Australian Government

Australian Radiation Protection and Nuclear Safety Agency

SAFETY GUIDE

Predisposal Management of Radioactive Waste

RADIATION PROTECTION SERIES No. 16

Radiation Protection Series

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

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

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

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

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

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

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

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

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

Published by the Chief Executive Officer of ARPANSA in September 2008

Foreword

Radioactive waste arises from the industrial, medical and research use of radioactive materials. Waste generated from the use of radioactive material that falls below regulatory concern or within discharge limits can be disposed of to the atmosphere, sewer or landfill. Some low-level radioactive waste can be stored for short periods until it has decayed to very low-level radioactive waste or to levels below regulatory concern and disposed of with non-radioactive waste. Other wastes must be managed pending access to disposal facilities.

This Safety Guide sets out non-prescriptive, best-practice guidelines for organisations managing radioactive waste. The Safety Guide will support the regulatory arrangements that currently apply in the individual jurisdictions. The Safety Guide should also assist in ensuring adequate monitoring, safety assessment and maintenance of radioactive waste in storage, for the purpose of ongoing safety and security.

The draft Safety Guide was released for public comment from 22 January 2008 until 14 March 2008. Thirteen submissions were received and reviewed. The final version of the Safety Guide was approved by the Radiation Health Committee at its meeting of 16-17 July 2008. The Radiation Health and Safety Advisory Council advised me to adopt the Safety Guide on 8 August 2008.

John Loy PSM
CEO of ARPANSA

25 September 2008

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1. Introduction

1.1 CITATION

This Safety Guide may be cited as the *Safety Guide for the Predisposal Management of Radioactive Waste (2008).*

1.2 BACKGROUND

Radioactive waste is generated in Australia through the operation and decommissioning of research reactors, the use of radioactive materials in industry, medicine, education, research and consumer products, the mining and milling of ores and their processing, and in the remediation of contaminated sites. Radioactive waste must be safely managed for the protection of human health and the environment.

The low and intermediate level radioactive waste from research installations, nuclear applications in medicine and industry, and radioisotope production facilities can be diverse and variable in nature, with a wide range of radioactivity levels and containing many different radionuclides.

The radiation protection legislation of the States, Territories and the Commonwealth establish requirements for the safe management of radioactive waste prior to its disposal.

The International Atomic Energy Agency (IAEA) has published Safety Requirements for the *Predisposal Management of Radioactive Waste, including Decommissioning* (IAEA 2000b) and the Safety Guides listed in the following table. Recommendations in these IAEA documents were considered in developing the guidance provided in this Safety Guide.

Number	Title	Date
WS-G-2.3	Regulatory Control of Radioactive Discharges to the Environment Supersedes Safety Series No. 77	2000
WS-G-2.5	Predisposal Management of Low and Intermediate Level Radioactive Waste	2003
WS-G-2.6	Predisposal Management of High Level Radioactive Waste	2003
WS-G-2.7	Management of Waste from the Use of Radioactive Materials in Medicine, Industry, Research, Agriculture and Education	2005
WS-G-6.1	Storage of Radioactive Waste	2006

The following IAEA draft safety guides are at various stages of development:

Number	Title
DS284	Safety Assessment for Nuclear and Radiation Facilities other than Reactors and Waste Repositories *Held-up pending development of Safety Requirements on Assessment and Verification.*
DS353	Predisposal Management of Radioactive Waste *(A requirements level document to supersede the predisposal part of WS-R-2)*
DS390	Classification of Radioactive Waste *(To update SS 111-G-1.1 (1994))*
DS421	Protection of the Public against Exposure to Natural Sources of Radiation including NORM Residues

1.3 Purpose

Implementation of the measures recommended in this Safety Guide should ensure that predisposal management of radioactive waste is performed safely with no adverse impact upon public health or the environment and the pretreatment, treatment and conditioning steps described should enable waste to be made suitable for storage and/or disposal.

A purpose of this Safety Guide is to assist regulators, persons responsible for facilities that generate and manage radioactive waste and other specialists in achieving compliance with regulatory requirements.

The Safety Guide should also assist in ensuring adequate monitoring, safety assessment and maintenance of radioactive waste in storage, for the purpose of ongoing safety and security.

The information in this Safety Guide is advisory and should be read in conjunction with applicable regulatory requirements.

1.4 Scope

This Safety Guide applies to the predisposal management of radioactive wastes, including the following:

- low and intermediate level radioactive waste from operations such as research reactors, radioisotope production facilities, and from medical, educational, research, industrial and commercial uses of radioactive materials; and
- radioactive wastes that with temporary storage will decay to exemption levels or to levels suitable for disposal as waste with very low levels of radioactivity.

This Safety Guide does not apply to the management of spent reactor fuel, and operational wastes managed at mining and mineral processing sites to which the *Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing* (ARPANSA 2005) applies.

Predisposal management of waste includes all steps or activities in the management of waste, from its generation up to acceptance for disposal at a repository or other disposal site, disposal as very low level wastes or the removal of regulatory control. Predisposal management may include pretreatment, treatment, conditioning, decommissioning, storage, activities in preparation for transport and any associated activities such as characterising the waste, the waste form or the waste package. The intermediate goals of treatment and conditioning include making the waste safe for storage and addressing security issues.

The ultimate aim of treatment and conditioning is to prepare waste for disposal by ensuring that the waste will meet the waste acceptance criteria of a disposal facility. Hence this Safety Guide does provide some guidance on mode of disposal for different waste types and generic waste acceptance criteria for disposal. However, the disposal of radioactive waste is not within the scope of this Safety Guide. Requirements for disposal in a near-surface facility can be found in the *Code of Practice for the Near-Surface Disposal of Radioactive Waste in Australia* (NHMRC 1992) ('the Near-Surface Disposal Code').

Some very low level waste or waste streams from the management and processing of radioactive materials may be suitable for discharge to the environment or disposal at a municipal tip. Nationally uniform limits for such waste discharge and tip disposal are proposed to be included in Schedule 8 of the *National Directory for Radiation Protection (NDRP)*. As Schedule 8 is still in preparation at the time of publishing this Safety Guide, the regulatory requirements of the Authorities listed in Annex I of this Safety Guide should be consulted until Schedule 8 is completed and adopted as a regulatory requirement.

Some guidance is given on assessing non-radiological hazards of radioactive waste; however, detailed recommendations on non-radiological hazards are beyond the scope of this Safety Guide.

1.5 STRUCTURE

Specific guidance on managing particular types of waste that occur in Australia is provided in Annexes A to F. Annex G describes generic waste acceptance criteria for disposal.

1.6 INTERPRETATION

This Safety Guide provides guidance on actions, conditions and procedures for managing radioactive waste. Some recommendations in this Safety Guide are expressed as 'should' statements which indicate that the measures recommended be undertaken or equivalent alternative measures be undertaken to comply with regulatory requirements.

Other statements indicated by 'may', 'might' or 'could' indicate suggestions for a course of action, but there are likely to be other methods that can achieve the same level of safety.

The recommendations and suggestions in this document are guidance and are not to be considered mandatory by a regulator. Alternative measures and methods should be acceptable if they provide a level of safety and effective control equal to or better than the measures and methods described in this Safety Guide.

2. Protection of Human Health and the Environment

2.1 GENERAL

The objective of predisposal management of low and intermediate level radioactive waste is to ensure that the waste is managed in a manner that protects human health and the environment, both now and in the future, without imposing undue burdens on future generations. As well as controlling impacts on future human health, the aim should be to limit reliance on actions to be undertaken by future generations. As far as practicable, the predisposal management of waste should not rely on complex long term institutional arrangements or actions as a necessary safety feature.

Radioactive waste should be treated and conditioned to enhance its long term safety and security. If there is an established disposal facility, the waste should be treated and conditioned to meet the waste acceptance criteria of the disposal facility. If there is no established disposal facility, undertaking irreversible treatments that might limit future options should be avoided, unless there are clear safety and security benefits. Guidance on this issue is provided in Section 4.4.

Where the predisposal management of radioactive waste has the potential for release or migration of radionuclides beyond jurisdictional boundaries, the effects beyond the boundaries should be discussed by the operator and/or the regulatory authority with the relevant regulatory authority in the neighbouring jurisdiction.

A safety culture should be fostered and maintained in organisations involved in the predisposal management of radioactive waste, from its generation to its eventual disposal, so as to encourage an enquiring, learning and self-disciplined attitude to protection and safety and to discourage complacency.

2.2 RADIATION MANAGEMENT PLAN

A Radiation Management Plan which describes the operations and procedures for managing the radiation exposures of staff and the public should be prepared.

The radiation exposure of any person as a result of activities in the predisposal management of radioactive waste should be optimised, with due regard to dose constraints and with exposures of individuals kept within specified limits. In designing a facility and planning operations, the Responsible Person should take into account the possible exposures to both workers and the public. The doses should be kept below established dose limits and as low as is reasonably achievable, economic and social factors being taken into account (ALARA).

Optimisation and limits are described in Radiation Protection Series No. 1: *Recommendations for Limiting Exposure to Ionizing Radiation (Printed 1995 – Republished 2002) and the National Standard for Limiting*

Occupational Exposure to Ionizing Radiation (Printed 1995 – Republished 2002) (ARPANSA 2002).

Operations and procedures should be optimised to ensure that the magnitude of individual doses, the number of people exposed, and the likelihood that potential exposures will occur should all be kept as low as reasonably achievable, economic and social factors being taken into account (ALARA). Optimisation takes into account good practice at the facility and other similar, well managed facilities. Strategies are ranked in order of reduction in detriment and an optimum is reached when any further step to reduce the detriment would involve resources out of proportion to the consequent reduction (ARPANSA 2002).

The Radiation Management Plan should include processes and procedures for dealing with incidents and accidents and define responsibilities for emergency response.

2.3 Radioactive Waste Management Plan

The Radioactive Waste Management Plan is a plan for managing radioactive waste generated by the use of radioactive materials. The Plan encompasses all predisposal management processes within the facility to which it applies. For radioactive waste management facilities that treat or condition radioactive waste and where environmental impacts are possible, a Radioactive Waste Management Plan should be prepared that describes the process to be undertaken and demonstrates operations can be undertaken safely and securely with minimal impact on the environment. The purpose of the Radioactive Waste Management Plan is to ensure the protection of the public and the environment against ionizing radiation. A key feature will generally be an appropriate assessment of the effects of radionuclides on the human population and on the environment, including non-human biota. A Radioactive Waste Management Plan should also be prepared if significant changes are made to an existing licensed facility or for facilities that store liquid wastes for short term decay, such as iodine-131 holding tanks.

Most facilities that only store small quantities of solid radioactive waste do not require a Radioactive Waste Management Plan. However, preparation of a Radioactive Waste Management Plan is generally appropriate for a facility storing a substantial amount of radioactive waste.

Examples of sound operational and engineering practices and administrative controls that could be included in a Radioactive Waste Management Plan include:

- thorough planning for and careful execution of activities for the management of waste, including the eventual decommissioning of the facilities;
- the physical, chemical and/or biological characterisation of waste;
- pre-work assessments and use of training mock-ups to minimise exposures during operational and maintenance activities, if warranted by the hazards;

- the use of remote handling technologies for operational and maintenance activities, if warranted by the hazards;
- establishing controls, such as activity limits and checking by trained personnel, if items are transferred or removed from areas of higher contamination to areas of lower contamination; and
- verifying the adequacy of controls to limit the exposure of workers and the public by means of personal, area and discharge monitoring.

The Radioactive Waste Management Plan should include a safety assessment. Guidance on undertaking such safety assessments is provided in Section 2.4.

The Radioactive Waste Management Plan does not need to repeat information available elsewhere in the facility management system, but it should provide references to relevant procedures, responsibilities and schedules. The facility should have clear assignment of responsibilities, procedures, processes and schedules for managing radioactive waste. Guidance on management systems and quality assurance is provided in Section 2.5.

A facility for the predisposal management of waste should be designed so that as far as possible incidents will be avoided and accidents prevented, and if they do occur the consequences will be mitigated. All stages in treatment and conditioning should be assessed systematically using a HAZOP (Hazard and Operability) or other appropriate systematic analysis to identify hazards. The HAZOP method is a structured multidisciplinary team approach to hazard analysis. Hazards should be eliminated if practicable; if not, they should be minimised by means of changes to the design or to operational procedures. Results of any HAZOP analyses should be included in the Radioactive Waste Management Plan.

The design and operation of facilities for the predisposal management of radioactive waste should take into account any potential hazards due to other non-radioactive physical, chemical or biological characteristics of the waste. Protection from non-radiological hazards should be provided in accordance with the relevant standards on health and safety and environmental protection.

Decommissioning should be considered in the design of facilities to be used for the predisposal management of radioactive waste, with its complexity commensurate with the facility's size and operations performed. Design options and operating practices that will facilitate the decommissioning of the facility should be chosen, and a decommissioning plan that can be updated during the life of the facility should be prepared.

2.4 SAFETY ASSESSMENT

A safety assessment should be prepared as part of the Radioactive Waste Management Plan. A safety assessment provides the basis for the safety case that demonstrates the facility can operate safely and the proposed pretreatment, treatment, conditioning and storage operations can be undertaken safely. The detail, scope and rigour of such an assessment will depend on the nature of the waste management operations and on the radiological hazard.

If waste management is one activity of a larger facility, the Safety Assessment Report of the overall facility could include assessment of the waste management activities. There may be no need to produce a separate Safety Assessment Report for operations involving management of waste.

