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Guide for Radiation Protection in Existing Exposure Situations

Radiation Protection Series G-2

Radiation Protection Series

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) publishes Fundamentals, Codes and Guides in the Radiation Protection Series (RPS), which promote national policies and practices that protect human health and the environment from harmful effects of radiation. ARPANSA develops these publications jointly with state and territory regulators through the Radiation Health Committee (RHC), which oversees the preparation of draft policies and standards with the view of their uniform implementation in all Australian jurisdictions. Following agreement and, as relevant, approvals at the Ministerial level, the RHC recommends publication to the Radiation Health and Safety Advisory Council, which endorses documents and recommends their publication by the CEO of ARPANSA.

To the extent possible and relevant for Australian circumstances, the RPS publications give effect in Australia to international standards and guidance. The sources of such standards and guidance are varied and include the International Commission on Radiological Protection (ICRP); the International Commission on Non-Ionizing Radiation Protection (ICNIRP); the International Atomic Energy Agency (IAEA); and the World Health Organization (WHO).

Fundamentals set the fundamental principles for radiation protection and describe the fundamental radiation protection, safety and security objectives. They are written in an explanatory and non-regulatory style and describe the basic concepts and objectives of international best practice.

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Guides provide recommendations and guidance on how to comply with the Codes or apply the principles of the Fundamentals. They are written in an explanatory and non-regulatory style and indicate the measures recommended to provide good practice. They are generally expressed as 'should' statements.

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Radiation Protection Series G-2

12 September 2017

This publication was prepared jointly with the *Radiation Health Committee*. The *Radiation Health and Safety Advisory Council* advised the CEO to adopt the Guide.

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The mission of ARPANSA is to protect people and the environment from the harmful effects of radiation.

Published by the Chief Executive Officer of ARPANSA in September 2017.

Acknowledgement of Country

ARPANSA proudly acknowledges Australia's Aboriginal and Torres Strait Islander community and their rich culture and pays respect to their Elders past and present. We acknowledge Aboriginal and Torres Strait Islander people as Australia's first peoples and as the Traditional Owners and custodians of the land and water on which we rely.

We recognise and value the ongoing contribution of Aboriginal and Torres Strait Islander people and communities to Australian life and how this enriches us. We embrace the spirit of reconciliation, working towards the equality of outcomes and ensuring an equal voice.

Foreword

The management of risks from ionising radiation requires actions that are based on fundamental principles of radiation protection, safety and security. The *Fundamentals for Protection Against Ionising Radiation (2014)* (RPS F-1) was published as part of ARPANSA's Radiation Protection Series (RPS) to provide an understanding of the effects of ionising radiation and associated risks for the health of humans and the environment. RPS F-1 is the top tier document in the Australian national framework to manage risks from ionising radiation and explains how radiation protection, safety and security can work individually and collectively to manage radiation risks. Finally, it presents ten principles and their application in management of radiation risks.

This *Guide for Radiation Protection in Existing Exposure Situations* (2017) sets out the Australian approach to protection of occupationally exposed persons, the public and the environment in 'existing exposure situations', i.e. situations of exposure that already exist when a decision on the need for control is taken. Existing exposure situations include situations of elevated exposure to radiation of natural origin. They also include situations of exposure due to residual radioactive material that derives from past practices that were not subject to regulatory control or that remains after an emergency exposure situation.

ARPANSA, jointly with state and territory regulators in the Radiation Health Committee (RHC), has developed this Guide based on the requirements relating to existing exposure situations described in the Safety Requirements GSR Part 3 of the International Atomic Energy Agency (IAEA); *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards* (IAEA 2014). Further guidance material will be developed relating to existing exposure situations and made available in the form of case-specific studies.

I wish to thank all contributors to drafting and review, and commend this Guide to users and stakeholders across all Australian jurisdictions.

Carl-Magnus Larsson
CEO of ARPANSA

12 September 2017

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1. Introduction

1.1 Citation

This publication may be cited as the Existing Exposure Guide (2017).

1.2 Background

The International Commission on Radiological Protection (ICRP) in its *2007 Recommendations of the International Commission on Radiological Protection*, *ICRP Publication 103* (ICRP 2007), takes a consistent approach for all types of radiation **exposure** situations, with the central consideration being the **optimisation** of **radiation protection.**

This Guide applies to **existing exposure situations** and aims to promote the implementation of the relevant requirements of the International Atomic Energy Agency (IAEA) General Safety Requirements Part 3, *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards* (GSR Part 3) (IAEA 2014). Appendix 1 lists the guidance contained in this publication, cross-referenced to GSR Part 3. GSR Part 3 is published on the IAEA website [http://www-ns.iaea.org/standards/documents/general.asp].

1.3 Purpose

The purpose of this Guide is to provide guidance on protection of **occupationally exposed persons**, members of the public, and of the **environment**; from the harmful effects of **ionising radiation** in existing exposure situations.

1.4 Scope

This Guide applies to existing exposure situations, for the control of **occupational exposure**, **public exposure** and **environmental exposure**. Existing exposure situations are exposure situations that already exist when a decision on the need for control has to be taken, including prolonged exposure situations after emergencies. The Guide establishes a framework for existing exposure situations within Australia and is derived from recent ICRP and IAEA recommendations, in particular the requirements of GSR Part 3. These clauses in this Guide largely paraphrase GSR Part 3, to promote consistency with best practice for existing exposure situations.

Existing exposure situations in this Guide apply to exposure due to:

a) **contamination** of areas by residual **radioactive material** deriving from:

   (i) past activities that were never subject to **regulatory control** or that were subject to regulatory control but which resulted in situations that, if they were being controlled today, do not meet current radiation protection standards

   (ii) a **nuclear or radiological emergency**, after the response to the emergency has been declared to be ended

b) commodities, including food, animal feed, drinking water and construction materials, that incorporate radionuclides deriving from, or contaminated by, material stated in (a) above or contaminated by radioactive material

c) natural **sources**, including:

(i) **radon** and **radon progeny** in workplaces, other than those workplaces for which exposure due to other radionuclides in the uranium decay chain or the thorium decay chain is controlled as a **planned exposure situation**, in dwellings, and in other buildings with high **occupancy factors** for members of the public and workers who are not considered occupationally exposed

(ii) **radionuclides of natural origin**, regardless of activity concentration, in commodities including food, animal feed, drinking water, agricultural fertiliser and **soil amendments**, construction materials, and **residual radioactive material** in the environment

(iii) materials, other than those stated in (c)(ii) above, in which the activity concentration of no radionuclide in either the uranium decay chain or the thorium decay chain exceeds 1 Bq g^{-1} and the activity concentration of ^{40}K exceeds 10 Bq g^{-1}. When these conditions are exceeded in any **practice**, treatment as a planned exposure situation is required

(iv) exposure of aircrew to **cosmic radiation**.

The application of this guidance is intended to ensure that suitable **protective measures** are taken to reduce any adverse health effects, by preventing **tissue reactions** (deterministic effects) and by reducing the risk of **stochastic health effects** to both members of the public and workers, in existing exposure situations. It therefore considers all hazard types in Australia regardless of potential consequences. This guide applies a risk based approach when considering **justification** and optimisation of strategies for managing existing exposure including **remedial actions** and **protective actions**.

Wildlife may require protection in order to maintain biological diversity, conservation of species, or the health and status of natural habitats, communities or ecosystems, or anything that may be otherwise required from a conservation point of view in accordance with relevant legislation.

1.5 Interpretation

This Guide is explanatory in nature and is not required to be complied with per se. Jurisdictions may, at their discretion, mandate clauses in Section 3 within their respective legal and regulatory framework. While clauses in the *Code for Radiation Protection in Planned Exposure Situations* (RPS C-1) (ARPANSA 2016) do not apply directly to existing exposure situations, some remedial or protective actions may trigger relevant clauses in RPS C-1.

1.6 Structure

This Guide consists of four Sections, an Annex, two Appendices, a Glossary and References.

- Section 1 describes the background, purpose and scope of the Guide.
- Section 2 describes the radiation protection principles for existing exposure situations.
- Section 3 describes the framework for managing existing exposure situations.
- Section 4 describes considerations for radiation protection in existing exposure situations.
- Annex A provides guidance on the implementation of **reference levels** in existing exposure situations in Australia.
- Appendix 1 provides the existing exposure guide clauses from the GSR Part 3 Requirements.

- Appendix 2 provides the ten principles of **radiation risk** management from the fundamentals for protection against ionising radiation (RPS F-1).

The meanings of technical terms used in this Guide are defined in the Glossary. Terms defined in the Glossary appear in bold type on first mention in the text. Publications underpinning this Guide are listed in the References section.

Additional guidance relating to specific scenarios can be found with electronic versions of this Guide on the ARPANSA website, www.arpansa.gov.au.

2. Radiation protection principles for existing exposure situations

2.1 Principles for protection

The system of **protection and safety** aims to assess, manage and control exposure to radiation so that radiation risks, including risks of health effects and risks to the environment, are reduced to the extent reasonably achievable. The components of the system of protection and safety are illustrated in Figure 2.1.

The *Fundamentals for Protection Against Ionising Radiation* (RPS F-1) (ARPANSA 2014) sets out the underlying principles that form the basis of the system used to manage risks from ionising radiation in Australia. The ten principles are outlined in Appendix 2. The *Fundamentals* cover all circumstances of radiation exposure and should be applied to all sources and all individuals exposed to radiation, as well as to environmental exposures. All exposures are classified into the following three types of exposure situations consistent with the *2007 Recommendations of the International Commission on Radiological Protection*, *ICRP Publication 103* (ICRP 2007) and GSR Part 3 (IAEA 2014).

