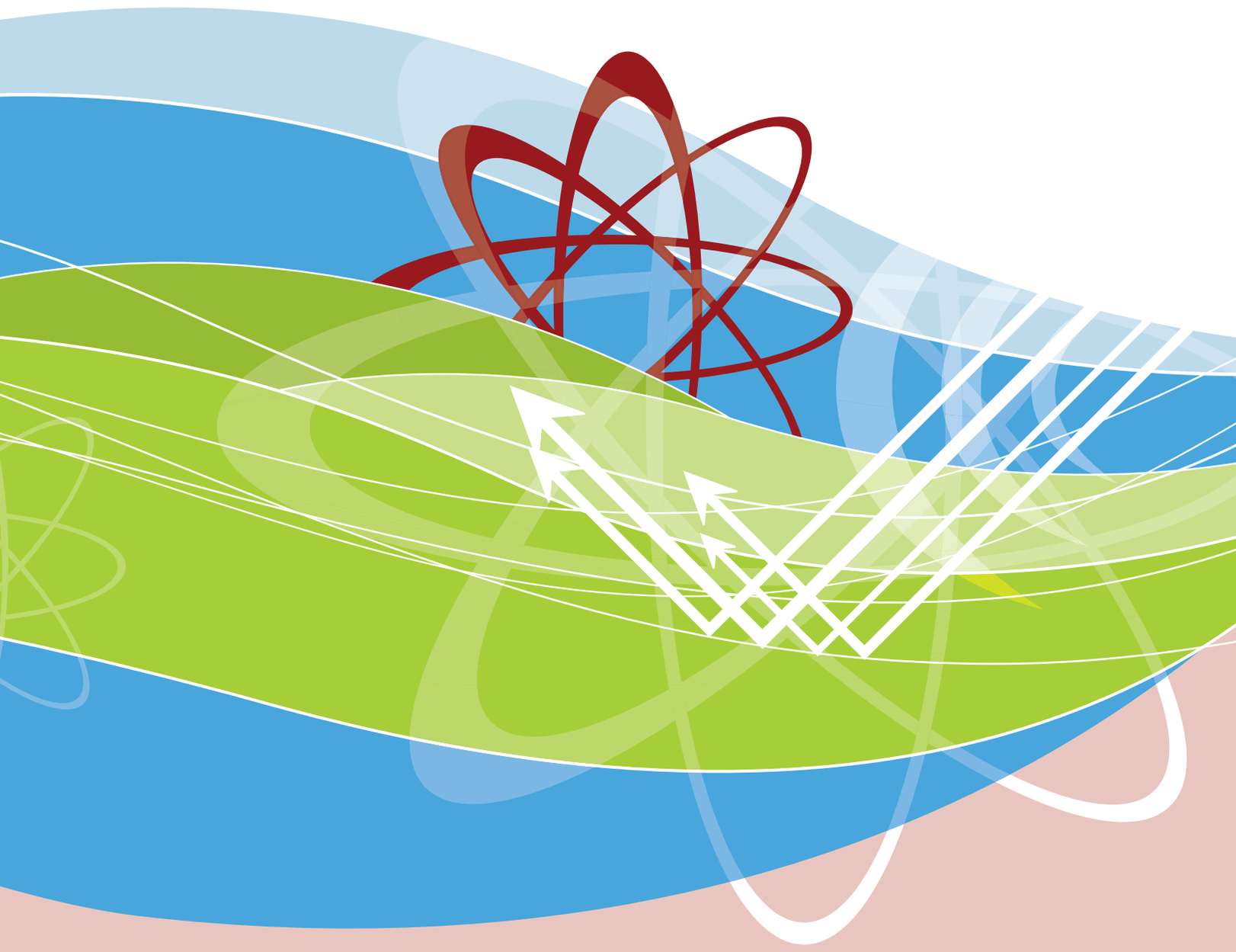
Australian Government
Australian Radiation Protection and Nuclear Safety Agency

FUNDAMENTALS

Protection Against Ionising Radiation



Radiation Protection Series F-1

Radiation Protection Series

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) produce a number of publications to promote practices which protect human health and the environment from harmful effects of radiation. For the publication categories within the Radiation Protection Series, namely ***Fundamentals***, ***Codes of Practice*** and ***Guides***, ARPANSA is assisted in this task by the Radiation Health Committee (RHC), which oversees the preparation of draft documents and recommends publication to the Radiation Health and Safety Advisory Council, which endorses documents and recommends their publication by the CEO of ARPANSA.

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.

Codes of Practice are regulatory in style and may be referenced by regulations or conditions of licence. They contain either general safety or security requirements which may be applicable for all dealings with radiation, or practice-specific requirements. They provide overarching requirements and are expressed as 'must' statements which are to be satisfied to ensure an acceptable level of safety and/or security.

Guides provide recommendations and guidance on how to comply with the Codes of Practice 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.

These three categories of publication are informed by public comment during drafting, and are also subject to a process of assessment of regulatory impact. Further information on these consultation processes may be obtained by contacting ARPANSA.

In addition, ARPANSA has taken over responsibility for the administration of the former *Radiation Health Series* published by National Health and Medical Research Council as well as codes developed under the *Environment Protection (Nuclear Codes) Act 1978*. These publications are being progressively reviewed and republished as part of the Radiation Protection Series.

ARPANSA also produces a range of other publications that provide general or technical information on radiation related topics. This includes technical reports, fact sheets, regulatory guides etc. While these are also published by ARPANSA, they are produced independently from the RHC.

All ARPANSA publications (including earlier editions of codes and guides for which ARPANSA is now responsible) are available in electronic format, and can be downloaded free of charge by visiting ARPANSA's website at www.arpansa.gov.au/Publications.

Further information can be obtained by telephoning ARPANSA on 1800 022 333 (freecall within Australia) or +61 (03) 9433 2211.

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February 2014

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ARPANSA
619 Lower Plenty Road
YALLAMBIE VIC 3085

Tel: 1800 022 333 (Freecall) or +61 3 9433 2211
Email: info@arpansa.gov.au
Website: www.arpansa.gov.au

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 February 2014.

FOREWORD

The management of risks from ionising radiation requires actions that are based on fundamental principles of radiation protection, safety and security. This publication, the *Fundamentals for protection against ionising radiation* (2014) provides an understanding of the effects of ionising radiation and associated risks for the health of humans and of the environment. It further 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.

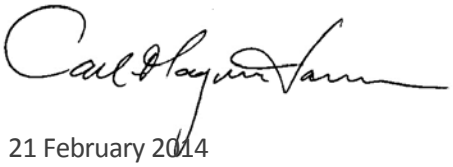
This publication is the top tier document in the Australian national framework to manage risks from ionising radiation as laid out in the Radiation Protection Series (RPS). It is not mandatory and provides the underpinning science and protection principles. The way such principles translate into mandatory requirements is set out in the *National Directory for Radiation Protection* (the NDRP) and in relevant Codes of Practice, and is implemented through jurisdictional legislation and conditions of licence.

