Australian Government

Australian Radiation Protection and Nuclear Safety Agency

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Code for the Disposal of Radioactive Waste by the User

Levels for disposal and discharge of radioactive waste by the user to landfill, sewer and the atmosphere

Radiation Protection Series C-6

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.

Codes 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 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 publications are informed by public comment during drafting and are subject to a process of assessment of regulatory impact.

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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 2018.

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 peoples 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 of 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 such risks.

RPS F-1 acknowledges that activities involving radiation are introduced for a purpose, and the regulatory framework should not unduly limit justified use of radiation. An exposure arising from the planned operation of a radiation source or facility that causes exposure to a radiation source is called a 'planned exposure' and in these planned exposure situations, some level of exposure can be expected to occur. The primary means of controlling exposure in planned exposure situations is by good design of facilities, equipment, operating procedures and through training; all of which contribute to optimisation of protection.

This *Code for Disposal of Radioactive Waste by the User (2018)* sets out the requirements in Australia for disposal and discharge levels for radioactive material to landfill, sewer and the atmosphere below which no authorisation is required from the relevant regulatory authority

ARPANSA, jointly with state and territory regulators in the Radiation Health Committee (RHC), has developed this Code.

This Code is intended to complement the requirements of the relevant Work Health and Safety legislation in each jurisdiction. The relevant regulatory authority should be contacted should any conflict of interpretation arise. A listing of such authorities is provided at www.arpansa.gov.au/Regulation/Regulators.

Carl-Magnus Larsson
CEO of ARPANSA

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Contents

1. Introduction

1.1 Citation

This Code may be cited as the *User Disposal Code (2018)*.

1.2 Background

Radioactive waste is radioactive material for which no further use is foreseen, and which is under regulatory control by the relevant regulatory authority. Disposal is the recognised end point for the management of radioactive material under a hierarchy of waste controls.

Six classes of waste form the basis for the Australian radioactive waste classification scheme, *Safety Guide for Classification of Radioactive Waste* (RPS 20) (ARPANSA 2010).

Typically, in accordance with the Australian waste classification scheme:

- Very low level waste (VLLW) is suitable for disposal in a near-surface, industrial or commercial, landfill type facility with limited regulatory control. Such landfill type facilities may also contain other hazardous waste.
- Low level waste (LLW) requires robust isolation and containment for periods of up to a few hundred years and is suitable for disposal in engineered near-surface facilities.
- Intermediate level waste (ILW) requires a greater degree of containment and isolation than that provided by near-surface disposal, and requires disposal at greater depths, in the order of tens of metres to a few hundred metres. In some cases borehole disposal facilities may be suitable for ILW.

Australia has no high level waste (HLW) and is unlikely to possess any in the foreseeable future.

Radioactive material is used extensively in medical, research and industrial applications. While the use of radioactive material has significant medical, research and industrial benefits, there is often a need to dispose of waste material generated during the particular process. As ionising radiation can be detrimental to human health and the broader environment, it is important to dispose of unwanted radioactive material with minimum effect on the health and safety of people and the environment. For very low level liquid and gaseous wastes, planned and controlled discharge to the environment is an appropriate and legitimate practice when undertaken within limits authorised by the relevant regulatory authority.

1.3 Purpose

This Code sets out levels for the disposal and discharge of radioactive material to landfill, sewer and the atmosphere below which no authorisation is required from the relevant regulatory authority.

It is intended that the Code can be incorporated into regulatory instruments to ensure a uniformed approach to the disposal and discharge of radioactive material across Australia.

1.4 Scope

This Code relates to the disposal and discharge of radioactive material containing relatively low levels of radioactivity, or radionuclides of short half-life, such as are generated by medical, industrial and research uses of radioactivity in Australia. Users generating wastes containing more radioactivity than can be managed by the methods described here must consult the relevant regulatory authority.

