Australian Government

Australian Radiation Protection and Nuclear Safety Agency

RECOMMENDATIONS

Classification of Radioactive Waste

Radiation Protection Series Publication No.

Comment on the draft Recommendations should be forwarded by 18 September 2009 to:

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

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 the Radiation Health and Safety Advisory Council, which reviews the publication program for the ***Series*** and endorses documents for publication, and by the Radiation Health Committee, which oversees the preparation of draft documents and recommends publication.

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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**.

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

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RECOMMENDATIONS

Classification of Radioactive Waste

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The mission of ARPANSA is 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 MMMM 2009

Foreword

(To be completed).

Signature

PA Burns
Acting CEO of ARPANSA

Date

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Contents

1. Introduction

1.1 Citation

These Recommendations may be cited as the *Recommendations for Classification of Radioactive Waste* (2009).

1.2 Background

Radioactive waste is generated in several different kinds of facilities and it may arise in a:

- wide range of concentrations of **radionuclide**s; and
- variety of physical and chemical forms.

These differences result in an equally wide variety of options for the management of the waste. There is a variety of alternatives for **processing** waste and for short term or long term storage prior to disposal. Likewise, there are various alternatives for the safe disposal of waste, ranging from near surface disposal in engineered vaults or trenches to disposal in engineered facilities located in stable underground geological formations at depths of several hundred metres.

Several schemes have evolved internationally for classifying radioactive waste according to the physical, chemical and radiological properties that are of relevance to particular jurisdictions, facilities or circumstances in which radioactive waste is managed. Differences between schemes, including differences in terminologies, make communication on waste management practices difficult both nationally and internationally, particularly in the context of the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* (IAEA 2006). Any waste classification scheme developed in Australia would need to take into account consistency with international developments.

Different types of waste may be grouped for operational waste management purposes. For example, waste containing radionuclides with short half-lives may be separated from waste containing radionuclides with longer half-lives, or compressible waste may be separated from non-compressible waste. The topic of operational waste management is addressed in a separate RPS publication. Apart from waste containing only short lived radionuclides, all other types of radioactive waste need to be managed and disposed of in a manner consistent with the:

- Code of practice for the near-surface disposal of radioactive waste in Australia (NHMRC 1992);
- Safety Guide for the Predisposal Management of Radioactive Waste (ARPANSA 2008); and
- National Directory for Radiation Protection (NDRP) (ARPANSA 2004).

There may however, be a case for disposal of short-lived radioactive waste from a security point of view rather than storing it. The security of sources is beyond the scope of this document. For further information on the security of sealed radioactive sources, refer to the *Code of Practice for the Security of Radioactive Sources (2007)* (RPS11) (ARPANSA 2007).

The suitability of waste for disposal in a particular disposal facility is required to be demonstrated by the **safety case** and supporting safety assessment for the facility (IAEA 20yy).

1.3 Purpose

The purpose of these Recommendations is to set out a general scheme for classifying radioactive waste that is based primarily on considerations of long term safety and disposal of the waste. These Recommendations identify the conceptual boundaries between different classes of waste and provide guidance on the definition of the different classes of waste on the basis of long term safety considerations.

They will assist in the development and implementation of appropriate waste management strategies, and will facilitate communication and information exchange within and among jurisdictions.

While the usefulness of classification schemes for the safe operational management of radioactive waste, including the transportation of waste, is recognised, such schemes are subject to different considerations and are not addressed in these Recommendations.

1.4 Scope

These Recommendations:

- cover radioactive waste ranging from that requiring engineered barriers to ensure long term safety, to that having such low activity concentrations that it is not required to be managed or regulated as radioactive waste;
- cover disused sealed radioactive sources, when they are considered waste, and waste containing naturally occurring radionuclides;
- are applicable to waste arising from all origins including:
  - planned facilities and practices;
  - existing situations; and
  - incidents or accidents.

Although the classification scheme developed in these Recommendations is focused on solid radioactive waste, the fundamental approach could also be applicable to the management of liquid and gaseous waste, with appropriate consideration given to aspects such as processing of such waste to produce a solid waste form that is suitable for disposal.

The Recommendations do not give consideration to non-radioactive hazardous constituents of radioactive waste if they do not affect radiological safety. It will therefore be necessary to take into consideration the non-radiological hazard associated with such constituents in accordance with national requirements, but this is outside the scope of these Recommendations.

It is important that the characteristics of any particular radioactive waste are known for decisions to be made on its processing, storage and disposal. Approaches to and methods for the characterisation of radioactive waste can be found in the Safety Guide for the Predisposal Management of Radioactive Waste (ARPANSA 2008).

The classification scheme is based on the safety aspects of waste management, in particular the safety aspects of disposal. The importance of security aspects of the management of radioactive waste is recognised and although security is not explicitly addressed in these Recommendations, safety and security are generally compatible as they both require isolation. A substantial difference in safety and security aspects of waste management could, however, arise for waste containing mainly short lived radionuclides. On the basis of security considerations, the degree of containment and isolation necessary in the short term will most likely be greater than the degree of containment and isolation necessary in the long term to ensure safety.

1.5 STRUCTURE

This document consists of three sections and four annexes.

- Section 1 describes the background, purpose and scope of these Recommendations.
- Section 2 expands on the general scope and objectives of classification schemes for radioactive waste as outlined above. It discusses the purpose and limitations of the classification scheme described in these Recommendations, and explains the approach adopted in the development of the scheme for classification of radioactive waste. Section 2 also discusses the criteria and waste management practices considered in the determination of waste classes.
- Section 3 outlines the scheme for classification of radioactive waste.
- Annex 1 describes various types of radioactive waste and illustrates the application of the waste classification scheme developed in these Recommendations to these types of radioactive waste.
- Annex 2 discusses the various purposes of and approaches to waste classification and discusses qualitative and quantitative methods for waste classification.
- Annex 3 provides a list of the Australian radiation regulatory authorities.
- Annex 4 provides a list of current ARPANSA Radiation Protection Series documents and those documents still available from the former NHMRC Radiation Health Series.

2. The Classification of Radioactive Waste

These Recommendations primarily give consideration to the long term safe management of radioactive waste. This approach does not preclude the consideration of other aspects, such as occupational safety, which are pertinent in operational waste management.
Classification of radioactive waste may be helpful in planning a disposal facility and at any stage between the generation of raw waste and its disposal. It will help:

- At the conceptual level
  - In devising waste management strategies;
  - In planning and designing waste management facilities; and
  - In assigning radioactive waste to a particular **conditioning** technique or disposal facility.
- At the legal and regulatory level
  - In the development of legislation; and
  - In the establishment of regulatory requirements and criteria.
- At the operational level
  - By encouraging consideration of waste management – including minimisation, classification, **segregation**, delay and decay – during planning stages of the process/plant lifecycle;
  - By defining operational activities and in organising the work to be undertaken with the waste to ensure appropriate segregation and management of waste according to classification criteria/guidelines;
  - By providing a broad indication of the potential hazards associated with the various types of radioactive waste;
  - By facilitating record keeping; and
  - By ensuring adequate design of waste packages to minimise radiation dose to workers.
- For communication
  - By providing terms or acronyms that are widely understood in order to improve communication among all parties with an interest in radioactive waste management, including generators and managers of radioactive waste, regulators and the public.

