency, the appropriate OIL should be used to assist the decision making process for implementing protective measures. These levels are indicated in Table 4 and their implementation in an emergency situation is indicated in the flow diagram in Figure 3, reproduced from SS109 (IAEA 1994a).

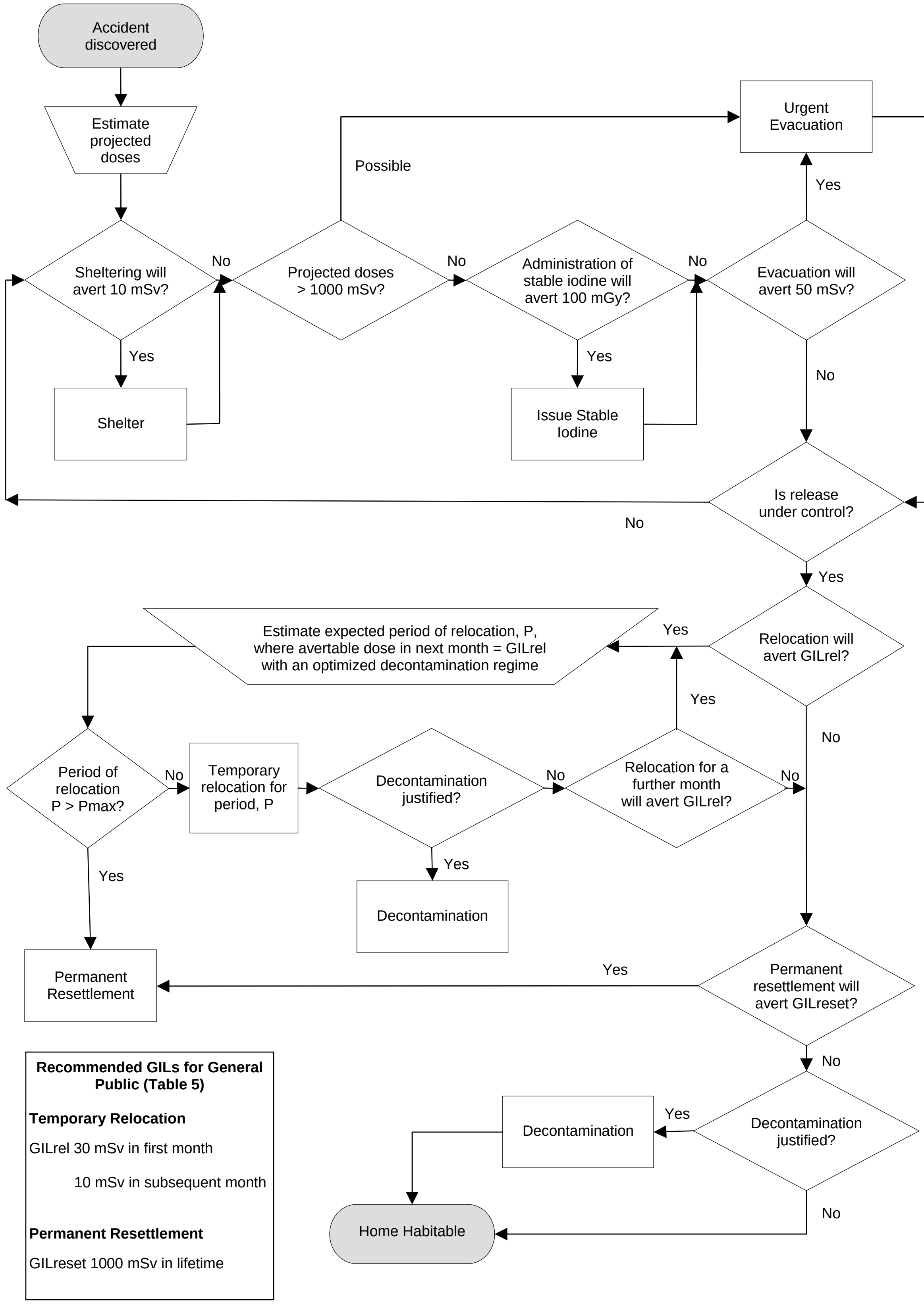
The actual radiation accident may be different from the accident used for the emergency planning. In this case the implementation of protective measures should still be based on the use of environmental monitoring data and the OILs, with consideration of the actual emergency situation and the possible consequences to health of human exposure, the area in which it arises, the distribution of people in the immediate neighbourhood, the radionuclides involved, likely pathways of exposure, meteorological conditions and the time available for implementation and warning of people. In addition, psychological factors arising in the exposed population must be taken into account as these may interfere with the implementation of the protective measures.

4.6.1 Protective Measures in the Precautionary Action Zone (PAZ)

In the PAZ, the pre-planned protective measures should be carried out automatically. In this zone action must be taken immediately following notification of the accident, consequently there will not be time to make radiological measurements for comparison with OILs. In pre-planning the emergency response, the boundary of the PAZ should be based on an estimate of the potential doses which affected persons might receive. These doses should be based on the credible worst case design based events for facilities, and the worst case credible events for other sources. The estimate will obviously need to include such factors as:

- the radionuclide involved
- the potential mix of more than one radionuclide
- the activities of the radionuclides
- whether the radiation exposure will be external, internal or a mixture of the two
- an estimate of the time required to implement the protective action.

Fig. 3. Flowchart showing the decision process for implementation of immediate and longer term protective actions (based on IAEA 1994a).



4.6.2 Protective Measures in the Urgent Protective Action Planning Zone (UPZ)

In the UPZ, the early response in an emergency will necessitate radiation monitoring to assess the radiation dose levels in the field. In this zone the protective actions should only be carried out following comparison of actual radiological measurements to the appropriate OILs. Default OIL values are listed in Table 8. The protective measures listed as “urgent” are those for which unwarranted delays could result in unnecessary exposure of individuals and the population. These urgent protective measures are sheltering, evacuation and issue of stable iodine.

The radiation measurements should be compared with the appropriate OIL prior to implementing any protective measures. The rapid measurement and reporting of this monitoring data ensures that the protective measures have the maximum benefit in reducing the radiation exposure to members of the public. As the emergency response develops, more detailed monitoring should be undertaken to measure and identify the radionuclides in the air and on the ground to confirm the validity of the default OIL values or to revise the OILs using the procedures in Annex C.

The derivation of OIL2 for ambient dose rate in the plume assumes that radioiodine is present in the plume. Air sampling for radioiodine in the early phase of the release should be carried out to confirm whether radioiodine is present in the plume. The use of the default OIL2 value in the absence of radioiodine may lead to the implementation of iodine prophylaxis when it is not required and the implementation of sheltering at a lower level than is optimal. However, it is considered that the risks associated in implementing these protective measures under these circumstances are outweighed by any potential benefits gained in implementing them with minimal delay. As the air sampling data becomes available, OIL2 should be revised using the procedures in Annex C.

4.6.3 Protective Actions for the Long Term Protective Action Planning Zone (LPZ)

The action for this zone will be based on environmental monitoring and food sampling and generally more time will be available to take effective action. However, it may be prudent to consider whether temporary food bans should be recommended early in the PAZ and UPZ when evacuation has not been necessary.

It is necessary to distinguish between the protective measures of evacuation and relocation. Evacuation is the urgent removal of people from an affected area, but it is possible that they may return when the radiation levels become low. On the other hand, relocation involves the removal of people from an affected area, either permanently or for a long period, until decontamination or radioactive decay has resulted in the levels in that area being satisfactorily low. Evacuated people would be relocated if the levels in the affected areas remain unacceptably high.

4.7 Longer Term Protective Measures

Urgent protective measures are designed to protect the population and may be applied successfully for short periods of time. Sheltering is effective only until the concentrations of radionuclides within the shelter become comparable with those outside. Sheltering must in any case be stopped when the concentrations outside begin to decline below those inside (e.g. when the source of exposure has been removed or any "cloud" containing radioactive material has passed). The timescale over which sheltering may be useful ranges from a few hours to a couple of days.

- Iodine prophylaxis should be used only as short term protective countermeasure and the control of ingestion of radioactive iodine in food is the preferred long-term protective measure to reduce the exposure to radio iodine.
- Evacuation may be tolerable for up to two or three days or possibly up to a week. After that time, other arrangements will be required.

Several other protective actions, such as those listed as "intermediate" in Table 1, may be considered that are likely to be for a longer time. These include temporary relocation and permanent resettlement, food and water control, restriction and discarding of foodstuffs, decontamination, control of contaminated livestock, and restriction of feedstuffs for animals. Recommended GILs for these longer term protective measures are given in Table 4. The optimised levels are likely to be accident specific but, for temporary relocation and permanent resettlement, are unlikely to differ much from the international guidance (IAEA 1994a).

These longer term measures should be carried out in as informed a manner as possible. Calculations of the radiological impact of the protective measure would be based on measurements, using information in Annex C. This would be compared with other potential risks, including social and economic penalties, of introducing the protective measures. Any protective measure should only be introduced if it will do more good than harm and the levels at which it is introduced and stopped should be optimised.

4.8 Control of Foodstuff

Events that result in widespread contamination by radioactive materials could result in a need to impose restrictions on foodstuffs. Such contamination could occur, for example, following a release of radioactivity to the environment from a reactor or other large radioactive materials facility (or satellite re-entry). Emergencies involving rupture of high activity sealed sources are likely to require only very localised restrictions on foodstuffs, if any are required at all.

Contamination of foodstuffs could occur directly, by radioactivity from a plume being deposited on to exposed foods or water supplies. Or, radioactivity may be deposited on crops, such as cereals and vegetables, or pastures.

For radioactivity deposited on crops, the amount that eventually finds its way to foodstuffs depends on how the radioactivity is taken up by the plant, into stem, leaves, roots, etc. This will in turn depend on the growing season. Similarly, the amount of radioactivity deposited on pastures that eventually finds its way into meat and dairy products will depend on the proportion of the animal's diet that is from pasture. Further, the amount of radioactivity left in foodstuffs before consumption will depend on the method of preparation and on cooking processes.