The Safety Assessment Report should describe the structure, systems and components of the facility, the waste to be processed and all the associated operations for both normal activities and in the event of an incident or accident. The report should address the impacts of routine waste operations and any credible abnormal occurrences. The report should identify possible incident and accident scenarios which might occur and should demonstrate that the appropriate measures to minimise the likelihood of such incidents or accidents are in place and that their consequences would be mitigated. The Safety Assessment Report should be included in a safety case demonstrating that the facility can operate safely.

The aim of the safety assessment is to demonstrate that the performance objectives are satisfied for the possible incidents and accidents and that the overall process is acceptable for licensing or authorisation. The results should include predicted impacts on the workers, the public and the environment.

Depending on the nature of the waste management operations and the radiological hazard, the Safety Assessment Report for a waste management facility could include:

- a description of the components of the facility, the site and surrounds that are relevant to the management of the waste to be processed or stored in the facility. Remote locations will generally present unique features that should be addressed specifically;
- the proposed inventory of waste and a description of chemical, biological and physical hazards posed by the waste;
- a list of relevant regulations and safety guidelines pertinent to each stage of the waste management operation;
- the identification of relevant safety criteria required by the regulatory body; including design and performance expectations relevant to the waste processes, operations and activities and the criteria for an acceptable radiological impact. The consequences included in the safety criteria would normally include impact on workers, the public and the environment;
- the identification of normal and abnormal operating scenarios that encompass the range of what could credibly go wrong. Conditions, processes and events that potentially influence the integrity and safety of waste operations and that might originate outside or inside the facility should be considered;
- the data and information used to assess the scenarios, the source of the data and its accuracy;

- a description of the conceptual and/or mathematical modelling used to assess the scenarios and quantify the potential consequences. Abnormal operational conditions should be assessed based on their consequences and likelihood;
- input data used in conceptual and/or mathematical modelling, which should be clearly referenced, including the source and accuracy of data used;
- documentation of the results of the safety assessment; and
- a comparison of the results of the safety assessment with the safety criteria.

If the safety assessment does not meet the safety criteria, then the results of the assessment should be used to determine whether changes to facility design, changes to operating procedures etc, can be implemented to meet the safety criteria or whether the proposal should be abandoned. Sensitivity and uncertainty analyses may identify the parameters that most affect the results of the safety analysis. Preparation of a safety assessment will be an iterative process, performed until a facility design and operational system can be demonstrated to meet all safety requirements.

Assumptions made in conducting the safety assessment should encompass the range of operations that will occur in practice and a realistic range of abnormal incidents and accidents in relation to waste management. The safety assessment should be further developed if proposed processes or operating procedures are outside the envelope of processes or procedures assumed in the original safety assessment or if a new incident or accident scenario is identified.

Conditions, processes and events that originate outside the facility should be identified on a site specific basis. Challenges to safety that originate within the facility should be based on the nature of the facility and on the processes and activities that take place in it. Annexes to the IAEA *Safety Guide on Predisposal of Radioactive Waste* (IAEA 2003d) provide lists of possible conditions, processes and events for consideration in the safety assessment of a major facility for the management of radioactive waste.

The Safety Assessment Report should include an assessment of the radiological impact of liquid and gaseous releases that may be routinely or abnormally discharged to the environment from the facility. The adequacy of equipment used to monitor and control the levels of such discharges should also be assessed. There is no need to assess the radiological impact of releases of very low levels of radioactivity that satisfy the requirements and limits for the disposal of radioactive waste by the user proposed to be included in Schedule 8 of the *National Directory for Radiation Protection*. The regulator could have more specific requirements and guidance on acceptable levels for any liquid and gaseous releases.

The Safety Assessment Report should be reviewed periodically and updated as necessary on the basis of the information gathered by monitoring the workplace and the environment. The facility should have a modifications policy which includes an assessment of whether a proposed modification potentially changes the safety case. If changes are to be made to the operational procedures or facility design, the assessment should demonstrate the potential risks are not unduly increased as a result of the proposed changes. Significant modifications to procedures or design may require regulatory approval.

Records of all incidents and accidents (and also of incidents and accidents that were averted) should be periodically reviewed to determine if the safety assessment needs to be updated.

The safety assessment may identify features important to the safe operation of the facility or activity. These features should receive special consideration in the Radiation Management Plan and the Radioactive Waste Management Plan.

2.5 Management System (Quality Assurance)

The term 'management system' describes the integrated system that brings together requirements for safety management, quality management, environmental management, security and business management.

The management system should focus on important safety, security, environmental and business issues. The level of detail and control in the management system should be commensurate with the risk of adverse outcomes.

A larger organisation might already have a management system applying to all operations of the organisation operating the facility. If there is no overall organisational management system, then a management system should be implemented for the predisposal management of the radioactive waste.

The management system should meet the international quality management system standard ISO 9001 (2000) or a comparable management system standard and the IAEA safety requirements for management systems for nuclear facilities and activities (IAEA 2006a). The IAEA Safety Guide (IAEA 2006b) provides guidance on implementing management systems for nuclear facilities and activities including radioactive waste management facilities.

The management system should address the managerial tasks, including planning and scheduling activities, responsibilities and the use of resources. These tasks and the results of the activities should be documented. The responsibilities and authorities of the personnel and organisations involved should be clearly specified. Procedures for business-critical processes should be part of the management system, as should training requirements. The management system should be identified in a proposal submitted for approval by the regulatory body.

Quality control should be applied to all stages and elements of the predisposal management of radioactive waste. Quality control in the management system should be at a level to demonstrate effective control of the radioactive waste and demonstrate that the waste meets physical, chemical and containment requirements at each stage of the predisposal management activity and for acceptance of the waste for disposal.

The management system should include procedures and processes for:

- pretreatment (including characterisation) of the waste;
- approval of the treatment and conditioning processes for the waste;
- development of the specifications for packages for radioactive waste;
- confirmation of the characteristics for waste packages; and
- review of quality control records.

Records generated at all stages of the predisposal management of waste are important for demonstrating the compliance of the waste package with the specifications. Such records should ensure the traceability of the characteristics of the waste from its generation through to its processing and storage. A system for managing and archiving documentation should be established. Examples of the contents of such records for waste packages include:

- characterisation data for the waste as generated;
- values of the key process parameters for the waste during its pretreatment, treatment and conditioning;
- calibration records for equipment and systems used for process control;
- characterisation of the waste form and the associated container (e.g. material certificates for the container and its lid and welds or seals, including quality control tests and their records);
- values of significant monitoring parameters; and
- identification of waste packages and storage locations.

If no treatment or conditioning facility is available, it may be necessary to store the waste for long periods before disposal. In such cases the record keeping system should be designed to ensure that the quality and integrity of the records, as well as the marking and labelling of waste packages, are of sufficient quality to identify, maintain and preserve such information for sufficient time. An appropriate backup system to protect this information should also be established.

An audit program should be established to verify that the requirements of the management system are being met, procedures are being followed and the correct records are being kept. Important features of the audit program are transparency and accountabilty mechanisms, including who the audits will be reported to and how to keep the community informed of audit results.

Audits should be used to verify that waste management processes are being conducted within specified parameters, in compliance with the procedures for safe operation and with the requirements established by the regulatory body in a licence or an authorisation of another type.

3. Responsibilities Associated with Predisposal Management of Radioactive Waste

3.1 General

The overall objective of predisposal management of radioactive waste is to produce waste packages that can be handled, transported, stored and disposed of securely and safely. Waste should be conditioned to meet acceptance requirements for its disposal. There should be a clear and documented allocation of responsibility for safety during the entire predisposal management process.

Based on the perceived risk, the regulator might require pre-operational and commissioning tests prior to granting authorisation to commence operations using radioactive materials to demonstrate compliance with the requirements for design and other safety and security requirements.

Owing to the potential time period between the conditioning of radioactive waste and its disposal, the regulator could require assurance that there would be the necessary human, technical and financial resources available when required and that data and records will be maintained for an appropriate period of time.

3.2 Responsible Person

The Responsible Person is defined as having overall management responsibility for the facility. Prior to commencing the construction or significant modification of any facility for the predisposal management of radioactive waste, the Responsible Person should submit to the regulatory body an application including a Radiation Management Plan (Section 2.2) and, if required, a Radioactive Waste Management Plan (Section 2.3) that details the proposed design and operational practices. The application should demonstrate that the proposed operational procedures will provide effective control of the radioactive waste at all times. The application should justify the proposed practices and demonstrate that the activities can be performed safely and securely.

The scope and detail of the application to the regulator should be commensurate with the level of hazard. Waste processing that involves higher risk and larger amounts of waste will require more detailed analysis to demonstrate adequate levels of safety and environmental impact.

Any transfer of radioactive waste should be made only to authorised organisations. Prior to any transfer of radioactive waste to another organisation, the Responsible Person should ensure that:

- the regulator in the jurisdiction to which the waste is destined has been notified and consent for the transfer obtained;

- the accepting organisation possesses sufficient technical and administrative means to manage the waste;
- continuity of effective control during the transport of radioactive waste is maintained;
- transport complies with the *Code of Practice for the Safe Transport of Radioactive Material* (RPS2) (ARPANSA 2008) and the relevant legislation of all jurisdictions involved; and
- information is supplied to the intended recipient of the waste and confirmation of intended acceptance of the waste is received.

The Responsible Person should accept responsibility for the safety of all activities in the predisposal management of waste, even if the work is contracted to a third party.

In general, treatment of radioactive waste requires approval from the regulator before any treatment or conditioning is undertaken. The Responsible Person should ensure that all necessary regulatory approvals are in place before any operations are undertaken on any waste.

If the waste is destined for an established disposal facility, the Responsible Person should ensure that the waste package meets the acceptance requirements for that facility. If no disposal facility is available, the Responsible Person should consider the compatibility of the waste package with the anticipated acceptance requirements for disposal, so as to be able to provide reasonable assurance that the conditioned radioactive waste will be accepted for disposal.

4. Elements of Predisposal Management of Radioactive Waste

4.1 Interdependencies

Interdependencies exist between the steps in the management of radioactive waste. At the planning phase, various alternatives are usually possible for each step in the management of radioactive waste. All the different steps should be evaluated, as part of an integrated system in which the steps are complementary and mutually dependent. The most appropriate treatment and conditioning options are those that lead to a waste form and package that meets the acceptance requirements of the disposal facility, whilst minimising waste volumes and doses resulting from these operations.

Personnel and/or organisations responsible for subsequent steps should be fully consulted and informed of proposed processing of the waste. For example, the Responsible Person of the storage facility should be involved in planning for treatment and conditioning needed to ensure that the packaged waste is suitable for the conditions of the store.

4.2 Waste Minimisation

Low and intermediate level waste is generated by a wide range of activities that use radioactive materials or radioactivity, including the operation and decommissioning of nuclear facilities and the cleanup of sites. The generation of waste should be kept to the minimum practicable. Waste minimisation relates to minimising the total volume of waste and the total amount of radioactivity. All processes that generate waste should be assessed before commencement and regular reviews undertaken to determine if the amount of radioactive waste can be reduced by changes in process design or operational procedures. The chemical characteristics of the waste being generated should also be assessed to optimise subsequent processing of the waste.

Waste minimisation aims to reduce the amount of radioactive waste generated at source. Waste minimisation aspects to be considered in facility design include:

- selection of materials, processes and structures, systems and components for the facility;
- selection of design options that favour waste minimisation during operations and when the facility is eventually decommissioned;
- use of effective and reliable techniques and equipment; and
- clear demarcation of zones and equipment potentially containing radioactivity to prevent spread of contamination.

Waste minimisation aspects to consider during operations include:

- segregating the different types of radioactive waste (e.g. long-lived alpha emitting waste, short-lived beta/gamma waste, waste with very low concentrations of radioactivity, concentrated liquids, low concentration liquids) if this segregation optimises subsequent treatment and conditioning steps;

- minimising the amount of non-radioactive material used in controlled areas to prevent contamination and generation of additional waste;
- keeping non-radioactive wastes well separated from radioactive waste in a controlled area. Non-radioactive waste should be checked before being removed from a controlled area to confirm it is non-radioactive;
- planning activities and the use of equipment for handling waste to limit generation of secondary radioactive waste;
- decontaminating equipment and materials to minimise the volume of waste that is radioactive, together with control of secondary waste arising from decontamination; and
- recycling and reusing materials and structures, systems and components that are potentially contaminated.

Waste contaminated with radionuclides of short half-life (of the order of less than 6 years) may be collected and stored until the radioactivity decays sufficiently to meet exemption levels in the *National Directory for Radiation Protection* (ARPANSA 2004).

4.3 Waste Characterisation

The effective management of low and intermediate level waste depends on knowledge of the waste characteristics and the contained radioactivity. Until the waste has been characterised, management should be based on conservative assumptions of its physical and chemical properties and the contained radioactivity. Knowledge of the generation process and experience of waste generated earlier from the same process or from similar processes can be used to estimate the characteristics of the waste, but this estimate should be sufficiently conservative to cover the possible range of activities and hazardous properties.

Characterisation of radioactive waste may occur in several stages. Knowledge of the generation process provides the first estimate of the characteristics of waste; then direct measurements improve the information on the properties of the waste. The initial measurement could be determining the dose rate emitted from the waste. Later measurements could be by gamma spectroscopy, and waste could be sampled for further analysis, e.g. alpha, beta spectroscopy and/or chemical analysis. The aim of waste characterisation is to define waste properties sufficiently to demonstrate acceptance for successive waste management steps, and ultimately to meet waste acceptance criteria for the disposal facility.