- **Planned Exposure Situations**: situations where radiation protection can be planned in advance, before exposures occur and where the magnitude and extent of exposures can be reasonably predicted. Planned exposure situations may result in exposures that are anticipated to occur (normal exposures) and in potential exposures that are not anticipated to occur, but may do so.

- **Emergency Exposure Situations**: situations that may occur during the operation of planned exposure situations if loss of control or breakdown of radiation protection occurs, or from malicious acts, or from any other unexpected situation that requires urgent action in order to reduce or avoid undesirable consequences. These exposure situations are not planned and exposures may not be able to be controlled.

- **Existing Exposure Situations**: these are exposure situations that already exist when a decision on control has to be taken, including prolonged exposure situations after emergencies.

The system also considers the three principles of radiation protection, being:

- justification (that any activity involving radiation should do more good than harm)
- optimisation (that actual exposure, likelihood of exposures and number of exposed persons should be as low as reasonably achievable (ALARA), taking into account economic and societal factors)
- **dose limits** (levels of radiation **dose** that must not, under normal circumstances, be exceeded).

Under Principle 10 of the *Fundamentals* (ARPANSA 2014), **protective measures** to reduce existing or unregulated radiation risks must be **justified** and optimised.

There are four categories of exposure identified in the *Fundamentals* (ARPANSA 2014), specifically:

- occupational (all exposure incurred by workers in the course of their work)
- public (exposure incurred by members of the public from radiation sources, excluding any occupational or **medical exposure** and the normal local **natural background** radiation)
- medical (incurred by patients undergoing medical diagnosis or treatment)
- environmental (associated with protection of the environment and incurred by non-human **biota** (or wildlife)).

Dose criteria serve as boundaries within which the optimisation process takes place and serve to reduce inequities of exposure. The three types of dose criteria are the following:

- reference levels (in emergency or existing controllable exposure situations, this represents the level of dose or risk, above which it is judged to be inappropriate to plan to allow exposures to occur, and below which optimisation of protection should be implemented; the chosen value for a reference level will depend upon the prevailing circumstances of the exposure under consideration for the public and non-human biota).
- **dose constraints** (a prospective and source-related restriction on the individual dose from a source, which provides a basic level of protection for the most highly exposed individuals from a source, and serves as an upper bound on the dose in optimisation of protection for that source).
- dose limits (the value of the **effective dose** or the **equivalent dose** from planned exposure situations that shall not be exceeded).

For protection of non-human biota, the *Guide for Radiation Protection of the Environment* (RPS G-1) (ARPANSA 2015) provides guidance on screening dose rates and methodologies that may assist in reaching a regulatory decision. Further guidance on environmental protection under different exposure situations can be found in *ICRP Publication 124* (ICRP 2014).

Figure 2.1: The system of radiological protection, illustrating the interrelationships between the principles of protection, the exposure situations, the categories of exposure, the dose criteria, and the application of the system.

The implementation of the system of radiological protection requires that the exposure situation is well understood through an assessment that considers all relevant aspects of the exposure. The information from the assessment will form the basis for decisions on actions (if deemed necessary). Such decisions need to be taken in a transparent manner including, as relevant, taking the views and knowledge of stakeholders into consideration. Stakeholders are regarded as an asset who will contribute knowledge to the process, and the consultation contributes to informed decisions and the best possible outcomes. Accountabilities need to be established and communicated, so that it becomes clear who the decision maker is and on what grounds decisions are taken.

2.2 Identification of existing exposure situations

Existing exposure situations are exposures from sources that already exist when decisions to control them are made. The source can be natural, such as cosmic radiation in aviation and space flights, **naturally occurring radioactive material (NORM)**, or radon. The source can also be artificial, such as contaminated sites from past activities or **accidents**.

Existing exposure situations have a number of common features. Exposures often affect places of living and day-to-day activities. The exposures need to be measured and the distribution of individual doses can be very wide. Existing exposure situations do not present a potential for accidents. In many cases, the exposure can be at least partially controlled by exposed individuals themselves (self-help protection).

Protection of the environment should be considered in existing exposure situations. Unlike protection of people, protection of non-human biota addresses protection of populations/ecosystems and not individuals. Further guidance for the protection of non-human biota is provided in RPS G-1 (ARPANSA 2015).

To understand if there is a problem the exposure situation needs to be characterised to determine the nature of the source and the different **exposure pathways** to people and the environment. This will provide an understanding of the feasibility and net benefits of preventive measures, which would be directed in reducing or preventing exposures. For a national approach to environmental health risk assessment, the enHealth presents a general methodology applicable to a range of environmental health hazards (enHealth 2012).

Some work environments and activities may entail exposures that need to be managed as existing exposure situations, using reference levels to guide optimisation (for example, aircrew exposed to cosmic radiation at cruising altitude and workers exposed to radon in the workplace). In other cases, the nature of the work activity and associated exposures may warrant treatment as planned exposure situations and be subject to dose limits and constraints (e.g. workforce involved in **remediation** of existing (legacy) situations). The employer in all circumstances has primary responsibility for the protection of workers and the management of exposures. Once an exposure has been identified, careful management is needed, applying a **graded approach**.

Figure 2.2 shows a systematic way for identifying and managing an existing exposure situation. The decision box titled 'Is control justified?' determines whether there is a need to take protective measures (e.g. remedial actions and/or protective actions) If after a risk characterisation has been completed and it is determined that there is no significant potential for radiological exposure, no protective measures are required. If it is determined that there is a significant potential for radiological exposure within an existing exposure situation, a protection strategy should be developed and justified that considers remedial actions and/or protective actions. In some situations, protection must be achieved through management in accordance with RPS C-1 (ARPANSA 2016) on radiation protection in planned exposure situations.

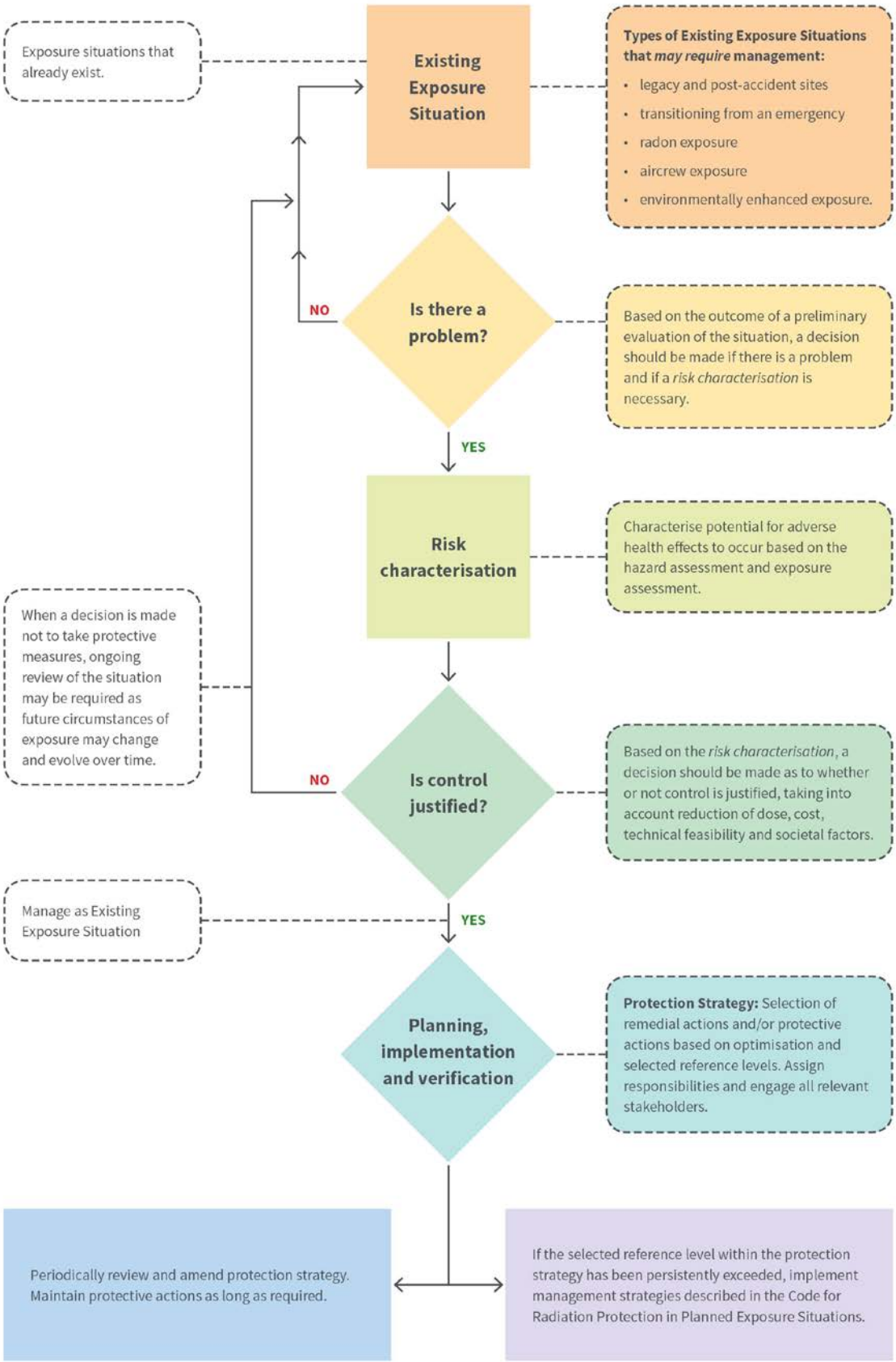

Figure 2.2: A systematic way for identifying an existing exposure situation and chose management strategy. Refer to enHealth guidance for a national approach to environmental health risk assessment (enHealth 2012).