Once radioactivity enters the foodstuffs, guidance on acceptable levels is required. In Australia, food is controlled by each State or Territory and the Commonwealth in accordance with the Australia New Zealand Food Standards Code. This Code currently contains no guidance about levels of radioactive contamination permissible in foodstuffs. However, the Code is currently under revision and Australia is seeking to align the revised Code with the most recent recommendations of the Codex Alimentarius Commission as far as possible. The Codex contains guideline levels for radionuclides in foods, following accidental radioactive contamination, for use in international trade. Any differences between Australian requirements and those of Codex must be capable of being justified on scientific grounds under World Trade Organisation Sanitary and Phytosanitary provisions. Also, both imported and domestically produced foods should meet the same set of standards. Foods for export must meet the requirements of the Codex.

The numbers in the Codex for guidance on levels of radioactivity in foods following accidental contamination are based on an effective dose of 5 mSv being received in one year due to eating or drinking 750 kg (adult) or 350 kg (infant) of the contaminated foodstuff in any one group. These are the estimated total food intakes for a year for adults and infants. The numbers also use the most restrictive dose conversion factors (activity consumed converted to dose), which are usually those for infants. These numbers are so conservative that it is most unlikely that any person would receive a dose of more than a small fraction of one millisievert, from consumption of foods contaminated at these levels.

Each State and Territory (and the Commonwealth) has provision for emergency establishment of criteria for foodstuffs likely to be a risk to public health. The information in Table 5, of generic intervention levels for use in emergencies, is to provide guidance in such situations. The numbers in Table 5 are consistent with those in the Codex Alimentarius and are intended for use, for one year, following an accident that results in contamination of foodstuffs intended for international trade. The numbers are applicable for foods prepared for consumption. They would be unnecessarily restrictive if applied to dried or concentrated foods prior to dilution or reconstitution.

In the early phase of an emergency, when there is limited data on specific radioactive materials concentrations in foodstuffs, it will not be possible to directly apply the numbers in Table 5. Then, the decision making may be based on the OILs in Table 8. The dose rate specified in OIL5 of that table could be used to identify areas where an initial restriction on foodstuffs could be required. OILs 6 and 7 can then be used to identify foodstuffs for which an immediate, temporary ban may be recommended.

Although control of foodstuffs is generally a longer-term measure, there may be a need for rapid control of foodstuffs if there is a potential for exposure of children to iodine, e.g. from milk.

The values in Table 5 are for guidance only. The Codex makes provision for higher levels to be permissible for foods, such as tea or spices, which make up a very small part of the food intake. Acceptability of these higher levels varies, internationally.

Also, although the Codex values are suitable for domestic use in an emergency, the local authority may exert some discretion in the application of these guidelines. This is particularly the case if one foodstuff is an essential part of any diet. Then, higher values may be acceptable in some circumstances.

5. Protection of Emergency Personnel

Under normal conditions, exposure of people to radiation is subject to the system for radiation protection for practices, including compliance with the dose limits specified in Table 9 (ARPANSA/NOHSC 2002).

In an emergency, where there may be a need for emergency personnel to take action to save lives or to bring an accident under control, these dose limits may no longer be appropriate. The need for emergency personnel to be exposed to radiation in an emergency must be justified and the protection against the exposure to that radiation must be optimised. This applies to all emergencies.

Emergency response may be considered for two distinct scenarios:

- The first scenario is an emergency occurring in a facility or on a site where radioactive materials are routinely dealt with. Such sites in Australia will have pre-planned emergency procedures for foreseeable events. Thus, emergency responders are likely to be knowledgeable in radiation protection and the hazards associated with the radioactive materials on site. Decisions will therefore be made initially by on-site personnel on the basis of prepared emergency procedures.
- The second type of scenario requires an independent technical adviser to advise whether emergency personnel, including fire service personnel and ambulance and police officers are required to take actions that may result in their exposure to radiation. Such emergencies could include discovery of lost radioactive source(s), discovery of damaged radioactive source(s) and possibly some associated contamination by radioactive material, accidents involving transport packages containing radioactive materials, or a situation where there is release of radiation to the environment such as may occur, for example, for some reactor emergencies.

Thus, in some emergencies, on-site workers, who already have considerable knowledge of the radioactive materials and their potential hazards, will be involved in the emergency response. In other situations, such as transport accidents, the first responders are likely to be police or fire service personnel. They will have less formal training in radiation protection than on-site workers. However, the International Regulations for transport of radioactive materials, which are adopted in Australia, recognise this possibility and packages are designed and contents limited so that, even in accidents, doses to emergency personnel and to the public will be well below the limits in Table 9. In the event of a transport and other emergencies involving radiation exposure, the initial safe distances in Table 6 should be used in minimising the dose to emergency personnel.

In all situations, minimising the radiation exposure of emergency personnel is a key objective in the management of the incident. Where possible, exposures should be kept within the dose limits of Table 9. In emergency situations where this is not possible, every effort should be made to keep the doses to emergency personnel below those specified in Table 10, consistent with provision of the emergency response. Higher doses may be permissible in some circumstances but doses to emergency personnel for all actions, including life-saving action, must be kept well below those at which serious deterministic health effects may occur (see Table 3). The benefits to others in these circumstances must clearly outweigh the risks to emergency personnel.

Doses received during emergency actions should be treated separately from normal exposures. In particular, a worker should not be prevented from returning to radiation work because of doses received during an emergency.

In addition to the above, general advice, more explicit information may be applicable at different phases of an accident. Such advice may be applicable for three categories of conditions:

- Category 1: urgent action at the site of the accident, including actions to save lives and to bring the accident under control;
- Category 2: implementing early protective actions and taking action to protect the public; and
- Category 3: recovery operations.

Persons working under Category 1 conditions are likely to be plant operators but may also be emergency service personnel such as fire-fighters.

The following should be ensured for these people:

- They must be fully informed of the health risks associated with exposure in such areas. A brief discussion of the health risks associated with exposure to radiation is provided in Annex B, and the range of health effects are illustrated in Annex D.
- They must be members of established emergency organizations or other persons who are fully aware of radiation hazards and the consequences of radiation exposure.
- They should be in good health and be well trained.
- They must wear personal monitors that provide estimates of personal dose equivalent, Hp(10).
- Gamma ray survey meters, calibrated in terms of ambient dose equivalent rate, H*(10)/h, must be used.
- Female workers, who have declared a pregnancy must not be put into a situation where the radiation exposure to the fetus could exceed the limit, specified in Table 9, for a member of the public.
- Breathing protection, protection of the skin against beta radiation and contamination and other protective devices must be provided and used when necessary.

- Thyroid blocking agents should be administered when a radioiodine inhalation hazard exists.
- Several persons should be used, when appropriate, to keep an individual's dose as far below the thresholds for deterministic effects as possible.
- They must retreat from a situation, once any predetermined dose level, specified in Table 10, is reached. Dose rate measurements from the gamma survey meter can be used to estimate the time that could be spent in an area before any predetermined dose level is reached. During the planning phase for emergencies, specified action may be assigned to certain dose rates. It is recommended that a dose rate of 10 µSv/h be used to indicate that an emergency involving radiation exposure has occurred and that the relevant response plan should be implemented.
- The sum of the doses received by any individual involved in several emergency situations in their lifetime should not exceed the dose levels specified in Table 10.
- The benefits to others must clearly outweigh the risks to the workers.

Emergency personnel in Category 2 conditions are likely to incur additional exposure whilst carrying out measures to avert dose to the public. These emergency personnel could include police, medical personnel, drivers and crews of vehicles used for evacuation, ambulance crews, etc. Their doses can be controlled and should be kept within the limits for normal occupational exposure. All such emergency personnel should be provided with some training for radiation work and should understand the risks involved. They should be provided with any necessary protection, such as personal protective equipment and iodine tablets.

Recovery operations, Category 3, should be treated as a normal radiation practice, where actions can be planned and exposures controlled. The dose limits in Table 9 would apply.

In all three categories of conditions, exposures of emergency personnel must be assessed and recorded. The risks of the exposures received must be explained to each individual by an independent technical expert with appropriate radiation protection experience.

Table 1

PROTECTIVE MEASURES FOR AVERTING EXPOSURES VIA VARIOUS PATHWAYS

Protective measures	Main exposure pathways	Timing
Sheltering	External irradiation from facility, plume and ground deposits. Inhalation of radioactive material in plume. Deposition on skin and clothes.	early
Administration of stable iodine compounds	Inhalation of radioiodine. Ingestion of radioiodine.	early
Urgent evacuation	External irradiation from facility, plume and ground deposits. Inhalation of radioactive material in plume. Deposition on skin and clothes.	early
Temporary relocation and permanent resettlement	External irradiation from ground deposits. Ingestion of contaminated food and water. Inhalation of resuspended radionuclides.	intermediate
Food and water control, restriction and discarding of foodstuffs	Ingestion of contaminated food and water.	intermediate and late
Decontamination of persons and clothing	External irradiation and/or internal irradiation.	early - intermediate
Improvised respiratory protection	Inhalation of radionuclides.	early
Control of access	External irradiation from ground deposits. Inhalation of resuspended radionuclides.	early - intermediate
Control of contaminated livestock	Ingestion of radionuclides.	intermediate - late
Restrictions or prohibitions on the use of contaminated products (for fertilization, combustion, soil improvement, etc.)	Intakes of radionuclides.	late
Restriction of feedstuffs for animals (e.g. transfer from pasture to indoor feeding)	Ingestion of radionuclides.	early - intermediate intermediate

Table 2

SOME POSSIBLE EMERGENCIES, RADIATION EXPOSURE ROUTE AND POSSIBLE PROTECTIVE MEASURES

Emergency situation	Resulting hazard	Possible protective measures
loss of a high activity sealed source	high (gamma) dose rates in vicinity of source. Pathway 1.	move people away from possible location of the source.
the destruction of a high activity sealed source	dispersion of contaminants in the immediate neighbourhood, the environment generally or into products used by the public. Pathways 1 and 2 and 3.	locate contaminants and persons exposed; decontamination could require drastic measures, such as scraping of roadways; destruction of buildings may have to be considered; localised restrictions on foodstuffs and water may be necessary.
uncontrolled releases of radioactive contaminants from a nuclear research reactor	dispersion of the contaminants over a region downwind from the reactor. Pathways 1, 2 and 3.	Shelter from plume; take stable iodine; evacuation may be considered; decontamination procedures for persons and buildings and roadways; restrict foodstuffs and water.
uncontrolled releases from the nuclear reactor on a visiting ship	dispersion of the contaminants over a region downwind from the ship and into the harbour Pathways 1, 2 and 3.	Shelter from plume; take stable iodine; evacuation may be considered; decontamination procedures for persons and buildings and roadways; restrict foodstuffs and water.
burn-up of a nuclear reactor in a satellite out of control in re-entry to the earth's atmosphere	radioactive contaminants might be distributed over a long, narrow region of a few thousand square kilometres. Pathways 1 and possibly 3.	Alert persons in path. Warn persons to keep away from debris. Locate and collect debris.