Radiation science and epidemiology are continuously advancing scientific areas, and new data of relevance to management of radiation risks can be expected in the future, in particular (but not exclusively) as our understanding of the biology of cancer induction deepens, we gather more data on non-cancer effects, epidemiological studies provide data with increased statistical power, and we gain more understanding on environmental impact. Our basic scientific assumptions and risk models have so far proved to be robust and to accommodate the advancing frontiers of science. However, regulators need to keep a watchful eye on scientific developments, and make necessary changes to the framework for managing radiation risks as our understanding of such risks improves.

In managing radiation risks in planned exposure situations it also has to be recognised that such activities involving radiation are introduced for a purpose, and the regulatory framework should not unduly limit justified use of radiation. The principles laid out in these Fundamentals will, if applied in accordance with good regulatory practice in relation to the uses of radiation in society that have been deemed justified, provide a high level of protection from the harmful effects of radiation.

These Fundamentals are also applicable to the prevention of incidents, accidents and acts with malicious intent, which may lead to an emergency exposure situation. Further, principles that relate to managing radiation risks from existing exposure situations that have resulted from a previous emergency or activity involving radiation have been developed. Finally, the Fundamentals are applicable to environmental exposures of wildlife in the natural environment.

This publication, together with the Code of Practice for Radiation Protection in Planned Exposure Situations as Applied to Workers, the Public and the Environment (expected to be published in 2014) supersede RPS 1 *Recommendations for Limiting Exposure to Ionizing Radiation (1995) and National Standard for Limiting Occupational Exposure to Ionizing (republished 2002).*



21 February 2014
Carl-Magnus Larsson
CEO of ARPANSA

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Note: Technical terms that are described in the Glossary appear in **bold type** on their first occurrence in the text.

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1. INTRODUCTION

1.1 Citation

This publication may be cited as *Fundamentals for Protection Against Ionising Radiation* (2014).

1.2 Background

Australia's system for managing radiation risks[1] from **ionising radiation** is closely aligned with international best practice as laid out in the Recommendations of the International Commission on Radiological Protection (ICRP), the International Atomic Energy Agency's (IAEA) Safety and Security Series and Codes of Conduct, and in relevant Conventions to which Australia is a party. These Fundamentals draw on international best practice and describe the basis for protection against radiation risks, which underpins the requirements in the *National Directory for Radiation Protection* (NDRP) and in Codes of Practice.

1.3 Purpose

The purpose of these Fundamentals is to provide an ethical and scientific basis for the establishment of measures that, when implemented, should ensure that people and the environment are duly protected from the harmful effects of ionising radiation. They are the basis on which the Australian system for management of radiation risks is founded.

1.4 Scope

The Fundamentals encompass all situations of exposure to ionising radiations of workers, the public, patients and the environment. They provide a high-level basis for actions that form part of the management of radiation risks, whether such actions are based on **radiation protection**, safety considerations, security considerations, or a combination thereof.

The terms safety and security, as used in these Fundamentals, refer to safety and security in relation to radiation risks, not to other aspects of safety and security.

While safeguards (the control of nuclear material through actions to prevent proliferation of nuclear arms) contribute to management of radiation risks, they do not fall within the legislation relevant to these Fundamentals, and are thus excluded from further consideration here.

1.5 Interpretation

The Fundamentals are explanatory and descriptive in nature and not required to be complied with per se; hence the use of the word 'must' in these Fundamentals should not be understood as a regulatory requirement. The way the Fundamentals translate into regulatory

[1] Radiation risk as referred to throughout these Fundamentals means 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.

requirements is laid out in the NDRP and in relevant Codes of Practice, and is implemented through jurisdictional legislation and conditions of licence.

The Fundamentals are expressed in a way that should be accessible to those with an interest in, and basic knowledge of, radiation issues. They are not burdened with highly detailed information on radiation science or regulatory frameworks.

Terms used in this document are defined in the Glossary. All existing specific and binding requirements to address the principles set out in these Fundamentals can be found in the relevant Codes of Practice and in the NDRP.

1.6 Structure

This document consists of four sections and one annex.

Section 1 describes the background, purpose and scope of these Fundamentals.

Section 2 provides an overview of basic quantities and units, and a brief summary of the science of radiation effects on human health and on the environment.

Section 3 presents the objectives of managing radiation risks as they relate to radiation protection, safety, and security.

Section 4 describes principles and their specific relevance to management of radiation risks.

Annex 1 provides a list of the Australian radiation regulatory authorities.

The meanings of several terms used in these Fundamentals that are central to the national radiation protection framework are defined in the *Glossary*. Terms defined in the Glossary appear in bold type on first occurrence in the text.

The *References* section provides some high-level references to international frameworks.

2. EFFECTS OF IONISING RADIATION ON HUMAN HEALTH AND ON THE ENVIRONMENT

2.1 Interaction of ionising radiation with biological material

Ionising radiation has since the origin of life been part of the natural environment surrounding all living matter on Earth. People and wildlife are continuously exposed to radiation that may be of natural origin (e.g. cosmic radiation and radiation emanating from bedrock) or has been introduced in the environment as modern societies have developed and a range of human activities have expanded.

Ionising radiation is the term used to describe the particles and electromagnetic radiations that have sufficient energy to cause ionisation as they interact with matter. Ionising radiation (e.g. X-rays, fission radiation) can be generated by certain apparatus or results from the decay of **radioactive** material. The **activity** of radioactive material is the rate at which radioactive decay processes take place, it is measured in becquerels (Bq), where 1 Bq is defined as one disintegration per second.

The process of ionisation involves the removal of electrons from atoms, or sometimes the addition of electrons to atoms. Resulting modifications to molecules and molecular structures can lead to damage of cells in living organisms. This chapter briefly reviews the biological action of ionising radiation and the associated effects and risks.

2.2 The concept of radiation dose

The amount of ionisation produced in a given mass of matter is proportional to the amount of energy imparted by ionising radiation in that mass. The amount of energy deposited per unit mass of matter can therefore be used to quantify radiation exposure and this quantity is called **dose**.

The fundamental dosimetric quantity in radiation protection is the **absorbed dose**, which is the energy absorbed from radiation per unit mass of the matter with which the radiation interacts. The energy absorbed can be expressed in grays (Gy), where 1 Gy is one joule per kilogram for all types of materials.