2.3 Protection strategy

In planned exposure situations, protective actions can be implemented prior to the introduction of a source and are thus effective from the moment a radiation source is introduced. In emergency exposure situations, they must often be implemented urgently in order to be efficient and are sometimes based on incomplete information. In existing exposure situations, protective measures are implemented *after* characterisation of the exposure situation, and it generally takes time to progressively reduce or maintain exposures through optimisation. However, regardless of the type of exposure situation, protective measures can be envisaged and planned in advance.

When a decision is made not to take protective measures, ongoing review of the situation should be considered as future circumstances of exposure may change and evolve over time.

When an existing exposure situation is identified, responsibilities for protection and safety should be assigned and appropriate reference levels should be established.

Reference levels should be used prospectively in the planning phase and retrospectively as a benchmark for evaluating the effectiveness of the remedial and/or protective actions that have been implemented.

Protection strategies supported by a **safety assessment** that describes the appropriate remedial action plan or protection plan is aimed at the timely and progressive reduction of the radiation risks. Eventually, if possible, the removal of restrictions on the use of, or access to the area, or the removal of protective actions of a particular situation may be lifted.

A safety assessment should be used as a documented process for the evaluation of safety — for example, evaluation of the magnitude of hazards, evaluation of the performance of safety measures and judgement of their adequacy, or quantification of the overall radiological impact or safety of the existing exposure situation.

Remedial and/or protective actions should be justified, by use of decision-aiding techniques and processes, as necessary, resulting in a net positive benefit, taking account all relevant factors that are to be considered in the planning and implementation of the protection strategy.

Verification of the effectiveness of specific remedial and/or protective actions is important throughout the remedial action plan or protection plan. This involves comparison of the actual radiological exposures against the initial estimates, and the measures established for their control. If the actual exposures significantly differ from the initial estimates, the plan should be revised to account for the actual conditions being experienced. In cases where the actual exposures exceed those predicted, an investigation should be undertaken to improve understanding of the situation, and to prevent exposures that are higher than anticipated.

For exposures in workplaces that persist above the reference level, and it is not possible to reduce exposure below this reference level, then workers should be considered as occupationally exposed. In such cases, the application of the relevant clauses for occupational exposure in planned exposure situations as described in the *Code for Radiation Protection in Planned Exposure Situations*, RPS C-1 (ARPANSA 2016) apply.

The relevant **regulatory body** should review the integrity of the final remediation or protection report and use the information that has been provided to verify the nature, extent and duration of any post-remediation or post-protection control measures and their effectiveness.

3. Framework for managing existing exposure situations

The framework for managing existing exposure situations is derived from the requirements of GSR Part 3 (IAEA 2014) and is based on the most recent Recommendations of the ICRP, as laid out in *Publication 103* (ICRP 2007).

3.1 General guidance

Responsibilities specific to existing exposure situations

3.1.1 When an existing exposure situation is identified, responsibilities for protection and safety should be assigned and appropriate reference levels should be established (see Annex A).

3.1.2 The legal and regulatory framework for protection and safety should include provision for the management of existing exposure situations. The legal and regulatory framework, should as appropriate:

(a) specify the types of exposure situations that are included in the scope of existing exposure situations[1]

(b) specify the general principles underlying the protection strategies developed to reduce exposure when remedial actions and protective actions have been determined to be justified[2]

(c) assign responsibilities for the establishment and implementation of protection strategies to the relevant authorities and, as appropriate, to registrants, licensees and other parties involved in the implementation of remedial actions and protective actions

(d) provide for the involvement of interested parties in decisions regarding the development and implementation of protection strategies.

3.1.3 An established protection strategy for an existing exposure situation should ensure that it specifies:

(a) the objectives to be achieved by means of the protection strategy

(b) appropriate reference levels (see Annex A).

3.1.4 The implementation of the protection strategy should include:

(a) arrangements for evaluation of the available remedial actions and protective actions for achieving the objectives, and for evaluation of the efficacy of the actions planned and implemented

(b) ensuring that information is available, to individuals subject to exposure, on potential health risks and on the means available for reducing their exposures and the associated risks.

(c) consideration of environmental exposures and risks to non-human biota.

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[1] In the case of exposure due to radon, the types of situations that are included in the scope of existing exposure situations will include exposure in workplaces for which the exposure due to radon is not required by or directly related to the work and for which annual average activity concentrations due to ^{222}Rn might be expected not to exceed the derived reference level established in accordance with clause 3.3.3.

[2] Such actions include remedial actions such as the removal or reduction of the source giving rise to the exposure, as well as other longer term protective actions such as restriction of the use of construction materials, restriction of the consumption of foodstuffs and restriction of land use or of access to land or buildings.

3.2 Guidance for public exposure

The clauses in respect of public exposure in existing exposure situations (clauses 3.2.1-3.2.17) apply to any public exposure arising from the situations specified in Section 1.4.

Justification for protective actions and optimisation of protection and safety

3.2.1 A protection strategy for the management of existing exposure situations should be established in accordance with clauses 3.1.1 and 3.1.3, commensurate with the radiation risks associated with the existing exposure situation, and that remedial actions or protective actions are expected to yield sufficient benefits to outweigh the detriments associated with taking them, including detriments in the form of radiation risks.[3]

3.2.2 Remedial actions or protective actions should ensure that the form, scale and duration of such actions are optimised. While this optimisation process is intended to provide optimised protection for all individuals and non-human biota subjected to exposure, priority must be given to those groups for whom the dose exceeds the reference level. All reasonable steps should be taken to prevent doses from remaining above the reference levels. Reference levels should typically be expressed as an annual effective dose to the **representative person** in the range of 1-20 mSv or other corresponding quantity, the actual value depending on the feasibility of controlling the situation and on experience in managing similar situations in the past. For non-human biota, general guidance outlined in RPS G-1 (ARPANSA 2015) can be applied, as appropriate.

3.2.3 There should be a periodic review of reference levels to ensure that they remain appropriate in the light of the prevailing circumstances.

Responsibilities for remediation of areas with residual radioactive material

3.2.4 For the remediation of areas with residual radioactive material deriving from past activities or from a nuclear or radiological emergency (Section 1.4(a)), provisions should be made in the framework for protection and safety for:

(a) the identification of those persons or organisations responsible for the contamination of areas and those responsible for financing the remediation program, and the determination of appropriate arrangements for alternative sources of funding if such persons or organisations are no longer present or are unable to meet their liabilities

(b) the designation of persons or organisations responsible for planning, implementing and verifying the results of remedial actions

(c) the establishment and ongoing review of any restrictions on the use of or access to the areas concerned before, during and, if necessary, after remediation

(d) an appropriate system for maintaining, retrieval and amendment of records which cover: the nature and the extent of contamination; the decisions made before, during and after remediation; and information on verification of the results of remedial actions, including the results of all monitoring programs after completion of the remedial actions.

[3] The implementation of remedial actions (remediation) does not imply the elimination of all radioactivity or all traces of radioactive substances. The optimisation process may lead to extensive remediation but not necessarily to the restoration of previous conditions.

3.2.5 A strategy for **radioactive waste** management should be put in place to deal with any waste arising from the remedial actions, ensuring that provision for such a strategy is made in the framework for protection and safety.

3.2.6 The persons or organisations responsible for the planning, implementation and verification of remedial actions should, as appropriate, ensure that:

(a) a remedial action plan, supported by a **safety assessment**, is prepared and is submitted to the relevant regulatory body for approval

(b) the remedial action plan is aimed at the timely and progressive reduction of the radiation risks and eventually, if possible, the removal of restrictions on the use of or access to the area;

(c) any additional doses received by members of the public as a result of the remedial actions are justified on the basis of the resulting net benefit, including consideration of the consequent reduction of the annual dose

(d) in the choice of the optimised remediation option:

(i) radiological impacts on people and the environment are considered together with non-radiological impacts on people and the environment, including technical, societal and economic factors

(ii) the costs of the transport and management of radioactive waste, the radiation exposure of and health risks to the workers managing the radioactive waste, and any subsequent public or environmental exposure associated with its disposal are all taken into account.

(e) a mechanism for public information is in place and interested parties are involved in the planning, implementation and verification of the remedial actions, including any monitoring following remediation

(f) a monitoring program is established and implemented

(g) a system is in place for maintaining adequate records relating to the existing exposure situation and for actions taken for protection and safety is in place

(h) procedures are in place for reporting to the relevant regulatory body on any abnormal conditions relevant to protection and safety.

3.2.7 The relevant regulatory body should take responsibility for:

(a) review of the safety assessment submitted by the responsible person or organisation, approval of the remedial action plan and of any subsequent changes to the remedial action plan, and granting of any necessary **authorisation**

(b) establishment of criteria and methods for assessing safety

(c) review of work procedures, monitoring programs and records

(d) review and approval of significant changes to procedures or equipment that may have radiological environmental impacts or that may alter the exposure conditions for workers taking remedial actions or for members of the public

(e) where necessary, establishment of regulatory requirements for control measures following remediation.

3.2.8 The person or organisation responsible for carrying out the remedial actions should:

(a) ensure that the work, including management of the radioactive waste arising from that work, is conducted in accordance with the remedial action plan

(b) take responsibility for all aspects of protection and safety, including undertaking a safety assessment

(c) monitor the area regularly during remediation so as to verify levels of contamination, to verify compliance with the requirements for radioactive waste management, and to enable any unexpected levels of radiation to be detected and the remedial action plan to be modified accordingly, subject to the approval of the relevant regulatory body

(d) perform a radiological survey after completion of remedial actions to demonstrate that the end point conditions, as established in the remedial action plan, have been met

(e) prepare and retain a final remediation report and should submit a copy to the relevant regulatory body.