Pathways of exposure:
1. External sources, due to radiation emitted from high activity sealed sources and/or to radioactive contaminants in the air or deposited on the ground, buildings, equipment or the body.
2. Internal sources, due to inhalation of radioactive contaminants in the air.
3. Internal sources, due to ingestion of contaminated water and/or foodstuffs grown in the affected areas, with special concern with certain foods, such as crustaceans and molluscs, which can concentrate contaminants.

Table 3

THRESHOLDS OF OCCURRENCE OF DETERMINISTIC EFFECTS AND CORRESPONDING RISKS OF STOCHASTIC EFFECTS FOR ACUTE EXPOSURE

Organ or tissue	Dose in less than 2 days (Gy) [a]	Deterministic Effects		Lifetime risk of stochastic effects [b]
		Type of Effect	Time of occurrence	
Whole Body (Bone Marrow)	1 [c]	Death	1-2 Months	1×10^{-1} (fatal cancer) [d]
Lung	6	Death	2-12 months	5×10^{-2} (lung cancer) [b]
Skin	3	Erythema	1-3 weeks	1×10^{-3} (skin cancer) [e]
Thyroid	5	Hypothyroidism	First year-several years	5×10^{-3} (fatal thyroid cancer) [f]
Lens of Eyes	2	Cataract	6 months - several years	Not applicable
Gonads	3	Permanent sterility	Weeks	(genetic effects) 3×10^{-2}
Fetus	0.1	Teratogenesis	–	Not applicable

a Projected absorbed dose delivered in a short period of time. Applicable to a population characterised by typical age distribution and for doses below which deterministic effects will not normally occur. These values may not be appropriate for special radiosensitive groups.

b Average risk of stochastic effects to individuals who are exposed to doses at the levels of the threshold in the first column, but do not exhibit deterministic effects. Except for the lung, the figures do not take into account the dose and the dose rate effectiveness factor (DDREF), as the dose is delivered in a short period of time (absorbed dose greater than 0.2 Gy or dose rate greater than 0.1 Gy/h).

c Vomiting could occur in radiosensitive individuals in the first day after exposure to a doses above 0.5 Gy.

d Including a risk of 1×10^{-2} of leukaemia.

e Expresses only the risk of fatal skin cancer, which represents only a small fraction of the total skin cancers since most skin cancers are curable.

f Most thyroid cancers are curable, and since this figure represents only the risk of fatal thyroid cancers, the value should be multiplied by about 10 for the total risk of thyroid cancer, as recommended in ICRP Publication 60 (ICRP 1991). The risk factor in this table is from a reassessment of child thyroid cancer risk (NRPB 2001).

Table 4

RECOMMENDED GENERIC INTERVENTION LEVELS FOR PROTECTIVE MEASURES FOR THE GENERAL PUBLIC

Protective action	Generic intervention level [a, b]
Urgent protective measures	
Sheltering	10 mSv [c]
Evacuation	50 mSv [d]
Iodine prophylaxis	100 mGy for Adults [e] 30 mGy for Children
Temporary relocation and permanent resettlement	
Temporary relocation	30 mSv in first month [f] 10 mSv in a subsequent month [g]
Permanent relocation	1 Sv in lifetime [h]

a These levels are of avertable dose, i.e. the action should be taken if the dose that can be averted by the action, taking into account the loss of effectiveness due to any delays or for other practical reasons, is greater than the figure given.

b The levels in all cases refer to the average over suitably chosen samples of the population, not to the most exposed individuals. However, projected doses to groups of individuals with higher exposures should be kept below the thresholds for deterministic effects (Table 3)

c Sheltering is not recommended for longer than 2 days. Authorities may wish to recommend sheltering at lower intervention levels for shorter periods or so as to facilitate further protective measures, e.g. evacuation.

d Evacuation is not recommended for a period longer than 1 week. Authorities may wish to initiate evacuation at lower intervention levels, for shorter periods and also where evacuation can be carried out quickly and easily, e.g. for small groups of people. Higher intervention levels may be appropriate in situations in which evacuation would be difficult, e.g. for large population groups or with inadequate transport.

e Avertable dose to the thyroid. For practical reasons, one intervention level is recommended for all age groups.

f The avertable dose applies to an average population being considered for temporary relocation

g A month here refers to any period of about 30 days and not to a calendar month

h A lifetime is normally taken as 70 years in order to protect the most sensitive groups.

Table 5

RECOMMENDED GENERIC ACTION LEVELS FOR FOODSTUFFS (IAEA 1994A)

Foods destined for general consumption		
Isotope group G	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 LWR reactor accidents.

Table 6

EXAMPLES OF INITIAL SAFE DISTANCES IN RADIOLOGICAL ACCIDENTS (IAEA 2000)

Situation	Initial safe distance
Intact package with a I-WHITE, II-YELLOW or III-YELLOW label	Immediate area around the package
Damaged package with a I-WHITE, II-YELLOW or III-YELLOW label	30 m radius initially or at readings of 100 μSv/h
Undamaged common source (consumer item) such as smoke detector	Immediate area around the source
Other unshielded or unknown source (damaged or undamaged)	30 m radius initially or at readings of 100 μSv/h
Spill	Spill area plus 30 m around
Major spill	Spill area plus 300 m around
Fire, explosion or fumes	300 m radius initially or at readings of 100 μSv/h

Table 7

OPERATIONAL INTERVENTION LEVELS (OILS) FOR MEMBERS OF THE PUBLIC IN RADIOLOGICAL EMERGENCIES BASED ON AMBIENT DOSE RATE MEASUREMENTS FROM GAMMA-EMITTING RADIONUCLIDES

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

Table 8

OPERATIONAL INTERVENTION LEVELS IN A REACTOR ACCIDENT

Basis	OIL	Default value		Protective measure
Ambient dose rate in plume	OIL1	1 mSv/h [(a)]		Evacuation
	OIL2	100 μSv/h [(b)]		Sheltering
	OIL2	100 μSv/h		Iodine Prophylaxis Adult
	OIL2c	20 μSv/h		Iodine Prophylaxis Child
Marker radionuclide concentration in plume: I-131		50 kBq/m³ [(c)]		Iodine Prophylaxis Adult
		10 kBq/m³ [(c)]		Iodine Prophylaxis Child
Ambient dose rate from deposition	OIL3	1 mSv/h		Evacuation or substantial sheltering
	OIL4	200 μSv/h		Temporary relocation
	OIL5	1 μSv/h		Restriction of foodstuffs
Marker radionuclide concentrations in ground deposition		General food	Milk	
I-131	OIL6	10 kBq/m²	2 kBq/m²	Restriction of foodstuffs
Cs-137	OIL7	2 kBq/m²	10 kBq/m²	Restriction of foodstuffs
Marker radionuclide concentrations in food, milk, water		General food	Milk and water	
I-131	OIL8	1 kBq/kg	0.1 kBq/kg	Restriction of foodstuffs
Cs-137	OIL9	0.2 kBq/kg	0.3 kBq/kg	Restriction of foodstuffs

(a) If there is no indication of core damage or radioiodine is not present in the plume then, OIL1 = 10 mSv/h.

(b) If there is no indication of core damage or radioiodine is not present in the plume then, OIL2 = 1 mSv/h.

(c) Based on marker radionuclide I-131 delivering 50% of total thyroid dose from inhaled airborne radioactivity in the plume, over a 4 hour exposure.

Table 9

ARPANSA's *Recommendations for limiting exposure to ionizing radiation* (2002) – Dose Limits

Application	Dose Limits[1]	
	Occupational	**Public**
Effective dose	20 mSv per year, averaged over a period of 5 consecutive calendar years[2,3]	1 mSv in a year[4]
Annual equivalent dose in:		
the lens of the eye	150 mSv	15 mSv
the skin[5]	500 mSv	50 mSv
the hands and feet	500 mSv	–

1. The limits shall apply to the sum of the relevant doses from external exposure in the specified period and the 50-year committed dose (to age 70 years for children) from intakes in the same period.

2. With the further provision that the effective dose shall not exceed 50 mSv in any single year. In addition, when a pregnancy is declared by a female employee, the embryo or fetus should be afforded the same level of protection as required for members of the public.

3. When, in exceptional circumstances, a temporary change in the dose limitation requirements is approved by the appropriate authority, one only of the following conditions shall apply: (a) the effective dose limit shall not exceed 50 mSv per year for the period, which shall not exceed 5 years, for which the temporary change is approved, or (b) the period for which the 20 mSv per year average applies shall not exceed 10 consecutive years and the effective dose shall not exceed 50 mSv in any single year.

4. In special circumstances, a higher value of effective dose could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year.

5. The equivalent dose limit for the skin applies to the dose averaged over any 1 cm^2 area of skin, regardless of the total area exposed.

NOTE: The above dose limits table is directly extracted from ARPANSA's *Recommendations for limiting exposure to ionizing radiation (2002)*, however the Radiation Health Committee now advises that the exceptional circumstances clause in note 3 of the table is not recommended for use in Australia.

Table 10

IAEA Total Effective Dose Guidance for Emergency Workers
(IAEA 2000)

Tasks	Total effective dose guidance [mSv]
Type 1: Life saving actions	<500 [a]
Type 2: Prevent serious injury Avert a large collection dose Prevent the development of catastrophic conditions	<100
Type 3: Short term recovery operations Implement urgent protective actions Monitoring and sampling	<50
Type 4: Longer term recovery operations Work not directly connected with an accident	Occupational exposure guidance, as given in Table 9.