To satisfy all these purposes, an ideal radioactive waste classification scheme should meet several objectives, namely to:

- cover the full range of radioactive waste types;
- be of use at all stages of radioactive waste management and be able to address the interdependencies between them;
- relate radioactive waste classes to the associated potential hazards for both present and future generations;

- be sufficiently flexible to serve specific needs;
- be straightforward and easy to understand;
- be accepted as a common basis for characterising waste by all parties, including regulators, operators and other interested parties; and
- be as widely applicable as possible.
- It is clearly not possible to develop a unique classification scheme satisfying fully all these objectives simultaneously. For instance, a classification scheme cannot at the same time be universally applicable and still reflect the finer details of all the steps of radioactive waste management. Compromise is needed to ensure simplicity, flexibility and broad applicability of the scheme. While the national classification scheme is aimed at ensuring long-term safety following ultimate disposal, it is recommended that consideration be given to the implications and subsequent management of potential waste arisings through the whole waste management lifecycle in order to ensure:
- the selection of appropriate disposal options; and
- where required, the provision of safe interim storage before disposal.

The boundaries between the classes are not intended to be seen as hard lines, but rather as transition zones whose precise determination will depend on the particular situation (Kim et al 1996). The classification scheme is intended to cover all types of radioactive waste. Consequently, waste classes cannot be defined in terms of all the specific properties of the waste at this generic level. Rather, general concepts for defining waste classes are provided. The waste management facility operator should use the classification scheme for guidance on the waste appropriate for acceptance at their facility subject to their safety case.

Consideration should be given as to when a particular material is declared waste. Material for which no further use is foreseen should be declared waste for this guidance. Arrangements and procedures related to such a declaration may be subject to the approval of the relevant regulatory authority.

The classification scheme outlined in these Recommendations:

- is mainly based on safety considerations for the lifetime of the waste; and
- can be applied for all waste management practices such as segregation, **treatment** and storage as well as disposal.

For certain waste management practices (e.g. processing, transport and storage), more detailed classification may be required. This could be expressed in terms of sub-classes of the general waste classes set down in this publication. Aspects that could be considered in the development of a more detailed classification scheme for specific waste management practices are discussed in Annex 2.

The classification scheme is not intended to and cannot substitute the specific safety assessment required for a **waste management practice** or **facility.** A waste management option that varies from that indicated by the generic waste classification scheme may also be determined as safe and viable on the basis of a specific safety assessment.

The main consideration for defining waste classes in this publication is long term safety. Waste is classified according to the degree of containment and isolation required to ensure its safety in the long term, with consideration given to the hazard potential of different types of waste. This reflects a graded approach towards the achievement of safety, as the classification of waste is on the basis of the characteristics of the practice or source, with account taken of the magnitude and likelihood of exposures.

The parameters used in the classification scheme are:

- the **activity** content of the waste (which can be expressed in terms of activity concentration, specific activity or total activity of the waste);
- the half-lives of the radionuclides contained in the waste;
- the hazards posed by different radionuclides; and
- the types of radiation emitted.

Depending on the physical or chemical type of waste considered, activity levels may be expressed in terms of:

- total activity;
- activity concentration; or
- specific activity.

These parameters are not used to present precise quantitative boundaries between waste classes. Rather, they are used to provide an indication of the severity of the hazard posed by specific types of waste.

The specification of criteria for the different waste classes will need to take account of the type of waste. For example, criteria specified in terms of total activity or activity concentration that would be suitable for bulk amounts of waste will generally not be adequate to classify disused sealed radioactive sources. The implementation of the classification scheme will, therefore, have to take account of the specific characteristics of the potential hazard posed by the waste.

Dose criteria used for the management of waste containing naturally occurring radionuclides may be different from those used for the management of waste arising in nuclear installations and developed on the basis of considerations of optimisation of protection. Such differences may influence the disposal option selected for large volumes of waste containing naturally occurring radionuclides such as **tailings** from mining and minerals processing.

The degree of containment and isolation provided in the long term varies according to the disposal option selected. The classification scheme set out in this publication is based on the consideration of long term safety provided by the different disposal options currently adopted or envisaged for radioactive waste. In the classification scheme, the following options for management of radioactive waste are considered, with an increasing degree of containment and isolation in the long term:

- Exemption;
- Storage for decay of very short lived waste until the exemption levels are reached;

- Disposal in engineered surface landfill type facilities;
- Disposal in engineered facilities, such as trenches, vaults or shallow boreholes, at the surface or at depths down to a few tens of metres;
- Disposal in engineered facilities at intermediate depths between a few tens of metres and several hundred metres (including existing caverns) and disposal in boreholes of small diameter; and
- Disposal in engineered facilities located in deep stable geological formations at depths of a few hundred metres or more.

The depth of disposal is only one of the factors that will influence the adequacy of a particular disposal facility; all the safety requirements for disposal will apply (IAEA 2000).

3. The Radioactive Waste Classification Scheme

3.1 OVERVIEW

A comprehensive range of waste classes has been defined and general boundary conditions between the classes are provided in this document. In cases when there is more than one disposal facility within a particular jurisdiction, the quantitative boundaries between the classes for different disposal facilities may differ in accordance with scenarios, geological and technical parameters and other parameters that are relevant to the site specific safety assessment.

In accordance with the approach outlined in Section 2, six classes of waste are derived and used as the basis for the classification scheme:

(1) **Exempt waste (EW):** Waste that meets the criteria for exemption from regulatory control for radiation protection purposes.

(2) **Very short lived waste (VSLW):** Waste that can be stored for decay over a limited period of up to a few years and subsequently cleared from regulatory control according to arrangements approved by the relevant regulatory authority, for uncontrolled disposal, use or discharge. This class includes waste containing primarily radionuclides with very short half-lives often used for industrial, medical and research purposes.

(3) **Very low level waste (VLLW):** Waste that does not necessarily meet the criteria of EW, but does not need a high level of containment and isolation and therefore is suitable for disposal in a near surface, industrial or commercial, landfill type facility with limited regulatory control. Such landfill type facilities may also contain other hazardous waste. Typical waste in this class includes soil and rubble with low activity concentration levels. Concentrations of longer lived radionuclides in VLLW are generally very limited.

(4) **Low level waste (LLW):** Waste that is above exemption levels, but with limited amounts of long lived radionuclides. Such waste requires robust isolation and containment for periods of up to a few hundred years and is suitable for disposal in engineered near surface facilities. This class covers a very broad range of waste. Low level waste may include short lived radionuclides at higher activity concentration levels and long lived radionuclides, but only at relatively low activity concentration.

(5) **Intermediate level waste (ILW):** Waste that, because of its content, particularly of long lived radionuclides, requires a greater degree of containment and isolation than that provided by near surface disposal. However, ILW needs little or no provision for heat dissipation during its storage and disposal. Intermediate level waste may contain long lived radionuclides, in particular alpha emitting radionuclides, which will not decay to an activity concentration acceptable for near surface disposal during the time for which institutional controls can be relied upon. Therefore waste in this class requires disposal at greater depths, in the order of tens of metres to a few hundred metres.