Consideration should be given to segregating different types of radioactive waste to facilitate waste management and optimise subsequent treatment and conditioning steps. A decision to segregate different types of waste should be based on a risk based analysis that demonstrates safety, security or management benefits. Segregation can be justified if it allows a significant amount of waste to be classified at a lower level of hazard and/or reduce the amount or volume of waste that is classified at a higher level of hazard. Waste can be segregated on the basis of radiological, physical, chemical and pathogenic properties. Security considerations may also drive segregation practices.

It may be advantageous to segregate waste on the basis of half-life to facilitate management and meet the categories in waste acceptance criteria for disposal. It is suggested that radioactive waste be categorised into three half-life categories:

- short-lived material with half-life less than 6 years (i.e. includes cobalt-60 with half-life 5.3 years);
- medium-lived material with half-life more than 6 years but less than 40 years (i.e. includes caesium-137 with half-life 30.1 years and strontium-90 with half-life 28.8 years); and
- long-lived material with half-life more than 40 years.

The above categories of 6 years and 40 years half-life are consistent with the Near-Surface Disposal Code (NHMRC 1992). The Near-Surface Disposal Code uses ≤5 years and ≤30 years but as rounded numbers and this means that Co-60 with a half-life of 5.3 years is considered to be short-lived waste and Cs-137 with a half-life of 30.1 years is included in ≤30 years. Using 6 years and 40 years makes clear that Co-60 is included in the short-lived category and Cs-137 is included in the medium life category.

Radioactive waste can also be segregated on the basis of the level of radioactivity and the radiotoxicity of the contained radionuclides. An indication of the radiotoxicity of the radionuclide(s) is the exemption level given in the *National Directory for Radiation Protection* (ARPANSA 2004). It may be worthwhile to segregate waste containing mainly alpha emitting radionuclides from waste with no or very low levels of alpha emitting radionuclides because alpha emitters usually have higher radiotoxicity than non-alpha emitters, require a greater degree of containment and may need to be treated differently for disposal. Viable strategies may involve other types of segregation, for example the separation of low energy beta/gamma emitters from high energy beta/gamma emitters.

Other non-radiological considerations for segregation include:

- form: solid, gaseous and liquid wastes are generally treated separately;
- combustible or non-combustible;
- compressible or non-compressible;
- metallic or non-metallic;
- fixed or non-fixed surface contamination;
- materials and objects that are pyrophoric, explosive, chemically reactive or otherwise hazardous;
- items containing free liquids or pressurized gases;

- waste containing infectious agents or is regulated as medical waste; and
- animal carcasses and putrescibles materials.

Segregation is only worthwhile if the segregated wastes will be treated differently as they move through the waste management steps to disposal or if waste acceptance criteria for disposal are likely to be different.

Some waste generated in a facility may be able to be treated as non-radioactive waste if it can be demonstrated by measurement that the radioactivity of all radionuclides is below the exemption limit listed in the *National Directory for Radiation Protection* (ARPANSA 2004). The Responsible Person should check to ensure that the process proposed to exempt waste meets the requirements of the regulator. Where the operator is unsure, or does not have suitable radioactivity measurement facilities, they may choose to consult with the regulator on whether the waste meets exemption limits.

4.4 WASTE PROCESSING

Radioactive waste processing can be divided into three steps (IAEA 2003e):

> **Pretreatment** includes any or all of the operations prior to waste treatment, such as collection, segregation, chemical adjustment and decontamination.
>
> **Treatment** includes operations intended to benefit safety and/or economy by changing the characteristics of the waste. Three objectives of treatment are: volume reduction, removal of radionuclides and change of composition.
>
> **Conditioning** includes those operations that produce a waste package suitable for handling, transport, storage and/or disposal. Conditioning may also include the conversion of the waste to a solid waste form, enclosure of the waste in containers, and, if necessary, provision of an overpack.

There may be some situations where waste processing will be managed at different locations e.g. for centralised storage in a location different from that in which the waste was generated. There is also the possibility of centralised conditioning facilities. Thus, the three stages mentioned here may be interspersed with 'storage' and 'transport' activities within/between stages.

In deciding on treatment and conditioning processes, consideration should be given to the suitability of the resultant waste packages for transport and storage, including retrieval, and to their suitability for emplacement in a disposal facility on the basis of the anticipated disposal waste acceptance requirements.

Treatment and conditioning may include changing the chemical form of radioactive waste. The potential dose to workers and/or the public from routine operations or from any credible abnormal occurrences may be greatly reduced by changing the chemical form. The mobility of radioisotopes in the environment, the likelihood of ingestion and inhalation, and the committed dose per unit intake can depend on the chemical form of the radioisotope. The benefits of changing the chemical form of radioactive waste should be considered in managing radioactive waste.

In many cases, decisions about predisposal management of radioactive waste have to be made before waste acceptance requirements for disposal are known. If the final disposal route is not known or has not been chosen, planning for earlier steps should consider a realistic range of options. Processing or conditioning steps selected for particular waste types should not impose significant constraints on following steps in managing the waste or foreclose viable options. Irreversible conditioning processes should, subject to the following paragraph, be avoided until all steps are fully defined.

In some cases however, safety and/or security benefits may justify undertaking irreversible treatment or conditioning processes. For example, solidification of liquid waste is nearly always justified by the increased safety associated with storing solids rather than liquids. If there is sufficient safety or security justification for undertaking irreversible conditioning, the Responsible Person should prepare an assessment to demonstrate the benefits of the proposed action. The generic waste acceptance criteria in Annex G and waste acceptance criteria of similar overseas disposal facilities may provide sufficient information to allow a case to be made for treatment and conditioning.

The assessment of the benefits of undertaking irreversible processing should be included in any application to the regulator seeking approval for undertaking the proposed waste treatment. However, even if the regulator approves the application to undertake the proposed waste processing, the Responsible Person remains responsible for ensuring that the processed waste will be acceptable for disposal when the waste disposal facility comes into operation.

A waste package should have a durable label bearing an identification number, weight, and contact dose rate including the date of measurement. Other properties of the waste package should be easily retrievable from records. A proper record of each waste package should be kept in a records management system. Records should be securely stored, easily accessible and retrievable over an extended period.

Information recorded for each waste package should include where practicable:

- the identification number of the package;
- radionuclide and activity content;
- a description of the purpose for which the material was utilised;
- details of the package contents – type of source containment (if applicable), conditioning matrix and matrix containment;
- mass;

- the external size and/or volume of the package;
- the maximum dose rate at contact and at 1 metre, and the date of measurements; and
- the presence and activity of fissile materials, if any.

Annexes to this Safety Guide provide specific guidance on pretreatment, treatment and conditioning for the following six types of waste:

- devices containing low levels of long-lived alpha emitters (dials and luminous devices containing radium and smoke alarms) (Annex A);
- devices containing higher levels of long-lived alpha emitters (radium needles and tubes, neutron sources) (Annex B);
- disused sealed sources of low radioactivity (<100 MBq) and gaseous tritium light sources (Annex C);
- disused sealed sources of higher radioactivity (>100 MBq) (Annex D);
- laboratory and medical waste (Annex E); and
- residues from industrial processing and waste from remediation of contaminated sites (Annex F).

4.5 Waste Storage

Radioactive waste storage is required at all stages of waste management to provide isolation from humans, safety, security and environmental protection. The IAEA has developed recommendations on the planning, siting, design and operation of radioactive waste storage facilities (IAEA 2006b).

The siting of a radioactive waste storage facility will depend on many factors including the design of the facility and the radiological hazards associated with the stored waste. The level of siting requirements and the rigour and scope of the safety assessment for waste storage facilities depend on the potential radiological hazard of the waste stored and the activities to be undertaken in the store.

Waste storage facilities can be:

- part of a hospital, university, industrial site or small research institute where the use of radioactive materials is incidental to the main objective of the facility and the amount of radioactivity in storage is relatively small;
- associated with nuclear installations such as research reactors or radiopharmaceutical production facilities where the site selection may be based on the factors important for the main facility and approval for the main facility will include the storage facility; and
- isolated facilities receiving a wide variety of waste from a number of different locations but built separately from other licensed facilities.

The storage of waste in centralised facilities rather than a multitude of small on-site facilities should be considered, since there are opportunities to realise economies of scale and provide better long-term security and safety of the stored waste.

Waste in storage may be in solid, liquid or gaseous form; it might be raw waste, treated waste or conditioned waste ready for transport and disposal. The facilities and procedures should be appropriate for the level of risk and hazard of the stored waste.

Inspection procedures should be implemented to detect degradation of waste packages before there is any release of radioactivity from a package, and the facility should be designed with passive features to ensure containment of radioactivity even if such degradation occurs. This might mean, for example, bunds, floor drains to a holding tank, and/or sealed floors that can be readily decontaminated.

Sufficient storage capacity should be provided for waste generated in normal operations, with a reserve capacity for waste generated in any incidents or abnormal events.

Storage conditions should ensure waste can be readily retrieved for subsequent steps, e.g. further processing or disposal. Adequate space should be available for inspection of items and checking for contamination before dispatch.

Radioactive waste should be stored in packages or containers suitable for the type of storage and foreseeable timeframe of storage. Storage conditions should ensure the integrity of waste in storage is maintained and any degradation minimised. Air conditioning, heating and/or humidity control may need to be provided. The need for active systems to maintain safety should be minimised.

Each stored item, storage container or tank containing radioactive liquid should be clearly and uniquely labelled. A description of the radioactive contents and the activity either when stored or most recently determined should also be available. See 4.4 for further details.

Tanks for the storage of liquids should be constructed of chemically resistant material such as stainless steel, plastic, rubber-lined carbon steel or fibreglass. Secondary containment should be provided around the tank to prevent the spread of contamination in the event of leakage. The provision of adequate shielding should also be considered.

Collection and storage tanks should have equipment for stirring, venting and transferring waste to prevent the build-up of sediment or the accumulation of hazardous gases. Provision should be made for sampling and for reserve capacity if necessary for unplanned events. The floor of the room or area where liquid waste is stored or processed should be sealed against the penetration of liquids for ease of decontamination.

Design of the storage facility should permit regular radiation monitoring and inspection of the waste packages to obtain an early indication of any physical deterioration, signs of leakage or build-up of gases in the containers.

Radiation monitoring and visual inspection should also be performed whenever the waste is handled or moved (placed into storage, retrieved or transported off the site). Where appropriate, there should be enough space in the store for stacking, sorting and visual inspection of packages.

Storage facilities with potentially physically mobile forms of waste, i.e., putrescibles, liquids and gases, should have spare redundant containment available should any problems with the integrity of containment arise.

The storage facility should be adequately ventilated to exhaust any gas generated in normal operation or under anticipated accident conditions. The potential for gas generation by radiolysis or chemical reaction should be assessed, and if necessary monitored (dependent on facility design and/or quantity of stored material). Stores with waste containing uranium or radium should be monitored for radon levels and radon concentrations should be acceptable before entry of staff. The extraction system should be filtered if there is possibility for emissions of particulate materials. The radiological impact of radon in the extracted air and where appropriate, methods for ameliorating the hazard, should be addressed in the Radioactive Waste Management Plan.

Measures to prevent, detect and control fires should be incorporated into the design of facilities for the storage of combustible waste. The store should be constructed of durable, fire resistant material.

The store should be designed to ensure that the dose received by a member of the public located in an accessible area of the store is less than the dose limit of the general public, i.e. less than 1 mSv in a year (ARPANSA 2002). The estimate of the dose to a member of the public should be based on conservative assumptions about the possible period that the member of the public could occupy that location.

Provision should be made for cooling if there is a potential for heat-generating waste to be present.

A document control system should be established to maintain an inventory of all waste in storage, to track the movements of all waste items and to record all inspections and maintenance activities. The management system and quality assurance are further discussed in section 2.5.

Radiation warning signs should be displayed at each entrance to the store and possibly on the internal walls and external surrounds of the facility.

Adequate baseline surveys should be conducted. Pre-operational background monitoring of the local environment is necessary to identify if there are other sources of radioactivity in the area or unusually high natural background levels.

Potential pathways for environmental emissions from a storage facility should be assessed and those determined to be significant should be monitored to verify that any release of radioactivity is within limits. The level of environmental monitoring should relate to the risk of significant environmental impact. Therefore, environmental monitoring would be more comprehensive where the hazard posed by the waste is greater (generally for a large purpose-built store) than for a small store in a hospital or university. Possible environmental releases to be considered in designing the environmental monitoring program include: airborne emissions, and releases into sewer, surface water and ground water.

Radioactive waste management facilities intended to hold sealed radioactive sources should also be designed and operated in compliance with regulatory requirements for security of the radioactive sources. Further information on the requirements for security of sources can be found in the *Code of Practice for Security of Radioactive Sources* (ARPANSA 2007).

4.6 Acceptance Criteria for Radioactive Waste Disposal

The objective of treating and conditioning radioactive waste is to produce waste packages that can be handled, transported, stored and disposed of securely and safely. In particular, the final packaging should meet the waste acceptance criteria of the disposal facility.

If a disposal facility is not established and the waste acceptance criteria are not known, an assessment should be undertaken to determine the type of disposal appropriate to the particular waste stream and an estimate made of the range of likely waste acceptance criteria for that type of disposal. Generic waste acceptance criteria are discussed in Annex G. In some cases, it may be necessary to place packaged waste in an overpack which meets the specific waste acceptance criteria for the particular disposal facility.

Waste acceptance criteria for disposal in a range of facilities are likely to require minimal voids in the waste package, minimal free liquids and that toxic materials are below specified limits.