[a] This dose can be exceeded if justified BUT every effort shall be made to keep dose below this level and certainly below the thresholds for deterministic effects. The workers should be trained on radiation protection and understand the risk they face. They must be instructed on the potential consequences of exposure. The benefits to others must clearly outweigh the risks to the workers.

Please note: The Radiation Health Committee (RHC) recommends that these upper bound dose constraints should only be applied when normal operational dose constraints are not appropriate.

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Glossary

Absorbed dose

the energy absorbed per unit mass by matter from ionizing radiation which impinges upon it.

Accident

an unintended event which causes, or has the potential to cause, employees or members of the public to be exposed to radiation from which the individual doses or collective doses received do not lie within the range of variation which is acceptable for normal operation. An accident may result from human error, equipment failure or other mishap; it may require emergency action to save life or to safeguard health, property or the environment; it requires investigation of its causes and consequences and, possibly, corrective action within the program for control of radiation; and it may require remedial action to mitigate its consequences.

Action level

an intervention level applied to exposure to radiation; when a public exposure action level is consistently exceeded, remedial action to reduce exposure should be considered; when an occupational exposure action level is consistently exceeded within a practice, a program of radiation protection should apply to that practice.

Activity

the measure of quantity of radioactive materials, except when used in the term 'human activity'.

Alpha particle

a charged particle, consisting of two protons and two neutrons, emitted by the nucleus of a radionuclide during radioactive decay (a-decay).

Beta particle

an electron or positron emitted by the nucleus of a radionuclide during radioactive decay (b-decay).

Collective effective dose

a measure of the total radiation exposure of a group of people which is obtained by summing their individual effective doses.

Committed effective dose

the effective dose which a person is committed to receive from an intake of radioactive material.

Committed equivalent dose

the equivalent dose which an organ or tissue is committed to receive from an intake of radioactive material.

Controlled area

an area to which access is subject to control and in which employees are required to follow specific procedures aimed at controlling exposure to radiation.

Critical group

a group of members of the public comprising individuals who are relatively homogeneous with regard to age, diet and those behavioural characteristics that affect the doses received and who receive the highest radiation doses from a particular practice.

Deterministic effect

an effect, such as partial loss of function of an organ or tissue, caused by radiation and manifest only above some threshold of dose, the severity of the effect depending upon the dose received.

Detriment

a measure, or measures, of harm caused by exposure to radiation and usually taken to mean health detriment; it has no single definition, but can be taken to be an attribute or a collection of attributes which measure harm, such as attributable probability of death and reduction of life expectancy.

Dose

a generic term which may mean absorbed dose, equivalent dose or effective dose depending on context.

Dose constraint

a prospective restriction on anticipated dose, primarily intended to be used to discard undesirable options in an optimization calculation.

in occupational exposure, a dose constraint may be used to restrict the options considered in the design of the working environment for a particular category of employee.

in medical exposure, a dose constraint for volunteers in medical research may be used to restrict the options considered in the design of an experimental protocol.

in public exposure, a dose constraint may be used to restrict the exposure of the critical group from a particular source of radiation.

Effective dose

a measure of dose which takes into account both the type of radiation involved and the radiological sensitivities of the organs and tissues irradiated.

Equivalent dose

a measure of dose in organs and tissues which takes into account the type of radiation involved.

Exposure

either: the circumstance of being exposed to radiation;

or: a defined dosimetric quantity now no longer used for radiation protection purposes.

(The context in which the word is used should avoid ambiguity.)

Gamma ray

ionizing electromagnetic radiation emitted by a radionuclide during radioactive decay or during a nuclear (isomeric) transition.

Incident

an event which causes, or has the potential to cause, abnormal exposure of employees or of members of the public and which requires investigation of its causes and consequences and may require corrective action within the program for control of radiation, but which is not of such scale as to be classified as an accident.

Intervention

action taken to decrease exposures to radiation which arise from existing situations.

Intervention level

a reference level of an environmental or dosimetric quantity, such as absorbed dose rate; if measured values of that quantity are found to consistently exceed the intervention level, remedial action should be considered.

Ionizing radiation

radiation which is capable of causing ionization, either directly (for example: for radiation in the form of gamma rays and charged particles) or, indirectly (for example: for radiation in the form of neutrons).

Justification

the notion that human activities which lead to exposure to radiation should be justified, before they are permitted to take place, by showing that they are likely to do more good than harm.

Limitation

the requirement that radiation doses and risks should not exceed a value regarded as unacceptable.

Neutron

an elementary particle of mass 1.675×10^{-27} kg having some properties similar to the proton but carrying no charge; neutrons are constituents of all nuclei except for the stable isotope of hydrogen.

Optimization

the process of maximising the net benefit arising from human activities which lead to exposure to radiation.

Practice

a type of human activity; in a radiological context, a human activity which may result in exposure to ionizing radiation and to which a system of radiation protection applies.

Public exposure

exposure of a person, or persons, to radiation which is neither occupational nor medical exposure.

Radiation

electromagnetic waves or quanta, and atomic or sub-atomic particles, propagated through space or through a material medium.

Radiation weighting factor

a factor which modifies absorbed dose in an organ or tissue to yield equivalent dose and which is determined by the type and energy of the radiation to which the organ or tissue is exposed.

Radioactive decay

the spontaneous transformation of the nucleus of an atom into another state, accompanied by the emission of radiation; for a quantity of such atoms, the expectation value of the number of atoms present decreases exponentially with time.

Radioactive material

material which spontaneously emits ionizing radiation as a consequence of radioactive decay.

Radionuclide

a species of atomic nucleus which undergoes radioactive decay.

Responsible person

in relation to any radioactive source, radiation apparatus, prescribed radiation facility or premises on which unsealed radioactive are stored or used responsible person means the person:

(a) having overall management responsibility including responsibility for the security and maintenance of the source, apparatus, or facility;
(b) having overall control over who may use the source, apparatus, or facility; and
(c) in whose name the source, apparatus, or facility, would be registered if this is required.

Stochastic effect

an effect known to occur sometimes as a consequence of exposure to radiation, but which may or may not be expressed in a particular exposed person, the likelihood of the effect occurring being a function of the dose received.

Tissue weighting factor

a factor which modifies equivalent dose in an organ or tissue to yield effective dose and which is the partial contribution from the organ or tissue to the total detriment resulting from uniform irradiation of the whole body.

Annex A

STABLE IODINE PROPHYLAXIS

Summary

In the event of a radiation accident involving the release of the radioactive isotopes of iodine, there is the potential for internal radiation exposure following incorporation and uptake of radioiodine into the thyroid. This will occur through inhalation of contaminated air and ingestion of contaminated food and drink. Stable iodine administered before, or promptly after, intake of radioactive iodine saturates the thyroid gland and blocks or reduces the accumulation of radioactive iodine in the thyroid. Prompt action to implement stable iodine prophylaxis, and thereby reduce the dose to the thyroid, can avert a significant portion of the health impact. It is recommended that:

(a) The priority for emergency planning for stable iodine prophylaxis should be the protection of neonates, children aged under ten years, and pregnant and nursing women.

(b) A generic optimized intervention level for adults for iodine prophylaxis of 100 mGy thyroid dose provides an operational basis for prompt decision making and efficient application in the event of a radiation emergency involving the release of radioiodine.

(c) In planning for the administration of stable iodine for the protection of children, a generic optimized intervention level for iodine prophylaxis of 30 mGy thyroid dose is recommended in order to take into account the higher sensitivity to radioiodine of children and the embryo/fetus.

(d) Detailed emergency plans should provide for the stable iodine tablets to be administered promptly, as the health benefit afforded reduces with increased delay in administration.

(e) The pre-distribution of stable iodine tablets can be helpful in specific circumstances. For emergencies involving the release of radioiodine from a facility, pre-distribution of stable iodine to individual households in the Urgent Protective Action Zone may be used as part of local planning arrangements.

(f) The combination of sheltering with stable iodine prophylaxis should form an important element in the provision of overall protection.

(g) Although there are no strong grounds for preferring the iodate form over the iodide form, there is some evidence that the iodate form may be a stronger intestinal irritant.

(h) Emergency plans provide for the prompt implementation of food restrictions based on the appropriate recommended Action Levels.

(i) Continued administration of stable iodine should not replace other more appropriate response measures such as evacuation or food restriction.

Health Effects from Radioiodine

Thyroid cancer is one of the less common forms of cancer. The male age adjusted rates for thyroid cancer are in the range 7 to 60 per million men per year. The equivalent range for females is 16 to 255 per million women per year. Iodine intake, diet and other factors can affect risk factors (UNSCEAR 2000). Thyroid cancer is an uncommon form of cancer in children, with an incidence rate of about 1 to 2 cases per million per year in Australia for children under the age of 12 years. The risk for adolescents is ~6 cases per million and for adults ~45 cases per million. It is one of the most curable of cancers, with survival rates in Australia after treatment of ~95% after 5 years.

Exposure to radiation can increase the risk of thyroid cancer. This is discussed in more detail in ARPANSA Technical Report “Radiation and Thyroid Cancer Technical Considerations for the Use of Stable Iodine after a Nuclear Reactor Accident in Australia” (ARPANSA 2004). Studies on individuals exposed to external radiation or to internal exposure, from ingestion or inhalation of radioactive iodine, provide values for the radiation induced thyroid cancer risk. These risks are specified as:

- The excess relative risk (ERR), which is the ratio of the risk per unit exposure relative to the natural thyroid cancer rate at a particular age; or
- The excess absolute risk (EAR), which is the risk per unit exposure at a particular age.

The Life Span Study (LSS) of Hiroshima bomb survivors provides detailed estimates of age dependence of thyroid cancer for external radiation exposure. These results are summarised in the 2000 Report of the United Nations Committee on the Effects of Atomic Radiation (UNSCEAR 2000). For the LSS group, the relative risk decreases smoothly with age, and the values of relative risk are ten times higher for infants than for adolescents. However, the absolute risk is relatively constant for the 0 to 18 year group, with a value of ~4 per 10,000 Person.Year.Gy (P.Y.Gy).