(6) **High level waste (HLW):** Waste with activity concentration levels high enough to generate significant quantities of heat by the radioactive decay process or waste with large amounts of long lived radionuclides that need to be considered in the design of a disposal facility for such waste. Disposal in deep, stable geological formations usually several hundred metres or more below the surface is the generally recognised option for disposal of HLW.

Quantitative values of allowable activity content for each significant radionuclide will be specified on the basis of safety assessment for individual disposal sites (outside the scope of this document).

3.2 Waste Classes

A conceptual illustration of the waste classification scheme is presented in Figure 1. The vertical axis represents the activity content[1] of the waste and the horizontal axis represents the half-lives of the radionuclides contained in the waste. In some cases, the total activity, rather than activity concentration, may be used to determine the class of the waste. For example, waste containing only very small amounts of certain radionuclides (e.g. low-energy beta emitters) may be excluded or cleared from regulatory control.

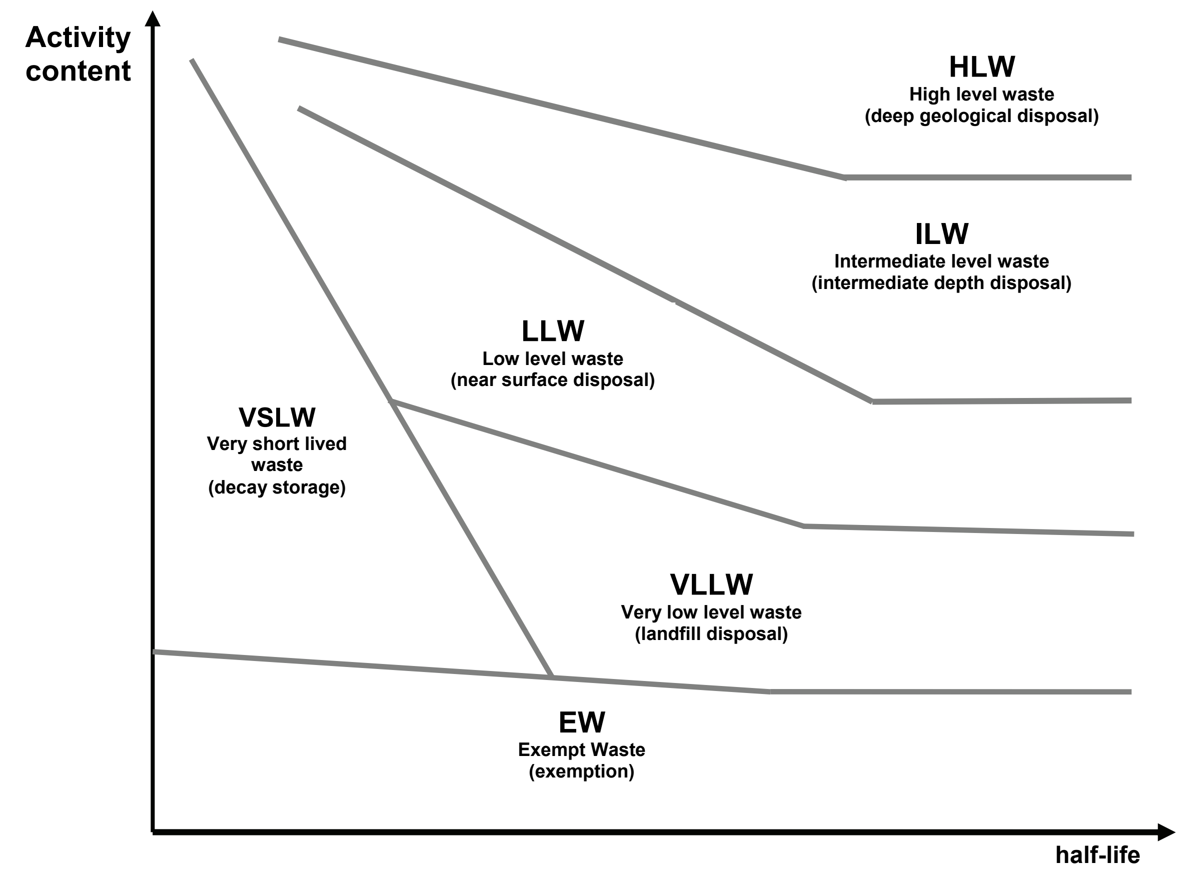

Figure 1. Conceptual illustration of the waste classification scheme.

[1] The term 'activity content' is used because of the generally heterogeneous nature of radioactive waste; so activity content is a generic term that covers activity concentration, specific activity and total activity.

Considering the vertical axis of Figure 1, the activity content of radioactive waste can range from negligible to very high, i.e. very high concentration of radionuclides or very high specific activity. The higher the activity content, the greater the need to contain the waste and to isolate it from the biosphere. Below exemption levels, the management of the waste can be carried out without consideration of its radiological properties.

Considering the horizontal axis of Figure 1, the half-lives of radionuclides contained in radioactive waste can range from short (seconds) to very long time spans (millions of years). In terms of radioactive waste safety, it is beneficial to make a distinction between waste containing radionuclides with half lives less than about forty years and waste containing longer lived radionuclides because the radiological hazards associated with the former are significantly reduced over a few hundred years by radioactive decay. A reasonable degree of assurance can be given that institutional control measures to contribute to the safety of near surface disposal facilities for waste containing radionuclides with half lives of less than about forty years can be kept in place over such timeframes. Limitations placed on the activity (total activity, specific activity or activity concentration) of waste that can be disposed of in a given disposal facility will depend on the:

- radiological, chemical, physical and biological properties of the waste; and
- particular radionuclides it contains.

A more detailed discussion of each waste class is presented as follows:

Exempt waste (EW)

Exempt waste contains such small concentrations of radionuclides that it does not require provisions for radiation protection, irrespective of whether the waste is disposed of in conventional landfills or recycled. Such material is exempt from regulatory control and does not require any further consideration from a regulatory control perspective.

Liquid or gaseous effluents discharged to the environment under appropriate regulatory control is conditionally exempted waste, in as much as discharged material requires no further consideration from the perspective of radiation protection and safety. The NDRP (ARPANSA 2004) provides exemption levels and discharge limits for **radioactive material**s.

Very short lived waste (VSLW)

Very short lived waste contains only radionuclides of very short half-life with activity concentrations above the exemption levels. Such waste can be stored until the activity has fallen beneath the levels for exemption, allowing for the waste to be managed as conventional waste. Examples of very short lived waste are waste:

- from sources using ^{192}Ir and ^{99m}Tc; and
- containing other radionuclides with half-lives of the order of 100 days or less arising from industrial, medical and research applications.

Although these Recommendations focus on the classification of solid radioactive waste, it should be noted that storage for decay is frequently used in the management of liquid and gaseous waste containing short half-life radionuclides, which is stored until the activity concentration has fallen beneath the applicable levels for discharge to the environment.

The main criteria for the classification of waste as VSLW are the:

- half-life of the predominant radionuclides; and
- acceptability of the amounts of longer half-life radionuclides.