In biological materials, cells have a finite size and different types of ionising radiations, if they do not pass freely through, may transfer all their energy to a few cells or may transfer small amounts of energy to a large number of cells, with the former causing more severe biological effects than the latter. This is taken into consideration by the application of a factor related to the type of radiation, called the **radiation weighting factor**. This allows comparison of the energy deposition behaviour of all types of radiations with X-rays and gamma rays defined as having a radiation weighting factor of one.

The multiplication of the absorbed dose in biological tissues by the radiation weighting factor gives a quantity called **equivalent dose**, with the unit sievert (Sv), to distinguish it from the absorbed dose.

Epidemiological studies of irradiated humans have shown that different organs and tissues have different sensitivities to radiation with respect to their likelihood of developing **stochastic effects** (for a discussion of stochastic effects, see section 2.4). To allow for this, a **tissue**

weighting factor is applied to organs and tissues to determine their relative contribution to the total detriment for an average individual that has been exposed to ionising radiation.

The products of the equivalent doses to organs and tissues in humans and the tissue weighting factors gives a quantity called **effective dose**, which also has the unit sievert (Sv). Effective dose can be summed over the whole body and allows dose contributions from different types of exposures to be compared directly.

The dose to tissues, organs or the whole body may be delivered from one or multiple sources of radiation outside the body (external exposure) or inside the body (internal exposure). For external exposure, the radiation dose will only be incurred as long as the body, or parts thereof, is exposed, either from an apparatus that can be switched on and off, or by radioactive material present in the environment. Radioactive material can also be inhaled, ingested with food and drinks or absorbed through breaks in the skin. In that case, radioactive material taken up and retained by the body will continue to give rise to radiation exposure internally for as long as they remain in the body. Such internal exposures are often estimated in terms of a committed dose that is the dose which an individual is committed to receive from an intake of radioactive material over the period subsequent to that intake.

In order to differentiate between different magnitudes of exposure of the whole body, it is convenient to talk about:

- very low doses (below 10 millisievert (mSv), which corresponds to the range of exposure any member of the public may experience under normal circumstances on a yearly basis
- low doses (10 to 100 mSv), which incorporate doses that may be incurred by a few individuals as a result of their profession, or as a result of multiple diagnostic examinations using computed tomography
- moderate doses (100 mSv to 1 Sv), where transient responses may be detected if the dose is incurred under relatively short time periods, and where, at the higher end, acute effects of short-term exposures are to be expected
- high doses (more than 1 Sv), where acute effects of short-term exposures will occur.

In addition to the acute effects referred to above, other effects may become evident in the long term. The health effects of exposure to different levels of dose are described briefly in the following sections.

2.3 Tissue reactions

Ionisation in biological materials may cause cellular damage that leads to the death of a cell, or the cell may be damaged in such a way that it cannot reproduce or otherwise fulfil its original function.

Most organs and tissues of the body are unaffected by the loss of even substantial numbers of cells, as natural cell and tissue repair mechanisms make good the loss, but if the number lost is large enough, and sometimes with the onset of secondary reactions, there will be observable harm reflecting a loss of tissue function. These types of effects are called **tissue reactions** (in many cases also referred to as deterministic effects) and are characterised by a threshold dose below which no clinical effect is observed and by the severity of the effect being proportional to radiation exposure. Such effects can be acute and develop within hours to weeks after an exposure (e.g. reddening of exposed areas of the skin), or delayed, as in the case of radiation-induced fibrosis and opacity of the lens of the eye.

2.3.1 Acute effects

Whole-body exposure resulting in a dose of several hundred mSv within a short time-frame may lead to transient tissue reactions but not to acute illness. Short-term exposure corresponding to a few Sv leads to a variety of symptoms including anaemia and immunodeficiency, but a subject may recover under intensive medical care. Above 5 Sv, deaths are likely due to the additional complication of loss of epithelial and mucosal tissue; at even higher doses death is certain due to massive failure of the central nervous system. The clinically observable illness caused by ionising radiation and manifested in these ways is referred to as acute radiation syndrome.

2.3.2 Other effects

A variety of studies have demonstrated an association between exposure to ionising radiation at moderate to high doses that may be characterised as tissue reactions, although determination of a threshold dose is not necessarily straightforward. Effects and diseases include, but are not limited to:

- *Effects on the developing embryo and foetus*. Effects may vary depending on dose and stage of development during exposure, and include malformations and impaired development of the central nervous system.
- *Cardiovascular diseases*. There is evidence of an association between radiation exposure and cardiovascular disease, but the significance of this below doses to the heart of approximately 0.5 Sv is unclear.
- *Opacity and cataract*. Impaired vision caused by radiation-induced opacity or cataract may develop after radiation exposure of the lens of the eye. The threshold dose for such effects appears to be approximately 0.5 Sv to the lens of the eye, although uncertainties remain.
- *Immunological diseases*. At high doses, immunodeficiency may result from death of lymphocytes, leading to increased susceptibility to infections as part of the acute radiation syndrome. The response to lower doses is complex, including both suppression and stimulation. The interaction between responses of the immune system to radiation on one hand, and infectious diseases and cancer on the other hand, remains an important area of research.

Exposures that lead to the effects described here can be avoided by the application of a dose limit for whole body and specific organs, and regulatory action provides protection against such exposures. Exposures of this magnitude can result from serious accidents or other types of emergencies. Dose limits do not apply to the exposure of patients as part of their diagnosis or treatment. The use of radiation for therapeutic purposes, in particular, may lead to localised high-dose exposure of healthy tissue surrounding a cancer. The purpose of radiotherapy is to kill the cancerous cells and dose limits do not apply as they would counteract the clinical purpose of the irradiation. Some damage to neighbouring healthy tissue may be unavoidable during radiation therapy.

2.4 Cancer and heritable effects

Where irradiation causes modification of a cell, that cell may continue to reproduce and may develop into cancer. This can occur after a few years but also after a prolonged delay of tens of years. The occurrence of radiation-related cancer in a population is random and referred to as

a stochastic effect. For this type of effect it is the likelihood of the effect occurring that increases with increasing dose, not the severity of the effect.

Because there is currently no means by which we can distinguish between a radiation-induced cancer and a cancer that would have occurred in the absence of the exposure, the effect in an individual cannot be unequivocally attributed to an exposure event. In some situations, however, it may be possible and justified to conclude that a cancer is likely, or very likely, to have been caused by an exposure event.

If the damage occurs in cells that are part of the reproductive system there is a possibility that some resulting effects could be expressed in the offspring of the exposed person. This particular type of effect is called 'heritable' and is also a stochastic effect. This effect has been observed in experiments on mammalian species and there is no reason to believe it does not occur in humans, although it has so far not been confirmed in epidemiological studies.