2. Radiation protection of people and the environment

The *Fundamentals for Protection Against Ionising Radiation* RPS F-1 (the Fundamentals)(ARPANSA 2014) outlines the system of radiation protection in Australia. Section 4 of the *Fundamentals* describes the ten principles that guide actions to manage radiation risks to protect human health and the environment from the possible harmful effects of ionising radiation, namely:

1. Clear division of responsibilities
2. Legislative and regulatory framework
3. Leadership and management for safety
4. Justification
5. Optimisation of protection
6. Limitation of risks
7. Protection of present and future generations
8. Prevention of accidents and malicious acts
9. Emergency preparedness and response
10. Protective actions to reduce existing or unregulated radiation risks.

The approach to radiation protection taken in the *Fundamentals* is based on three types of radiation exposure situations: planned, emergency, and existing exposure, consistent with the International Commission on Radiological Protection (ICRP), the *Recommendations of the International Commission on Radiological Protection, ICRP Publication 103 (*ICRP 2007).

Disposal and discharge of radioactive waste is a planned exposure situation. In such situations, radiation protection can be planned in advance before exposures occur and the magnitude and extent of exposures can be reasonably predicted.

The approach to managing radiation risks in planned exposure situations is guided by principles 1 – 8 and is described in the Code for *Radiation Protection in Planned Exposure Situations*, RPS C-1 (ARPANSA 2016). As such, all requirements in RPS C-1 apply to the disposal and discharge of radioactive waste.

Radioactive materials may present a range of external radiation hazards depending on their activities and emissions and may, if ingested or inhaled, present a variety of internal radiation hazards to the human body dependent upon the nuclide and its chemical and physical forms. However, the radioactive materials considered in this Code are those which are in the lowest category of activities and which present such a low hazard to the human body that it is considered safe for disposal and discharge to be undertaken by the user.

3. Safety requirements for disposal and discharge of radioactive waste by the user

3.1 General Requirements

Disposal of radioactive material to landfill

3.1.1 A person must not dispose of radioactive material to landfill unless that person does so in accordance with:

a) requirements of S1.1 of Schedule 1, or

b) an authorisation from the relevant regulatory authority.

Discharge of radioactive material to the sewer

3.1.2 A person must not discharge radioactive material to the sewer unless that person does so in accordance with:

a) requirements of S1.2 of Schedule 1, or

b) an authorisation from the relevant regulatory authority.

Discharge of radioactive material to the atmosphere

3.1.3 A person must not discharge radioactive material to the atmosphere unless that person does so in accordance with:

a) requirements of S1.3 of Schedule 1, or

b) an authorisation from the relevant regulatory authority.

Schedule 1: Requirements and limits for the disposal and discharge of radioactive waste by the user

S1.1: Disposal of radioactive material via landfill

No authorisation is required from the relevant regulatory authority to dispose of radioactive material for final placement into landfill if the material:

1. is in solid form
2. is contained within packaging designed so that:
   (a) the smallest overall external dimension of each package is not less than 10 cm
   (b) the package can be easily handled
   (c) there are at least two complete layers of packaging between the radioactive material and the exterior of the package, one layer of which is waterproof;
   (d) the outer layer of each package:
      (i) as far as practicable, prevents the collection and retention of water, and
      (ii) can be easily decontaminated
   (e) as far as practicable, the packaging will retain its contents during transport to the landfill site
   (f) no individual package contains more than the relevant levels for Landfill Package Activity given in Column 2 of Table S1.1 of this Schedule
   (g) the dose-rate at the surface of any individual package does not exceed 5 $\mu Sv.h^{-1}$
   (h) the maximum non-fixed external contamination on any individual package does not exceed:
      (i) 4 $Bq.cm^{-2}$ for beta and gamma emitters, or
      (ii) 0.4 $Bq.cm^{-2}$ for alpha-emitters having a half-life greater than 10 days
3. is limited to no more than 10 packages containing radioactive material from the person initiating the disposal in any 7 day period at the one landfill site
4. is not placed in the recycling waste stream, and
5. is recorded in a register that is kept by the person initiating the disposal.