Since the intent of storage for decay is to eventually exempt the material, possibly with conditions, acceptable concentration levels of long half-life radionuclides are set by the exemption levels. The boundary for the half-life of predominant radionuclides cannot be specified generically because it depends on the planned duration of the storage and the initial activity concentration of the waste. However, in general, the management option of storage for decay is applied for waste containing radionuclides with a half-life of the order of 100 days or less.

The classification of waste as VSLW will depend on the point in time at which the waste is assigned a classification. Through radioactive decay, VSLW will eventually move into the class of exempt waste. For VSLW there is a need to fully segregate at the source to maximise decay and eliminate cross-contamination with longer lived waste. Thus the classification scheme is not fixed but depends on the actual conditions of the waste in question at the time of assessment. This reflects the flexibility that radioactive decay provides for the management of radioactive waste.

Very low level waste (VLLW)

Substantial amounts of waste arise from the operation of medical, industrial or research facilities with activity concentration levels in the region of or slightly above the levels specified for the exemption of material from regulatory control. Other such waste, containing naturally occurring radionuclides, may originate from the mining or processing of ores and minerals. The management of this waste, in contrast to exempt waste, requires consideration from the perspective of radiation protection and safety, but the extent of the provisions necessary is limited in comparison to the provisions required for waste in the higher classes (LLW, ILW or HLW). Waste with such a limited hazard, which is nevertheless above or close to the levels for exempt waste, is termed very low level waste.

An adequate level of safety for VLLW may be achieved by its disposal in engineered surface landfill type facilities. Disposal requirements are addressed in Schedule 8 of the NDRP (ARPANSA 2004) or, in the case of waste arising from mining and mineral processing, in RPS9 (ARPANSA 2005).

The designs of such disposal facilities range from simple covers to more complex disposal systems and, in general, such disposal systems require active and passive institutional controls. The time period for which institutional controls are exercised will be sufficient to provide confidence that there will be compliance with the safety criteria for disposal of the waste.

In order to determine whether a particular type of waste can be considered to fall into the class of VLLW, acceptance criteria for engineered surface landfill type facilities have to be derived. This can be carried out either by:

- using generic scenarios similar to those applied in the derivation of exemption levels; or
- undertaking a safety assessment for a specific facility in a manner approved by the regulatory body.

The derived criteria will depend on:

- the actual site conditions and the design of the engineered structures; or
- in the case of the use of generic scenarios, on assumptions made to take account of these factors.

For this reason, generally valid criteria cannot be defined in this document. Nevertheless, it is expected that with a level of engineering and controls consistent with industrial waste disposal, a landfill facility can safely accommodate waste containing:

- short-lived, artificial radionuclides with activity concentrations of one or two orders of magnitude above the levels for exempt waste and with limited total activity, as long as expected doses to the public are within criteria established by the relevant regulatory authority; and
- long-lived radionuclides, the total activity and the acceptable activity concentrations of which will be generally expected to be more limiting in view of the long half-life radionuclides involved.

Depending on site factors and the design, it may be possible to demonstrate the safety of higher activity concentrations.

An approved landfill that will accept radioactive waste but is not specifically designed or intended to do so should:

- have sufficient capacity so that the radioactive waste only occupies a small percentage of the total volume;
- have 2 m or so of soil or clean fill cover over the radioactive waste;
- have leachate control;
- be suitable for any other of the waste characteristics e.g. it will need to be able to cater for clinical waste, if applicable; and
- take into account land use restrictions post-closure.

Incineration, dispersion in the atmosphere or disposal to sewer may also be options for some of the waste in this class, depending on the physical, chemical and biological form of the waste.

Another management option for some waste falling within this class, such as waste rock from mining operations, may be the authorised use of the material (e.g. for road construction). In this case, criteria can be derived for the definition of general exemption values contained in the NDRP (ARPANSA 2004).

Low level waste (LLW)

Contact radiation dose rate, while not necessarily a determining factor for the long term safety of a disposal facility, remains an issue that has to be considered:

- in handling the waste;
- in transporting the waste; and
- for operational radiation protection purposes at waste management and disposal facilities.

Low level waste is waste that is suitable for near surface disposal. Near surface disposal is, in turn, suitable for waste that contains such an amount of radioactive material that robust containment and isolation for limited periods of time up to a few hundred years are required. This class covers a very wide range of radioactive waste, ranging from radioactive waste with an activity content level just above the level for VLLW, i.e. not requiring shielding or particularly robust containment and isolation, to radioactive waste with an activity concentration such that shielding and more robust containment and isolation are necessary for periods up to a few hundred years. Furthermore, the waste acceptance criteria will vary at different sites. For example, the waste acceptance criteria at a "wet" site would be different from the criteria for an "arid" site. Therefore there could be a huge range of "near surface" disposal sites all of which are suitable for some forms of LLW.

Because low level waste may have a wide range of activity concentrations and may contain a wide range of radionuclides, there are various design options for near surface disposal facilities. These design options:

- may range from simple to more complex engineered facilities;
- may involve disposal at varying depths, typically from the surface down to 30 metres;
- will depend on:
  - safety assessments;
  - national practices; and
- are subject to approval by the relevant regulatory authority.

Low concentrations of long lived radionuclides may be present in low level waste. Although the waste may contain high concentrations of short lived radionuclides, significant radioactive decay of these will occur during the period of reliable containment and isolation provided by the site, the engineered barriers and institutional control. Classification of waste as low level waste should, therefore, relate to the particular radionuclides in the waste, and account should be taken of the various exposure pathways, such as:

- ingestion (e.g. in the case of long term migration of radionuclides to the accessible biosphere in the post-closure phase of a disposal facility); and
- inhalation (e.g. in the case of human intrusion into the waste).

Boundary between Low Level Waste and Intermediate Level Waste

Radioactive waste suitable for disposal near the surface and at intermediate depths may, in most instances, be differentiated on the basis of the need for controls over timeframes for which institutional control can be guaranteed and thus human intrusion into the waste can be prevented. The suitability of a disposal facility for a particular inventory of waste is required to be demonstrated by the safety case for that facility (IAEA 20yy).

It is generally assumed that institutional controls can be relied upon for a period of up to around 300 years. Under this assumption, bounding values for low level waste in terms of activity concentration levels can be derived by estimating doses to the exposed **representative person** after this period of institutional control. Since the management of such waste in a near surface facility is, in many cases, the only practicable option, longer periods of institutional control may need to be considered, with periodic safety review of the facility. An example of such a special situation arises for radionuclides for which the activity content will not decrease significantly over such timescales such as:

- waste from the mining and processing of uranium; and
- other materials containing significant amounts of long-lived radionuclides.

A precise boundary between LLW and intermediate level waste (ILW) cannot be provided, as limits on the acceptable activity concentration will differ between individual radionuclides or groups of radionuclides. Waste acceptance criteria for a particular near surface disposal facility will be dependent on:

- the actual design of the facility; and
- planning for the facility (e.g. engineered barriers, duration of institutional control, site specific factors).

Restrictions on activity concentration levels for long lived radionuclides in individual waste packages may be complemented by:

- restrictions on average activity concentration levels; or
- simple operational techniques such as placing waste packages with higher activity concentration levels at selected locations within the disposal facility.