For moderate and high doses, there is a linear or curvilinear (linear-quadratic) relationship between radiation dose and cancer incidence. In the low and very low dose range, the shape of the dose-response curve is uncertain. For radiation protection purposes, it is assumed that the dose-response relationship for stochastic effects can be extrapolated from the region of certain effects to zero dose, i.e. that radiation-related stochastic effects occur also at low and very low radiation doses, albeit with greatly reduced likelihood. This is called the linear, no-threshold (LNT) hypothesis. Some epidemiological observations support this assumption whereas some experimental studies point to other than linear relationships. In the absence of certainty, the LNT hypothesis forms the basis for a prudent approach to radiation protection.

For radiation protection purposes, the estimates of stochastic risk use the detriment-adjusted nominal risk coefficient of dose. This includes the risks of all cancers and hereditary effects, averaged over all variation caused by age, gender, race and other factors, and the severity of the disease ('detriment'); into one common number. This is estimated by the International Commission on Radiological Protection [ICRP 2007] to be approximately 5% per Sv. This risk coefficient may need to be adjusted as new scientific knowledge becomes available.

Whilst the nominal risk coefficient can be used to manage radiation risks in an exposed population, it needs to be recognised that the risk may vary between different subgroups of a population. Factors to consider, among others, are age at exposure, gender, genetic disposition and life style factors such as smoking in the case of lung cancer. Exposure during childhood may pose a greater risk for detrimental effects than the same exposure during adult life. Measures to protect children and the foetus against radiation risks may therefore need to be more stringent than those implemented for the adult population.

As indicated above, there is uncertainty around the dose-response relationship for stochastic effects at low and very low doses. Irrespective of the form of the dose-response relationship, to manage the potential risks at such exposures, doses should in all cases be kept as low as reasonably achievable.

2.5 Environmental effects

Just as ionising radiation affects humans, it may affect other living organisms. This may lead to effects in the environment, impacting individuals, populations, species and whole ecosystems. Such effects, which arise from the biological effects of ionising radiation in wildlife are in these Fundamentals referred to as environmental effects.

Environmental effects may include:

- increased morbidity (or reduced fitness) of individuals within populations
- increased mortality
- reduced reproductive success (reduced number of offspring caused by reduced fertility or other factors)
- subtle effects including mutations and effects on ecosystem functions that are currently the subject of much research.

Regulatory consideration of scenarios that may put the environment at risk (either individuals or species that may be protected for conservation purposes, or populations or ecosystems) protects against effects of ionising radiation of environmental concern.

3. OBJECTIVES AND BASIC CONCEPTS IN MANAGING RADIATION RISKS

As reviewed in Section 2, ionising radiation may have harmful effects on both human health and on the environment. This section concerns objectives and basic concepts in managing radiation risks, through actions that are based on radiation protection, safety, or security considerations, either alone or in combination, while not unduly limiting the benefit of activities involving radiation. The objectives and means of implementation are partially overlapping, and collectively provide a framework that, when appropriately implemented, protects human health and the environment from the harmful effects of ionising radiation by:

- implementing strategies to optimise protection
- preventing accidents and mitigating their effects should they occur
- preventing actions with malicious intent that may cause harm from ionising radiation.

3.1 Radiation protection

3.1.1 Objectives

The objective of radiation protection stems from, and is aligned with, the primary aim of *The 2007 Recommendations of the International Commission on Radiological Protection* [ICRP 2007], namely:

> to contribute to an appropriate level of protection of people and the environment against the detrimental effects of radiation exposure without unduly limiting the desirable human actions that may be associated with such exposure.

To protect people, dose or dose rate limits may be specified and dose-reduction strategies implemented, so as to remove the risk of acute effects and tissue reactions and to reduce the risk of stochastic effects. With regard to wildlife, the objective is to prevent or reduce the frequency of deleterious radiation effects, such as those that cause morbidity, early mortality or reduced reproductive success to a level where they would have a negligible impact on the maintenance of biological diversity, the conservation of species, or the health and status of natural habitats, communities and ecosystems [ICRP 2008].

3.1.2 Categories of exposure

Because of the variety and complexity of situations that may give rise to radiation exposure and the need to develop an effective system of radiation protection, exposures to radiation are divided into four categories of exposure: occupational, medical, public and environmental. This enables the development of requirements which are applicable to each category, recognising the substantially different circumstances of exposures.

Occupational exposures are incurred at work and principally as a result of working directly with radiation. Exposure to radiation from natural sources is generally excluded from occupational exposure, except when the exposure is a direct consequence of a planned exposure situation.

Medical exposure is the exposure incurred by patients as part of their medical or dental diagnosis or treatment. It also includes doses received by volunteers in a program of biomedical research involving their exposure, and doses received by persons (other than those occupationally exposed) who are knowingly exposed while voluntarily helping in the support and comfort of patients.

Public exposure covers all exposures of people other than occupational exposure and medical exposure. Exposures of the embryo or foetus of pregnant workers are considered to be public exposures.

Environmental exposure is the exposure of wildlife to all additional radiation sources resulting from human activities. Wildlife may require protection in order to maintain biological diversity, conservation of species, or the health and status of natural habitats, communities and ecosystems, or anything that may be otherwise required from a conservation point of view in accordance with relevant legislation.

3.1.3 Types of exposure situations

The system set out in these Fundamentals covers all circumstances of radiation exposure and should be applied to all sources and all individuals exposed to radiation, as well as to environmental exposures.

Protection from exposure to radiation may take different forms when developing precise and quantitative requirements, depending on who is accountable for the exposure, who is accountable for protection and how amenable to control the exposure situation is.

To facilitate the development of a practical system of radiation protection all exposures are classified into the following three types of exposure situations.

- **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. In these situations there is no ongoing human activity causing the exposure and the situation following the accident may not be under the control of a person or organisation which can be held accountable. While some legal person may ultimately be found liable at law, that person may not be capable of taking the necessary immediate protective actions. Consequently, an appropriate organisation needs to initiate the necessary actions, and the regulatory situation is distinctly different from the case of planned exposure situations. 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.

These situations may cause exposures high enough to warrant consideration and possible application of protective actions. The choice of protective actions would depend on the controllability of the sources of exposure and on the prevailing economic, societal and cultural circumstances.

3.2 Safety and security objectives

The **safety** objective is the same as the objective of radiation protection, i.e. to protect people and the environment from the harmful effects of radiation. It is aligned with the IAEA *Fundamental Safety Principles* [IAEA 2006], which further state that in order to achieve this objective, measures have to be taken:

(a) To control the radiation exposure of people and the release of radioactive material to the environment;

(b) To restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation;

(c) To mitigate the consequences of such events if they were to occur.