S1.2: Discharge of radioactive material via sewer

No authorisation from the relevant regulatory authority is required to discharge radioactive material into the sewerage system if the material:

1. consists of aqueous materials
2. is released so that:
   (i) the annual activity of a radioactive material from the site to a sewer does not exceed the level given in column 3 of Table S1.1 of this Schedule, and

(ii) the concentration at the input to a waste water treatment plant, calculated as the activity in (i) divided by the annual flow[1] through the waste water treatment plant to which the sewer connects, does not exceed that in column 4 of Table S1.1 of this Schedule, and

3. is recorded in a register that is kept by the person initiating the disposal.

S1.3: Discharge of radioactive material to the atmosphere

No authorisation is required from the relevant regulatory authority to discharge radioactive material into the atmosphere if the material is:

1. limited so that the annual activity released at the point of discharge does not exceed the levels given for air discharge in column 5 of Table S1.1 of this Schedule, and
2. recorded in a register that is kept by the person initiating the disposal.

Table S1.1 Levels for periodic disposal and discharge of very low-level radioactive material by the user below which no authorisation is required from the relevant regulatory authority

Column 1	Column 2 Landfill disposal	Column 3 Sewerage discharge	Column 4 Sewerage discharge	Column 5 Air discharge
Radionuclide	**Landfill package activity values(1),(2)** **(Bq)**	**Annual activity to sewer from a site(3),(4)** **(Bq)**	**Resultant concentration(3) at input to a waste water treatment plant** **($Bq.m^{-3}$)**	**Annual activity released to atmosphere from the point of discharge(3)** **(Bq)**
^{3}H	10^{10}	2.0×10^{11}	9.1×10^{6}	1.0×10^{12}
^{14}C	10^{8}	1.8×10^{8}	1.0×10^{3}	1.0×10^{11}
^{18}F	10^{7}	2.3×10^{9}	1.0×10^{5}	2.5×10^{13}
^{22}Na	10^{7}	1.0×10^{6}	1.1×10^{0}	1.0×10^{7}
^{24}Na	10^{6}	1.0×10^{8}	1.1×10^{3}	1.0×10^{10}
^{32}P	10^{6}	1.0×10^{7}	7.1×10^{0}	1.0×10^{9}
^{33}P	10^{9}	3.0×10^{8}	6.3×10^{1}	3.0×10^{10}
^{35}S(inorganic)	10^{9}	3.3×10^{8}	1.1×10^{4}	1.0×10^{9}
^{36}Cl	10^{7}	7.1×10^{6}	3.3×10^{2}	1.0×10^{8}
^{45}Ca	10^{8}	3.0×10^{9}	1.1×10^{5}	1.0×10^{9}
^{51}Cr	10^{8}	1.0×10^{9}	1.1×10^{3}	1.0×10^{10}
^{59}Fe	10^{7}	1.0×10^{7}	1.1×10^{1}	1.0×10^{9}
^{57}Co	10^{7}	6.3×10^{8}	1.6×10^{2}	1.0×10^{10}
^{60}Co	10^{6}	5.6×10^{6}	7.9×10^{0}	8.3×10^{9}
^{63}Ni	10^{9}	6.3×10^{10}	6.6×10^{3}	8.3×10^{12}