It is possible to determine bounding activity concentrations for LLW, such as those found in the near surface disposal Code (NHMRC 1992), on the basis of:

- generic site characteristics;
- generic facility designs;
- specified institutional control periods; and
- dose limits to individuals.

Limitations for the disposal of long lived radionuclides for a particular disposal facility will be established on the basis of the safety assessment.

Intermediate level waste (ILW)

Intermediate level waste is defined as waste that contains long lived radionuclides in quantities that need a greater degree of containment and isolation from the biosphere than provided by near surface disposal. Disposal in a facility at a depth of between a few tens and a few hundreds of metres is indicative for intermediate level waste. Disposal at such depths has the potential to provide a long period of isolation from the accessible environment if:

- both the natural barriers and the engineered barriers of a disposal system are selected properly; and
- the waste is conditioned to produce a long-term stabilised wasteform within suitable **packaging**.

In particular, there is generally no detrimental effect of erosion at such depths in the short to medium term. Another important advantage of disposal at intermediate depths is that compared to near surface disposal facilities suitable for LLW, the likelihood of inadvertent human intrusion is greatly reduced. Consequently, long term safety for disposal facilities at such intermediate depths will not depend on the presence of institutional controls.

The boundary between the LLW class and the ILW class cannot be specified in a general manner in relation to activity concentration levels, because allowable levels will depend on the actual waste disposal facility and its:

- associated safety case; and
- supporting safety assessment.

For the purposes of communication pending the establishment of disposal facilities for intermediate level waste, generic safety cases may be used to determine whether certain waste constitutes LLW or ILW.

High level waste (HLW)

High level waste is defined as waste that contains such large concentrations of both short and long lived radionuclides that, compared to ILW, a greater degree of containment and isolation from the accessible environment is needed to ensure long term safety. HLW generates significant quantities of heat from radioactive decay, and normally continues to generate heat for several centuries. It should be noted however that Australia does not have any HLW and is unlikely to have any in the foreseeable future. Further description of HLW can be obtained from IAEA DS390 (IAEA 20xx).

3.3 Additional Considerations

The use of the classification scheme should take into account the specific types and properties of radioactive waste. The precise criteria according to which waste is assigned to a particular waste class will depend on the specific situation in the jurisdiction in relation to the nature of the waste and the disposal options available or under consideration. One important type of waste that requires specific consideration is disused sealed radioactive sources. Another important type of waste that requires specific consideration is waste containing elevated levels of radionuclides of natural origin, in view of the bulk quantities arising. Annex 1 provides an overview of important types of radioactive waste and discusses the special considerations necessary when using the classification scheme for these different types of waste. Figure 3 is a logic diagram illustrating the use of the classification scheme to assist in determining disposal options.

Although heat generation is a characteristic of high level waste, other waste may also generate heat, albeit at lower levels. The amount of heat generated is dependent upon the types and amounts of radionuclides in the waste (half-life, decay energy, activity concentration, total activity, etc.). Furthermore, consideration of heat removal is very important (thermal conductivity, storage geometry, ventilation, etc.) ensuring that heat build-up does not diminish the layers of defence-in-depth in the engineered barriers. Therefore, the significance of heat generation cannot be defined by means of a single parameter value. The impact of heat generation on the barriers can vary by several orders of magnitude depending on the influencing parameters and the methods in place for heat removal. Management of decay heat should be considered if the thermal power of waste packages reaches several W/m^3. More restrictive values may apply, particularly in the case of waste containing long lived radionuclides.

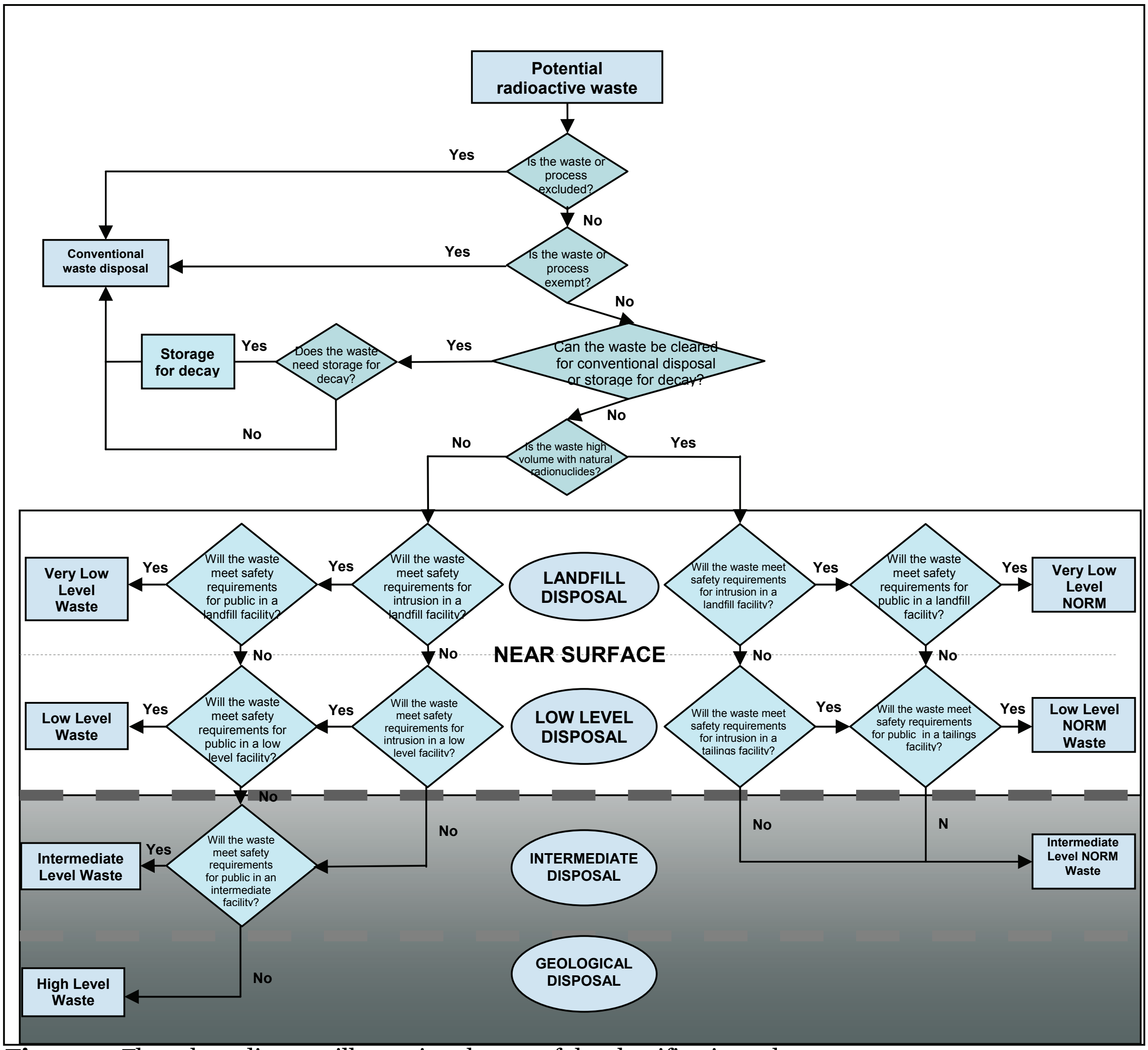

Figure 2. Flow chart diagram illustrating the use of the classification scheme

Annex 1

Origin and Types of Radioactive Waste

Most practices involving the use of radionuclides result in the generation of radioactive waste including:

- the medical, industrial or research use of radioisotopes and sealed radioactive sources;
- the operation of research reactors
- the (mostly large scale) mining and processing of mineral ores or other materials containing naturally occurring radionuclides, which in some cases have to be managed as radioactive waste. An example includes the processing of phosphate ore and oil or gas exploration;
- intervention actions, which are necessary after accidents or to remediate areas affected by past practices; and
- Disposal of disused sealed radioactive sources (including orphan sources).