The Chernobyl accident dispersed large quantities of radioactive iodine over Belarus, Russia and Ukraine, resulting in a significant thyroid dose to individuals, mainly through ingestion of contaminated milk and food. From studies in Belarus and Russia the most recent estimates for the absolute risk for child thyroid cancer are ~2.3 per 10,000 P.Y.Gy, for children <10 years and ~1 per 10,000 P.Y.Gy for adolescent <18 years. No statistically significant increase in thyroid cancers has been found from adult exposure. The dose response was linear from thyroid dose of less than 100 mGy to more than 2 Gy. The present estimates of absolute risk for internal exposure are about half that from the LSS studies, but the Chernobyl studies have only been followed for 15 years, and the rate may continue to rise.

The selective and rapid concentration and storage of radioactive iodine in the thyroid gland results in internal radiation exposure of the thyroid, which may lead to an increased risk of thyroid cancer and benign nodules and, at high doses, hypothyroidism. These risks can be reduced or even prevented by proper implementation of stable iodine prophylaxis.

Health Effects from Stable Iodine

The effectiveness of stable iodine as a specific blocker of thyroid radioiodine uptake is well established, as are the doses necessary for blocking uptake. As such, it is reasonable to conclude that stable iodine will likewise be effective in reducing the risk of thyroid cancer in individuals or populations at risk for inhalation or ingestion of radioiodines (WHO 1999).

Short-term administration of stable iodine at thyroid blocking doses involves an extremely low risk of any side effects (less than 1 in 10^6) and, in general, less risk in children than adults (WHO 1999). The risks of thyroidal side effects from stable iodine administration are likely to be higher in iodine deficient regions. These risks include sialadenitis (an inflammation of the salivary gland), gastrointestinal disturbances, allergic reactions and minor rashes. In addition, persons with known iodine sensitivity should avoid stable iodine. There is also an increased risk in connection with thyroid disorders, such as auto-immune thyroiditis, Graves' disease and nodular goitre. Such disorders are common in the adult population and in the elderly but relatively rare in children.

Neonates ideally should receive the lowest dose of stable iodine and repeat dosing should be avoided to minimize the risk of hypothyroidism during that critical phase of brain development. Stable iodine from tablets (either whole or fractions) or as fresh saturated solution may be diluted in milk, formula, or water and the appropriate volume administered to babies. It is recommended that neonates (within the first month of life) treated with stable iodine be monitored for this effect and that thyroid hormone therapy be instituted in cases in which hypothyroidism develops.

Pregnant women should be given stable iodine for their own protection and for that of the fetus, as iodine (whether stable or radioactive) readily crosses the placenta. However, because of the risk of blocking fetal thyroid function with excess stable iodine, repeat dosing with stable iodine of pregnant women should be avoided. Lactating females should be administered stable iodine for their own protection, as for other young adults, and potentially to reduce the radioiodine content of the breast milk, but not as a means to deliver stable iodine to infants, who should get their stable iodine directly.

In addition, advances in the preparation and storage of potassium iodide formulations in other countries have demonstrated this form to be as stable as potassium iodate. This leads to the conclusion that:

(a) The risks of adverse effects from the administration of a single dose of stable iodine are extremely low and should not be considered a significant cause for concern when determining Intervention Levels for stable iodine prophylaxis; and

(b) There is no strong medical reason for preferring the use of potassium iodate over potassium iodide, or vice versa.

Planning for Administration of Stable Iodine

The administration of stable iodine to the public is an effective early measure for the protection of the thyroid to prevent deterministic effects and to minimize stochastic effects for persons of any age. However, it is primarily intended for the protection of children and the embryo/fetus.

The decision to initiate stable iodine prophylaxis should generally be made on the basis of predetermined conditions specified in the emergency plans. These conditions can include the accident classification and levels of measurable quantities that will trigger response. For emergency planning purposes it is recommended that the implementation of iodine prophylaxis should be based on the use of optimised Generic Intervention Levels, which in turn are specified in terms of avertable dose.

Adults

The avertable dose is defined as the dose to be saved by the particular protective action; in this case, the difference between the dose to be expected with stable iodine prophylaxis and that to be expected without it. The principal, expected benefit of stable iodine prophylaxis is a reduction in the low risk of thyroid cancer incidence, whilst the main harmful consequences are potentially the risk of adverse reactions to stable iodine and the cost of maintaining plans to enable prompt administration of stable iodine, should the need arise.

> *It is recommended that an optimized Generic Intervention Level for iodine prophylaxis of 100 mGy thyroid dose for adults provides an operational basis for prompt decision making and efficient application in the event of a radiation emergency involving the release of radioiodine.*

Children

It is essential that the highest priority for stable iodine prophylaxis should be the protection of the thyroids of newborn babies (neonates), children, and pregnant and nursing women. In general, the potential benefit of iodine prophylaxis will be greater in the young, firstly because the small size of the thyroid means that a higher radiation dose is accumulated per unit intake of radioactive iodine. Secondly, the thyroid of the fetus, neonate and young infant has a higher yearly thyroid cancer risk per unit dose than the thyroid of an adult and, thirdly, the young will have a longer time span for the expression of the increased cancer risk.

There is currently no international consensus on the intervention level for child iodine prophylaxis. For radiation induced thyroid cancer the absolute risk is constant between the ages of 0 and 18 years and has a value of about 0.4 cases/million/year/mGy and drops to close to zero for adults. For exposed children, implementing iodine prophylaxis at a Generic Intervention Level of 100 mGy retains an additional risk of up to 40 cases (4 fatalities) per million persons per year (ARPANSA 2004). For the range of Australian radiation emergency scenarios involving the release of radioactive iodine, it is estimated that child exposure to this radioiodine could result in a maximum of 3 cases (0.3 fatalities), expected over the subsequent 50 years (ARPANSA 2004).

In a guidance document published in 1999, the WHO suggests that iodine prophylaxis for children be considered at a 10 mGy child thyroid dose (WHO 1999). The child thyroid cancer risk for 10 mGy is one tenth that for 100 mGy, but the health benefit does not scale proportionally. For the range of Australian radiation emergency scenarios involving the release of radioactive iodine from a loss of coolant accident, the application of protective measures at 10 mGy intervention level could result in a reduction of a maximum of 1.4 cases from the expected 3 cases expected over the next 50 years. The application of protective measures at the 50 mGy or 100 mGy intervention level would not reduce this estimate of cases (the projected child thyroid doses are below the intervention levels), while the implementation of child iodine prophyllaxis at 30 mGy intervention level could result in a reduction of a maximum of 1 case from these estimated 3 cases expected over the subsequent 50 years (ARPANSA 2004). There is a small health benefit in using a lower value than 100 mGy for the Intervention Level for child iodine prophylaxis, but there is minimal benefit in using 10 mGy over 30 mGy.

Full effectiveness of stable iodine for thyroidal blocking is achieved by administration shortly before exposure or as soon after as possible. For stable iodine prophylaxis to be effective against inhaled radioiodine, it must be administered within a few hours of the inhalation. Clearly, there is a trade-off between the number of people to whom stable iodine tablets are issued and the promptness with which they can be administered: enlarging the planning zone will not inevitably increase the overall level of protection achieved. The framework established for responding to an emergency must allow flexibility to tailor the response to the specific circumstances of the accident, and so to ensure that those most at risk are given priority in protection. A reduction to less than 30 mGy would provide only a small additional protection to exposed children, to be balanced against the implementation of emergency plans – for example, a possible delay in protection for those most at risk resulting from the requirements for the administration of stable iodine tablets to a larger population. On balance, issuing stable iodine at an Intervention Level of 30 mGy provides an adequate level of protection for children and would be more likely to be effectively implemented than an Intervention Level of 10 mGy.

> *In planning for the administration of stable iodine for the protection of children, an optimized Generic Intervention Level for iodine prophylaxis of 30 mGy thyroid dose is recommended in order to take into account the higher sensitivity to radioiodine of children and the embryo/fetus.*

Shelter in Place

The protective measure of shelter in place involves individuals going inside solidly constructed and reasonably airtight buildings, closing doors and windows, and turning off ventilation systems. The building materials can provide shielding against external irradiation, and can slow down the rate of ingress of radioactive material that could be inhaled.

Stable iodine prophylaxis has the potential to reduce a significant part of the risk resulting from inhalation of radioiodine, but it provides no protection against external irradiation by this radionuclide (ie from the plume or from contamination on the ground). Shelter in place, as a stand-alone protective measure, does not provide a substantial degree of protection against thyroid cancer risk, when radioisotopes of iodine are major components of the release. Used together, stable iodine prophylaxis and shelter in place offer a greater proportional degree of protection than simple multiplication of their individual effectiveness would indicate.

> *It is recommended that the combination of shelter in place with stable iodine prophylaxis should form an important element in the provision of overall protection.*

Food Restrictions

Stable iodine prophylaxis should be planned for protecting against the inhalation exposure pathway only. Other prompt measures should be planned to protect young children from exposure to radioiodine in food and milk. It is clear that the main exposure pathway to radioiodine from the Chernobyl accident, in Belarus, the Russian Federation and the Ukraine, was the ingestion of contaminated food, particularly milk.

To protect against inhaled radioactive iodine, a single dose of stable iodine would generally be sufficient, as it gives adequate protection for one day. Owing to the sensitivity of the neonate (newborn baby) and fetus thyroid to large doses of iodine, repeated administration of stable iodine should be avoided for neonates and pregnant and lactating women; in the event of a delay in imposing appropriate food restrictions, clear advice on dietary consumption is essential for these groups. Whilst repeated (daily) dosages of stable iodine would protect the thyroid gland from prolonged exposure to radioiodine in foods, the continued administration of stable iodine to provide protection against exposures that can be avoided by other means is clearly not desirable (and for neonates would be harmful).

It is recommended that emergency plans are in place for the prompt implementation of food restrictions based on the appropriate recommended Action Levels.