Annex A

Management of Devices Containing Low Levels of Long-Lived Alpha Emitters (Dials and Luminous Devices and Smoke Alarms)

This Annex covers the management of luminous watches containing radium, smoke alarms containing americium and similar items where the amount of radioactivity per item is less than about 100 kBq.

ISSUES RELATING TO DIALS AND LUMINOUS DEVICES CONTAINING RADIUM

Luminous paint containing radium-226 was used in a number of applications. The radium content of the paint varied from 0.2-5 MBq (0.005-0.12 mg) radium per gram of paint depending upon whether it was used in clocks, watches or instrument dials. Radium was also used in some electronic valves and starting switches. The amount of radium varies from hundreds of Bq in electronic valves to the order of tens of kBq in some luminous applications.

Radium-226 has a high radiotoxicity because it is an alpha emitter that behaves like calcium and concentrates in bone. Radium-226 has a half-life of 1600 years and its decay chain includes eight radionuclides, four of which are alpha emitters. The first decay produces radon-222, a noble gas with a half-life of 3.6 days which may escape from devices containing radium-226 and lead to inhalation doses. Facilities where radium-containing waste is stored should be well ventilated and have means for monitoring radon levels in the air. The likelihood of radioactive radon gas being released from waste containing radium-226 and the potential dose to personnel should be evaluated in assessing the suitability of packages for containing radium waste and the means of storage.

The management of more intense radium sources, such as radium needles and Ra/Be neutron sources, is discussed in Annex B.

ISSUES RELATED TO SMOKE ALARMS CONTAINING AMERICIUM-241

Many domestic smoke alarms contain less than 40 kBq americium-241. The radiation source is americium-241 dioxide in a gold matrix covered by a silver foil. The foil is thin enough to allow alpha emissions to enter the ionization chamber but the short range of alpha particles in air ensures that alpha particles do not escape from the smoke alarm. Even if the foil containing the radioactivity is removed from a smoke alarm, the alpha particles do not penetrate the dead layer of human skin. Americium-241 also emits a low energy gamma ray, but the gamma dose rate from a domestic smoke alarm is low. The americium dioxide used in a smoke alarm is extremely insoluble and, even if swallowed, would pass through the digestive system and not be absorbed.

The Radiation Health Committee advised that from environmental and public health perspectives, the disposal of small numbers of individual smoke alarms with domestic rubbish does not represent any hazard (ARPANSA 2001). When significant numbers of smoke alarms are collected together for bulk disposal, they should be treated as radioactive waste. It may be acceptable in some jurisdictions to dispose of significant numbers of smoke alarms in municipal land fills provided each smoke alarm is accompanied by at least a specified amount of non-radioactive waste.

Pretreatment

The paint used in luminous devices can degrade and lead to radium contamination. Items containing radium should be collected and stored in sealed containers to control possible spread of contamination.

For items of historic value, consideration could be given to replacing the components marked with the radioactive luminous paint with non-radioactive replicas. However, there could be further contamination by radon progeny so all items should be checked for any residual contamination before being released for general access.

The first step in managing items containing low levels of long-lived alpha emitters is to determine the radioactivity in each item. In some cases, the items will be marked at manufacture with the contained radioactivity. For these items containing small amounts of long-lived radioactivity, it is reasonable to base their management on the level of radioactivity marked on each item. If there is no record of the amount of radioactivity on the item or in associated records, a gamma spectroscopy measurement should be undertaken to determine the amount of contained radioactivity. If there are a large number of similar items, enough representative items should be measured to provide a good estimate of the total radioactivity.

Items containing more than 100 kBq of radium-226 or americium-241 should be assessed to determine if they can safely be managed using the guidance in this Annex, or if they should be managed using the guidance in Annex B as an item containing a higher level of alpha emitters.

Treatment

The total volume of material to be managed as radioactive waste can sometimes be minimised by separating the components containing the radioactivity from components with no radioactivity. Any attempt to separate non-radioactive from radioactive components should be undertaken in facilities with monitoring for contamination. The foil containing the americium-241 may be able to be safely removed from a smoke alarm, but this would result in more concentrated radioactivity which may reduce disposal options.

Conditioning

The small amount of radioactivity in each luminous item or smoke alarm means that if a number of items are encapsulated into a cement mortar or other matrix, the radioactivity can be considered to be dispersed in the package. Accidents, incidents or intrusions that result in a broken, drilled or shattered package would result in the radioactivity being mixed with matrix material. The consequent dose to an unintentional intruder or bystander is likely to be much less than the public dose limit for a realistic range of intrusion and accident scenarios. Nevertheless, the waste should be managed as low level waste with appropriate access controls, mitigation procedures and barriers.

Items containing low levels of long-lived alpha emitters may be encapsulated in, for example, 20 to 60 litre drums using a cement mortar. Encapsulation in such a drum provides security and enables many items to be consolidated into one package. Encapsulation also reduces the likelihood of contamination if radium paint deteriorates and limits release of radium. A 60 litre drum is small enough for most future disposal options for low level waste, but might be too big for borehole disposal (see Annex G).

The safety and security benefits of encapsulating items containing low levels of long-lived alpha emitters in a cement mortar may justify undertaking this irreversible treatment even if no disposal route is established and there are no waste acceptance criteria.

Some items such as luminous antique watches can have value to collectors and need to be secured against pilfering.

The 60 litre drum may be encapsulated into a 205 litre drum with cement mortar once a disposal facility is available, depending on the waste acceptance criteria for the waste facility. The disadvantage of encapsulating the smaller drum into a 205 litre drum is that the total weight of the 205 litre drum can exceed 500 kg, which may require special handling equipment.

DISPOSAL

The low level of radioactivity in each luminous device and smoke alarm means they should be acceptable for disposal in a near-surface disposal facility.

Annex B

Management of Devices containing Higher Levels of Long-Lived Alpha Emitters (Radium Needles and Tubes, Neutron Sources)

Issues Relating to Radium Needles and Tubes and Radium Neutron Sources

Prior to 1976, radium was commonly used in medicine in Australia for treatment of cancer. For applications in medicine and industry, radium was usually encapsulated in platinum, platinum-iridium and other alloys, and sometimes in gold. Such medical items are commonly called needles or tubes, depending on their use. Typical dimensions of needles are 1.7 mm diameter and 15-20 mm in length, and of tubes are 3 mm diameter and 20-25 mm in length. For special applications, medical sources can have lengths of up to 60 mm and more. Typical dimensions of cell-filled needles are 0.8 mm in diameter and 15 to 45 mm in length (IAEA 1996).

The activity range for medical radium sources rarely exceeds 4 GBq (100 mg radium) with the average source being about 200 MBq (5.0 mg radium) for needles and about 260 MBq (6.5 mg radium) for radium tubes. Over 90% of the radium needles and 78% of the radium tubes are within the activity band of 40-400 MBq (1 to 10 mg) (IAEA 1996).

Radium-226 and its properties are described in Annex A.

Most radium sources were produced to earlier standards and leakage of radium sources is highly possible. The chemical form of the radium needles and tubes makes the spread of contamination from a leaking source a real and serious possibility.

Radium-226 was also used in neutron sources. About 30% of Ra/Be neutron sources have a radium-226 radioactivity that exceeds 20 GBq (500 mg radium) and the radioactivity of a small number of sources exceeds 40 GBq (1 g radium) of radium.

Some Ra/Be neutron sources were used for reactor start up operations. If the radium is irradiated in a nuclear reactor, some of the target atoms are converted into actinium-227 and thorium-228, both shorter lived alpha emitters, which can increase the neutron yield by a factor up to 50 times.

All waste containing radium is a potential source of radon, a radioactive gas that can be dispersed into the air of a storage facility. The likelihood of radioactive radon gas being released from waste containing radium-226 and the potential dose to personnel should be evaluated in assessing the suitability of packages for containing radium waste and the means of storage.

Pretreatment

The first step in pretreatment is to gain information on the amount of radium and the integrity of the source. Legacy radium needles and tubes are prone to leakage, so an assessment should be made to determine whether to open any container or to overpack. In general, if there is reasonable confidence that the sources are not leaking, it is better to remove the needles or tubes from any existing container so that all needles and tubes can be placed in a new capsule with appropriate quality control. However, if there is a likelihood that the sources are leaking it may be preferable to overpack.

Contamination control and contamination checks should be carried out at all stages of pretreatment, treatment and conditioning. Precautions for damaged and leaking sources include surface wipes for loose contamination, area monitors and personal dosimeters, appropriate for the contamination being handled and radiation from that contamination.

Adequate ventilation, filtration systems and shielding should be in place to protect personnel and the environment. Personal protection equipment is important to prevent internal and external contamination. This equally applies to conditioning and temporary storage. These precautions are particularly relevant to sources for which there is not a complete set of records. Any lack of information may increase the risk during the handling and conditioning operations.

Sources should be characterised by gamma spectroscopy to determine or verify their total radioactivity. Shielding corrections for the source container and any packaging might have to be estimated. Storage, transport and ultimately disposal will require a documented estimate of the total radioactivity.

Neutron sources are often shielded by borated paraffin or other hydrocarbon. The presence of this flammable shielding material of neutron sources can limit the use of flame cutting and grinding tools for volume reduction purposes. Special consideration should be given to the transport of Ra/Be sources which may require additional shielding for neutrons [ref. *Code of Practice for the Safe Transport of Radioactive Material* (ARPANSA 2008)].

TREATMENT/CONDITIONING

The conditioning of radium sources needs strict requirements and quality assurance procedures to guarantee their safe storage for an extended period of many decades.

It is recommended that to achieve adequate containment of the radium and radon, the spent radium needles and tubes should be enclosed in a leak-tight stainless steel capsule. Preferably, the capsule should be sealed by welding. The method of source encapsulation should take into account the following factors:

- the number of sources to be encapsulated;
- the size of sources;
- the activity of the sources; and
- the type of ionizing radiation (alpha, gamma, beta, neutrons, etc.).

The capsule should fit into a suitable radiation shield in order to minimise radiation dose rates for storage and transportation.

Special radiological precautions should be taken when handling Ra/Be neutron sources with activities greater than 1 GBq because of the significant neutron and gamma dose rate.

In the Annex to IAEA-TECDOC-886 (IAEA 1996), the IAEA provides detailed instructions for one method of encapsulating radium sources. In the IAEA method, radium sources are placed in a leak tight stainless steel capsule that is welded shut or in a stainless steel capsule with a screw top and metal gasket seal. The sealed capsule should have enough air space to ensure that the pressure rise from helium generated in the decay of radium does not lead to excessive pressure build-up over the life of the capsule. When sealed, the capsule should be tested for leak tightness e.g. by using a vacuum bubble test.

Other encapsulation techniques may be used that meet the waste acceptance criteria for disposal. The encapsulation in stainless steel capsules facilitates the retrieval of the capsule when it is taken from storage for final disposal.

In the IAEA method (IAEA 1996), the capsules are placed inside a lead container for shielding, and the lead container is placed in a cavity in a 205 litre mild steel drum with a concrete lining. In the case of neutron sources, hydrogenous material such as wax or high density polyethylene should also be considered. The concrete provides physical protection and security of the sources.

Where practicable, lead should not be used in a package destined for disposal because lead is a toxic material and its presence might limit disposal options. Lead can be used for shielding so long as the capsule containing the radium is removed from the lead shield before disposal. The use of lead in a limited number of packages may be acceptable if this avoids double handling of waste and provides operator protection. The use of lead shielding may be unavoidable in some cases. If lead is used, its presence must be recorded in the package description and the environmental impact considered.

The design of the shielding package should take into account the following factors:

- the total radioactivity of the sources to be stored in the package;
- retrievability;
- physical security;
- radiation protection; and
- storage period.

For transport, it is advantageous if the capsules containing radium can be transported in Type A packages. Where practicable, the radioactivity of radium-226 in a package should be limited to less than 3 GBq. Under the *Code of Practice for the Safe Transport of Radioactive Material* (ARPANSA 2008), a Type A package shall contain less than 200 GBq for a special form radium-226 and less than 3 GBq for other radium-226, provided that the only radioactivity in the package is the radium and the radium progeny nuclides. The limit of 200 GBq applies only if the source or package has a special form certificate. The special form certificates for most old sources are likely to be out of date and unlikely to be renewable.

During interim storage it is advisable to keep the welded capsule containing the radium sources retrievable to avoid prejudicing their further management. In order to ensure physical security of the sources, the shielding package should be closed by a locking device and have a gross weight of at least 100 kg. The shielding package should limit radiation exposure and be suitable for storage for periods of many decades.

DISPOSAL

Waste items containing higher levels of long-lived alpha emitters (including radium needles and tubes and neutron sources) are an intermediate level radioactive waste. The combination of long half-life and high radioactivity concentration is likely to make these items unsuitable for near-surface disposal. Hence waste containing higher levels of long-lived alpha emitters is likely to need storage until a deep borehole or other geological waste disposal facility is established.

As discussed in Annex G, keeping package diameters to 100 mm or less gives confidence that the waste will be able to be disposed of in almost any borehole facility.

Annex C

Management of Disused Sealed Sources of Low Radioactivity (<100MBq) and Gaseous Tritium Light Sources

Issues Relating to Low Radioactivity Disused Sealed Sources

Disused sealed sources of low radioactivity present fewer management problems than high radioactivity sources because they have a low contact dose rate and many are suitable for near-surface disposal.