The radioactive waste that is generated is as varied in form, activity concentration and type of contamination as it is in type of generating action. It may be solid, liquid or gaseous. Activity concentration levels range from high levels associated with residues from fuel **reprocessing** to very low levels associated with radioisotope applications in laboratories, hospitals, etc. Equally broad is the range of half-lives of the radionuclides contained in the radioactive waste.

This Annex briefly and qualitatively describes the:

- major waste generating practices; and
- types of radioactive waste generated by each practice.

This Annex also illustrates the application of the classification scheme developed in these Recommendations to some of the types of radioactive waste described.

Waste from mining and minerals processing containing elevated levels of naturally occurring radionuclides

The initial step in the nuclear fuel cycle is the mining of uranium or thorium ores that are then used to produce nuclear fuel. However, other radioactive products may be separated from the ores for a variety of applications. Mining practices lead to the extraction of ore that:

- is sufficiently rich to justify processing; and
- contains uranium or thorium in such small quantities that further processing is not economically justified.

The mined materials not subjected to further processing are generally accumulated as waste rock piles, usually in close proximity to the mines. The waste rock, or mullock, resulting from the mining of uranium and thorium ores generally contain elevated levels of naturally occurring radionuclides and need to be managed as radioactive waste for radiation protection purposes and safety reasons.

The richer ores from which uranium or thorium are to be separated are sent to mills and plant for processing, usually consisting of crushing and chemical processing. After removal of the uranium, the residues (tailings) contain little of the parent nuclide of the **decay chain** of the mined element, but they still contain most of its decay products. Some of the decay products may be more susceptible to leaching and emanation from the tailings than from the original ore. Additionally, tailings from processing can contain significant amounts of hazardous chemicals, including heavy metals such as copper, arsenic, molybdenum and vanadium; these need to be considered in assessing the safety of planned management options.

Similar types and quantities of radioactive waste containing naturally occurring radionuclides also arise from the extraction and/or processing of other materials that happen to be rich in naturally occurring radioactive materials; these materials include:

- phosphate minerals;
- mineral sands;
- some gold bearing rocks;
- coal; and
- hydrocarbons,

and contain long lived radionuclides at relatively low concentrations. The concentration of the radionuclides in these waste streams may exceed the levels for exempt waste as recommended in Section 3 of this document. In recent years an increasing awareness has arisen that action is required to reduce doses due to exposure to such waste (often referred to as **NORM**) and regulatory control is necessary to ensure safety. The characteristics of such waste, however, are sufficiently different from those of other waste that specific regulatory considerations may be required. Of particular relevance are the long half-lives of radionuclides present and the usually large volumes of materials arising.

The classification scheme described in Section 3 covers such waste from mining and processing, but specific consideration needs to be given to its special properties and the regulatory approach applied. Some waste, such as some scales arising in the oil and gas industry, may have high activity concentration levels. These may necessitate the management of such waste as LLW, or, in some cases, ILW.

Waste from institutional practices

Institutional uses of radioactive materials include practices in the fields of research, industry and medicine. These practices, particularly in the field of research, are very varied and result in the generation of waste of different classes. Institutional waste can be generated in gaseous, liquid or solid form.

Waste from research reactors

ANSTO possesses the only facilities in Australia for managing **spent fuel**, as all the spent fuel produced in Australia comes from research reactors once operated, or currently operated, by ANSTO. No spent fuel is, however, designated for direct disposal in Australia. Currently it is anticipated that all spent fuel managed in Australia by ANSTO will be transported overseas for reprocessing, long-term storage or disposal. The spent fuel still contains residual U-235 which could be potentially recovered for reuse and therefore is not classified as radioactive waste whilst in transit from Australia. The waste resulting from the reprocessing of some of the spent fuel will be returned to Australia in a conditioned waste form and will be classified as intermediate level solid waste (non heat generating).

The waste generated by the operation of ANSTO's OPAL reactor comprises predominantly low level solid wastes and a smaller volume of intermediate level waste. The low level waste consists of cleaning materials used in the reactor facility, such as:

- used personal protection equipment (overshoes, coats, etc);
- contaminated processing items (vials, pipettes, plastic tubing);
- papers;
- towels;
- tissue paper; and
- spent ion exchange resins.

The following items, which constitute only a small volume, generated by OPAL may be classified as intermediate level waste:

- activated stainless steel components (including irradiation rigs);
- used thermocouples;
- control rods; and
- other similar items.

Waste from the production and use of radioisotopes

The production and use of radioisotopes generate radioactive waste from the following practices.

- **Production of radioisotopes:** The type and volume of waste generated depends on the radioisotope and its production method. Generally, the volume of radioactive waste generated from these practices is small but the activity concentration levels may be significant. Given the short half-lives of many of the isotopes used, on-site delay and decay storage is usually applied in the production of radioisotopes.
- **Applications of radioisotopes:** The use of radioisotopes may generate small volumes of waste. The type and volume of waste generated will depend on the application.

Waste from decommissioning of nuclear installations (research reactors)

At the end of the useful life of a nuclear installation, administrative and technical actions are taken to allow the removal of some or all of the regulatory requirements from the facility. The decontamination and dismantling of a nuclear facility and the cleanup of the site will lead to the generation of radioactive waste that may be activated or contaminated and may vary greatly in:

- type;
- activity concentration;
- size; and
- volume.

This waste may consist of solid materials such as:

- process equipment;
- construction materials;
- tools; and
- soils.

The largest volumes of waste from the dismantling of nuclear installations will mainly be VLLW and LLW. To reduce the amount of radioactive waste, decontamination of materials is widely applied. Liquid and gaseous waste streams may also originate from decontamination processes.

Waste from decommissioning of radionuclide laboratories and other facilities

Other facilities where unsealed radioactive materials are used, handled or stored such as radionuclide laboratories in hospitals, universities, research institutes will also require decommissioning. The waste generated may be similar to that arising from the decommissioning of research reactors however, the volumes of waste generated will be substantially smaller.

Waste from university and medical radionuclide laboratories

Typical wastes from medical and research laboratory use are very diverse but are generally either of short half life (e.g. Tc-99m used in nuclear medicine) or of low activity or activity concentration (e.g. radium check sources; radio-immunoassay kits; C-14 tracer; tritium in blood samples). Volumes of such waste tend to be small from a single laboratory).