1 The annual flow is calculated as the average dry weather flow applied over a full year.

Column 1	Column 2 Landfill disposal	Column 3 Sewerage discharge	Column 4 Sewerage discharge	Column 5 Air discharge
Radionuclide	**Landfill package activity values(1),(2) (Bq)**	**Annual activity to sewer from a site(3),(4) (Bq)**	**Resultant concentration(3) at input to a waste water treatment plant ($Bq.m^{-3}$)**	**Annual activity released to atmosphere from the point of discharge(3) (Bq)**
^{65}Zn	10^7	7.0×10^6	3.2×10^2	3.0×10^{10}
^{67}Ga	10^7	1.0×10^9	1.1×10^3	1.0×10^{11}
^{85}Kr	10^5	–	–	7.7×10^{15}
^{89}Sr	10^7	2.0×10^9	1.7×10^3	1.0×10^9
^{90}Sr	10^5	1.0×10^7	4.6×10^2	3.0×10^{10}
^{90}Y	10^6	4.2×10^{10}	1.1×10^5	1.0×10^{11}
^{99}Mo	10^7	1.0×10^9	1.1×10^3	1.0×10^{10}
^{99}Tc	10^8	2.0×10^6	8.9×10^1	1.0×10^8
^{99m}Tc	10^8	7.0×10^8	1.1×10^4	1.0×10^{12}
^{111}In	10^7	1.0×10^9	1.1×10^3	1.0×10^{10}
^{123}I	10^8	8.3×10^9	1.1×10^4	1.0×10^{11}
^{125}I	10^7	1.0×10^9	1.1×10^3	1.0×10^9
^{129}I	10^6	1.8×10^7	8.3×10^2	1.3×10^9
^{131}I	10^7	1.0×10^8	1.1×10^2	1.0×10^9
^{137}Cs	10^5	1.7×10^7	5.1×10^1	1.4×10^{10}
^{147}Pm	10^8	1.0×10^{11}	1.1×10^5	1.0×10^{11}
^{153}Sm	10^7	3.2×10^{10}	1.5×10^6	6.3×10^{12}
^{201}Tl	10^7	1.0×10^9	1.1×10^3	1.0×10^{11}
^{223}Ra	10^6	1.3×10^8	5.7×10^3	5.9×10^8
^{241}Am	10^5	1.3×10^8	5.8×10^3	1.0×10^8

Notes

(1) When there is a mixture of radionuclides in the material to be disposed of to landfill:

$$\sum_i \frac{C_i}{X_i} \leq 10$$

Where C_i is the activity of each isotope *i* to be disposed of, and

X_i is the landfill package activity value given in Table S1.1 for each isotope *i*.

(2) For disposal of solid radioactive material to landfill where the radionuclides are not listed in this table, a disposal level for landfill package activity of 10 times the exemption limit for that radionuclide, or mixture of radionuclides calculated in accordance with Note (1) above, applies.

(3) When there is a mixture of radionuclides in the material to be discharged to a sewer or to air:

$$\sum_i \frac{C_i}{X_i} \le 1$$

Where C_i is the activity or activity concentration of each isotope *i* to be disposed of, and

X_i is the activity or activity concentration discharge value, as appropriate, as given in Table S1.1 for each isotope i.

(4) A 'site' may be, for example, a university or a hospital from which there could be several individual points of discharge to the one sewer. The activities in this column are the total activity discharged from that site to the one sewer.

Annex 1: Derivation of disposal and discharge levels in Schedule 1

A1 Introduction

The requirements for the disposal and discharge of unwanted radioactive material by the user were reviewed and updated by the Radiation Health Committee in 2014 and formally added to the *National Directory for Radiation Protection* (RPS 6) (ARPANSA 2017) in 2017. Details of the review of disposal and discharge requirements are outlined in this annex.

Prior to inclusion in the National Directory, requirements for the disposal and discharge of radioactive material by the user were given in Radiation Health Series publication No. 13, the *Code of Practice for the Disposal of Radioactive Wastes by the User* (RHS 13) (NHMRC 1985). RHS 13 provided a means of determining activities of radioactive material that could be authorised for disposal to sewer or to landfill. Disposal of higher activities of radioactive material required additional consultation with and authorisation from the regulatory authority. The activity levels are calculated using RHS13 were based on 'reasonable' assumptions but not on any specific exposure scenarios.

A2 Review of disposal and discharge requirements

The Radiation Health Committee (RHC) decided that an agreed set of activities and activity concentrations for each commonly used isotope should be prepared to promote a uniform approach to disposal and discharge of radioactive material in Australia. The RHC specified that the revised requirements should include disposal to landfill and discharge to sewer and atmosphere.

Further, RHC agreed that the levels should be such that no authorisation of the relevant regulatory authority would be required if the person were to dispose or discharge of the material with an activity or activity concentration below the level specified for the particular isotope. Where, however, this were not the case, regulatory authorisation would be required.