The radioactive material in low radioactivity sources is usually encased in plastic or metal. The source is designed to contain the radioactivity for the design purpose and certified life of the source. To ensure the source is not damaged, low activity sealed sources should not be subjected to compaction, shredding or incineration, which may be acceptable methods of treatment/conditioning for other waste types.

Even though most sealed sources with radioactivity less than 100 MBq do not pose a significant risk to individuals, society and the environment, measures should be established to deter unauthorised access to stored disused sources and the presence of the source verified at set intervals.

The preferred options for managing low activity disused sources are by return to the manufacturer or reuse. If return to manufacturer or reuse are not viable options, then the sources should be managed as radioactive waste. In this case, it is often preferable to keep individual radioisotopes, e.g. Co-60 and Am-241, separate.

Pretreatment

Low radioactivity sources should be segregated to facilitate storage and disposal. The degree of segregation depends on the number and types of sources. At a minimum, sources should be segregated into short-lived, medium-lived and long-lived sources using the criteria discussed in Section 4.3.

If a large number of sources is being managed, it may be advantageous to further segregate the sources based on the radionuclides present and the type of source.

Many disused short-lived sources can be managed by storage to allow the radioactive material to decay to below the exemption level, when they no longer need to be managed as radioactive waste. A period of 10 half-lives reduces the level of radioactivity of any source by a factor of 1000. For many sources a period of 10 half-lives will allow the source to decay to insignificance, but a longer period may be required for more intense sources.

If decay to exemption levels is not viable, the source will need to be stored until a disposal route is available. Most low activity (<100 MBq) disused sources are likely to meet the waste acceptance criteria for near-surface disposal facilities.

Treatment

It is usually preferable to remove the radioactive sources from gauges and instruments to minimise the volume of material to be managed as radioactive waste.

Consideration should be given to keeping the source in any source housing and shielding if of relatively small volume for ease of handling the source safely.

Sources should initially be consolidated into stainless steel containers that are marked with a radioactivity symbol and stored in a secure location. A label on the container should indicate container number, the radioactivity contained, the maximum contact dose rate and the reference date(s) for the radioactivity and the dose rate.

To facilitate transport to and from storage locations, it is preferable to consolidate material in Type A containers for transport or in containers that fit into Type A containers.

CONDITIONING

The extent of conditioning depends on the likely disposal route. If there is uncertainty as to whether a group of sealed sources will be accepted for disposal, the sources should not be irretrievably conditioned until waste acceptance criteria are issued for an established repository unless there are clear safety or security benefits. Guidance on this issue is provided in Section 4.4.

Sources should be stored in containers made from stainless steel or other material suitable for the expected period of storage. For small sources, the container could be stored in a concrete lined drum to provide shielding. The container should be retrievable from the concrete lined drum. See discussion in Annex B on storage options for radium needles.

Larger containers could be backfilled with a grout or other matrix, but it would be preferable not to backfill until it is clear what is required by the repository waste acceptance criteria.

DISPOSAL

A near-surface repository may be licensed to accept sealed sources of particular radionuclides and below a specified radioactivity level. The limits on low radioactivity sources at a disposal facility should be based on the post closure safety case submitted in support of the disposal facility licence and the licence conditions imposed by the regulator. Annex G discusses generic waste acceptance criteria where there is no established waste disposal facility.

Most low radioactivity (<100 MBq) disused sources are likely to be accepted at a near-surface disposal repository. Also likely to be accepted are short-lived and medium-lived disused sources that will decay to insignificant levels within the institutional control period of the repository. Medium-lived sources of higher radioactivity and long-lived sources are likely to require deeper disposal, such as a deep borehole or other geological facility.

Annex D

Management of Disused Sealed Sources of Higher Radioactivity (>100MBq)

Issues Relating to Higher Radioactivity Disused Sealed Sources

Disused sealed sources of higher activity present management problems because of the high radioactivity content and the usually high radiation dose rate when the sources are not shielded.

The radioactivity in some sealed sources can be in a dispersible powder form. The source is designed to be a robust item for the certified life of the source and the design purpose of the source. To ensure the source is not damaged, sealed sources should not be subjected to compaction, shredding or incineration, which may be acceptable for other waste types.

The radioactivity level in some sources is high enough to pose a significant risk to individuals, society and the environment. This places particular requirements on the security of these sources. Security requirements for high radioactivity sealed sources are provided in the *Code of Practice for the Security of Radioactive Sources* (ARPANSA 2007) ('the Security Code').

Sources containing higher levels of radioactivity are usually treated as a special case when it comes to disposal. Due to the higher radioactivity concentrations, intrusion scenarios in the safety assessment for disposal of sealed sources may be more limiting than for more dispersed radioactive waste. The waste acceptance criteria for a disposal facility are likely to have specific requirements for sealed sources. As far as possible, irreversible treatments should be avoided in processing higher activity sealed sources until clear waste acceptance criteria are developed.

Pretreatment

Pretreatment includes collection of waste, segregation of waste and waste decontamination. The purpose of pretreatment is to reduce the amount of waste requiring further processing and disposal or to alter the packaging or waste form to facilitate further treatment.

Disused sealed sources should be collected and the records pertaining to each waste item examined. Records should include details of the following:

- the source container identification number;
- the radionuclide(s) present;
- the activity of the source and date of measurement;
- identification of the purpose for which the material was utilised;
- the surface dose rate and the date of measurement;
- the mass and volume of the package; and
- the Responsible Person.

If any of these details are not available then they should be determined before proceeding with further waste processing.

Source certification documentation should be reviewed and the originals stored in a secure location. The certification period on the source documentation should be checked and a renewal sought from the regulator before the certification period expires. Transport of sealed sources becomes more difficult if the special form certification has lapsed.

Disused sealed sources that can be reused or returned to the manufacturer should be dealt with at this stage, removing the need for their further management as radioactive waste. For reuse to be a viable option, the source certification should be current for the expected period of future use. Otherwise, return of disused sealed sources to their manufacturer is the preferred option. The manufacturer should have the capability to assess whether the source or contained radioactivity can be recycled, disassembled or transferred to waste and the personnel and facilities to disassemble and recertify sources if appropriate.

If return to manufacturer or reuse are not options, then the sources need to be managed as radioactive waste.

Sealed sources of higher activity should be segregated on the basis of half-life to facilitate management. A possible segregation would be based in the definition of short-lived, medium-lived and long-lived radionuclides discussed in Section 4.3.

Many short-lived sources can be managed by storage to allow decay. They can also potentially be disposed of to near-surface disposal facilities because their radioactivity decays to insignificant levels during the institutional control period of the facility. After a period of 10 half-lives, i.e. 53 years for cobalt-60, the radioactivity reduces by a factor of 1000. For some high radioactivity cobalt-60 sources, 20 half-lives or more would be required for the level of radioactivity to reduce to insignificant levels.

Medium-lived sources can take many hundreds of years to decay to insignificant levels. Hence their disposal options depend on the particular radionuclide(s) in the source. Only low level medium-lived sources are suitable for disposal in a near-surface repository. In general, it is preferable to dispose of medium-lived sources of higher activity in a geological facility or deep borehole facility.

Long-lived sources of higher activity need to be disposed of in a geological facility or deep borehole facility.

Disused sources can leak and potentially lead to the inhalation of, or contamination with, toxic materials. Consequently, general and industrial safety rules should be observed whenever disused sources are handled. Adequate ventilation and filtration systems should be in place to protect personnel and the environment.

SECURITY

The Security Code and the *Code of Conduct on the Safety and Security of Radioactive Sources* (IAEA 2004a) place special requirements on radioactive sources that pose a significant risk to individuals, society and the environment. The Security Code applies to sources in use as well as disused sources that appear as waste and places specific requirements on the management of sources containing higher levels of radioactivity.

The Security Code defines categories for sources that could potentially cause severe health effects. When a source is declared waste, its category should be reassessed after taking into account any radioactive decay. Security arrangements implemented for the disused source should correspond to the source category and the security group of the source.

Source and Container Integrity

Sources should be checked for leakage of radioactive contents. Source leakage is usually assessed by performing wipe tests. The type of test undertaken is dependent upon the radionuclide and the activity of the source. Leak checking should be undertaken by competent personnel from an organisation that has been approved by the regulator. If the source is found to be leaking, the source should be overpacked in a container approved for storage while the future course of action is assessed and approved.

Removal of a leaking source from any housing or shielding will require monitoring of the removed material. Material found to be contaminated should be decontaminated or treated as radioactive waste.

For sources that are not leaking, consideration should be given to their potential reuse. If a source is reusable, it should be transferred to the new user or placed into storage for future use. If the source can not be reused then the source should be returned to the manufacturer if possible. Disused sources that are not reusable and cannot be returned to the manufacturer should be treated as waste.

The source management strategy should be risk-based and consistent with national and international guidance. The management strategy will take into account the radionuclide half-life, the source activity, the types of radiation emitted, the characteristics of the source design and form of the radioactive substance.

Many higher activity sealed sources come with a primary container which provides shielding and a locking system to secure the source. In the short term, the disused source should be kept in this primary container to provide shielding and security. The state of the primary container should be assessed as part of the source characterisation and a decision made whether to keep the source in the primary container or to design and construct a replacement container.

Treatment

The first stage of treatment is volume reduction by removal of extraneous parts of the source housing and instrument components. The volume reduction should be performed only to the extent that maintains an adequate level of safety and security for the source being treated. A means of locking the source in its housing should be kept or new locking system provided. The extraneous material removed should be checked for contamination and managed accordingly, either by storage or cleaning if contaminated, or by disposal or reuse if not contaminated.

The next stage of volume reduction is removal of the sources from the original devices and, if appropriate, grouping them together with similar sources for conditioning. This can allow the use of standard storage containers and shielding, as well as optimising safety and security measures. Source removal requires dedicated facilities and experienced personnel. Damaged and leaking sources will require extra precautions as well as specialised equipment providing both shielding and containment. Care should be taken not to weaken or damage the source.

Waste packages for disused sources should confine the radioactivity in the source both under normal conditions and under accident conditions. The storage container should shield radiation to allow for handling, protect the source against mechanical and corrosion effects and prevent unauthorised access to the source.

A source holder or source containment device should be selected that is appropriate to the form and type of the source it is to contain. For example, some caesium sources are made of caesium chloride powder which can corrode a stainless steel capsule from the inside in the long-term. Whilst low activity caesium-137 sources are now usually prepared in ceramic form, making the radionuclide less dispersible, the ceramic form is not suitable for high activity caesium-137 sources.

Wherever possible, a number of sources should be consolidated into one container to minimise the volume of waste for disposal. The number and activity of sources for consolidation should be carefully considered to ensure the limits for transportation as an acceptable category are not exceeded. If possible, the total activity in a package should be kept within the limits for transport as a Type A package. Limits for the amount of radioactivity in a Type A container for different radionuclides are specified in the *Code of Practice for the Safe Transport of Radioactive Material* (ARPANSA 2008).

CONDITIONING

The conditioning process for disused sealed sources normally involves immobilising the waste in a suitable matrix, containing the immobilised waste in a suitable container and providing any additional packaging. The purpose of the conditioning process is to produce a packaged waste suitable for the selected disposal option and which meets requirements for waste handling, storage and transport.

Sealed sources of higher radioactivity should not be irreversibly conditioned until waste acceptance criteria are available for a disposal facility. This usually means that the source should not be immobilised in a matrix until there is a disposal facility available to accept the waste. However, safety considerations may warrant some immobilisation to provide adequate safety during storage (see also discussion in Section 4.4 on undertaking irretrievable treatments).

The conditioning matrix should ensure low leachability of radionuclides from the waste form. The matrix should also be compatible with both the waste and the container.

Sources can be encapsulated into welded or sealed steel capsules, and stainless steel drums to facilitate future management. Due to the toxicity of lead, the use of lead pots for containment should be kept to a minimum. Free space within containers should be kept to a minimum to reduce the possibility of collapsing voids and ensure structural stability should the waste packages themselves be relied upon for maintaining the structure of the disposal facility.

DISPOSAL

Sealed sources of higher activity present a particular problem for disposal because the radioactivity in the source exists in a very concentrated form and the source might maintain its integrity beyond the institutional control period of a repository.

Short-lived sources containing even high levels of radioactivity could be suitable for near-surface disposal if they decay to insignificant levels during the institutional control period of the disposal facility. Very short-lived sources could be stored until the level of radioactivity is less than exemption levels.

Medium and long-lived disused sources containing higher levels of radioactivity are an intermediate level radioactive waste unsuitable for near-surface disposal. Much of this waste will have to be stored until a geological waste disposal facility, such as a borehole facility, is established.

Annex E

Management of Laboratory and Medical Waste

ISSUES RELATING TO LABORATORY AND MEDICAL WASTE

Radioactive laboratory and medical waste is very diverse; it can contain a wide range of radionuclides with a wide range of activities in many different forms. This Annex considers unsealed source forms. A good understanding of the generation process usually provides knowledge of the radionuclides present and their concentrations. If knowledge of the generation process is poor, then the waste should be characterised to provide the information required for waste management.

Care should be taken to segregate waste that may contain radioactivity from non-radioactive waste to minimise the amount of radioactive waste. Measurements should be undertaken on all waste that may contain radioactivity so that waste containing radionuclides below regulatory exemption limits can be treated as non-radioactive waste. Exemption limits are listed in the *National Directory for Radiation Protection* (ARPANSA 2004).

Waste that exceeds the regulatory exemption limits should be assessed to determine if it can be disposed of to the sewer or to a municipal tip. The requirements and limits for discharge of waste with very low levels of radioactivity to the sewer or disposal of small amounts of low level waste to municipal tips will be covered in Schedule 8 of the *National Directory for Radiation Protection*.