Some of the uses involve exempt quantities of radioactive materials. Some of the applications result in waste that can be stored until it decays to below the exemption levels. Others result in waste that can be disposed of as per Schedule 8 of the NDRP (ARPANSA 2004), utilising all options of disposal to landfill, venting to atmosphere, incineration or disposal to sewer.

Some waste may be sent for chemical processing e.g. for reclamation of scintillant.

A few applications, involving higher activities of long lived isotopes, may result in waste that requires disposal in a near surface facility.

Generally therefore, this type of waste is either exempt or VLLW, with only a small percentage being LLW.

Disused sealed radioactive sources

A particular type of waste is disused sealed radioactive sources. Sealed radioactive sources are characterised by the concentrated nature of their radioactive contents and are widely used in medical or industrial applications. They may still be hazardous at the end of their useful lives and will require appropriate management, as they usually contain large and highly concentrated amounts of a single radionuclide and in many cases may not meet the waste acceptance criteria for near surface disposal facilities even when the source radionuclides are not particularly long lived. Radioactive sources unsuitable for near surface disposal require emplacement at greater depths and therefore fall within the ILW class or, in some cases, even the HLW class.

Sources may be described according to the activity and half-life of the radionuclides they contain. Sources containing radionuclides with half-lives of less than 100 days (for example, ^{90}Y, ^{192}Ir, or ^{198}Au used in brachytherapy) may be stored for decay and eventually disposed of as exempt waste. Other sources such as those containing ^{137}Cs, ^{60}Co or ^{238}Pu have longer half-lives and other management options will be required. A breakdown of different types of sources is given in Table 1 (IAEA 1999).

Radioactive material in the environment

Radioactive residues have been deposited on the earth's surface as a result of a variety of practices including:

- residues from nuclear weapon testing; and
- past practices, such as uranium mining, which were subject to less stringent regulatory control than that required by present day safety standards.

The waste arising from remediation operations will have to be:

- managed as radioactive waste; and
- either:
  - stabilised in-situ; or
  - disposed of in an appropriate disposal facility.

Table 1. Example of Disused Sealed Radioactive Sources

Example in Figure 3	HALF-LIFE	ACTIVITY	VOLUME	EXAMPLE
i	<100 d	100 MBq	Small	Y-90, Au-198 (brachytherapy)
ii		5 TBq	Small	Ir-192 (brachytherapy)
iii	<15 y	<10 MBq	Small	Co-60, H-3 (tritium targets), Kr-85
iv		<100 TBq	Small	Co-60 (irradiators)
v	<40 y	<few GBq	Small	Cs-137 (brachytherapy, moisture density detectors)
vi		~1 PBq	Small	Cs-137 (irradiators), Sr-90 (thickness gauges, radioisotope thermoelectric generators (RTGs))
vii	>40 y	<40 MBq	Small, but may be large numbers of sources (up to tens of thousands)	Pu, Am, Ra (static eliminators)
viii		<10 GBq		Am-241, Ra-226 (gauges)
ix	«100-300 y	<100 GBq (tritium) <10 MBq (C-14) <5 MBq (β/γ with $T_{1/2}$ >5 yr) <1 GBq (β/γ with $T_{1/2}$ ≤5 yr)	Solid waste with radioactive constituents, mainly beta or gamma emitting radionuclides. Long-lived alpha-emitting radionuclides should only be present at very low concentrations.	Lightly contaminated or activated items such as paper, cardboard, plastics, rags, protective clothing, glassware, laboratory trash or equipment, certain consumer products and industrial tools or equipment. It may also comprise lightly contaminated bulk waste from mineral processing or lightly contaminated soils.

Example in Figure 3	HALF-LIFE	ACTIVITY	VOLUME	EXAMPLE
x	Varied	<5 TBq (tritium) <50 MBq (C-14) <10 MBq (α) <500 kBq (Ra-226) <1 GBq (β/γ with $T_{1/2}$ >5 yr) Unlimited (β/γ with $T_{1/2}$ ≤5 yr)	Solid waste and shielded sources with considerably higher activities of beta- or gamma-emitting radionuclides than in the example above. Long-lived alpha-emitting radionuclides should be at relatively low levels.	Solid waste and shielded sources with considerably higher activities of beta- or gamma-emitting radionuclides than those listed in example ix (above). Long lived alpha-emitting radionuclides should be at relatively low levels.
xi	Varied	<5 TBq (tritium) <50 MBq (C-14) <10 MBq (α) <500 kBq (Ra-226) <1 GBq (β/γ with $T_{1/2}$ >5 yr) Unlimited (β/γ with $T_{1/2}$ ≤5 yr)	Solid waste containing alpha-, beta- or gamma-emitting radionuclides with relatively high activity concentrations.	Bulk materials, such as those arising from downstream processing of radioactive minerals, significantly contaminated soils, or large individual items of contaminated plant or equipment for which conditioning would prove to be impractical.
xii	Varied		Waste that does not meet the specifications in the previous three examples.	Sealed radioactive sources, gauges or bulk waste that contain radionuclides at higher concentrations than listed in the previous three examples.

Example of the use of the waste classification scheme

An example of the use of the classification scheme described in this document for waste likely to be generated in Australia is given in Figure 3. It shows the waste classes into which different types of sealed radioactive sources described in Table 1 and waste containing naturally occurring radionuclides typically will fall. Waste containing naturally occurring radionuclides can vary considerably in its characteristic and could hence fall into several classes for disposal. Some could have very low activity concentration levels and not require disposal as radioactive waste. Other waste with higher, but limited concentrations could be appropriate for near surface disposal and such waste with higher concentrations were specific radionuclides may have been concentrated may require disposal at greater depth than typical for near surface disposal. This example illustrates that the waste classification scheme is able to accommodate a variety of different types of waste. Similar diagrams can be developed for other types of waste.