The **security** objective can be described in similar terms to those above, placing emphasis on the protection of people, property, society and the environment, from harmful effects of radiation following a security event. It links in with the protective elements of the IAEA Nuclear Security Fundamentals *Objective and Essential Elements of a State's Nuclear Security Regime* [IAEA 2013] , and is aligned with the *Code of Conduct on the Safety and Security of Radioactive Sources* [IAEA 2004], which states:

5.(a) The objectives of this Code are, through the development, harmonization and implementation of national policies, laws and regulations, and through the fostering of international co-operation, to:

(i) achieve and maintain a high level of safety and security of radioactive sources;

(ii) prevent unauthorised access or damage to, and loss, theft or unauthorised transfer of, radioactive sources, so as to reduce the likelihood of accidental harmful exposure to such sources or the malicious use of such sources to cause harm to individuals, society or the environment; and

(iii) mitigate or minimize the radiological consequences of any accident or malicious act involving a radiation source.

3.3 Interdependence of radiation protection, safety and security

Radiation protection, safety measures and security measures have in common the aim of protecting human health and the environment by managing radiation risks. The measures need to be applied, as necessary and appropriate, to all facilities and activities, and to radiation sources and radioactive material in any form. 'Facilities' include, but are not limited to, nuclear facilities, irradiation installations, some mining and raw material processing facilities and places where radioactive materials are produced, processed, used, handled, stored or disposed of. 'Activities' includes the production and use of radiation sources for industrial, research and medical purposes, the transport of radioactive sources, the

decommissioning of facilities, radioactive waste management activities and some aspects of remediation of sites affected by residues from past activities.

Often, facilities, activities, sources and radioactive material that are sensitive from the radiation protection or safety perspective will also be security-sensitive, highlighting the need for an integrated approach to achieve the necessary protection of human health and the environment. In addition, all measures, whether they are related to radiation protection, safety or security need to be designed and implemented in a manner so that security measures do not compromise safety or radiation protection, and *vice versa*. This requires a holistic perspective where the interdependencies are fully recognised.

4. PRINCIPLES OF RADIATION RISK MANAGEMENT, AND THEIR APPLICATION

This section outlines ten principles that guide actions to manage radiation risks in order to protect human health and the environment from the harmful effects of ionising radiation. The principles are generally applicable although in practice different principles may be more or less important in relation to particular circumstances. The appropriate application of all relevant principles is required.

4.1 Clear division of responsibilities

Principle 1

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.

The person or organisation responsible for any facility or activity that gives rise to radiation risks, or for carrying out a program of actions to reduce radiation exposure, has the prime responsibility for managing the associated radiation risks. A person or organisation authorised to operate a facility or conduct an activity retains the prime responsibility in this regard and this responsibility cannot be delegated. The responsibilities of the authorised person or organisation are to be fulfilled in accordance with applicable protection objectives and requirements as established or approved by the appropriate authority. Adequate planning is a necessity to prevent planned exposure situations from becoming existing exposure situations, such as obsolete buildings and legacy sites with no identified responsible person or organisation.

Since radioactive waste management can span many human generations, consideration has to be given to the functions of the authorised persons or organisations and the appropriate authority's responsibilities in relation to present and likely future operations and impacts. This requires provision for the long term continuity of responsibilities, record keeping and the fulfilment of funding requirements.

Some radioactive material or exposures that occur naturally are not amenable to control. The regulatory system can exclude such materials and exposures from any regulatory control. In some situations, the exposure, or the amount or concentration of radioactivity being dealt with is low, and the activity may be inherently safe (i.e. no accident scenario of radiological concern can be foreseen). The responsible person or organisation may under such circumstances carry out the activities without any consideration to its radiological properties. This is referred to as being exempt from control.

Likewise, controlled dealing with material may give rise to secondary material or dealings of insignificant radiological concern, which do not require any control from the radiological point of view. Removal of control, in such cases, is referred to as clearance.

For existing exposure situations that are unregulated and where there is no clearly identifiable person or organisation responsible for the exposure, consideration has to be given to whether protective measures can be reasonably taken to reduce radiation exposures and to remediate adverse conditions, and whether the situation needs to be brought under regulatory control. These situations usually arise for exposures to radiation of natural origin, or those that arise from human activities conducted in the past. This issue is further dealt with under Principle 10.

4.2 Legislative and regulatory framework

Principle 2

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

A properly established legal and governmental framework provides for the regulation of facilities and activities that give rise to radiation risks and for the clear assignment of responsibilities. Government is responsible for the adoption within its national, state or territory legal systems of such legislation, regulations and other standards and measures as may be necessary to fulfil all its jurisdictional responsibilities and international obligations effectively, and for the establishment of an independent **regulatory body** with the appropriate legal authority, technical and managerial competence, and human and financial resources to fulfil its responsibilities.

It is also essential that the legislative and regulatory framework provides for transparency in decision making, allowing for interested parties ('stakeholders') to contribute to decisions relating to management of radiation risks. Such mechanisms provide for a broader basis for the decision making and for more informed decisions.

The legal framework in Australia includes a range of radiation-specific legislation across the Commonwealth, states and territories. Each jurisdiction has one or more organisations with the functions of a regulatory body in relation to the control of radiation and radioactive materials.

These regulatory bodies have, through the Radiation Health Committee established under the ARPANS Act, developed the *National Directory for Radiation Protection* (NDRP). The Australian Health Ministers' Conference (AHMC) – now called the Standing Council on Health – endorsed the development of the NDRP in August 1999 as the means of achieving uniformity in radiation protection practices between jurisdictions, and has agreed that the regulatory elements of the NDRP shall be adopted in each jurisdiction as soon as possible, using existing Commonwealth/state/ territory regulatory frameworks.

These Fundamentals constitute the top level document within a suite of publications, the Radiation Protection Series (RPS) that – taken together – provide a comprehensive basis for a nationally uniform approach to the management of radiation risks as specified in the NDRP. Detailed mandatory requirements for specific circumstances of exposure to radiation are given in Codes of Practice. Best-practice guidance on how to meet the objectives and requirements is given in other documents in the RPS suite of documents. These documents provide more detailed information on the application of the framework for radiation protection to be applied in different practices and circumstances.

4.3 Leadership and management for safety

Principle 3

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.

Leadership in matters relevant to management of radiation risks has to be demonstrated at the highest levels in an organisation. This can be achieved and maintained by means of an effective management system. This system has to integrate all aspects of management so that requirements for management of radiation risks are established and applied coherently with other requirements, including those for human performance and quality, and so that protection is not compromised by other requirements or demands such as, for example, productivity and commercial gains. The management system also has to ensure the promotion of a safety and security culture, the regular assessment of performance and the application of lessons learned from experience. A safety and security culture includes individual and collective commitment to safety and security, accountability at all levels and measures to encourage a questioning and learning attitude and to discourage complacency with regard to safety and security.