For waste containing short-lived radionuclides, it may be feasible to store the material to allow the radioactivity to decay to activities such that they meet proposed requirements and limits in Schedule 8 of the *National Directory for Radiation Protection*. Radioactive waste held for decay should be kept in secure stores and each container should be clearly labelled with adequate information which may include numbering and a bar-code for cross-referencing with a waste tracking database, a description of the radioactive contents, the activity when stored, the anticipated date when it may be released from the store and the name of the person responsible for placing it in the store. In many instances in nuclear medicine, it may suffice to label containers of short-lived radionuclides with the date of storage. An accurate inventory of all containers and their contents in the store at any time should be maintained.

Waste from different processes may contain different radionuclides and have different concentrations. The different wastes should be segregated if segregation provides a significant benefit in optimising waste management of the different waste types. Segregation is most important if an organisation deals with both short-lived and long-lived radionuclides, or if it deals with both beta/gamma and alpha emitters. Waste containing or possibly containing alpha emitters should be segregated from waste with no alpha emitters, because disposal limits for alpha emitters are much more restrictive than limits for beta/gamma emitters.

The low activity concentration of much laboratory and medical waste means that most will be acceptable in a near-surface repository and the generic waste acceptance criteria described in Annex G are likely to provide a reasonable basis for treating and conditioning laboratory waste.

The US National Council on Radiation Protection and Measurements has issued a report on management techniques to minimise off-site disposal of low-level radioactive waste (NRCP 2003). This report provides additional guidance on minimising and treating many types of laboratory wastes.

PRETREATMENT

The first pretreatment operation should be to collect the radioactive waste and segregate items on the basis of radiological, physical, chemical and pathogenic properties. Waste containing predominantly short-lived radionuclides should not be mixed with long-lived waste.

Segregation is only worthwhile if the segregated wastes will be treated differently as they move through the waste management steps to disposal or if waste acceptance criteria for disposal are likely to be different.

Knowledge of the processes generating the waste may provide adequate knowledge of the radioactivity and radionuclides in the waste. If this is not sufficient the waste should be characterised. The initial characterisation could be based on knowledge of the process generating the waste and the radionuclides involved in the process, combined with dose rate and perhaps preliminary gamma spectroscopy. This initial characterisation could provide enough information to allow disposal or storage options to be determined.

Wastes of different types and radioactivity concentrations (or total radioactivity in the case of sources) may be segregated (Section 4.3) to facilitate waste management according to the overall waste management strategy and the available facilities.

Considerations for segregation include:

- radioactivity concentration: higher radioactivity waste separated from lower radioactivity waste;
- radioactive decay: waste containing long-lived alpha emitters should be separated from waste with no alpha emitters;
- form: solid, gaseous and liquid wastes are treated separately;
- combustible or non-combustible;
- compressible or non-compressible;
- metallic or non-metallic;
- fixed or non-fixed surface contamination;
- materials and objects that are pyrophoric, explosive, chemically reactive or otherwise hazardous;
- items containing free liquids or pressurized gases;
- waste containing infectious agents or is regulated as medical waste; and
- animal carcasses and putrescibles materials.

A more definitive characterisation should be undertaken prior to any treatment and/or conditioning. This characterisation should be sufficiently comprehensive to provide adequate information for assessing treatment steps and demonstrating compliance with the Transport Code (ARPANSA 2008) and disposal waste acceptance criteria.

If all radionuclides in a waste package have half-lives less than about a year, consideration should be given to storing the waste in a storage facility approved by the regulatory authority until radioactivity has decayed to exemption levels.

Other actions undertaken in pretreatment could be to adjust the characteristics of the waste to make it more amenable to further processing and to reduce or eliminate certain hazards posed by the waste owing to its radiological, physical, chemical or pathogenic properties.

Larger items with limited contamination can sometimes be decontaminated to reduce the volume of waste. Mechanical, chemical and electrochemical methods can be used to remove surface contamination from a large item. The decontamination process should be planned to ensure that the characteristics of the secondary waste are compatible with the requirements for future management. The assessment as to whether to undertake decontamination should take into account the total amount of waste that will be generated by the decontamination (including any plastic sheeting, cleaning equipment, and liquid waste) and doses to workers from the decontamination.

Some items can be disassembled to remove smaller radioactive components or contaminated items from a larger volume of non-radioactive material.

Waste acceptance criteria for disposal are likely to contain exclusions for PCBs, hazardous materials, infectious waste, putrescible waste and explosive materials; and limits on some combustible materials, lead and lead compounds, surfactants, flammable liquids, pressurised gases, chelating agents, organic liquids and free liquids. Estimates of these and similar hazardous and/or toxic components should be determined from process knowledge or direct measurement, and the information documented and stored with the inventory so that it is available when the waste is sent for storage and disposal.

In the hospital environment, linen including bedding, towels and personal clothing which may be contaminated with radioactive materials should remain segregated from other linen and waste until it has been monitored. If found to be contaminated, the article should be stored for decay until the amount of radioactivity is below the exemption limit [Schedule 4 of the *National Directory for Radiation Protection* (ARPANSA 2004)] for the particular radionuclide. At that time the article can be laundered with other linen or disposed of as non-radioactive waste including return to the owner.

LIQUID WASTE

Liquid radioactive waste can be generated in laboratory or medical applications of radioactive materials. Limited quantities of aqueous liquids with low concentrations of radioactive material may be suitable for discharge to the sewer, under the requirements and limits for discharge of radioactive waste by the user proposed to be included in Schedule 8 of the *National Directory for Radiation Protection*. Liquid waste potentially containing radioactivity which would cause the discharge exemption limit to be exceeded should be collected and stored for decay or other treatment determined by the chemical, physical and biological hazards of the liquid including the radionuclide half life.

Where aqueous liquid radioactive waste is regularly produced in a laboratory at a level where the effluent from laboratory sinks may conceivably cause the discharge to the sewer to exceed the proposed exemption level, sinks should be connected to a holding or delay tank system and these sinks should be restricted to uses involving radioactive materials. Where the volume of liquid radioactive waste is small, a labelled screw top container in the working area may be adequate.

Toilets used by inpatients being treated with radioiodine should be clearly marked and only used by those patients. Acknowledging that single rooms within hospitals are a valuable resource, such designated toilets when not in use by patients undergoing radioiodine therapy treatment may be safely used for other patients if monitored and decontaminated correctly. If the effluent from these toilets may cause the exemption limit for discharge of iodine-131 from the premises to the sewer to be exceeded, the relevant regulatory authority may require that the toilets be connected to a holding tank system. The radioactivity and volume of the tank contents should be monitored continuously. Sufficient time should be allowed for decay of stored iodine-131 to below the exemption level for discharge to the sewerage system before a tank is emptied.

Holding tanks for short-lived radionuclide wastes are usually constructed in sets of two or more, so that one may be filling while the contents of a full one may be discharged after sampling or elapse of a sufficient period for radioactive decay. Tanks for temporarily holding liquid waste should:

- be leak-free;
- have visual indicators of the volume of the contents and warning devices to indicate when the tank is almost full;
- be enclosed in a secondary enclosure of sufficient volume to hold the contents if at any time there should be a loss of tank contents;
- have facilities to monitor the amount of radioactivity or to allow easy withdrawal of representative samples;
- have a means to allow inspection of build-up of deposits on the base or sides and to allow access for clearing (incorporation of mechanical agitators may reduce the incidence of deposits); and
- have sanitary controls and methane monitoring if the tank holds human or animal wastes.

Liquid waste should be characterised on the basis of process knowledge and preliminary measurement. Mixing liquid waste streams should be limited to those streams that are radiologically similar and chemically compatible. It is usually preferable to treat a small amount of more concentrated liquid waste rather than treat the large volume created when the more concentrated liquid is mixed into a larger volume of liquid with low or very low levels of radioactivity.

Aqueous liquid waste streams should not be mixed with organic liquid waste. Organic liquid waste may be flammable, and its collection and storage should incorporate provisions for adequate ventilation and fire protection.

The non-radiological characteristics of liquid waste should be assessed to determine if there are other hazardous components in the waste that limit the management options for the waste.

TREATMENT

Treatment of laboratory waste may include:

- volume reduction by compaction of solid waste, by disassembly of bulky waste components or equipment, and by incineration of combustible waste;

- concentration and collection of radionuclides from liquid and gaseous waste streams by evaporation or ion exchange for liquid waste streams and filtration of gaseous waste streams; and
- change of form or composition by chemical processes such as precipitation, flocculation and acid digestion as well as chemical and thermal oxidation.

In general, treatment of radioactive waste requires approval from the regulator before any treatment or conditioning is undertaken. In some cases, this could already be included under an existing licence; in others, specific approval will be required.

Compaction can be an effective method for reducing the volume of a compressible waste. The characteristics of the material to be compacted and the desired volume reduction should be well defined and controlled. Issues to be taken into consideration in assessing the safety of compaction should include:

- possible release of volatile radionuclides and other airborne radioactive contaminants as gases or dust;
- possible release of contaminated liquid during compaction;
- chemical reactivity of the material during and after compaction; and
- potential fire and explosion hazards due to pyrophoric or explosive materials or pressurized components.

Disassembly and other size reduction techniques may be used for waste that is bulky or oversized in relation to the intended processing. Processes for size reduction can include sawing, hydraulic shearing, abrasive cutting, plasma arc cutting and cutting with high temperature flames. Preventing the spread of particulate contamination should be considered in the choice of method and in the operation of the equipment.

Combustible solid waste and radioactive organic liquids may be incinerated, calcined or treated with other advanced oxidation techniques suitable for reducing the volume of waste and producing a stable waste form. After incineration, calcination or advanced oxidation, radionuclides from the waste are distributed between the residue, the products from cleaning the exhaust gases and any stack discharges. The distribution of radioactivity and other combustion products to each of these waste streams should be assessed for all normal and abnormal conditions. Any proposal for incineration, calcination or other advanced oxidation technique should be referred to the regulator for approval.

If the radioactive waste contains fissile material, the potential for criticality should be evaluated and eliminated by means of design features and administrative controls.

Used filters from treating gases at facilities using radioactivity are a solid radioactive waste. Care should be taken to ensure that radioactive materials trapped on filters are not dispersed during handling the filters or the subsequent treatment of filters. Many filters will have only low levels of radioactivity and it may be worth assessing whether the level of radioactivity is below the exemption levels given in the *National Directory for Radiation Protection* (ARPANSA 2004). Filters containing radioactivity can usually be compacted to reduce the volume of radioactive waste to be managed.

For any waste management process that potentially leads to airborne emissions, stack discharges should be monitored to ensure that the concentrations and amounts of radionuclides discharged are within the limits specified by the regulatory body and are consistent with the parameters modelled in the safety assessment.

Animal carcass waste might be incinerated or treated with lime and absorbent. Specific absorbents are available for dealing with biological material, and the specific instructions should be followed.

TREATMENT OF LIQUIDS

Long-lived liquid radioactive waste requiring storage should be converted to solid form as soon as practicable. Solid waste is easier to store safely and, as shown in Annex G, a repository for waste disposal is likely to only accept solid waste with limits on the amount of free liquid.

Treatment of organic liquid waste, e.g. contaminated oil, depends on the organic liquid involved so relevant advice on treatment options should be sought.

Methods for converting radioactive aqueous liquid waste to a solid form include:

- chemical precipitation, for example precipitating the radioactive component as hydroxide by raising pH;
- evaporation of liquid and management of the residue as solid radioactive waste;
- incorporation into a matrix, e.g. added to a sand cement mortar, bitumen polymer, ceramics or glass;
- adsorption of radioactivity onto a solid, e.g. alum followed by centrifuging to separate the solids from the liquid;
- the use of ion exchange resin; and
- filtration, ultrafiltration and reverse osmosis.

Chelating agents, organic liquids or oil and salt content in liquid waste may also be of concern in some conditioning processes.

CONDITIONING

Conditioning laboratory waste may include the conversion of the waste to a solid waste form, enclosure of the waste in containers, and, if necessary, provision of an overpack. Conditioning could also be encapsulation of contaminated items in an inert matrix, such as a cement or mortar.

Twenty litre, 60 litre and 205 litre steel drums are the preferred package sizes for laboratory radioactive waste. Galvanised or stainless steel drums have greater resistance to corrosion and may be preferred. A safety assessment should be performed to ensure that the drum selected is suitable for the particular waste type. Other sized packages or type of package should be used if the safety assessment demonstrates a significant advantage in doing so. A generator producing small amounts of radioactive waste might use smaller packages, but the smaller packages selected should be able to be packed into larger drums for ease of subsequent handling. If larger packages are indicated, future transport and handling requirements should be considered before deciding to use larger packages. Consideration should be given to cutting larger items to fit into a 205 litre drum.

The dose rate on the outside of the package containing radioactive waste should be measured to ensure the package is suitable for the storage facility and the proposed mode of transport. Some waste may need to be encapsulated in cement mortar to reduce the contact dose rate on the outside of the package. Alternatively, additional temporary shielding and control procedures could be used to control access to areas with higher dose rates.

Waste packages produced by conditioning should satisfy the criteria for transport, storage and disposal. To the extent practicable, conditioning of radioactive waste should produce a waste package with the following characteristics and properties:

- physical and chemical properties of the waste are compatible with any matrix materials and the container;
- low voidage;
- low permeability and leachability;
- chemical, thermal, structural, mechanical and radiation stability will be maintained for the required period of time;
- resistant to chemical substances and organisms;
- suitable for retrieval at the end of the storage period;
- suitable for transport to and handling at a disposal facility; and
- meets waste acceptance criteria of the disposal facility, or if the disposal facility is not yet established, meets the generic waste acceptance criteria in the *Code of Practice for Near-Surface Disposal of Radioactive Waste in Australia* (NHMRC 1992).