3.2.9 After the remedial actions have been completed, the relevant regulatory body should:

(a) review, amend as necessary, and formalise the type, extent and duration of any post-remediation control measures already identified in the remedial action plan, with due consideration of the residual radiation risks

(b) identify the person or organisation responsible for any post-remediation control measures;

(c) where necessary, impose specific restrictions for the remediated area to control:

(i) access by unauthorised persons or for unauthorised activities

(ii) removal of radioactive material or use of such material, including its use in **commodities**

(iii) future use of the area, including the use of water resources and its use for the production of food or animal feed, and the consumption of food from the area

(d) Periodically review conditions in the remediated area and, if appropriate, should amend or remove any restrictions.

3.2.10 The person or organisation responsible for post-remediation control measures should establish and maintain, for as long as required by the relevant regulatory body, an appropriate program, including any necessary provision for monitoring, to verify the long term effectiveness of the completed remedial actions for areas in which controls are required after remediation.

3.2.11 For those areas with long lasting residual radioactive material, in which a decision has been made to allow habitation and the resumption of social and economic activities, the relevant regulatory body, in consultation with interested parties should ensure that arrangements that are in place, as necessary, for the continuing control of exposure with the aim of establishing conditions for sustainable living, including:

(a) establishment of reference levels for protection and safety that are consistent with day-to-day life

(b) establishment of an infrastructure to support continuing 'self-help protective actions' in the affected areas, such as by the provision of information and advice, and by monitoring.

3.2.12 The conditions prevailing after the completion of remedial actions, if no restriction or controls have been imposed, should be considered to constitute the background radiation conditions for the purpose of assessing the radiological impact resulting from any future use of the site.

Public exposure due to radon indoors

3.2.13 As stated in clause 3.1.2, there should be assurance that:

(a) information is gathered on activity concentrations of radon in dwellings and other buildings with high occupancy factors for members of the public[4], through appropriate means, such as representative radon surveys (see Section 4.2)

(b) relevant information on exposure due to radon and the associated health risks, including the increased risks related to smoking, is provided to the public and other interested parties.

3.2.14 Where activity concentrations of radon, that are of concern for public health and workers that are not considered occupationally exposed, are identified on the basis of the information gathered as required in clause 3.2.13 (a), an action plan should be established comprising coordinated actions to reduce activity concentrations of radon in existing buildings and in future buildings, which includes[5]:

(a) establishing an appropriate **derived reference level** for ^{222}Rn for dwellings and other buildings with high occupancy factors for members of the public, with account taken of the prevailing social and economic circumstances that in general will not exceed an annual average activity concentration due to ^{222}Rn of 200 Bq m^{-3} [6] (see Annex A)

(b) reducing activity concentrations of ^{222}Rn and consequent exposures to levels at which protection is optimised

(c) giving priority to actions to reduce activity concentrations of ^{222}Rn in those situations for which such action is likely to be most effective[7]

(d) amending building codes to include appropriate preventive measures and corrective actions to prevent the ingress of ^{222}Rn and to facilitate further actions wherever necessary.

3.2.15 Responsibility should be assigned for:

(a) establishing and implementing the action plan for controlling public exposure due to ^{222}Rn indoors

(b) determining the circumstances under which actions are to be mandatory or are to be voluntary, with account taken of legal requirements and of the prevailing societal and economic circumstances.

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4 Buildings with high occupancy factors for members of the public including kindergartens, schools and hospitals.

5 Guidance on the preparation of an action plan for radon is provided by the World Health Organization (WHO 2009).

6 On the assumption of an equilibrium factor for ^{222}Rn of 0.4 and an annual occupancy of 7000 h, the value of activity concentration due to ^{222}Rn of 200 Bq m^{-3} corresponds to an annual effective dose of 10 mSv.

7 Examples of giving priority to reducing activity concentrations of ^{222}Rn in those situations for which such action is likely to be most effective include (i) specifying the levels of activity concentrations of ^{222}Rn in dwellings and other buildings with high occupancy factors at which protection can be considered optimised; (ii) identifying radon prone areas; (iii) identifying characteristics of buildings that are likely to give rise to elevated activity concentrations of ^{222}Rn; and (iv) identifying and requiring preventative measures for radon in future buildings that can be introduced at relatively low cost.

Exposure due to radionuclides in commodities

3.2.16 There should be established specific reference levels for exposure due to radionuclides in commodities such as construction materials, food, animal feed and drinking water, each of which should typically be expressed as, or be based on, an annual effective dose to the representative person that generally does not exceed a value of about 1 mSv (see Annex A).

3.2.17 Consideration should be given to the guideline levels for radionuclides in food traded internationally that could contain radioactive substances as a result of a nuclear or radiological emergency, which have been published by the Joint Food and Agriculture Organization of the United Nations, and the World Health Organization Codex Alimentarius Commission (FAO/WHO 2016). Consideration should be given to the guideline levels for radionuclides contained in drinking water that have been published by the World Health Organization (WHO 2011) (see Annex A).

3.3 Guidance for occupational exposure

The clauses in respect of occupational exposure in existing exposure situations (clauses 3.3.1-3.3.8) apply to any occupational exposure arising from the situations specified in Section 1.4.

Exposure in occupationally exposed workplaces

3.3.1 The clauses in respect of public exposure stated in clauses 3.2.1-3.2.3 should be applied to protection and safety for workers in existing exposure situations, other than in those specific situations identified in clauses 3.3.2-3.3.8.

Remediation of areas with residual radioactive material

3.3.2 Employers should ensure that the exposure of workers undertaking remedial actions is controlled in accordance with the relevant clauses on occupational exposure in planned exposure situations as established in Section 3 of the *Code for Radiation Protection in Planned Exposure Situations*, RPS C-1 (ARPANSA 2016).

Exposure due to radon in workplaces

3.3.3 A strategy for protection against exposure due to ^{222}Rn in workplaces should be established, including the establishment of an appropriate reference level for ^{222}Rn. The derived reference level for ^{222}Rn should be set at a value which does not exceed an annual average activity concentration of ^{222}Rn of 1000 Bq m^{-3}, with account taken of the prevailing social and economic circumstances[8] (see Annex A).

3.3.4 Employers should ensure that activity concentrations of ^{222}Rn in workplaces are as low as reasonably achievable below the derived reference level established in accordance with clause 3.3.3, and should ensure that protection is optimised.

[8] On the assumption of an equilibrium factor for ^{222}Rn of 0.4 and an annual occupancy of 2000 h, the value of activity concentration due to ^{222}Rn of 1000 Bq m^{-3} corresponds to an annual effective dose of 10 mSv.

3.3.5 If, despite all reasonable efforts by the employer to reduce activity concentrations of radon, the activity concentration of ^{222}Rn in workplaces remains above the derived reference level established in accordance with clause 3.3.3, the relevant clauses for occupational exposure in planned exposure situations as stated in Section 3 of the *Code for Radiation Protection in Planned Exposure Situations*, RPS C-1 (ARPANSA 2016) Planned Exposure Code, ARPANSA C-1 must apply.

Exposure of aircrew due to cosmic radiation

3.3.6 A determination should be made of whether an assessment of the exposure to aircrew due to cosmic radiation is warranted (see Section 4.3).

3.3.7 Where such assessment is deemed to be warranted, there should be an established framework which should include a reference level of dose and a methodology for the assessment and recording of doses received by aircrew from occupational exposure to cosmic radiation (see Annex A).

3.3.8 In accordance with clause 3.3.7:

(a) where the doses of aircrew are likely to exceed the reference level, employers of aircrew should:

(i) assess and keep records of doses

(ii) make records of doses available to aircrew

(iii) apply the relevant clauses for occupational exposure in planned exposure situations as stated in Section 3 of the *Code for Radiation Protection in Planned Exposure Situations*, RPS C-1 (ARPANSA 2016).

(b) employers should:

(i) inform female aircrew of the risk to the embryo or foetus due to exposure to cosmic radiation and of the need for early notification of pregnancy

(ii) apply the clause 3.2.12 in the *Code for Radiation Protection in Planned Exposure Situations*, RPS C-1 (ARPANSA 2016) in respect of notification of pregnancy.

4. The Australian context: specific guidance on the implementation of radiation protection in existing exposure situations in Australia

GSR Part 3 requires that when an existing exposure situation is identified, responsibilities for protection and safety are assigned and appropriate reference levels are established. Reference levels are used for optimisation of protection in existing exposure situations. For occupational exposure and public exposure in existing exposure situations, a reference level serves as a boundary condition in identifying the range of options for the purpose of optimisation in implementing protective actions. The reference level represents the level of dose or the level of risk above which it is judged to be inappropriate to plan to allow exposures to occur, and below which the optimisation of protection and safety is implemented.

GSR Part 3 requires that the reference level is set in the range of 1-20 mSv effective dose per year. The actual value chosen for the reference level will depend on the prevailing circumstances for the exposures under consideration. The optimised protection strategies are intended to keep doses below the reference level. When an existing exposure situation has been identified, actual exposures could be above or below the reference level. The reference level is used as a benchmark for judging whether further protective actions are necessary and, if so, in prioritising their application.

The main factors to be considered for setting reference levels for existing exposure situations are the feasibility of controlling the situation, and past experience with the management of similar situations. In most existing exposure situations, there is a desire from the exposed individual, as well as from the authorities, to reduce exposures to levels that are close to or similar to situations considered as 'normal'. This applies particularly in situations of exposures from material resulting from human actions, such as NORM residues and contamination from accidents (ICRP 2007). While an endpoint for the optimisation process should not be fixed, the optimised level of protection will depend on the situation. It is possible to establish intermediate reference levels (see Figure 4.1) that provide a starting point for the optimisation process.