An important factor in a management system is the recognition of the entire range of interactions of individuals at all levels with technology and with organisations. To prevent human and organisational failures, human factors have to be taken into account and good performance and good practices have to be supported.

A facility may only be constructed and commissioned or an activity may only be commenced once it has been demonstrated to the satisfaction of the appropriate authority by means of the initial safety assessment (comprising safety, security and radiation protection elements as appropriate) that the proposed measures are adequate. For operations that continue over long periods of time or in the case of changed circumstances, assessments should be reviewed and repeated as necessary. Incidents and accidents, and security events, have to be identified and analysed, and measures have to be taken to prevent their recurrence.

4.4 Justification

Principle 4

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

The principle of **justification** requires that any decision that alters a radiation exposure situation should do more good than harm. Introducing a new radiation source, reducing existing exposure or reducing the risk of potential exposure should achieve a sufficient individual or societal benefit to offset any detriment caused. When activities involving an increased or decreased level of radiation exposure, or a risk of potential exposure, are being considered, the expected change in radiation detriment should be explicitly included in the decision-making process.

Application of the principle of justification depends on whether or not the source can be directly controlled. In planned exposure situations, the justification principle requires that the activity produces sufficient net benefit to the exposed individuals or to society to offset the radiation detriment it causes.

For some existing exposure situations and emergency exposure situations, where exposures can be controlled by action to modify the pathways of exposure or by acting directly on the source, the justification principle requires that action to avert further exposure should do more good than harm.

Medical radiation exposure of patients — whether for diagnosis or treatment — is a special case, in that the benefit is primarily to the patient. The justification for such exposure is therefore considered first with regard to the specific procedure to be used and then on a patient by patient basis. The justification relies on the clinical judgement of medical practitioners or others appropriately qualified as to whether a diagnostic or therapeutic procedure would be beneficial.

Certain exposures are deemed to be unjustified including:

- increasing the radioactivity, by deliberate addition of radioactive material or by activation, of products such as food, beverages, cosmetics, toys, and personal jewellery or adornments
- imaging using radiation for theft detection, artistic or publicity purposes.

Certain exposures should be deemed unjustified without further analysis, unless there are exceptional circumstances. Such exposures include:

- radiological examination for occupational, health insurance, or legal purposes undertaken without reference to clinical indications
- human imaging using radiation for the detection of concealed objects for anti-smuggling.

4.5 Optimisation of protection

Principle 5

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

The principle of **optimisation** of protection requires that the likelihood of incurring exposures, the number of people exposed and the magnitude of the exposures should be all kept as low as reasonably achievable, taking into account economic and societal factors. The level of protection should be the best under prevailing circumstances and should provide for adequate margin of benefit over harm. There is a potential for the principle of optimisation to be misunderstood as implying a need to minimise exposures regardless of cost. This is partly because the LNT hypothesis postulates that there is no level of exposure below which there is no risk. The optimisation principle, however, offers a means to take a **graded approach** to management of radiation risks and focuses on achieving an ethically acceptable outcome, within the boundaries of the legal system, based on balancing risks and benefits.

Furthermore, optimisation can be applied to effective management of environmental exposures. For activities that may give rise to environmental concern, it is important that assessments consider both human health and environmental endpoints, so that the best decision can be taken on the basis of a holistic understanding of radiation risks.

The measures to reduce exposures that are applied to facilities and activities that give rise to radiation risks are considered optimised if they provide the highest level of protection that can reasonably be achieved throughout the lifetime of the facility or activity, without unduly limiting its utilisation. Radiation risks need to be assessed *a priori* and periodically reassessed throughout the lifetime of facilities and activities.

A **dose constraint** is a prospective source–related restriction on the individual dose from a source in planned exposure situations, which serves as an upper bound on the predicted dose in the optimisation of protection for a source. For occupational exposure it is a value of individual dose used to limit the range of options such that only values of dose below the constraint are considered in the planning process. For public exposure the dose constraint is an upper bound on the annual doses that members of the public could receive from a planned operation of a specified controlled source.

In many cases, experience in similar planned exposure situations will allow a dose constraint to be set. Protection measures should then be undertaken to optimise protection at or below the dose constraint.

Planned exposures may, as noted earlier, be either normal exposures, which are certain or almost certain to occur, or potential which means that they are not expected to occur but may do so under certain circumstances. Such potential exposures may be more appropriately approached by constraining the risk, or setting a risk target. The risk constraint or target can be formulated as the product of probability of the exposure (i.e. how likely it is that an exposure occur in a given time period), and resulting consequence, e.g. as a cancer risk should that exposure occur. Optimisation can also be applied to reduce the risk. Dose constraints and risk constraints or targets can be used in combination.

Dose constraints do not apply in medical applications or in protection of the environment. However, medical exposures and actions to protect the environment should also be optimised.

In the case of existing exposure situations and emergency exposure situations, there will be some level of dose (or risk) above which it is judged to be inappropriate to allow exposures to occur and for these cases remedial action will almost always be justified. This level of dose or risk is used to set a **reference level**. The reference level, once defined, guides the optimisation efforts for protection of both the public and of workers. A reference level may be expressed in terms of e.g. dose, dose rate, activity or activity concentration.

Neither dose constraints nor reference levels have the legal standing of a regulatory dose limit. Exceeding a dose constraint or a reference level after implementing a program of optimisation of protection does not constitute a regulatory infringement, but it would be cause to initiate a review of protection performance to find out whether improvements can be made.

For environmental protection, ranges of dose rates or benchmark values can be defined that, like reference levels, can be used to guide optimisation efforts. It might be prudent to consider the characteristics of the ecosystem under consideration, and the range of species and their respective sensitivities, as well as the assessment methodology, when establishing such a benchmark. The consideration of environmental protection will also depend on whether a

planned, emergency or existing exposure situation is at hand. Normally, the benchmarks will be set to adequately protect populations. However, environmental protection legislation may in certain instances require protection also of individuals (e.g. individuals of endangered species) and the existence of any such legislation may influence the actions taken to protect the environment from the harmful effects of radiation.

4.6 Limitation of risks

Principle 6

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

The principle of limitation of an individual's risk of harm applies to the total dose to any individual from regulated sources in planned exposure situations other than the medical exposure of the individual as a patient. The total dose refers to the increase in radiation dose received by those exposed as a consequence of the conduct of the planned exposure situation and are normally defined in law.

Limits are insufficient in themselves to ensure the best achievable protection under the circumstances, and both the optimisation of protection and the limitation of doses and risks to individuals are necessary to achieve the highest standards of safety.