Some materials require specific assessment before being encapsulated in concrete. Aluminium, magnesium and zirconium are known to react with the alkaline water of a cement slurry or water diffused from a concrete matrix to produce hydrogen.

The container may also need to provide radiation shielding. The selection of materials for the container and its outer surface finish should consider the ease of decontamination. An additional container or an overpack may be needed to meet the acceptance criteria if the container does not meet the relevant criteria for transport, storage or disposal. Any such package should be designed to maintain integrity and containment of the radioactivity for an extended period of storage if there could be a significant delay before an acceptable disposal route becomes available.

DISPOSAL

Most laboratory and medical radioactive wastes have a sufficiently low radionuclide concentration to be accepted at a near-surface disposal facility.

Other disposal options include delay/decay to below exemption levels for clearance or disposal in accordance with Schedule 8 of the NDRP (ARPANSA 2004).

Annex F

Management of Residues from Industrial Processing and Waste from Remediation of Contaminated Sites

Issues Related to Management of Residues from Industrial Processing

Industrial processing can produce large quantities of residues containing radioactivity; mainly low levels of naturally occurring radioactive materials (NORM) such as uranium, thorium and radium and their progeny. The radioactivity in bulk waste is usually distributed uniformly through the waste and the concentration of radioactivity is usually low.

Types of bulk waste that can include radioactivity include (Cooper 2004):

- scale from pipes and valves in the oil and gas industry;
- waste from mineral sands processing;
- waste from titanium paint production; and
- waste from the phosphate industry.

This Annex does not cover the management of radioactive waste from mineral processing where that waste is disposed of at a mine site and is covered by the *Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing* (ARPANSA 2005) ('the Mining Code'). The Mining Code addresses the control of occupational and public radiation exposures in the mining and mineral processing industries, and the management of radioactive waste generated in those industries. The radioactive waste from the mining and processing of uranium ores, thorium ores and mineral sands are covered by the Mining Code, but the Mining Code may also be applied to other mining and operations where the wastes contain radionuclides at a level that may cause harm to humans or to the environment.

The *National Directory for Radiation Protection* (ARPANSA 2004) specifies the criteria to exempt radioactive material or practices from notification, registration and licensing. Usually the large bulk of residues from industrial processing and waste from remediation of contaminated sites means that the contained radioactivity will exceed the limit on total radioactivity quantity prescribed in Schedule 4 of the National Directory. However the National Directory also allows material to be exempted if the radioactive material causes an annual effective dose to an individual member of the public of less than 10 µSv, and a collective effective dose to the critical group committed by one year of performance of the practice, as determined by the relevant regulatory authority, of less than 1 person Sv.

Issues Related to Management of Waste from Remediation of Contaminated Sites

Large quantities of radioactive waste can be generated from the remediation of sites where radioactive materials were used, where accidents involving radioactivity occurred or where industrial processing of naturally occurring radioactive materials took place. Most material collected during such remediation is likely to have low levels of radioactivity. For site remediation, it is worthwhile characterising the material in situ before excavation to determine which material is contaminated with radioactivity above the exemption concentration limits given in the *National Directory for Radiation Protection* (ARPANSA 2004). There may be little advantage in excavating such material on the basis of its radioactivity unless there is a clearly identified exposure pathway that may cause harm to humans or the environment.

The IAEA Safety Standard on *Remediation of Areas Contaminated by Past Activities and Accidents* (IAEA 2003f) provides guidance on managing contaminated sites.

PRETREATMENT

The main step in pretreatment is to characterise the waste and determine the level of contained radioactivity, the radionuclides present, the presence of other toxic or hazardous substances, and the mobility of the radioactive species in the waste. The process generating the waste should be optimised to minimise the amount of waste containing radioactivity generated and ensure that the radioactivity in the waste is, as far as practicable, insoluble and not mobile under storage and disposal conditions. If this cannot be achieved in the generating process, then the waste should be treated to reduce the mobility of the radioactive species.

The appropriate storage container depends on the amount of waste generated. Medium amounts of waste could be stored in 205 litre drums. If drums are used, they should be completely filled to minimise voidage and consideration be given to compressing the waste to reduce total volume. Waste to be placed in drums should be dry to reduce potential for corrosion of containers.

If the waste occurs in large volumes, packing into drums is likely not to be appropriate. Rather, a disposal route should if possible be identified, such as a dedicated near-surface facility. A dedicated storage facility may be required to store the waste until it can be disposed. It may be advantageous to reduce the total volume of waste and the number of shipments, by separating out some of the non-radioactive components of the waste. This, however, would increase the activity concentration of the material which may or may not be an overall advantage. Also the separation procedure might be difficult or expensive and might be an additional source of exposure to the workers carrying out the separation.

TREATMENT

The residues from industrial processing may need treatment to provide chemical stability, to remove free liquid and to provide structural stability. The need for structural stability depends on the method of disposal, which may require the waste to have a specified compressive and/or shear strength. For disposal, compressive strength is usually more important because potential for subsidence is a major concern for near-surface disposal facilities. Processes for treating residues from industrial processing and waste from site remediation should be assessed on a case by case basis for each different waste type.

The waste acceptance criteria for disposal of bulk waste are likely to include a requirement for dry solid waste, minimal voidage and a compressive strength adequate to prevent subsidence.

CONDITIONING

The conditioning requirements for bulk waste need to be assessed case by case. Some bulk waste types may be conditioned by mixing with cement to form a structurally stable waste form. Cement produces a highly alkaline environment, and the impact of the alkalinity on the bulk waste should be assessed.

DISPOSAL

Most bulk radioactive wastes that occur as residues from industrial processes or from remediation of contaminated sites have a sufficiently low radionuclide concentration to be accepted at a near-surface disposal facility, or a facility that meets the criteria for a near-surface activity. If there are large volumes of waste, consideration should be given to establishing such a facility close to the source of the waste, to minimise transport costs.

In the oil and gas industry, consideration should be given to injecting scale contaminated with naturally occurring radioactivity down a well with recharge water where it can be demonstrated that there is no likelihood of the well ever being used again for extraction. This returns the radioactivity back to the geological depths from which it came and isolates the radioactivity from humans and the environment.

Annex G

Generic Waste Acceptance Criteria for Disposal of Radioactive Waste

NEAR-SURFACE DISPOSAL

Radioactive waste that is acceptable for disposal in a near-surface repository should conform to the requirements of Categories A, B and C in the *Code of Practice for the Near-Surface Disposal of Radioactive Waste in Australia* (NHMRC 1992). Concentration limits for the different categories are given in the Appendix to the Near-Surface Disposal Code for a near-surface repository at an arid remote site for a 100 and a 200 year institutional control period. It would be reasonable to assume that a near-surface repository in an arid remote site in Australia would accept waste that meets the concentration limits provided in the Near-Surface Disposal Code for a repository with a 200 year institutional control period.

The following is a list of generic waste acceptance criteria for waste that should be accepted at any Australian near-surface repository. The waste:

- is a solid;
- has stable chemical and physical properties;
- contains no free liquid;
- is compatible with concrete and natural barriers;
- does not contain compressed gases;
- contains no hazardous material, such as PCBs, infectious waste, putrescible materials;
- contains no organic liquids or chelating agents;
- is structurally stable and has long term compressive strength;
- will not generate gases;
- does not contain flammable material (excluding paper, plastics or cloth which may be included within normal radioactive waste);
- contains less than 10 percent voidage; and
- can be placed into a package that meets the *Code of Practice for the Safe Transport of Radioactive Material* (ARPANSA 2008).

Once a waste repository is established there will be clear specifications for each of these waste acceptance criteria. For example, the repository licence could define 'no free liquids' as being less than 1 percent by volume, and provide that a given pressure will not result in the release of liquid. It might also define a threshold of 100 parts per million for defining when the presence of a 'hazardous material' would not be accepted. The licence could also define, 'will not generate gases' to exclude that from normal decomposition of paper, plastics or similar material often included within radioactive waste. 'No organic liquids' could exclude minor amounts included in solid material, such as wipes.

Until a repository is established, the above list of criteria could be used as a basis for a proposal to undertake irreversible treatment of radioactive waste that is likely to be destined for a near-surface repository. Irreversible treatment of radioactive waste should only be undertaken where there are necessary safety or security benefits. See Sections 2.1 and 4.4 for further details.

DEEP BOREHOLE FACILITY

The following is a list of generic waste acceptance criteria for waste that could be accepted at an Australian borehole disposal facility. The waste:

- is a solid;
- has stable chemical and physical properties;
- is small enough to fit in a borehole;
- contains no free liquid;
- is structurally stable; and
- can be placed into a package that meets the *Code of Practice for the Safe Transport of Radioactive Material* (ARPANSA 2008).

Although boreholes can be drilled with diameters of a metre or more, deep large diameter boreholes are difficult and expensive. There is a trade off between total depth and borehole diameter. It is likely that the safety case for disposal of higher radioactivity sources in a borehole facility would put greater emphasis on increased depth rather than increased diameter.

Standard drill rigs used for petroleum exploration can drill deep and could be used to establish a deep borehole disposal facility. Boreholes produced by petroleum exploration drill rigs are likely to have an internal diameter of 150 mm or more (based on an 8.5 inch drill). To allow for overpacking, this suggests that to ensure it is suitable for any borehole facility, a stainless steel package for radium needles and tubes or higher activity sources should be 100 mm or less in diameter. Keeping packages 100 mm or less in diameter therefore gives confidence that the waste will be able to be disposed of in any borehole disposal facility. Of course, if a borehole facility is established with a larger diameter borehole, then the waste acceptance criteria would be designed to accept larger diameter packages.

Annex H

Health Effects of Ionizing Radiation and Standards for Control of Exposure

Annex H was removed January 2015.

For information on the health effects of ionising radiation, refer to

RPS F-1 Fundamentals for Protection Against Ionising Radiation (2014)

Annex H was removed January 2015.

For information on the health effects of ionising radiation, refer to

RPS F-1 Fundamentals for Protection Against Ionising Radiation (2014)

Annex H was removed January 2015.

For information on the health effects of ionising radiation, refer to

RPS F-1 Fundamentals for Protection Against Ionising Radiation (2014)

Annex I

Regulatory Authorities

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

COMMONWEALTH, STATE/TERRITORY	CONTACT	
Commonwealth	Chief Executive Officer ARPANSA PO Box 655 Miranda NSW 1490 Email: info@arpansa.gov.au	Tel: (02) 9541 8333 Fax: (02) 9541 8314
New South Wales	Manager Hazardous Materials and Radiation Section Department of Environment and Climate Change PO Box A290 Sydney South NSW 1232 Email: radiation@environment.nsw.gov.au	Tel: (02) 9995 5000 Fax: (02) 9995 6603
Queensland	Director, Radiation Health Unit Department of Health 450 Gregory Terrace Fortitude Valley QLD 4006 Email: radiation_health@health.qld.gov.au	Tel: (07) 3406 8000 Fax: (07) 3406 8030
South Australia	Director, Radiation Protection Division Environment Protection Authority PO Box 721 Kent Town SA 5071 Email: radiationprotection@epa.sa.gov.au	Tel: (08) 8130 0700 Fax: (08) 8130 0777
Tasmania	Senior Health Physicist Health Physics Branch Department of Health and Human Services GPO Box 125B Hobart TAS 7001 Email: health.physics@dhhs.tas.gov.au	Tel: (03) 6222 7256 Fax: (03) 6222 7257
Victoria	Team Leader, Radiation Safety Department of Human Services GPO Box 4057 Melbourne VIC 3001 Email: radiation.safety@dhs.vic.gov.au	Tel: 1300 767 469 Fax: 1300 769 274
Western Australia	Secretary Radiological Council Locked Bag 2006 PO Nedlands WA 6009 Email: radiation.health@health.wa.gov.au	Tel: (08) 9346 2260 Fax: (08) 9381 1423
Australian Capital Territory	Manager Radiation Safety Radiation Safety Section ACT Health Locked Bag 5 Weston Creek ACT 2611 Email: radiation.safety@act.gov.au	Tel: (02) 6207 6946 Fax: (02) 6207 6966
Northern Territory	Manager Radiation Protection Radiation Protection Section Department of Health and Families GPO Box 40596 Casuarina NT 0811 Email: envirohealth@nt.gov.au	Tel: (08) 8922 7152 Fax: (08) 8922 7334

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

Annex J

ARPANSA Radiation Protection Series Publications

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

All publications listed below are available in electronic format, and can be downloaded free of charge by visiting ARPANSA's website at **www.arpansa.gov.au/Publications/codes/index.cfm**.

Radiation Protection Series publications are available for purchase directly from ARPANSA. Further information can be obtained by telephoning ARPANSA on 1800 022 333 (freecall within Australia) or (03) 9433 2211.