For existing exposure situations involving environmental contamination of a nature that may affect non-human biota, an initial assessment should be conducted to characterise the existing radiological conditions for the contaminated area, including baseline background data. This should include identifying the sources and pathways of exposure for key receptor organisms, estimating the dose rates to those organisms, and comparing with relevant environmental benchmarks as outlined in RPS G-1 (ARPANSA 2015).

When a decision is made not to take protective actions, ongoing review of the situation may be required since future circumstances of exposure may change and evolve over time.

When considering remedial actions in a certain area (e.g. location) the optimisation of protection of humans should take into account and be balanced with the impact of non-human biota in other areas, for example, relocation of waste (ICRP 2014). Considerations should be given when the protection of humans may result in irreversible impacts to the environment (such as when large removal of soil is considered). Optimisation for the protection of non-human biota (which considers populations and not individuals) is not necessarily the reduction of exposures to the most exposed individuals, but could be the reduction of the size of the area affected or the reduction of the number of individuals exposed. A proper balance should be reached to ensure more good than harm, when considering both optimisation for the protection of the public and non-human biota.

A decision should then be made as to what management or intervening action may be required, taking full account of the costs and benefits of the action. The outcome of the initial assessment should help guide the decision-making process.

Verification of the effectiveness of specific protective and remedial actions is important throughout the remediation process. This involves comparison of the actual radiological exposures against the initial estimates, and the measures established for their control. Employers should ensure that the exposure of workers undertaking remedial actions is controlled in accordance with the relevant clauses of occupational exposure in planned exposure situations as stated in the *Code for Radiation Protection in Planned Exposure Situations*, RPS C-1 (ARPANSA 2016). If the actual exposures significantly differ from the initial estimates, the plan should be revised to account for the actual conditions being experienced. In cases where the actual exposures exceed those predicted, an investigation should be undertaken to improve understanding of the situation, and to prevent actual doses that are higher than anticipated.

Authorities, taking into account the prevailing circumstances, may take advantage of the timing of the overall remediation program to adopt intermediate reference levels to improve the situation progressively (ICRP 2009). In cases of severe contamination, or lack of resources to comply with a full remediation program, it may be considered advantageous to select an intermediate reference level and then, in the light of experience and resource availability, revise the reference level. Intermediate reference levels can facilitate timely decision-making on remediation strategies and the effective deployment of resources. However, when establishing intermediate reference levels, consideration should again be given to the principles of justification and optimisation.

When selecting from a number of options, the decision about appropriate protective measures should be made on the basis of projected doses. These doses can inform the decision regarding appropriate reference levels, such that:

- if projected doses are above 20 mSv y^{-1}, protective actions are almost always justified
- if doses are below 1 mSv y^{-1}, protective actions are unlikely to be justified
- if the dose is between those two values, several factors could be considered, as illustrated in Figure 4.1.

If, during the course of remediation, unexpected radiation levels are detected, appropriate measures must be taken to ensure health and safety of workers. Once the new conditions are understood, it may be necessary to revise the site-specific remedial action plan accordingly, and obtain approval from the relevant regulatory body to the restart remediation activities.

The involvement of interested stakeholders should be implemented as early as practicable and needs to be tailored to the nature of the situation, as well as the stage of implementing protective measures. The involvement should allow the public to be included in the decision process (determining strategy, protective measures, etc.) in an active way. This process should begin as early as possible. Communication and information alone are not enough to make people confident in the decisions being made. It should be recognised that the type of engagement, the roles of different stakeholders, and any communication strategy should be established as soon as possible and could vary over the course of implementation of the protection strategy.

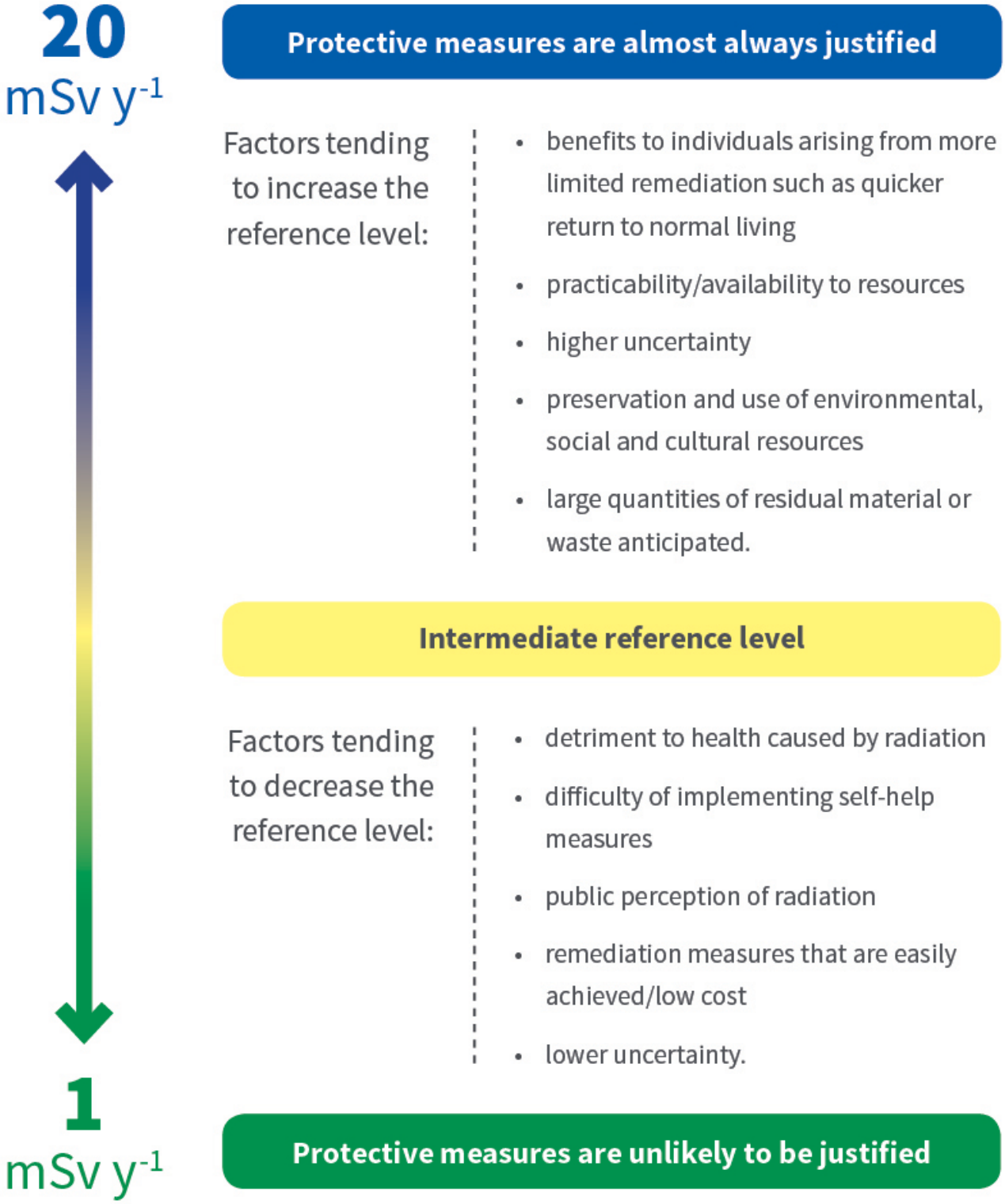

Figure 4.1: Key factors informing the selection of the reference level.

4.1 Remediation of legacy and post-accident sites

Remediation of contamination from past activities or accidents requires the establishment of a reference level in the range 1-20 mSv y^{-1} to guide optimisation of radiation protection. The overall remediation process involves four main activities: (1) initial site characterisation and selection of remediation criteria; (2) identification of remediation options and their optimisation, followed by subsequent development and approval of the remediation plan; (3) implementation of the remediation plan; and (4) post-remediation management (IAEA 2007).

In Australia, reasonably foreseeable exposure scenarios are such that it can be considered appropriate to set a *site-specific* reference level for remediation of contamination from past activities or accidents between 1 and 20 mSv effective dose per year. In the Australian context, an intermediate reference level for remediation of 10 mSv y^{-1} is appropriate as a starting point. The actual value will depend on prevailing circumstances and will guide the optimisation of radiation protection. The reference level for remediation applies to additional exposure (i.e. exposure above natural background levels). For undertaking the remediation of an existing exposure situation, occupational and public radiation dose limits apply to the remediation process and should take into account the relevant clauses of planned exposure situations as described in the Code for *Radiation Protection in Planned Exposure Situations*, RPS C-1 (ARPANSA 2016).

4.2 Radon exposure in homes and workplaces

Within the system of radiological protection, radon exposure has the characteristics of an existing exposure situation as the source is unmodified concentrations of ubiquitous primordial natural activity in the Earth's crust (ICRP 2007). Human activities such as construction of buildings, operation of mines or underground show caves (ARL 1996) may create or modify pathways that increase exposure to radon and its progeny. These pathways can be controlled by preventative and mitigating actions. The ICRP *Publication 126* (ICRP 2015) considers that, in most situations, a national radon protection strategy would be justified as radon is ubiquitous; it represents a significant source of radiation exposure in certain locations and, in many circumstances, it can be controlled.

For implementing protective measures to control radon in dwellings and mixed-use buildings, Australian guidance (ARL 1990) has been based on a derived reference level of 200 Bq m^{-3} averaged over a year.

In most workplaces, radon exposures of workers, that are not a result of their assigned or regular work activities are considered adventitious and are not considered to be occupational exposures. The ICRP in Publication 126 (ICRP 2015) recommends a specific graded approach in workplaces with the following steps:

- reducing the concentration of radon to a level that is as low as reasonably achievable, taking into account economic and societal factors, to the same derived reference level established for dwellings and multi-use buildings
- if difficulties are met in reducing levels, optimising protection is recommended using the actual parameters of the exposure situation, such as occupancy and other site specific factors, together with a derived reference level of 1000 Bq m^{-3} averaged over a year.