The revised approach

This Code is intended to:

- be as simple as possible but as complex as necessary
- have regard to current national and international guidance on disposal and discharge of radioactive material including the requirements for disposal and discharge of radioactive material in the IAEA Basic Safety Standards (IAEA 2014)
- have regard to currently available methodologies and international experience in dealing with disposal and discharge of radioactive material by users in hospitals, universities, etc.
- take account of likely exposure of people and of the environment
- be based on conservative but realistic, documented scenarios and modelling considered applicable to Australian conditions
- consider the direction of the *Fundamentals for Protection Against Ionising Radiation* (ARPANSA 2014) and *Code for Radiation Protection in Planned Exposure Situations* (ARPANSA 2016)
- consider current practice in all Australian jurisdictions.

In applying these criteria, disposal and discharge levels are expressed as an annual activity to account for exposure of people and an activity concentration for exposure of the environment were considered to be the simplest parameters.

Thus, this Code and the corresponding set of disposal and discharge levels in Schedule 1 represent activities and concentrations below which no authorisation for disposal and discharge would be required.

Thus, any person would be able to dispose of radioactive material below the activity specified in Schedule 1 to landfill. Further, any person could discharge radioactive material to a waterway or to the atmosphere below the specified activities and concentrations.

The specifications of the activities and concentrations were based on model sites such as universities or hospitals from which the discharges were made and from which there could be several individual points of disposal to the one sewer. The specified activities were therefore the total activity discharged from each site or facility to the one sewer.

The activity levels and concentrations in Schedule 1 are not limits and it is not intended to suggest that higher disposal or discharge levels would be unacceptable. The levels in Table S1.1 are considered to be screening levels below which *no* authorisation is required. Disposal or discharge above these levels can be acceptable but would require authorisation and additional supporting information may be requested by the relevant regulatory authority.

A3 The derivation of disposal and discharge levels for Schedule 1

The dose criterion for disposal and discharge by the user

Although each isotope has an exemption activity and exemption activity concentration as set by the International Atomic Energy Agency (IAEA), and adopted into the National Directory (RPS 6) (ARPANSA 2017), the IAEA makes clear that these exemption levels are not intended to apply to the control of discharges (IAEA 2010).

It was therefore considered necessary to derive levels for disposal and discharge to landfill sewerage and the atmosphere, below which no authorisation is required from the relevant regulatory authority, and that could be justified in accordance with international doctrine.

Exemption levels were derived based on scenarios where the maximum effective dose to an exposed individual would not be greater than 10 $\mu Sv.y^{-1}$ under plausible normal circumstances.

Given the restricted opportunity for the likely exposure of people to radiation from the disposal and discharge of radioactive material by the means specified in this Code, the threshold for exposure of any person above which authorisation would be required was set at 100 $\mu Sv.y^{-1}$. Disposal and discharge of radioactive material with activity (and activity concentration where relevant) below the levels in Schedule 1 of this Code would result in the exposure of a person of less than 100 $\mu Sv.y^{-1}$ and would not harm the environment. Disposal and discharge of radioactive material below these levels does not require authorisation.

It should be noted that where regulatory authorisation is required, i.e. when the levels in Schedule 1 of this Code are exceeded, the radiation regulator is likely to have some restrictions on exposure, such as 300 $\mu Sv.y^{-1}$ from any one source of radiation exposure or a limit of 1 000 $\mu Sv.y^{-1}$ to any person from all sources of radiation exposure. The person initiating the disposal might then need to carry out an assessment to show that these exposures will not be exceeded and that there will be no harm to the environment.

The models used to estimate exposure of people and the environment

Many of the models available for estimating exposures of people and the environment from disposal and discharges use an approach in line with that presented in IAEA Safety Report Series No. 19 (IAEA 2001). This approach uses simple transfer parameters that take account of several environmental processes, and implicitly assumes a state of equilibrium between the concentration in water or air and other environmental materials.

Once the concentration of discharged radionuclides in environmental materials is estimated, the routes by which 'receptors', such as representative members of the public, might come into contact with the discharged material are identified and a critical group determined.

This approach was considered appropriate for facilities where the application of annual averages is suitable.

In the models selected to generate the disposal and discharge levels for Schedule 1 of this Code, two main categories of exposure were considered:

- external exposure from radionuclides present in the air or in material incorporated in, for example, soils or sediment
- internal exposure from the inhalation or ingestion of radionuclides present in air or incorporated in water or foods respectively.