Stable Iodine Prophylactic Dosage

The recommended doses depend on age and are presented in Table A1. This advice is based on the use of tablets of 130 mg potassium iodide, or 170 mg potassium iodate, containing 100 mg stable iodine (WHO 1999).

Table A1: RECOMMENDED SINGLE DOSES OF STABLE IODINE ACCORDING TO AGE GROUP

Age group	Mass of stable iodine (mg)	Mass of potassium iodide (mg)	Mass of potassium iodate (mg)	Fraction of 100 mg (stable iodine) tablet
Neonates (birth to one month)	12.5	16	21	1/8
Infants (one month to 3 years)	25	32	42	1/4
Children (3 - 12 years)	50	65	85	1/2
Adolescents (over 12 years) and adults (including pregnant women and lactating mothers)	100	130	170	1

The dose for neonates is critical. The single dose of 12.5 mg stable iodine should not be exceeded. Potassium iodide solution may be used for accurate dosage or whole tablets may be divided, crushed and dissolved in milk or water and the appropriate fraction of the liquid administered to the infant.

In an emergency, administration of only one dose of stable iodine, which provides protection for 24 hours, should be sufficient to protect against the effects of inhaled radioiodine. Other interventions, including evacuation and control of foodstuffs if necessary, should be implemented to reduce the possibility of longer-term exposure to radioiodine via ingestion. Emergency workers may require longer-term protection against radioiodine and may then take one tablet every twenty-four hours, for a maximum of ten days, if necessary.

Contraindications

The WHO (WHO 1999) has indicated the following contraindications:

- past or present thyroid disease (e.g. active hyperthyroidism)
- known iodine hypersensitivity
- Dermatitis herpetiformis
- Hypocomplementaemic vasculitis.

Chemical Form, Storage and Packaging

The dosage is provided for both potassium iodide and potassium iodate. However, potassium iodide is preferred since potassium iodate may be a stronger intestinal irritant. Tablets should be stored in a cool, dry place, protected from light and moisture. The shelf life of the tablets will be indicated on the label as being five years from the date of manufacture. In Australia, the shelf life may be extended by the Therapeutic Goods Administration (TGA), following testing of the tablets. Labelling on the packaging must comply with TGA requirements in Australia.

Distribution of Stable Iodine

The effectiveness of stable iodine prophylaxis decreases with time after exposure to radioactive iodine. Thus, prompt administration, either before or within a few hours of exposure, is essential for the protective measure to be effective. Priority should be given to the most sensitive members of the population, that is, to children.

Some specific requirements should be taken into account when considering distribution of stable iodine tablets in Australia, in particular, iodine at the recommended dosages is currently listed under Schedule 2 of the Standard for Uniform Scheduling of Drugs and Poisons as published by the Therapeutic Goods Administration. Schedule 2 items are *"Substances which are for therapeutic use and which require supervision of their distribution, such that their availability to the public should be restricted to supply from pharmacies and, where there is no pharmacy service available, from general dealers in medicinal poisons"*.

The poisons' acts may permit administration of Schedule 2 items by specified groups, e.g. ambulance officers:

(i) at the direction of a medical practitioner; or

(ii) duly accredited or licensed person in each State or jurisdiction.

The pre-distribution of stable iodine tablets can be helpful in specific circumstances. For emergencies involving the release of radioiodine from a facility, pre-distribution of stable iodine to individual households in the Urgent Protective Action Zone may be used as part of local planning arrangements. For Australia, pre-distribution of tablets to suitable secure locations, e.g. police stations or ambulance stations in the suburbs and towns around a facilities with a nuclear reactor, including ports that host visiting nuclear powered warships, is recommended. Purchase of iodine from pharmacies should not be prohibited.

Stock of Tablets

Only the number of tablets required for a single dose to the population likely to require iodine prophylaxis, as determined from the intervention levels in Table 6, is required. The number of tablets pre-distributed to secure locations should be limited to the number that could be distributed within a couple of hours.

Information to be Provided with Stable Iodine Tablets

A patient information leaflet should be provided to the public at the time of emergency distribution of tablets. This leaflet might include the following advice:

- Why taking a tablet is necessary.
- The mass of iodine in each tablet.
- Who should take the tablets.
- The priority for prompt treatment of children.
- The dosage required by each age group.
- How the tablets should be taken (e.g. crushed and taken with water, milk, or fruit juice).
- When to take the tablet.
- Possible side effects.
- Whether there is a need to see a doctor afterwards.

Information and support may also be required for those people in areas where stable iodine prophylaxis is not required during an emergency. Planning for an emergency involving release of radioactive iodine sufficient to require implementing iodine prophylaxis should consider the need to provide advice to other groups requiring information about stable iodine, including general practitioners.

Annex B

HEALTH EFFECTS OF IONIZING RADIATION AND STANDARDS FOR CONTROL OF EXPOSURE

It is well known that high doses of ionizing radiation can cause harm, but there is continuing scientific uncertainty about effects at low doses. At levels of dose routinely encountered by members of the public and most present-day radiation workers, there is little or no epidemiological evidence of health effects. Radiation protection standards recognize that it is not possible to eliminate all radiation exposure, but they do provide for a system of control to avoid unnecessary exposure and to keep doses in the low dose range.

Extreme doses of radiation to the whole body (around 10 sievert* and above), received in a short period, cause so much damage to internal organs and tissues of the body that vital systems cease to function and death may result within days or weeks. Very high doses (between about 1 sievert and 10 sievert), received in a short period, kill large numbers of cells, which can impair the function of vital organs and systems. Acute health effects, such as nausea, vomiting, skin and deep tissue burns, and impairment of the body's ability to fight infection may result within hours, days or weeks. The extent of the damage increases with dose. However, 'deterministic' effects such as these are not observed at doses below certain thresholds. By limiting doses to levels below the thresholds, deterministic effects can be prevented entirely.

Doses below the thresholds for deterministic effects may cause cellular damage, but this does not necessarily lead to harm to the individual: the effects are probabilistic or 'stochastic' in nature. It is known that doses above about 100 millisievert, received in a short period, lead to an increased risk of developing cancer later in life. There is good epidemiological evidence – especially from studies of the survivors of the atomic bombings - that, for several types of cancer, the risk increases roughly linearly with dose, and that the risk factor averaged over all ages and cancer types is about 1 in 100 for every 100 millisievert of dose (i.e. 1 in 10,000 per millisievert).

At doses below about 100 millisievert, the evidence of harm is not clear-cut. While some studies indicate evidence of radiation-induced effects, epidemiological research has been unable to establish unequivocally that there are effects of statistical significance at doses below a few tens of millisieverts. Nevertheless, given that no threshold for stochastic effects has been demonstrated, and in order to be cautious in establishing health standards, the proportionality between risk and dose observed at higher doses is presumed to continue through all lower levels of dose to zero. This is called the linear, no-threshold (LNT) hypothesis and it is made for radiation protection purposes only.

There is evidence that a dose accumulated over a long period carries less risk than the same dose received over a short period. Except for accidents and medical exposures, doses are not normally received over short periods, so that it is appropriate in determining standards for the control of exposure to use a risk factor that takes this into account. While not well quantified, a reduction of the high-dose risk factor by a factor of two has been adopted internationally, so that for radiation protection purposes the risk of radiation-induced fatal cancer (the risk factor) is taken to be about 1 in 20,000 per millisievert of dose for the population as a whole.

* The sievert (Sv) is a unit of measurement of radiation dose (see ARPANSA's *Recommendations for limiting exposure to ionizing radiation (2002)*).

If the LNT hypothesis is correct, any dose carries some risk. Therefore, measures for control of exposure for stochastic effects seek to avoid all reasonably avoidable risk. This is called optimizing protection. However, risk in this sense may often be assessed in terms of risk to a population, and may not ensure sufficient protection of the individual. Consequently, the optimization approach is underpinned by applying dose limits that restrict the risk to individuals to an acceptable level. The fundamental regulatory philosophy is expressed in three principles, based on the recommendations of the International Commission on Radiological Protection (ICRP), which may be summarized as follows:

Justification: human activities that cause exposure to radiation may be permitted only if they do more good than harm;

Optimization of protection: exposure to radiation from justified activities should be kept as low as reasonably achievable, social and economic factors being taken into account; and

Limitation of individual dose: doses must not exceed the prescribed dose limits.

Determining what is an acceptable risk for regulatory purposes is a complex value judgement. The ICRP reviewed a number of factors in developing its recommendations, which have in general been internationally endorsed, including by the World Health Organization, the International Labour Organisation and the International Atomic Energy Agency. Australia's Radiation Health Committee, now established under the ARPANS Act[†], has recommended that the international standards be adopted in Australia. The recommended dose limits are summarized as follows:

Limit on effective dose*

	For occupational exposure	For members of the public
To limit individual risk	20 mSv per year, averaged over 5 years*	1 mSv in a year*

*for details, see ARPANSA's *Recommendations for limiting exposure to ionizing radiation (2002)*

In most situations, the requirements for limiting individual risk ensure that doses are below deterministic thresholds, but for cases where this does not apply, the recommended limits are as follows:

Annual limit on equivalent dose*

	For occupational exposure	For members of the public
To prevent deterministic effects		
in the lens of the eye	150 mSv	15 mSv
in the skin	500 mSv	50 mSv
in the hands and feet	500 mSv	–

*For details, see ARPANSA's *Recommendations for limiting exposure to ionizing radiation (2002)*

[†] The *Australian Radiation Protection and Nuclear Safety Act (1998)*

In the case of occupational exposure during pregnancy, the general principle is that the embryo or fetus should be afforded the same level of protection as is required for a member of the public. For medical workers, the ICRP recommends that there should be a reasonable assurance that fetal dose can be kept below 1 mGy[‡] during the course of the pregnancy. This guidance may be generalised to cover all occupationally exposed pregnant workers by keeping the fetal dose below 1 mSv. A full explanation of radiation protection principles and of the recommended standards for Australia is given in ARPANSA/NOHSC Radiation Protection Series No. 1: *Recommendations for limiting exposure to ionizing radiation (1995)* and *National standard for limiting occupational exposure to ionizing radiation* (both republished in 2002).