For exposures in workplaces that persist above the derived reference level of 1000 Bq m^{-3} averaged over a year, workers should be considered as occupationally exposed. In such cases, the application of the relevant clauses for occupational exposure in planned exposure situations as described in the Code for *Radiation Protection in Planned Exposure Situations*, RPS C-1 (ARPANSA 2016) apply.

The relationship between a measured radon concentration and effective dose depends upon several parameters including the equilibrium factor and the time of exposure, which can vary greatly between locations. However, the Australian values of derived reference level for radon is consistent with the reference level of 10 mSv y^{-1} (ICRP 2015) and provides an appropriate level of protection for the public and workers for exposure to radon in homes and workplaces in Australia. These derived reference levels are listed in Annex A of this Guide.

4.3 Aircrew exposure to cosmic rays

Aircrew are exposed to elevated levels of cosmic radiation while flying at high altitude. In Australia, it is expected that an assessment of exposure for aircrew of all domestic and long-haul crews would be warranted. The ICRP, in Publication 132 (ICRP 2016), recommends that a reference level in the 5-10 mSv y^{-1} range is selected by employers. The selected reference value is not a dose limit, but represents the level of dose below which exposure should be maintained and reduced as low as reasonably achievable, taking into account economic and societal factors. For Australia, a reference level of 6 mSv y^{-1} (see Annex A), is considered appropriate. Where the doses of aircrew are likely to exceed this reference level, and it is not possible to reduce exposure below this reference level, then the relevant clauses for occupational exposure in planned exposure situations as described in the *Code for Radiation Protection in Planned Exposure Situations*, RPS C-1 (ARPANSA 2016) apply.

For pregnant aircrew, additional protection of the embryo/foetus must be considered. The working conditions of a pregnant worker, after declaration of pregnancy, must ensure that the additional dose to the embryo/foetus would not exceed about 1 mSv y^{-1} during the remainder of the pregnancy. If a reference level is in use by employers, dose records or other pertinent assessment are to be kept to enable the optimisation of the reference level.

Radiation doses from cosmic radiation received by occasional flyers is sufficiently low that there is no need to warrant the introduction of protection measures. However, the ICRP recommends that general information about cosmic radiation associated with aviation be available for all passengers (ICRP 2016). Frequent flyers are considered as public exposure and are treated in the same way as occasional flyers (ICRP 2016).

The ICRP, in Publication 132 (ICRP 2016), recommends that, frequent flyers who have exposures comparable to aircrew should be managed as occupationally exposed on a case-by-case basis according to prevailing circumstances. This may result in individuals assessing their own exposure using freely available dose calculators in order to be aware of their exposure and adapt their flight frequency if they feel the need and therefore use this information to engage with their employer, if appropriate.

4.4 Radionuclides of natural origin in commodities and bulk materials

Radionuclides of natural origin occur in commodities including food, animal feed, drinking water, agricultural fertiliser and soil amendments (e.g. additives or pH adjustments), construction materials, and residual radioactive material in the environment. In the context of public exposure in existing exposure situations, all exposure pathways from a given source of exposure need to be considered, including the contributions from external exposure, inhalation and ingestion. A representative person can be exposed to multiple pathways from radionuclides of natural origin in commodities. Therefore, a reference level of 1 mSv y^{-1} for exposure to radionuclides in each of the commodities (see clauses 3.2.16-3.2.17 and Annex A of this Guide) is considered appropriate for Australia. For existing exposure situations with dose implications exceeding 1 mSv y^{-1}, a protection strategy should be developed by the employers in conjunction with the relevant regulatory body and implemented to ensure that any remedial action is justified, and to optimise protection and safety, as described in Section 3 of this Guide.

Food and drinking water

For radionuclides of natural origin in food, or contamination of food arising from radiation practices or accident, assessments are based on a reference level of 1 mSv y^{-1} for members of the public.

For importing foodstuffs after a major radiological or nuclear emergency has occurred, the Codex Alimentarius International Food Standards guideline levels are applied for one year after the accident (FAO/WHO 2016). The Codex provides guidance levels for specific radionuclides which are consistent with a reference level of 1 mSv y^{-1}. ARPANSA assessed that the Codex guideline levels were still sufficient beyond one year to ensure that the radiation dose due to artificial radionuclides in imported foods would be below 1 mSv y^{-1} (ARPANSA 2012).

For radionuclides of natural origin in drinking water or contamination of drinking water arising from past radiation practices that were not subject to regulatory control, the Australian Drinking Water Guidelines (NHMRC 2011) provides a single guideline value (1 mSv y^{-1}) for the annual exposure to radioactivity from drinking water. The guidelines also provide a process for assessing the radiological quality of the water, including a simple screening method to ensure compliance with the guideline value and an investigation process if the screening levels are exceeded.

When the existing or potential dose from the radionuclide content exceeds the guideline dose, a decision on the need for, and the degree of, remedial action should be based on advice from the relevant state health authorities, and should include a cost-benefit analysis. There may be some circumstances where there is no practical alternative but to accept a dose that exceeds the guideline dose of 1 mSv y^{-1}, together with a potential slight increase in the risk to health as a consequence. However, if doses from the use of a particular drinking water supply will exceed 10 mSv y^{-1}, action must be considered to reduce the existing or potential exposures.

Other commodities

The clauses for existing exposure situations in this Guide apply to material containing radionuclides of natural origin at an activity concentration of less than 1 Bq g^{-1} for any radionuclide in the ^{238}U and ^{232}Th decay series and of less than 10 Bq g^{-1} for ^{40}K.

When NORM residues are used as by-products in the form of fertilisers, soil amendments and construction materials (or components of such), the clauses for existing exposure situations apply, irrespective of the activity concentrations. The reasoning behind this is that these everyday commodities, while used in some

industrial activities, are also widely used by individual members of the public. Therefore, it would not be appropriate to apply the formal system of regulatory control for practices. In terms of the guidance for existing exposure situations, any restrictions that might need to be placed on these commodities would be imposed by the relevant national regulatory body in the form of simple criteria such as activity concentration limits, in much the same way that levels of other potentially hazardous constituents are controlled.

The use of bulk amounts of materials (e.g. agricultural fertiliser and soil amendments, construction materials, and residual radioactive material in the environment) containing radionuclides of natural origin, should be considered on a case-by-case basis by using a dose criterion of the order of 1 mSv y^{-1}, commensurate with typical doses due to natural background levels of radiation.

The clauses from the Code for *Radiation Protection in Planned Exposure Situations*, RPS C-1 (ARPANSA 2016) apply to material containing radionuclides of natural origin where the activity concentration of any radionuclide in the ^{238}U or ^{232}Th decay series exceeds 1 Bq g^{-1}, or if the activity concentration of ^{40}K exceeds 10 Bq g^{-1}.

4.5 Transition from an emergency exposure situation to an existing exposure situation

The termination of a nuclear or radiological emergency marks the end of the transition phase in a particular area or site and the beginning of either an existing exposure situation or a planned exposure situation (IAEA 2015).

Depending on the nature of the nuclear or radiological emergency, these processes may continue in the longer term after the emergency has been declared terminated. During this period, the implementation of remedial actions might be more efficient than carrying out further disruptive public protective actions.

Transition phase

In addition to the general prerequisites of an emergency exposure situation, the following prerequisites should be met in order to be able to declare the end of an emergency exposure situation and to move to an existing exposure situation:

- justified and optimised actions have been taken to reach the national generic criteria established to enable transitioning to an existing exposure situation, taking into account the criteria in relevant Australian Guides and Standards
- areas have been delineated which may not be inhabited and where it is not feasible to carry out social or economic activity. For these delineated areas, administrative and other provisions have been established to monitor compliance with the restrictions imposed
- a strategy is implemented for the restoration of infrastructure, workplaces and public services necessary to support normal living conditions in the affected areas
- any change or transfer of authority and responsibilities from the emergency response organisation to organisations responsible for the long-term recovery operations have been completed
- communication and consultation is continuous with all interested stakeholders, including local communities
- a long-term monitoring program (e.g. residual contamination) is implemented

- a long-term medical follow-up program for registered individuals, including mental health and psychosocial support for the affected population in relation to psychosocial health consequences is implemented
- administrative arrangements, legislative provisions and regulatory provisions are in place and/or underway for the management of the existing exposure situation.

Termination of an emergency

After terminating the emergency and entering into the existing exposure situation, the reference level for the residual dose in an existing exposure situation should be applied in the band of 1-20 mSv y^{-1} as stated in Section 3.2 and Annex A. This Guide recommends that the reference level for the optimisation of the protection strategy is selected from the lower part of the reference band of 1-20 mSv y^{-1} as a long-term objective for existing exposure situations (ICRP 2007 and ICRP 2009). Further guidance on selecting reference levels can be found in Figure 4.1.

Annex A: Reference levels for existing exposure situations in Australia

The reference levels for existing exposure situations in Australia are:

Application	Reference level
Exposure to indoor ^{222}Rn For applying optimisation of protection for dwellings, mixed-use buildings and most workplaces the derived reference level is 200 Bq m^{-3} [1] For applying occupational protection requirements the derived reference level is 1000 Bq m^{-3} [2]	10 mSv y^{-1}
Transition from an emergency exposure situation to an existing exposure situation[3]	20 mSv y^{-1}
Remediation of legacy and post-accident sites[4]	10 mSv y^{-1}
Aircrew exposure to cosmic rays[5]	6 mSv y^{-1}
Radionuclides of natural origin in commodities[6]	1 mSv y^{-1}
Radionuclides in bulk material of commodities[7]	1 mSv y^{-1}

1 If measured values are found to consistently exceed this level, consideration should be given to possible remedial action within the context of optimisation.