The relative importance of different exposure pathways were dependent on the:

- magnitude of the discharge
- route of discharge
- physical and chemical characteristics of the radionuclides discharged
- characteristics of the radioactive decay.

Disposal and discharge levels obtained using this methodology tend to be highly conservative and therefore are suitable for use for screening.

It was considered that regulators would benefit from adopting such generic models for assessing radiation dose to exposed persons.

Disposal to landfill

Scenarios adopted in the Commission of the European Communities were used to obtain the activities for disposal to landfill (EC 1993). Disposal to landfill is one of the scenarios considered in this European document and is not the most restrictive scenario for all radioisotopes. The landfill scenarios include exposure of the public from accidental tampering with the radioactive source and from inhalation, ingestion and skin exposure pathways. The landfill site is assumed to be a generic small site with a capacity of domestic waste of 1.5×10^4 t over an area of 1×10^{-2} km^2.

The use of the values from that document therefore provides some conservatism in the estimation of radiation exposures.

Based on the rationale described in the dose criterion above, the disposal levels for landfill package activity were calculated as ten times the exemption activity level listed in Schedule 4 of the National Directory for Radiation Protection (RPS6) (ARPANSA 2017).

Discharge to sewer

The derived levels of radioactive waste for discharge to the sewer by the user were based on calculation of the annual activity of radioactive material that could result in a dose of 100 $\mu Sv.y^{-1}$ to the most exposed individual and a concentration that would result in an exposure rate of less than 10 $\mu Gy.h^{-1}$ to the most exposed organism.

Exposure of people

Three methodologies were considered to determine exposure to people. Two methodologies were from the UK – that for calculation of Generalised Derived Constraints (GDCs) (NRPB 2000, NRPB 2010) and that for the 'Initial radiological assessment methodology' (Environment Agency 2006), which is based on dose per unit release (DPUR) data. The third methodology is that used by the IAEA to calculate clearance levels in its Tecdoc-1000 (IAEA 1998). It was noted that these models and data were developed for application in temperate European and North American conditions but were deemed applicable for the Australian situation, particularly in the urban areas where such disposal is likely to occur.

Estimates of the annual activities of radioactive materials that would not result in an annual dose above 100 µSv were derived using each methodology. Table S1.1 contains the minimum discharge levels calculated using each of the three methods.

All three approaches base their modelling on principles similar to those described in IAEA Safety Series 19 (IAEA 2001) but make different assumptions. The three data sources combined included all the isotopes in Schedule 1 of this Code. None of the three approaches considered exposure of the environment.

The methodologies considered three main exposure groups and relevant age groups (infants, adults, etc.) within each group and base their recommendations on the most restrictive scenario.

The three exposure groups considered were:

1. Sewage plant workers who were considered to spend a working year at the waste water treatment plant and who were exposed to radionuclides in sludge and effluent. Exposure from external radiation, inhalation and ingestion were considered.
2. Members of the public who were exposed to radionuclides in river water that has received treated effluent. Exposures occurred due to:
    - external exposure from sediments
    - drinking water and eating fish from the river
    - producing and consuming green vegetables and potatoes on land irrigated by the river water.

3. Members of the public assumed to live adjacent to farmland treated repeatedly with sewage sludge and to consume animal products produced from the treated land – foods consumed were assumed to have been produced on treated farmland, intakes were assumed to be at critical group levels.

The IAEA methodology did not consider the transfer of radionuclides to the terrestrial food chains due to irrigation or treatment with sewage sludge.

Each methodology made conservative, but slightly different assumptions.

Both UK methodologies assumed that the dry weather flow through the waste water treatment plant was ~60 $m^3.d^{-1}$, serving a population of 400 people. The IAEA assumed a plant that was 40 times larger.

The GDC calculation assumed that workers were exposed to sludge for 1000 $h.y^{-1}$; the DPUR calculation assumed exposure for 500 $h.y^{-1}$ and the IAEA methodology assumed exposure for 2000 $h.y^{-1}$.