4.7 Protection of present and future generations

Principle 7

People and the environment, present and future, must be protected against radiation risks

Radiation risks may transcend national borders and may persist for a long time. The possible radiological consequences — now and in the future — of current actions have to be taken into account in judging the adequacy of measures to control radiation risks. Radiological consequences for human health and the environment have to be considered not only for local populations and environments but also for populations and environments geographically remote from facilities and activities, including those across jurisdictional and national borders. Also future radiation risks have to be considered, and where effects could span generations, subsequent generations have to be adequately protected without any need for them to take significant protective actions.

As a general rule, any effects on human health and on the environment across jurisdictional borders, that would be deemed unacceptable within the jurisdiction that regulates or maintains oversight of the source of the exposure, should not be acceptable. Similarly, any effects on future populations or environments should be considered unacceptable if they are deemed unacceptable by today's standards.

In assessing transboundary and future radiation risks from planned exposure situations, it may be necessary to consider build-up of environmental concentrations of long-lived radionuclides in the environment resulting from the activities, which means that the duration of any such activity becomes a factor to consider. Furthermore, waste management, which falls under the

planned exposure category, may have impacts in the long term from disposal facilities where the integrity of any engineered or geological barrier will need to be assessed in a comprehensive safety assessment to determine the long-term risks to the public and environment.

Any planned exposure situation may, to a variable extent, give rise to potential exposures that are not covered by a base case scenario or reasonable variants of the base case scenario. Such potential exposures may result from, for example, accidents, security events (including inadvertent security breaches such as accidental intrusion into a facility), or unpredicted degradation of barriers. Such potential exposures will have to be included in the assessment of radiological consequences of planned activities, and to a variable extent be assessed against benchmarks (e.g. reference levels) derived for emergency and existing exposure situations for workers, the public and the environment.

4.8 Prevention of accidents and malicious acts

Principle 8

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

Accidents at facilities and resulting from activities have caused many of the most harmful consequences from radiation exposure. To ensure that the likelihood of an accident or incident having harmful consequences is extremely low, measures have to be taken to prevent the occurrence of failures or abnormal conditions that could lead to loss of control.

The primary means of preventing accidents or incidents and mitigating their consequences, as part of the safety regime, is **defence-in-depth**. The objective is to ensure that the likelihood of an accident having harmful consequences is extremely low. When properly implemented, defence-in-depth ensures that no single natural, technical, human or organisational factor or failure could give rise to harmful effects and that the combinations of failures that could give rise to significant effects are of a very low probability. Arrangements need to be established for an effective response at the scene, and as appropriate at the local, national and international levels, to a nuclear or radiation emergency. The primary goal of the arrangements should be to ensure that radiation risks would be minor for reasonably foreseeable incidents and to identify practical measures to mitigate the consequences for human life and the environment. The extent of the arrangements should take into account the likelihood and possible consequences of the emergency.

The security regime needs to identify any security-sensitive targets as well as the relevant threats and vulnerabilities. A graded approach can be applied and the defence-in-depth approach utilised as necessary and appropriate, depending on threats, vulnerabilities, and nature of the activity, facility, radiation source or radioactive material in question.

4.9 Emergency preparedness and response

Principle 9

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

An emergency resulting in elevated radiation risk to human health or to the environment may result from a variety of causes, including inadvertent actions, negligence or deliberate side-stepping of procedures covered by the safety regime or security regime, equipment failure, degradation of barriers, and acts with malicious intent.

The authorised person, the employer, the appropriate authority and other appropriate branches of government need to establish in advance arrangements for preparedness and response for nuclear or radiation accidents. The scope and extent of arrangements for emergency preparedness and response have to reflect a range of possible scenarios, the likelihood and the possible consequences of an emergency, the characteristics of the radiation risks and the nature and location of the facilities and activities. A full range of foreseeable events, including those of very low probability should be considered. These arrangements should ensure that, for foreseeable incidents, accidents and security events, radiation risks would be minor and all practical measures to mitigate any consequences for life, health and the environment for any incidents that do occur are taken.

When urgent protective actions need to be taken promptly in an emergency, it may be acceptable for emergency workers to receive, on the basis of informed consent, doses that exceed the occupational dose limits normally applied — but only up to a predetermined level.

As for safety-related events, management procedures need to be developed to be able to mobilise the necessary resources to effectively deal with security events. This may include the capability to locate, recover and secure any radiation source or radioactive material over which there is no control. Procedures need to be developed to mitigate radiological risks associated with a security event. In many cases, such processes would be similar to those used to mitigate radiological consequences of accidents.

4.10 Protective actions to reduce existing or unregulated radiation risks

Principle 10

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

Radiation risks may arise in situations other than in facilities and activities that are in compliance with regulatory control. In such situations, if the radiation risks are relatively high, consideration has to be given to whether protective actions can reasonably be taken to reduce radiation exposures, and whether the particular circumstance giving rise to the radiation exposure can be, or should be, brought under regulatory control.

Usually, there are two ways by which the radiation risk can be reduced. In both cases this may require bringing the situation under regulatory control and make it compliant with the regulatory system:

- The source can be treated or otherwise dealt with so as to pose less significant radiation risks. This can be achieved by dismantling structures that cause radiation risks, or enclosing them in a structure that would prevent deterioration and release of radioactive material (entombment, or enclosure in what is sometimes known as a ‘sarcophagus’); or it could involve removal of material or topsoil to prevent any exposure from the source itself or leaching of radioactive material, in which case there is a waste management component to be considered as well.

- The exposure pathway can be eliminated or reduced, e.g. by shielding, by preventing spreading of dust, by collection of leaching water, by restricting sales of certain produce or, under extreme circumstances, moving people out of the exposure pathway such as has been the case following major nuclear accidents.

The protective actions considered in these situations will have some foreseeable economic, societal and, possibly, environmental costs and may entail some radiation risks (e.g. to workers carrying out such actions). The protective actions are considered justified only if they yield sufficient benefit to outweigh the costs of the actions and any radiation risks or other detriments associated with taking them. Furthermore, protective actions need to be optimised to produce the greatest benefit that is reasonably achievable in relation to the costs.

An emergency exposure situation will eventually, when the urgent measures have been implemented and the situation has been brought under control, transition to an existing exposure situation. This may still be the cause of significant radiation risk for both humans and the environment. Criteria guiding actions to decommission facilities and environmental remediation need to be developed in advance of accidents. The desired endpoints for decommissioning and remediation may be different from full restoration (return of conditions to the ones existing before the activity commenced), and may be informed by the local conditions.

Adequate preparedness to remediate the effects of any environmental contamination arising from a radiation accident, including in the transport of radioactive materials, should include information on the following:

- division of responsibilities in accident recovery, including the role of stakeholders
- approaches to defining targets and end states
- potential methods and technology available for environmental remediation
- development of a generic waste management program, including the use of the concepts of exemption and clearance, predisposal management and conditioning, storage and disposal of the potentially large amounts of waste arising from environmental remediation.