2 Employers should ensure that the activity concentration of ^{222}Rn in the workplace is as low as reasonably achievable below this derived reference level and should ensure that protection is optimised. If, despite all reasonable efforts by the employer to reduce the activity concentration of radon, the activity concentration of ^{222}Rn in the workplace remains above the derived reference level, the relevant clauses for occupational exposure in planned exposure situations as stated in the *Code for Radiation Protection in Planned Exposure Situations*, RPS C-1 (ARPANSA 2016), must apply.

3 As a long-term objective the reference level for the optimisation of protection for the transition from an emergency exposure situation to an existing exposure situation should be selected from the lower part of the reference band of 1-20 mSv y^{-1}.

4 In Australia, an intermediate reference level of 10 mSv y^{-1} applies to legacy and post-accident sites and revision of the intermediate reference level to improve the situation progressively is required. The remediation of contamination from past activities or accidents requires a site-specific reference level in the range of 1 to 20 mSv y^{-1}, based on prevailing circumstances to guide the optimisation of radiation protection after an assessment of the site. The reference level for remediation applies to additional exposure (i.e. above natural background levels).

5 A reference level of 6 mSv y^{-1} is considered appropriate for use in Australia and is endorsed by employers.

6 Exposure to radionuclides in each of the commodities. The investigation levels for drinking water would be triggered at a lower dose than the 1 mSv y^{-1} reference level (for more information see NHMRC 2011).

7 The clauses for existing exposure situations apply to material containing radionuclides of natural origin at an activity concentration of less than 1 Bq g^{-1} for any radionuclide in the uranium decay chain or the thorium decay chain and of less than 10 Bq g^{-1} for ^{40}K. For radionuclides of natural origin, bulk amounts of material are to be considered on a case-by-case basis by using a dose criterion of 1 mSv y^{-1}.

Appendix 1: Derivation of existing exposure guide clauses from GSR Part 3 requirements

The following table cross-references each clause in Section 3 of this Guide to the relevant requirement in the Trusted International Standard, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards - General Safety Requirements, IAEA Safety Standards Series GSR Part 3 (IAEA 2014). GSR Part 3 is published on the IAEA website.

RPS G-2		IAEA GSR Part 3
Guidance	**Clause(s)**	**Requirement**
Responsibilities specific to existing exposure situations	3.1.1-3.1.4	Requirement 47
Justification for protective actions and optimisation of protection and safety	3.2.1-3.2.3	Requirement 48
Responsibilities for remediation of areas with residual radioactive material	3.2.4-3.2.12	Requirement 49
Public exposure due to radon indoors	3.2.13-3.2.15	Requirement 50
Exposure due to radionuclides in commodities	3.2.16-3.2.17	Requirement 51
Exposure in workplaces	3.3.1-3.3.8	Requirement 52

Requirements 1-33 in GSR Part 3 apply to planned exposure situations, Requirements 34-42 in GSR Part 3 apply to medical exposure situations and Requirements 43-46 in GSR Part 3 apply to emergency exposure situations. The provisions in those Requirements will be incorporated into separate Codes or Guides in the Radiation Protection Series.

Appendix 2: The ten principles of radiation risk management from the *Fundamentals for Protection Against Ionising Radiation* (2014)

The following ten principles of radiation risk management are explained in detail in Section 4 of the *Fundamentals for Protection Against Ionising Radiation* (2014) (RPS F-1):

1. Clear division of responsibilities

   (i) The prime responsibility for management of radiation risks must rest with the person or organisation responsible for facilities and activities that give rise to radiation risks.

2. Legislative and regulatory framework

   (ii) An effective framework including legislation, regulation and guidance to promote management of radiation risks, including an independent regulatory body, must be established and sustained.

3. Leadership and management for safety

   (iii) Effective leadership and management of radiation risks must be established and sustained in organisations concerned with, and facilities and activities that give rise to, radiation risks.

4. Justification

   (iv) Facilities and activities that give rise to radiation risks must yield an overall benefit.

5. Optimisation of protection

   (v) Protection must be optimised so that radiation risks are as low as reasonably achievable.

6. Limitation of risks

   (vi) Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm, and that the environment is protected.

7. Protection of present and future generations

   (vii) People and the environment, present and future, must be protected against radiation risks.

8. Prevention of accidents and malicious acts

   (viii) All practical efforts must be made to prevent and mitigate accidents, and acts with malicious intent, that may give rise to radiation risks.

9. Emergency preparedness and response

   *(ix) Arrangements must be made for emergency preparedness and response for **incidents**, accidents and malicious acts that may give rise to radiation risks.*

10. Protective actions to reduce existing or unregulated radiation risks

    (x) Protective actions to reduce existing or unregulated radiation risks must be justified and optimised.

Glossary

Accident

Any unintended event, including operating errors, equipment failures and other mishaps, the consequences or potential consequences of which are not negligible from the point of view of protection and safety.

Authorisation

The granting by a relevant regulatory body of written permission for a Responsible Person to conduct specified activities.

Biota

See ***wildlife***.

Contamination

Radioactive substances on surfaces or within solids, liquids or gases (including the human body), where their presence is unintended or undesirable, or the process giving rise to their presence in such places.

Cosmic radiation

See ***source***.

Derived reference level

Numerical value expressed in an operational or measurable quantity, corresponding to the reference level set in dose.

Dose

1. A measure of the energy deposited by radiation in a target.
2. Absorbed dose, committed dose (i.e. committed equivalent dose or committed effective dose), effective dose, equivalent dose or organ dose, as indicated by the context.

Dose limit

The value of a quantity used in certain specified activities or circumstances that must not be exceeded.

Effective dose, *E*

The quantity *E*, defined as a summation of the tissue or organ equivalent doses, each multiplied by the appropriate tissue weighting factor:

$$E = \sum_{\mathrm{T}} w_{\mathrm{T}} \,.\, H_{\mathrm{T}}$$

where H_{T} is the equivalent dose in tissue or organ T, and
w_{T} is the tissue weighting factor for a tissue or organ T.

From the definition of equivalent dose, it follows that:

$$E = \sum_{\mathrm{T}} w_{\mathrm{T}} \,.\, \sum_{\mathrm{R}} w_{\mathrm{R}} \,.\, D_{\mathrm{T,R}}$$

where w_R is the radiation weighting factor for radiation type R, and
$D_{T,R}$ is the average absorbed dose in the tissue or organ T delivered by radiation type R.

The SI unit for effective dose is joule per kilogram (J kg^{-1}), termed the sievert (Sv). An explanation of the quantity is given in Annex B of the ICRP Publication 103 (ICRP 2007).

Effective dose is a measure of dose designed to reflect the amount of radiation detriment likely to result from the dose.

Effective dose cannot be used to quantify higher doses or to make decisions on the need for any medical treatment relating to tissue reactions effects.

Values of effective dose from exposure for any type(s) of radiation and any mode(s) of exposure can be compared directly.

Emergency exposure situation

A situation of exposure that arises as a result of an accident, a malicious act, or any other unexpected event, and requires prompt action in order to avoid or reduce adverse consequences.

Emergency

A non-routine situation that necessitates prompt action, primarily to mitigate a hazard or adverse consequences for human health and safety, quality of life, property or the environment. This includes nuclear or radiological emergencies and conventional emergencies such as fires, release of hazardous chemicals, storms or earthquakes. It includes situations for which prompt action is warranted to mitigate the effects of a perceived hazard.

Exposure pathway

A route by which radiation or radionuclides can reach humans and cause exposure.

Nuclear or radiological emergency

An emergency in which there is, or is perceived to be, a hazard due to:

(a) the energy resulting from a nuclear chain reaction or from the decay of the products of a chain reaction, or

(b) radiation exposure.

Environment

The conditions under which people, animals and plants live or develop and which sustain all life and development, especially such conditions as affected by human activities. Protection of the environment includes the protection and conservation of:

- non-human species, both animal and plant, and their biodiversity
- environmental goods and services such as the production of food and feed
- resources used in agriculture, forestry, fisheries and tourism
- amenities used in spiritual, cultural and recreational activities
- media such as soil, water and air
- natural processes such as carbon, nitrogen and water cycles.

Environmental exposure

The exposure of animals, plants and other organisms in the natural environment.

Equivalent dose

The quantity $H_{T,R}$, defined as:

$$H_{T,R} = w_R \cdot D_{T,R}$$

where $D_{T,R}$ is the absorbed dose delivered by radiation type R averaged over a tissue or organ T, and w_R is the radiation weighting factor for radiation type R.

When the radiation field is composed of different radiation types with different values of w_R, the equivalent dose is:

$$H_T = \sum_R w_R \,.\, D_{T,R}$$

The SI unit for equivalent dose is joule per kilogram (J kg^{-1}), termed the sievert (Sv). An explanation of the quantity is given in Annex B of the ICRP Publication 103 (ICRP 2007).

Equivalent dose is a measure of the dose to a tissue or organ designed to reflect the amount of harm caused.

Equivalent dose cannot be used to quantify higher doses or to make decisions on the need for any medical treatment relating to tissue reactions effects.

Values of equivalent dose to a specified tissue or organ from any type(s) of radiation can be compared directly.

Existing exposure situation

A situation of exposure that already exists when a decision on the need for control needs to be taken. Existing exposure situations include exposure to natural background radiation that is amenable to control, exposure due to residual radioactive material that derives from past practices that were never subject to regulatory control, and exposure due to residual radioactive material deriving from a nuclear or radiological emergency after an emergency has been declared to be ended.

Exposure

The state or condition of being subjected to radiation. External exposure is exposure to radiation from a source outside the body. Internal exposure is exposure to radiation from a source within the body.