[‡] The gray (Gy) is a unit of radiation dose. For X-rays and gamma radiation, it is essentially equivalent to the sievert.

Annex C

USE AND 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 C1 lists the default OILs calculated on the basis of the characteristics of a significant reactor accident (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.

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 C1. 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.

Figure C1

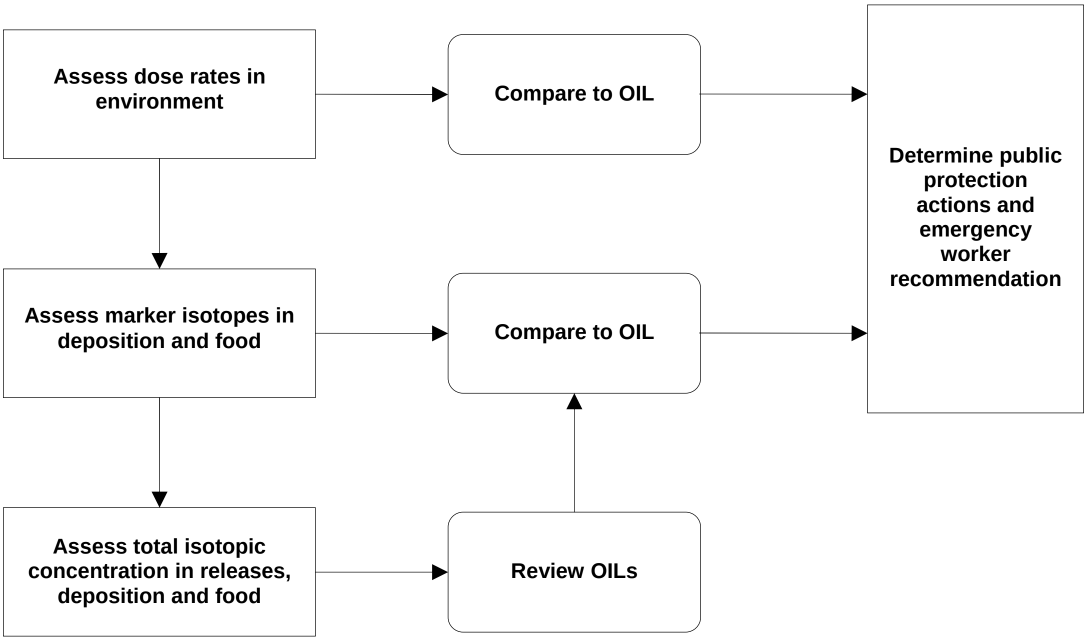


Table C1: Recommended Operational Intervention Levels in a Reactor Accident

Basis	OIL	Default value		Protective measure
Ambient dose rate in plume	OIL1	1 mSv/h [(a)]		Evacuation
	OIL2	100 µSv/h [(b)]		Sheltering
	OIL2	100 µSv/h		Iodine Prophylaxis Adult
	OIL2c	20 µSv/h		Iodine Prophylaxis Child
Marker radionuclide concentration in plume: I-131		50 kBq/m^3 [(c)]		Iodine Prophylaxis Adult
		10 kBq/m^3 [(c)]		Iodine Prophylaxis Child
Ambient dose rate from deposition	OIL3	1 mSv/h		Evacuation or substantial sheltering
	OIL4	200 µSv/h		Temporary relocation
	OIL5	1 µSv/h		Restriction of foodstuffs
Marker radionuclide concentrations in ground deposition		General food	Milk	
I-131	OIL6	10 kBq/m^2	2 kBq/m^2	Restriction of foodstuffs
Cs-137	OIL7	2 kBq/m^2	10 kBq/m^2	Restriction of foodstuffs
Marker radionuclide concentrations in food, milk, water		General food	Milk and water	
I-131	OIL8	1 kBq/kg	0.1 kBq/kg	Restriction of foodstuffs
Cs-137	OIL9	0.2 kBq/kg	0.3 kBq/kg	Restriction of foodstuffs

(a) If there is no indication of core damage or radioiodine is not present in the plume then, OIL1 = 10 mSv/h.

(b) If there is no indication of core damage or radioiodine is not present in the plume then, OIL2 = 1 mSv/h.

(c) Based on marker radionuclide I-131 delivering 50% of total thyroid dose from inhaled airborne radioactivity in the plume, over a 4 hour exposure

Assumptions used to Calculate Default Reactor-based OILs

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 C1 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 (Table 4) averted in one week.

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

OIL2: Take thyroid blocking agent based on ambient dose rates in the plume.

- Person is exposed for 4 hours, by which time a major 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 C1 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 mGy (100 mSv equivalent dose) (Table 5) can be averted.

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

- If the I-131 concentration in the plume is used as a marker radionuclide contributing 50% of total inhaled dose, then an exposure of an adult to 50 kB /m^3 of I-131 for 4 h would produce a thyroid dose of 100 mGy, based on the dose conversion factors in Table 5.

OIL2C: Take thyroid blocking agent based on ambient dose rates in the plume.

- Child is exposed for 4 hours, by which time a major wind shift would be expected.
- Unsheltered 10 year old 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 C1 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 below (200 × 0.41 / 0.23 ~ 350).
  - GIL_2 (Generic Intervention Level for iodine prophylaxis for children) organ dose of 30 mSv (Table 5) can be averted.

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

  - If the I-131 concentration in the plume is used as a marker radionuclide contributing 50% of total inhaled dose, then an exposure of a child to 20 kBq /m^3 of I-131 for 4 h would produce a thyroid dose of 30 mGy , based on the dose conversion factors in Table 5.

Committed Equivalent Dose To The Thyroid From One-Hour's Inhalation Of Contaminated Air

Radionuclide	Conversion factor [(mGy/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 (Table 5), 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 (Table 4) 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 (NRC 1993).
- The operational intervention level should be clearly higher than background (assumed 100 nSv/h), therefore the OIL5 was 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/m^2 (NRC 1977).
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 C2 [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 6).
$C_{g,\ j,\ core\ melt}$	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 using the transfer factors in Table C2 and the ratio of Cs-137 to the total of group 4 ≈ 0.3 (IAEA 1997).

Table C2: 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

PROCEDURE C1: REVISION OIL1

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 C1.
$\dot{H}_{thy}$	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].

PROCEDURE C2: REVISION OIL2

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 C1.
$\dot{H}_{thy}$	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 C2 [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].

PROCEDURE C3: 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 C1.

$\dot{H}_{thy}$ 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 C3: INHALATION DOSE RATE CONVERSATION FACTORS

Radionuclide	CF_1 Thyroid Inhalation Dose Conversion Factor [(mSv/h)/(kBq/m³)]	CF_2 Effective Inhalation Dose Conversion Factor [(mSv/h)/(kBq/m³)]
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}

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)]
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}
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.

PROCEDURE C4: REVISION OF OIL4

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 C4.
$CF_{4,i}$ Long term dose conversion factor for deposition from Table C4.

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 C5.
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 5.
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.

Table C4: 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}

Radionuclide	CF_3 (a) Ambient dose rate conversion factor for deposition [(mSv/h)/(kBq/m²)]	CF_4 (b) Long term dose conversion factor for deposition [(mSv/kBq/m²)]		
		1st Month	Subsequent Month	Lifetime (50 Year)
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}
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 1997

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 as recommended by U.S. EPA (US EPA 1992). 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].

Most principle isotopes contribute to the dose from external exposure from deposition for a reactor accident (NRC 1975).

This table 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 C5: 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.

PROCEDURE C5: REVISION OF OIL6

This procedure is used to recalculate the ingestion operational intervention levels OIL6 (deposition concentrations of marker isotopes I-131). OIL6s 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 6) 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 6.

$C_{g,I\text{-}131}$ 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 6) [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.

STEP 2

Prepare a set of recommended OIL for the major food types

PROCEDURE C6: REVISION OF OIL7

This procedure is used to recalculate the ingestion operational intervention levels OIL7 (deposition concentrations of marker isotopes Cs-137). 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 6) 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 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/m^2] 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 6.

$C_{g,Cs\text{-}137}$ Deposition concentration of Cs-137 [kBq/m^2] from field measurements.

$C_{G,i}$ Concentration of each radionuclide *I* in group G (see Table 6) [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.

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

n number of measured radionuclides in the isotope group G.

STEP 2

Prepare a set of recommended OIL for the major food types and provide to the Protective Action Manager.

PROCEDURE C7: REVISION OF OIL8

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. However, a complete isotopic analysis of all food types is not always practical, or can require considerable time or resources. 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 6). 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 6 [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 6 [kBq/kg].

STEP 3

Prepare a set of recommended OIL for the major food types and provide to the Protective Action Manager.

PROCEDURE C8: REVISION OF OIL9

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. However, a complete isotopic analysis of all food types is not always practical, or can require considerable time or resources. 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 6). 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 6 [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 6 [kBq/kg].

STEP 3

Prepare a set of recommended OIL for the major food types and provide to the Protective Action Manager.

If extensive food bans could result in shortages, then values of the operational intervention levels for the first week, which are 50 times higher, or the values for the first month, which are 10 times higher, are still reasonable (IAEA 1994a).

PROCEDURE C9: 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 C6.