RPS 1	Recommendations for Limiting Exposure to Ionizing Radiation (1995) and National Standard for Limiting Occupational Exposure to Ionizing Radiation (republished 2002)
RPS 2	Code of Practice for the Safe Transport of Radioactive Material (2008)
RPS 2.1	Safety Guide for the Safe Transport of Radioactive Material (2008)
RPS 3	Radiation Protection Standard for Maximum Exposure Levels to Radiofrequency Fields – 3 kHz to 300 GHz (2002)
RPS 4	Recommendations for the Discharge of Patients Undergoing Treatment with Radioactive Substances (2002)
RPS 5	Code of Practice and Safety Guide for Portable Density/Moisture Gauges Containing Radioactive Sources (2004)
RPS 6	National Directory for Radiation Protection – Edition 1.0 (2004)
RPS 7	Recommendations for Intervention in Emergency Situations Involving Radiation Exposure (2004)
RPS 8	Code of Practice for the Exposure of Humans to Ionizing Radiation for Medical Research Purposes (2005)
RPS 9	Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005)
RPS 10	Code of Practice and Safety Guide for Radiation Protection in Dentistry (2005)
RPS 11	Code of Practice for the Security of Radioactive Sources (2007)
RPS 12	Radiation Protection Standard for Occupational Exposure to Ultraviolet Radiation (2006)
RPS 13	Code of Practice and Safety Guide for Safe Use of Fixed Radiation Gauges (2007)
RPS 14	Code of Practice for Radiation Protection in the Medical Applications of Ionizing Radiation (2008)
RPS 14.1	Safety Guide for Radiation Protection in Diagnostic and Interventional Radiology (2008)

RPS 14.2 Safety Guide for Radiation Protection in Nuclear Medicine (2008)

RPS 15 Safety Guide for Management of Naturally Occurring Radioactive Material (NORM)

RPS 16 Safety Guide for the Predisposal Management of Radioactive Waste (2008)

Those publications from the NHMRC ***Radiation Health Series*** that are still current are:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

RHS 28 Code of practice for the safe use of sealed radioactive sources in bore-hole logging (1989)

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

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

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

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

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

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

References

Australian Radiation Protection and Nuclear Safety Agency 2001, *Radiation Health Committee Statement on Disposal of Domestic Smoke Detectors,* 1 November 2001.

Australian Radiation Protection and Nuclear Safety Agency 2002, *Recommendations for limiting exposure to ionizing radiation (1995), and National Occupational Health and Safety Commission 2002, National standard for limiting occupational exposure to ionizing radiation*, Radiation Protection Series No. 1, republished 2002, ARPANSA, Yallambie.

Australian Radiation Protection and Nuclear Safety Agency 2004, *National Directory for Radiation Protection Edition 1.0,* Radiation Protection Series No. 6, ARPANSA, Yallambie.

Australian Radiation Protection and Nuclear Safety Agency 2005, *Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing,* Radiation Protection Series No. 9, ARPANSA, Yallambie.

Australian Radiation Protection and Nuclear Safety Agency 2007, *Code of Practice for the Security of Radioactive Sources,* Radiation Protection Series No. 11, ARPANSA, Yallambie.

Australian Radiation Protection and Nuclear Safety Agency 2008, *Code of Practice for the Safe Transport of Radioactive Material*, Radiation Protection Series No. 2, 2008 Edition.

Cooper MB 2004, *Naturally Occurring Radioactive Materials (NORM) in Australian Industries – Review of Current Inventories and Future Generation,* Report prepared for the Radiation Health and Safety Advisory Council, EnviroRad Services Pty Ltd, Dec 2004.

International Atomic Energy Agency 1995a, *Methods to Identify and Locate Spent Radiation Sources,* TECDOC-804, IAEA, Vienna.

International Atomic Energy Agency 1995b, *Reference Design for a Centralized Spent Sealed Source Facility*, TECDOC-806, IAEA, Vienna.

International Atomic Energy Agency 1995c, *The Principles of Radioactive Waste Management*, Safety Series No. 111-F, IAEA, Vienna.

International Atomic Energy Agency 1996, *Conditioning and Interim Storage of Spent Radium Sources,* TECDOC-886, IAEA, Vienna.

International Atomic Energy Agency 1997, *Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management*, IAEA, Vienna.

International Atomic Energy Agency 1998, *Radiological Characterization of Shut Down Nuclear Reactors for Decommissioning Purposes*, Technical Report Series No. 389, IAEA, Vienna.

International Atomic Energy Agency 1999a, *Decommissioning of Medical, Industrial and Research Facilities*, Safety Standard Series No. WS-G-2.2, IAEA, Vienna.

International Atomic Energy Agency 1999b, *Decommissioning of Nuclear Power Plants and Research Reactors*, Safety Standard Series No. WS-G-2.1, IAEA, Vienna.

International Atomic Energy Agency 2000a, *Handling, Conditioning and Storage of Spent Sealed Radioactive Sources*, IAEA-TECDOC-1145, IAEA, Vienna.

International Atomic Energy Agency 2000b, *Predisposal Management of Radioactive Waste, Including Decommissioning Safety Requirements*, Safety Standards Series No. WS-R-2, IAEA Vienna, 2000.

International Atomic Energy Agency 2001a, *Decommissioning of Nuclear Fuel Cycle Facilities*, Safety Standards Series No. WS-G-2.4, Vienna 2001.

International Atomic Energy Agency 2001b, *Methods for the Minimization of Radioactive Waste from Decontamination and Decommissioning of Nuclear Facilities*, Technical Report Series No. 401, IAEA, Vienna.

International Atomic Energy Agency, 2003a, *Categorization of radioactive Sources*, IAEA-TECDOC-1344, IAEA, Vienna.

International Atomic Energy Agency 2003b, *Decommissioning of Small Medical, Industrial and Research Facilities*, Technical Report Series No. 414, IAEA, Vienna.

International Atomic Energy Agency 2003c, *Management of disused long lived sealed radioactive sources (LLSRS)*, IAEA-TECDOC-1357, IAEA, Vienna.

International Atomic Energy Agency 2003d, *Predisposal Management of Low and Intermediate Level Radioactive Waste, Safety Guide*, Safety Series No. WS-G-2.5, IAEA, Vienna.

International Atomic Energy Agency (IAEA) 2003e, Radioactive Waste Management Glossary, IAEA, Vienna.

International Atomic Energy Agency (IAEA) 2003f, Remediation of Areas Contaminated by Past Activities and Accidents, Safety Standards Series No. WS-R-3, IAEA, Vienna.

International Atomic Energy Agency 2003g, *Security of Radioactive Sources: Interim Guidance for Comment*, IAEA TECDOC-1355, June 2003.

International Atomic Energy Agency 2004a, *Code of Conduct on the Safety and Security of Radioactive Sources*, IAEA/CODEOC/2004, Vienna.

International Atomic Energy Agency 2004b, *Planning, managing and organizing the decommissioning of nuclear facilities: lessons learned*, TECDOC 1394, IAEA, Vienna.

International Atomic Energy Agency 2005a, *Management of Waste from the Use of Radioactive Material in Medicine, Industry, Agriculture, Research and Education*, Safety Standards Series, Safety Guide No. WS-G-2.7, Vienna.

International Atomic Energy Agency 2005b, *Regulations for the Safe Transport of Radioactive Material, 2005 Edition* Safety Standards Series No. TS-R-1, Vienna.

International Atomic Energy Agency 2006a, *Application of the Management System for Facilities and Activities*, Safety Standards Series, Safety Guide No. GS-G-3.1, Vienna.

International Atomic Energy Agency 2006b, *Storage of Radioactive Waste*, Safety Standards Series, Safety Guide No. WS-G-6.1, Vienna.

International Atomic Energy Agency 2006c, *The Management System for Facilities and Activities*, Safety Standards Series, Safety Requirements No. GS-R-3, Vienna.

International Standards Organisation 2000, *Quality Management Systems – Requirements*, ISO 9001, Third edition, Geneva.

National Council on Radiation Protection and Measurements 2003, *Management Techniques for Laboratories and Other Small Institutional Generators to Minimize Off-Site Disposal of Low-Level Radioactive Waste*, NRCP Report No. y143.

National Health and Medical Research Council NHMRC 1992, *Code of Practice for the Near-Surface Disposal of Radioactive Waste in Australia*, Radiation Health Series (RHS) No. 35.

Glossary

accident

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

ALARA principle

A principle of radiation protection philosophy that requires that exposures to ionizing radiation should be kept as low as reasonably achievable, economic and social factors being taken into account. The ALARA principle is equivalent to the principle of optimisation defined by the ICRP, which states that protection from radiation exposure is optimum when the expenditure of further resources would be unwarranted by the reduction in exposure that would be achieved.

characterisation, waste

Determination of the physical, chemical and radiological properties of the *waste* to establish the need for further adjustment, *treatment*, *conditioning*, or its suitability for further handling, *processing*, *storage* or *disposal*.

conditioning

Those operations that produce a *waste package* suitable for handling, transport, *storage* and/or *disposal*. Conditioning may include the conversion of the *waste* to a solid *waste form*, enclosure of the *waste* in *container*s, and, if necessary, providing an *overpack*.

criteria, safety

Conditions on which a decision or judgement can be based. They may be qualitative or quantitative and should result from established principles and standards.

decommissioning

Administrative and technical actions taken to allow the removal of some or all of the *regulatory control*s from a *facility*. This does not apply to a *repository* or to certain *nuclear facilities* used for mining and *milling* of *radioactive materials*, for which *closure* is used.

disposal

Emplacement of *waste* in an appropriate *facility* without the intention of retrieval. Some countries use the term *disposal* to include *discharge*s of effluents to the environment.

dose constraint

A prospective restriction on the *individual dose* delivered by a *source*, which serves as an upper bound on the *dose* in *optimisation* of *protection and safety* for the *source*.

exemption

The determination by a *regulatory body* that a *source* or *practice* need not be subject to some or all aspects of *regulatory control* on the basis that the *exposure* (including *potential exposure*) due to the *source* or *practice* is too small to warrant the application of those aspects.

exposure, radiation

The act or condition of being subject to irradiation. Exposure can either be external exposure due to *sources* outside the body or internal exposure due to *sources* inside the body.

incident

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

institutional control

Control of a *waste site* by an authority or institution designated under the laws of a country. This control may be active (*monitoring*, *surveillance* and remedial work) or passive (land use control) and may be a factor in the *design* of a *nuclear facility* (e.g. a *near surface repository*).

management system

A set of interrelated or interacting elements (system) for establishing policies and objectives and enabling the objectives to be achieved in an efficient and effective manner.

minimisation, waste

The process of reducing the amount and *activity* of *radioactive waste* to a level as low as reasonably achievable, at all stages from the *design* of a *facility* or activity to *decommissioning*, by reducing *waste* generation and by means such as recycling and reuse, and *treatment*, with due consideration for secondary as well as primary *waste.*

optimisation

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

overpack

A secondary (or additional) outer container for one or more *waste package*s, used for handling, transport, *storage* or *disposal.*

pretreatment

Any or all of the operations prior to *waste treatment*, such as collection, *segregation*, chemical adjustment and *decontamination*.

quality assurance

Planned and systematic actions necessary to provide adequate confidence that an item, process or service will satisfy given *requirement*s for quality, for example those specified in the *licence*.

repository, near-surface

A *facility* for *disposal* of *radioactive waste* located at or within a few tens of metres from the earth's surface.

Responsible Person

In relation to any radioactive source, ionizing or non-ionizing radiation apparatus, nuclear installation, prescribed radiation facility or premises on which unsealed radioactive sources are stored or used means the person:

(a) having overall management responsibility including responsibility for the security and maintenance of the source, apparatus, installation or facility;

(b) having overall control over who may use the source or apparatus, installation or facility; and

(c) in whose name the source, apparatus, installation or facility, would be registered if this is required.

safety assessment

An analysis to evaluate the performance of an overall system and its impact, where the performance measure is radiological impact or some other global measure of impact on safety.

safety case

An integrated collection of arguments and evidence to demonstrate the safety of a *facility*. This will normally include a *safety assessment*, but could also typically include information (including supporting evidence and reasoning) on the robustness and reliability of the *safety assessment* and the assumptions made therein.

scenario

A postulated or assumed set of conditions and/or events. They are most commonly used in *analysis* or *assessment* to represent possible future conditions and/or events to be modelled, such as possible accidents at a *nuclear facility*, or the possible future evolution of a *repository* and its surroundings.

segregation

An activity where *waste* or materials (radioactive and exempt) are separated or are kept separate according to radiological, chemical and/or physical properties which will facilitate *waste* handling and/or *processing*. For example, it may be possible to segregate radioactive from exempt material and thus reduce the *waste* volume.

treatment

Operations intended to benefit safety and/or economy by changing the characteristics of the *waste*. Three basic treatment objectives are: *volume reduction*, removal of *radionuclide*s from the *waste* and change of composition. Treatment may result in an appropriate *waste form*.

waste acceptance criteria

Quantitative or qualitative criteria specified by the *regulatory body*, or specified by an *operator* and approved by the *regulatory body*, for *radioactive waste* to be accepted by the *operator* of a *repository* for *disposal*, or by the *operator* of a storage facility for *storage*. Waste acceptance requirements might include, for example, restrictions on the *activity* concentration or the total *activity* of particular *radionuclide*s (or types of *radionuclide*) in the *waste* or *requirement*s concerning the *waste form* or *waste package*.

waste form

Waste in its physical and chemical form after *treatment* and/or *conditioning* (resulting in a solid product) prior to packaging. The waste form is a component of the *waste package*.

waste, radioactive

For legal and regulatory purposes, *waste* that contains or is contaminated with *radionuclide*s at concentrations or *activities* greater than *clearance levels* as established by the *regulatory body*. It should be recognised that this definition is purely for regulatory purposes and that material with *activity* concentrations equal to or less than *clearance level*s is radioactive from a physical viewpoint — although the associated radiological hazards are considered negligible.

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