Graded approach

For a system of control, such as a regulatory system or a safety system, a process or method in which the stringency of the control measures and conditions to be applied is commensurate, to the extent practicable, with the likelihood and possible consequences of, and the level of risk associated with, a loss of control.

Incident

Any unintended event, including operating errors, equipment failures, initiating events, accident precursors, near misses or other mishaps, or unauthorised act, malicious or non-malicious, the consequences or potential consequences of which are not negligible from the point of view of protection and safety.

Ionising radiation

For the purposes of radiation protection, radiation capable of producing ion pairs in biological material(s).

Justified

See 'Justification'

Justification

For a planned exposure situation, the process of determining whether a practice is beneficial overall, i.e. whether the expected benefits to individuals and to society from introducing or continuing the practice outweigh the harm (including radiation detriment) resulting from the practice.

Medical exposure

Exposure incurred by patients as part of their own medical or dental diagnosis (diagnostic exposure) or treatment (therapeutic exposure) by persons, other than those occupationally exposed, knowingly, while voluntarily helping in the support and comfort of patients, and by volunteers in a program of biomedical research involving their exposure.

Natural background

The doses, dose rates or activity concentrations associated with natural sources, or any other sources in the environment that are not amenable to control.

Natural Occurring Radioactive Material (NORM)

Radioactive material containing no significant amounts of radionuclides other than naturally-occurring radionuclides.

Nuclear or radiological emergency

See emergency.

Occupancy factor

A typical fraction of the time for which a location is occupied by an individual or group.

Occupational exposure

Exposure of workers incurred in the course of their work.

Occupationally exposed person

A worker who is exposed to ionising radiation arising from work undertaken within a practice.

Optimisation

For existing exposure situations, optimisation of protection and safety is the process of determining what level of protection and safety would result in the magnitude of individual doses, the number of individuals (workers and members of the public) subject to exposure and the likelihood of exposure being 'as low as reasonably achievable, economic and societal factors being taken into account' (ALARA).

Optimised

See 'Optimisation'.

Planned exposure situation

The situation of exposure that arises from the planned operation of a source or from a planned activity that results in an exposure due to a source. Since provision for protection and safety can be made before embarking on the activity concerned, associated exposures and their probabilities of occurrence can be restricted from the outset. The primary means of controlling exposure in planned exposure situations is by good design of installations, equipment and operating procedures. In planned exposure situations, a certain level of exposure is expected to occur.

Practice

Any human activity that introduces additional sources of radiation or additional exposure pathways, or that modifies the network of exposure pathways from existing sources, so as to increase the exposure or the likelihood of exposure of people or the number of people exposed.

Protection and safety

The protection of people against exposure to ionising radiation or exposure due to radioactive material and the safety of sources, including the means for achieving this, and the means for preventing accidents and for mitigating the consequences of accidents if they do occur.

For the purposes of this Guide, 'protection and safety' includes the protection of people against ionising radiation and safety. It does not include non-radiation-related aspects of safety. 'Protection and safety' is concerned with both radiation risks under normal circumstances and radiation risks as a consequence of **incidents**, as well as with other possible direct consequences of a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation. Safety measures include actions to prevent incidents and arrangements put in place to mitigate their consequences if they were to occur.

Protective actions

A response action for the purposes of avoiding or reducing doses that might otherwise be received in an existing exposure situation.

Protective measures

Reasonably measures to be taken to reduce radiation exposures to the public, wildlife and workers using remedial actions and or protective actions to adverse conditions.

Public exposure

Exposure incurred by members of the public due to sources in planned exposure situations, emergency exposure situations and existing exposure situations, excluding any occupational exposure or medical exposure.

Radiation

In this Guide, the term 'radiation' refers only to ionising radiation unless otherwise stated. For the purposes of radiation protection, ionising radiation is capable of producing ion pairs in biological material(s).

For most practical purposes, it may be assumed that weakly penetrating radiation includes photons of energy below about 12 keV, electrons of energy less than about 2 MeV, and massive charged particles such as protons and alpha particles.

Radiation protection

The protection of people and the environment from harmful effects of exposure to ionising radiation, and the means for achieving this.

Radiation risk

Detrimental health effects of exposure to ionising radiation including the likelihood of such effects occurring, and other risks including environmental risks, that might arise from exposure to ionising radiation; the presence of radioactive material (including radioactive waste) or its release to the environment; or a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation; alone or in combination.

Radioactive material

Scientific meaning: Material exhibiting radioactivity, emitting or relating to the emission of ionising radiation or particles.

Legal meaning: Material designated by the relevant regulatory body as being subject to regulatory control because of its radioactivity.

Radionuclides of natural origin

Radionuclides that occur naturally on Earth in significant quantities.

The term is usually used to refer to the primordial radionuclides ^{40}K, ^{235}U, ^{238}U, ^{232}Th and their radioactive decay products.

Contrasted with radionuclides of artificial origin; artificial radionuclides, anthropogenic radionuclides and human-made radionuclides.

Radioactive waste

For legal and regulatory purposes, material for which no further use is foreseen that contains, or is contaminated with, radionuclides at activity concentrations greater than clearance levels (refer to RPS C-1 for more information on the clearance process) as established by the regulatory body.

Radon

Any combination of isotopes of the element radon.

For the purposes of this Guide, radon refers to ^{220}Rn and ^{222}Rn.

Radon progeny

The short-lived radioactive decay products of ^{220}Rn and of ^{222}Rn.

For ^{222}Rn, this includes the decay chain up to but not including ^{210}Pb, namely ^{218}Po, ^{214}Pb, ^{214}Bi and ^{214}Po, plus traces of ^{218}At, ^{210}Tl and ^{209}Pb. ^{210}Pb, which has a half-life of 22.3 y, and its radioactive progeny — ^{210}Bi and ^{210}Po, plus traces of ^{206}Hg and ^{206}Tl — are, strictly, progeny of ^{222}Rn, but they are not included in this listing because they will not normally be present in significant amounts in airborne form. For ^{220}Rn, this includes ^{216}Po, ^{212}Pb, ^{212}Bi, ^{212}Po and ^{208}Tl.

Reference level

For an emergency exposure situation or an existing exposure situation, the level of dose, risk or activity concentration above which it is not appropriate to plan to allow exposures to occur and below which optimisation of protection and safety would continue to be implemented.

Regulatory body

An authority or a system of authorities designated by the government as having legal authority for conducting the regulatory process, including issuing authorisations, and thereby regulating nuclear, radiation, radioactive waste and transport safety. A list of relevant radiation regulatory authorities in Australia can be found on ARPANSA's website at www.arpansa.gov.au/regulation-and-licensing/regulation/state-territory-regulators.

Remedial action

The removal of a source or the reduction of its magnitude (in terms of activity or amount) for the purposes of preventing or reducing exposures that might otherwise occur in an existing exposure situation.

Remedial actions could also be termed longer term protective action, but longer term protective actions are not necessarily remedial actions.

Remediation

Any measures that may be carried out to reduce the radiation exposure due to existing contamination of land areas through actions applied to the contamination itself (the source) or to the exposure pathways to humans and the environment.

Representative person

An individual receiving a dose that is representative of the more highly exposed individuals in the population (see Publication 101a, ICRP 2006).

Residual radioactive material

Residual radioactive material is radioactive material that remains in the environment following some past practice including a past remediation.

Safety

For the purposes of this Guide, 'safety' means the protection of people and the environment against radiation risks, and the safety of facilities and activities that give rise to radiation risks. 'Safety' as used here includes the safety of nuclear installations, radiation safety, the safety of radioactive waste management and safety in the transport of radioactive material. It does not include non-radiation related aspects of safety.

Safety is concerned with both radiation risks under normal circumstances and radiation risks as a consequence of incidents, as well as with other possible direct consequences of a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation. Safety measures include actions to prevent incidents and arrangements put in place to mitigate their consequences if they were to occur.

Safety assessment

Assessment of all aspects of a practice that are relevant to protection and safety. For an authorised facility, this includes siting, design and operation of the facility.

Soil amendments

Soil amendments are materials which are worked into the soil to enhance the soil's physical properties. Soil amendments are any material such as lime, gypsum, sawdust, compost, animal manures, crop residue or synthetic soil conditioners that is worked into the soil or applied on the surface to enhance plant growth. Amendments may contain important fertiliser elements but the term commonly refers to added materials other than those used primarily as fertilisers.

Source

1. Anything that may cause radiation exposure — such as by emitting ionising radiation or by releasing radioactive substances or radioactive material — and can be treated as a single entity for purposes of protection and safety.

Natural source. A naturally occurring source of radiation, such as the sun and stars (sources of cosmic radiation), rocks and soil (terrestrial sources of radiation), or any other material whose radioactivity is for all intents and purposes due only to radionuclides of natural origin, such as products or residues from the processing of minerals, but excluding radioactive material for use in a nuclear installation and radioactive waste generated in a nuclear installation.

2. Radioactive material used as a source of radiation.

Stochastic health effect

A radiation induced health effect, the probability of occurrence of which is greater for a higher radiation dose and the severity of which (if it occurs) is independent of dose. Stochastic effects may be somatic effects or hereditary effects, and generally occur without a threshold level of dose. Examples include solid cancers and leukaemia.

Tissue reactions

Harmful reaction to radiation in a population of cells (tissue) where a threshold dose has to be exceeded for it to be expressed in a clinically relevant form, and where the severity of harm increases with the dose. Often used as synonymous to 'deterministic effects'. Tissue reactions is the preferred term as the effect is susceptible to a range of modifiers, i.e. is not strictly pre-determined.

Wildlife

Any wild animal or plant living within its natural environment. This excludes stock, farmed, feral or domesticated species. The objects of environmental protection and used interchangeably with non-human biota, plants and animals, and flora and fauna in this Guide.

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