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 C6: 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

Source: FEMA 1987

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 C7 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 C7 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

Element	Food	Preparation	RF
	Meat	boiling of meat	0.6
		boiling of bones	0.98
	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

Element	Food	Preparation	RF
		boiling bones	0.3
		frying	0.8
		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

Element	Food	Preparation	RF
	Milk	cream	0.07
		butter	0.006
		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

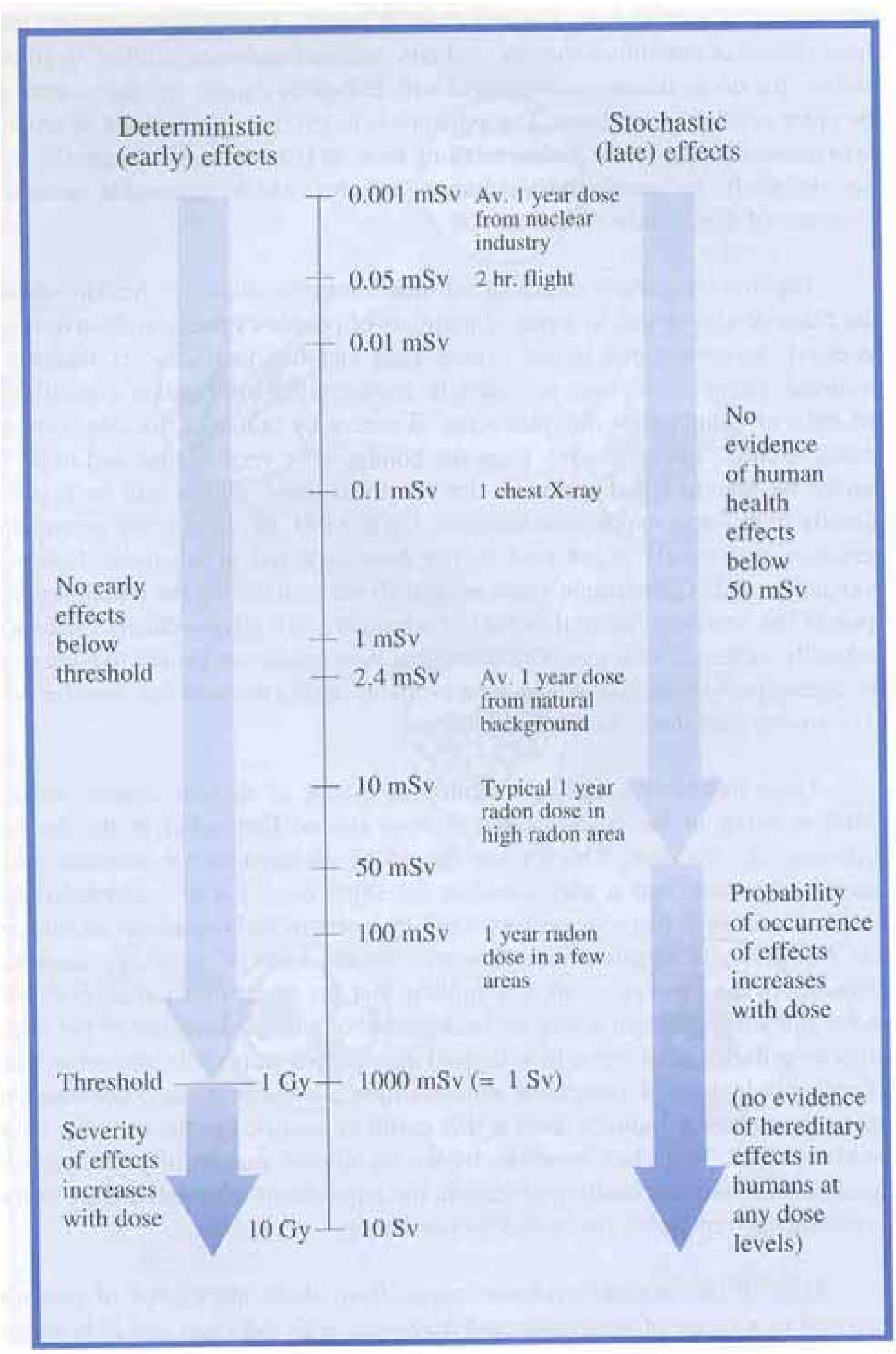
* Time between contamination of the surface and start of removal process.

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 D

EFFECTS OF RADIATION

(Source: Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD), *Radiation in Perspective – Application, Risks and Protection*, OECD, 1997, p. 54.)



Annex E

REGULATORY AUTHORITIES

Where advice or assistance is required from the relevant regulatory authority, it may be obtained from the following officers:

COMMONWEALTH, STATE / TERRITORY	CONTACT
Commonwealth	Director, Regulatory Branch ARPANSA PO Box 655 Tel: (02) 9541 8333 Miranda NSW 1490 Fax: (02) 9541 8348 Email: info@arpansa.gov.au
Australian Capital Territory	Manager Radiation Safety Radiation Safety Section ACT Health Locked Bag 5 Tel: (02) 6207 6946 Weston Creek ACT 2611 Fax: (02) 6207 6966 Email: radiation.safety@act.gov.au
New South Wales	Director Radiation Control Department of Environment and Conservation PO Box A290 Tel: (02) 9995 5000 Sydney South NSW 1232 Fax: (02) 9995 6603 Email: radiation@epa.nsw.gov.au
Northern Territory	Manager – Radiation Health Radiation Health Section Department of Health and Community Services GPO Box 40596 Tel: (08) 8922 7489 Casuarina NT 0811 Fax: (08) 8922 7334 Email: envirohealth@nt.gov.au
Queensland	Director, Radiation Health Department of Health 450 Gregory Terrace Tel: (07) 3406 8000 Fortitude Valley QLD 4006 Fax: (07) 3406 8030 Email: radiation_health@health.qld.gov.au
South Australia	Director, Radiation Protection Division Environment Protection Authority PO Box 721 Tel: (08) 8130 0700 Kent Town SA 5071 Fax: (08) 8130 0777 Email: radiationprotection.branch@state.sa.gov.au
Tasmania	Senior Health Physicist Health Physics Branch Department of Health and Human Services GPO Box 125B Tel: (03) 6222 7256 Hobart TAS 7001 Fax: (03) 6222 7257 Email: health.physics@dhhs.tas.gov.au
Victoria	Manager, Radiation Safety Program Department of Human Services GPO Box 4057 Tel: (03) 9637 4167 Melbourne VIC 3001 Fax: (03) 9637 4508 Email: radiation.safety@dhs.vic.gov.au
Western Australia	Secretary, Radiological Council Locked Bag 2006 Tel: (08) 9346 2260 Nedlands WA 6009 Fax: (08) 9381 1423 Email: radiation.health@health.wa.gov.au

Please note: This table was correct at the time of printing but is subject to change from time to time. For the most up-to-date list, the reader is advised to consult the ARPANSA web site (www.arpansa.gov.au). For after hours emergencies only, the police will provide the appropriate emergency contact number.

Annex F

ARPANSA RADIATION PROTECTION SERIES PUBLICATIONS

ARPANSA has taken over responsibility for the administration of the former NHMRC Radiation Health Series of publications and for the codes developed under the *Environment Protection (Nuclear Codes) Act 1978*. The publications are being progressively reviewed and republished as part of the *Radiation Protection Series.* Current publications in the *Radiation Protection Series* are:

RPS 1. Recommendations for Limiting Exposure to Ionizing Radiation (1995) and National Standard for Limiting Occupational Exposure to Ionizing Radiation (republished 2002)
RPS 2. Code of Practice for the Safe Transport of Radioactive Material (2001)
RPS 3. Radiation Protection Standard for Maximum Exposure Levels to Radiofrequency Fields – 3 kHz to 300 GHz (2002)
RPS 4. Recommendations on the Discharge of Patients undergoing Treatment with Radioactive Substances (2002)

Those publications from the NHMRC Radiation Health Series and the *Environment Protection (Nuclear Codes) Act* Series that are still current are:

RADIATION HEALTH SERIES

RHS 2. Code of practice for the design of laboratories using radioactive substances for medical purposes (1980)

RHS 3. Code of practice for the safe use of ionizing radiation in veterinary radiology: Parts 1 and 2 (1982)

RHS 4. Code of practice for the safe use of radiation gauges (1982)

RHS 8. Code of nursing practice for staff exposed to ionizing radiation (1984)

RHS 9. Code of practice for protection against ionizing radiation emitted from X-ray analysis equipment (1984)

RHS 10. Code of practice for safe use of ionizing radiation in veterinary radiology: part 3-radiotherapy (1984)

RHS 11. Code of practice for the safe use of soil density and moisture gauges containing radioactive sources (1984)

RHS 12. Administration of ionizing radiation to human subjects in medical research (1984)

RHS 13. Code of practice for the disposal of radioactive wastes by the user (1985)

RHS 14. Recommendations for minimising radiological hazards to patients (1985)

RHS 15. Code of practice for the safe use of microwave diathermy units (1985)

RHS 16. Code of practice for the safe use of short wave (radiofrequency) diathermy units (1985)

RHS 17. Procedure for testing microwave leakage from microwave ovens (1985)

RHS 18. Code of practice for the safe handling of corpses containing radioactive materials (1986)

RHS 19. Code of practice for the safe use of ionizing radiation in secondary schools (1986)

RHS 20. Code of practice for radiation protection in dentistry (1987)

RHS 21. Revised statement on cabinet X-ray equipment for examination of letters, packages, baggage, freight and other articles for security, quality control and other purposes (1987)

RHS 22. Statement on enclosed X-ray equipment for special applications (1987)

RHS 23. Code of practice for the control and safe handling of radioactive sources used for therapeutic purposes (1988)

RHS 24. Code of practice for the design and safe operation of non-medical irradiation facilities (1988)

RHS 25. Recommendations for ionization chamber smoke detectors for commercial and industrial fire protection systems (1988)

RHS 26. Policy on stable iodine prophylaxis following nuclear reactor accidents (1989)

RHS 28. Code of practice for the safe use of sealed radioactive sources in borehole logging (1989)

RHS 29. Occupational standard for exposure to ultraviolet radiation (1989)

RHS 30. Interim guidelines on limits of exposure to 50/60Hz electric and magnetic fields (1989)

RHS 31. Code of practice for the safe use of industrial radiography equipment (1989)

RHS 32. Intervention in emergency situations involving radiation exposure (1990)

RHS 34. Safety guidelines for magnetic resonance diagnostic facilities (1991)

RHS 35. Code of practice for the near-surface disposal of radioactive waste in Australia (1992)

RHS 36. Code of practice for the safe use of lasers in schools (1995)

RHS 37. Code of practice for the safe use of lasers in the entertainment industry (1995)

RHS 38. Recommended limits on radioactive contamination on surfaces in laboratories (1995)

ENVIRONMENT PROTECTION (NUCLEAR CODES) ACT SERIES

Code of Practice on the Management of Radioactive Wastes from the Mining and Milling of Radioactive Ores 1982

Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores 1987

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