Such remediation preparedness will help inform relevant stakeholders of radiation risks. It is a recognition within the international radiation safety community, based on lessons learned from past major nuclear accidents, that it is too late to begin planning for accident recovery after an accident has occurred.

ANNEX 1 RELEVANT REGULATORY AUTHORITIES

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

COMMONWEALTH, STATE/TERRITORY	CONTACT
Commonwealth	Chief Executive Officer ARPANSA PO Box 655 Tel: (02) 9541 8333 Miranda NSW 1490 Fax: (02) 9541 8314 Email: info@arpansa.gov.au
Australian Capital Territory	Manager, Radiation Safety Health Protection Service ACT Health Locked Bag 5005 Tel: (02) 6205 1700 Weston Creek ACT 2611 Fax: (02) 6205 1705 Email: hps@act.gov.au
New South Wales	Manager Hazardous Materials, Chemicals and Radiation Section Environment Protection Authority PO Box A290 Tel: (02) 9995 5000 Sydney South NSW 1232 Fax: (02) 9995 6603 Email: radiation@epa.nsw.gov.au
Northern Territory	Manager Radiation Protection Radiation Protection Section Department of Health GPO Box 40596 Tel: (08) 8922 7152 Casuarina NT 0811 Fax: (08) 8922 7334 Email: envirohealth@nt.gov.au
Queensland	Director, Radiation Health Unit Queensland Health PO Box 2368 Tel: (07) 3328 9987 Fortitude Valley BC QLD 4006 Fax: (07) 3328 9622 Email: radiation_health@health.qld.gov.au
South Australia	Manager Radiation Protection Environment Protection Authority GPO Box 2607 Tel: (08) 8463 7826 Adelaide SA 5001 Fax: (08) 8124 4671 Email: radiationprotection@epa.sa.gov.au
Tasmania	Senior Health Physicist Radiation Protection Unit Department of Health & Human Services GPO Box 125 Tel: (03) 6222 7256 Hobart TAS 7001 Fax: (03) 6222 7257 Email: radiation.protection@dhhs.tas.gov.au
Victoria	Team Leader, Radiation Safety Department of Health GPO Box 4541 Tel: 1300 767 469 Melbourne VIC 3001 Fax: 1300 769 274 Email: radiation.safety@health.vic.gov.au
Western Australia	Secretary, Radiological Council Locked Bag 2006 PO Tel: (08) 9388 4999 Nedlands WA 6009 Fax: (08) 9382 0701 Email: radiation.health@health.wa.gov.au

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

GLOSSARY

Absorbed dose

The fundamental dosimetric quantity is the mean energy imparted by ionising radiation to matter in a volume element and per unit mass of matter in that volume element.

Activity

The quantity of a radionuclide in a given energy state at a given time, defined as the number of spontaneous nuclear transformations from the given energy state per second.

Defence-in-depth

The application of more than a single protective measure for a given safety objective such that the objective is achieved even if one or more of the protective measures fails.

Dose

A generic term that may mean absorbed dose, equivalent dose or effective dose depending on context.

Dose constraint

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. For occupational exposures, the dose constraint is a value of individual dose used to limit the range of options considered in the process of optimisation. For public exposure, the dose constraint is an upper bound on the annual doses that members of the public should receive from the planned operation of any controlled source.

Effective dose

The sum of the tissue equivalent doses, each multiplied by the appropriate tissue weighting factor.

Emergency exposure situation

An unexpected 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 to reduce adverse consequences.

Environmental exposure

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

Equivalent dose

The absorbed dose delivered by a type of radiation averaged over a tissue or organ multiplied by the radiation weighting factor for the radiation type.

Existing exposure situation

A situation of exposure that already exists when a decision on the need for control needs to be taken, including prolonged exposure situations after emergencies.

Ionising radiation

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

Justification

The process of determining whether a practice is, overall, beneficial, as recommended by the International Commission on Radiological Protection's *System of Radiological Protection*, i.e. whether the benefits to individuals and to society from introducing or continuing the practice outweigh the harm (including radiation detriment) resulting from the practice.

Limitation

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

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.

(Nuclear) safety

The achievement of proper *operating conditions*, prevention of *accidents* or mitigation of *accident* consequences, resulting in *protection* of *workers*, the public and the environment from undue *radiation* hazards.

(Nuclear) security

The prevention and detection of, and response to, theft, *sabotage*, unauthorised access, illegal transfer or other *malicious* acts involving *nuclear material*, other *radioactive substances* or their associated *facilities*.

Occupational exposure

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

Optimisation

Optimisation of protection (and safety) is the process of determining what level of protection and safety makes exposures, and the probability and magnitude of potential exposures, 'as low as reasonably achievable, economic and societal factors being taken into account' (ALARA), as required by the International Commission on Radiological Protection System of Radiological Protection.

Planned exposure situation

A situation involving the deliberate introduction and operation of sources. Planned exposure situations may give rise both to exposures that are anticipated to occur (normal exposures) and to exposures that are not anticipated to occur (potential exposures).

Public exposure

Exposure incurred by members of the public from radiation sources, excluding any occupational or medical exposure and the normal local natural background radiation but including exposure from authorised sources and practices.

Radiation protection

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

Radiation weighting factor

A number by which the absorbed dose in a tissue or organ is multiplied to reflect the relative biological effectiveness of the radiation in inducing stochastic effects at low doses, the result being the equivalent dose.

Radioactive (radioactivity)

'Scientific' definition: Exhibiting radioactivity; emitting or relating to the emission of ionising radiation or particles.

'Regulatory' definition: Designated by the regulatory body as being subject to regulatory control because of its radioactivity.

Reference level

In an emergency exposure situation or an existing exposure situation, the level of dose, risk or activity concentration above which it is inappropriate to plan to allow exposures to occur, and below which optimisation of protection and safety would continue to be implemented. The chosen value for a reference level will depend upon the prevailing circumstances for the exposure under consideration. When an emergency exposure situation has occurred, or an existing exposure situation has been identified, the reference level may assume a different function as a benchmark against which protection options can be judged retrospectively. The implementation of a planned protective strategy may or may not include exposures above the reference level, depending on the success of the strategy.

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.

Safety

See (nuclear) safety

Security

See (nuclear) security

Stochastic 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 reaction

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.

Tissue weighting factor

A multiplier of the equivalent dose to an organ or tissue used for radiation protection purposes to account for the different sensitivities of different organs and tissues to the induction of stochastic effects of radiation.

Wildlife

An animal or plant living within its natural environment.

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