The GDC and IAEA calculations assumed that all the radionuclide remained in effluent and that all the radionuclide remained in sludge. The DPUR calculations partitioned the radionuclide between effluent and sludge.

The DPUR calculations were modified to allow exposure of workers to sludge for 1000 $h.y^{-1}$ and to remove the partitioning between effluent and sludge, thus making the assumptions closer to those used for the GDC calculations.

The GDCs are the discharge rates to a sewer given in $Bq.y^{-1}$ and are based on a dose criterion of 300 $\mu Sv.y^{-1}$. The IAEA also specified clearance levels (IAEA 1998) although these were based on 10 $\mu Sv.y^{-1}$ exposure scenarios. The DPUR methodology resulted in values for the dose, in $\mu Sv.y^{-1}$, resulting from a discharge of 1 $Bq.y^{-1}$ for various exposure pathways and age groups.

Therefore in order to determine the discharge levels for this Code, GDC values were divided by three to equate to 100 $\mu Sv.y^{-1}$. Conversely, the IAEA clearance levels were multiplied by a factor of 10. The (worst case, modified) DPUR values were scaled to yield the activity that corresponded to a dose of 100 $\mu Sv.y^{-1}$.

The most restrictive annual activity is listed in Table S1.1.

Although the three data sources gave different values, the agreement was reasonable for common radionuclides and the use of discharge levels from documented sources was considered to be the best approach. A person wishing to discharge radioactive material can use this information as a basis for calculations of potential exposures from higher activities of radioactive material.

Protection of the environment

A screening dose rate of 10 $\mu Gy.h^{-1}$ to biota was used as the no-effect level, below which environmental risks would be negligible.

Corresponding concentrations in freshwater and the marine environment were then calculated using the Erica assessment tool.

The ERICA assessment tool (Brown et al 2008) provides Environmental Media Concentration Limits (EMCLs) for water and sediment in freshwater and marine environments in its parameters database – risk characterisation. These EMCLs represent the lowest concentration derived from water or sediment for freshwater or marine environments below which all biota would receive an exposure of less than 10 $\mu Gy.h^{-1}$. The concentration in water (freshwater or marine) corresponding to the EMCL in sediment was obtained by dividing the sediment concentration by the distribution coefficient (Kd).

The minimum concentration obtained by these calculations for each isotope in the Erica database was used in the derivation of discharge levels for Table S1.1.

The exit point from a waste water (sewage) treatment plant was chosen as the calculation point for the concentrations derived from the Erica assessment tool. The activity concentration at the exit point was taken as equal to that at the input to the plant.

Concentrations at the input to the waste water treatment plant corresponding to the annual activity obtained for the three methodologies for protection of people, discussed above, were calculated. The concentration at the input to a waste water treatment plant listed in Table S1.1 is the minimum of the available concentrations (for protection of people and of the environment) for each isotope.

The environment considerations are very conservative and the most limiting organism may not even be present in many disposal situations. However, as Schedule 1 of this Code is intended for screening purposes, the use of the most conservative discharge level for each radionuclide was necessary hence the requirement in Schedule 1 of this Code for both the activity and the activity concentration to be met for discharge to sewer.

Not all the isotopes in Table S1.1 are contained in the ERICA assessment tool and discharge levels will be reviewed as more data becomes available.

Discharge to atmosphere

The same three methodologies discussed above were used to generate annual activities that could be discharged to the atmosphere with no authorisation. The calculations included those of doses arising from inhalation, external exposure and ingestion. Several assumptions were made regarding:

- discharge point height above ground
- wind patterns
- distance to closest human habitation
- distance to farmland
- consumption of food (crops and animal products) from this farmland
- build-up of radionuclides in the environment.

Again, radiation doses were calculated for methodologies available for each radionuclide cases and the most restrictive level was used as the discharge levels in Table S1.1.

Applicability of the discharge levels in Schedule 1 to short-term releases

Radioactive material discharged to the aquatic environment generally occurs over a short period each day and discharges are unlikely to be continuous.

The three methodologies used to generate annual activities in Table S1.1 assumed that the activity is discharged continuously and uniformly throughout the year. Given the other uncertainties in the assessment process, the results based on continuous release were considered appropriate for these normal operational daily variations in discharges.

Glossary

All definitions in this Glossary are intended to be consistent with the definitions in the IAEA Safety Glossary *IAEA Safety Glossary – Terminology Used in Nuclear Safety and Radiation Protection, 2016 Revision (IAEA 2016)*.

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.

Activity

The quantity, A, for an amount of radionuclide in a given energy state at a given time, defined as:

$$A(t) = \frac{\mathrm{d}N}{\mathrm{d}t}$$

where $\mathrm{d}N$ is the expectation value of the number of spontaneous nuclear transformations from the given energy state in the time interval $\mathrm{d}t$.

The SI unit for activity is reciprocal second (s^{-1}), termed the becquerel (Bq).

Authorisation

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

Clearance

Removal of radioactive material or radioactive objects within authorised practices from any further regulatory control by the relevant regulatory authority.

Clearance level

A value, established by the relevant regulatory authority and expressed in terms of activity concentration and/or total activity, at or below which regulatory control may be removed from a source of radiation within a notified or authorised practice.

Discharges

Planned and controlled releases into the environment, as a legitimate practice, within limits authorised by the relevant regulatory authority, of liquid or gaseous radioactive materials.

Disposal

The placement of waste in a purpose-built facility, which will eventually be closed, without any intention of retrieval of waste packages or recovery of the radioactive material in it for any purpose.

Dose

1. A measure of the energy deposited by radiation in a target.
2. A generic term that may mean 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.

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.

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.

Exemption level

A value, established by relevant regulatory authority and expressed in terms of activity concentration, total activity, dose rate or radiation energy, at or below which a source of radiation may be granted exemption from being subject to some or all aspects of regulatory control without further consideration.

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.

Exposure

The state or condition of being subject 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.

Facility

A general term that includes nuclear facilities, irradiation installations, some mining and raw material processing facilities such as uranium mines, radioactive waste management facilities, and any other places where radioactive material is produced, processed, used, handled, stored or disposed of, or where radiation generators are installed on such a scale that consideration of protection and safety is required.

A facility includes one for which little or no regulatory control may be necessary or achievable. The more specific term 'authorised facility' should be used to distinguish those facilities for which the relevant regulatory authority has given any form of authorisation.

Ionising radiation

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

Justification

For a planned exposure situation, the process of determining whether a practice is overall, beneficial, 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.

Near-Surface Disposal

Radioactive waste disposal located at or within a few tens of metres of the Earth's surface.

Optimisation of protection and safety

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).

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.

Potential exposure

Prospectively considered exposure that is not expected to be delivered with certainty but that may result from an anticipated operational occurrence or accident at a source or owing to an event or sequence of events of a probabilistic nature, including equipment failures and operating errors.

Radiation

In this Code, 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).

Radiation protection

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

Radiation risks

Detrimental health effects of exposure to radiation (including the likelihood of such effects occurring), and any other safety related risks (including those to the environment) that might arise as a direct consequence of:

(a) exposure to radiation

(b) the presence of radioactive material (including radioactive waste) or its release to the environment

(c) a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation.

Radiation source

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.

Radioactive material

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

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

Radioactive Waste

'Radioactive waste' is defined for regulatory purposes as material for which no further use is foreseen that contains, or is contaminated with, radionuclides at concentrations or activities greater than clearance levels as established by the relevant regulatory authority. Radioactive waste comprises radioactive material in solid, liquid or gaseous form.

Relevant regulatory authority

The radiation protection authority or authorities designated, or otherwise recognised, for regulatory purposes in connection with protection and safety relating to applications of ionising radiation. A list of relevant regulatory authorities in Australia can be found on ARPANSA's website at www.arpansa.gov.au/Regulation/Regulators.

Safety

For the purposes of this Code, '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.

Security

The prevention of, detection of, and response to, criminal or intentional unauthorised acts involving or directed at nuclear material, other radioactive material, associated facilities, or associated activities.

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