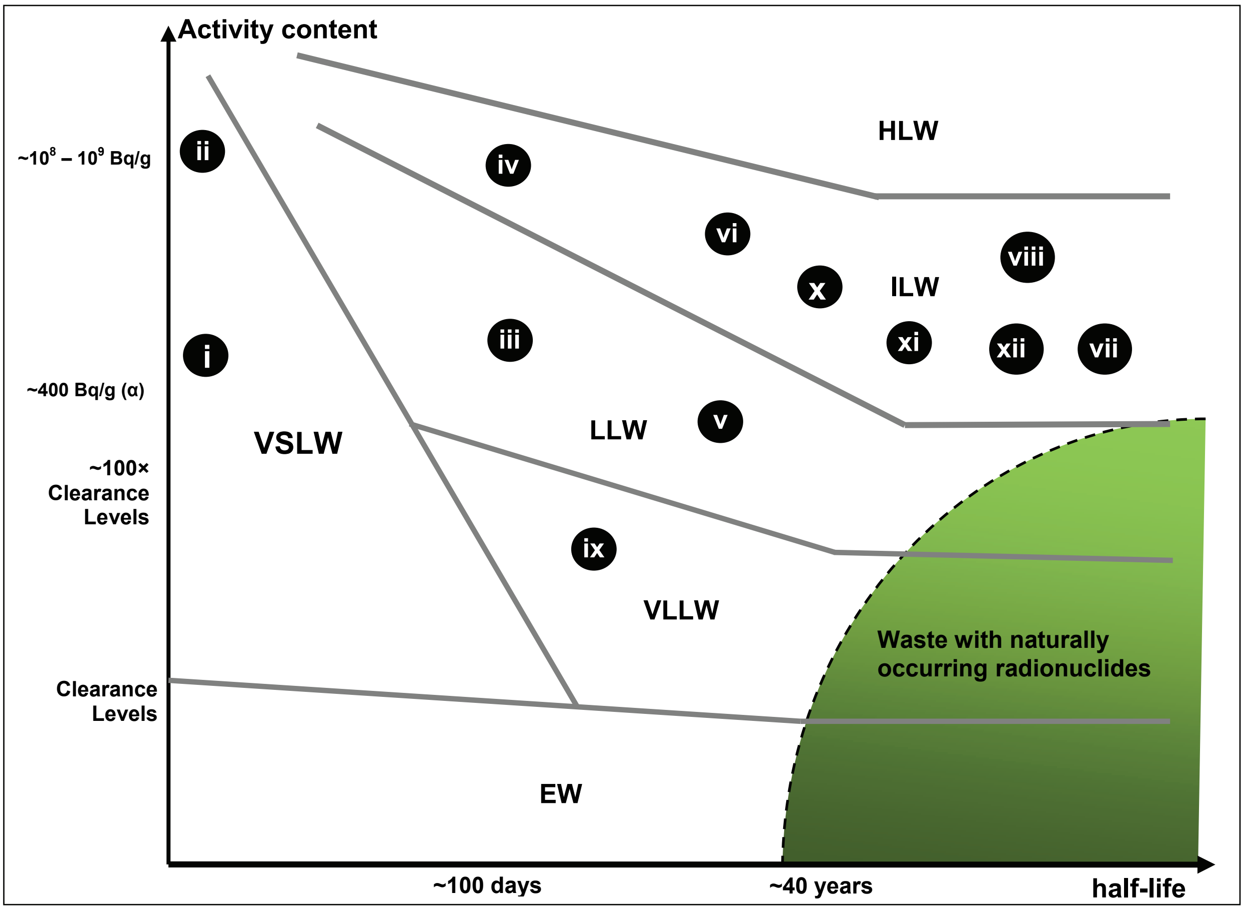

Figure 3 Illustrative example of the application of the waste classification scheme. The numbers refer to examples of disused sealed sources set out in Table 1.

Annex 2

Methods of Classification

Classification schemes for radioactive waste may be developed from different bases, such as:

- operational safety
- long term safety;
- process engineering demands;
- availability of management or disposal facilities;
- the source of generation;
- safety/regulatory related aspects; or
- process engineering demands.

A discussion of different purposes of and approaches to classification schemes for radioactive waste is given in this Annex.

Radioactive waste classification schemes can be set up at different levels and for various purposes. They may be defined at the international level, national levels, or at the operator level. Correspondingly, they will have different perspectives, for instance safety related aspects, origin and characteristics of the waste, engineering demands, and regulatory control.

Depending on the purpose of a radioactive waste classification scheme, different approaches exist. One basic approach to classification is a straightforward qualitative description of the individual classes. In this case, mainly the general characteristics of the radioactive waste are used as criteria for the classification. Nevertheless, numerical values to characterise broad bands or orders of magnitude may also be helpful for classification by this approach. The other basic approach is to base the classification on quantitative criteria, i.e. numerical values are given for the definition of waste classes.

The approach described in Section 3 of this document is based mainly on the long-term safety aspects of radioactive waste disposal, but can be used in the determination and implementation of the most appropriate arrangements for radioactive waste management. It is reasonable to use disposal as a basis for establishment of a classification scheme in order to maintain compatibility and coherence among the different stages of radioactive waste management.

A clear distinction has to be made between a classification scheme and a set of regulatory limitations. The purpose of classification is to help in maintaining radioactive waste management in a safe and economic manner within the framework of a national strategy and to facilitate communication, while the purpose of regulatory limitation is to ensure the safety of each licensed facility and practice. Therefore, the effort in developing precise limitations has to be applied within the regulatory framework of licensing or authorising specific radioactive waste management practices and facilities. The relevant regulatory authority will establish actual quantity or concentration limitations for the classification of radioactive waste. While a radioactive waste classification scheme may be useful for generic safety considerations, it is not a substitute for specific safety assessments performed for an actual facility and involving good characterisation of radioactive waste.

Qualitative Classification

There exist ‘natural’ classification schemes, e.g. grouping the radioactive waste in terms of their origin. An example for such a qualitative classification scheme is given in Annex 1. While this scheme is convenient for bookkeeping, notification and registration, it fails to meet many of the objectives listed on page 12.

Another ‘natural’ classification scheme is the differentiation of radioactive waste according to the physical state, i.e. solid, liquid, gaseous. This scheme stems from the process engineering needs for the treatment of the different radioactive waste streams and is often refined corresponding to individual radioactive waste treatment systems. A classification scheme of this type follows the technical needs and possibilities and therefore is mostly specific to individual facilities. It may, however, incorporate safety considerations such as the radiation protection measures necessary for radioactive waste classes with higher radiological hazard potential.

The classification scheme proposed by the IAEA in 1994 (IAEA 1994) used the principal waste classes of exempt, low and intermediate level waste (together with a subdivision into short-lived and long-lived waste) and high level waste. Boundary levels between waste classes were presented as orders of magnitude. Different countries use differing classification schemes. In the United States, for example, low and intermediate level waste is sub-divided into four classes (USNRC 2006). In addition, some countries also have a category of very low level radioactive waste (ASN 2005, METI 2005). A further distinction is made in many countries taking into consideration the half-life, physical states and other factors.

Quantitative Classification

Classification of radioactive waste in many cases is related to the safety aspects of the management of the waste in question. In this context, it provides a link between the waste characteristics and safety objectives that have been set up by the relevant regulatory authority or the operator of a waste management facility. As safety criteria are in general formulated in terms of numerical values, a quantitative approach to classification is necessary for this purpose. Quantitative criteria for a radioactive waste classification scheme may be activity level, half-life, thermal power, and/or radiological dose. To derive a quantitative classification scheme specific to a particular context, a common procedure should be used which is outlined in the following paragraphs.

The first step is a definition of the purpose of the classification scheme, since any classification scheme can only address a particular aspect of radioactive waste management. This implies the decision is based on such aspects as:

- the type of radioactive waste to be covered;
- the facility or practice considered;
- treatment options available;
- the corresponding application (planning, operation, post-operation);
- the safety objectives to be met;
- related social and economic factors; and
- the necessity for communication.

The next step requires the definition of the aspects considered in the scheme, for example:

- exposure of personnel;

- exposure of members of the public;
- contamination of the environment;
- safety from criticality;
- normal operation, incidents or accidental conditions;
- heat generation of radioactive waste; and
- process engineering aspects.

For some of these areas regulatory or technical constraints may exist that have to be taken into account. These may be, for example:

- limitations and requirements set by the relevant regulatory authority;
- the radioactive waste itself, characterised by the annual arising, total volume of generation, the range of radionuclides and their concentrations;
- facility specific conditions (e.g. waste form/waste package, engineering design);
- operational limits;
- pathways or scenarios prescribed for safety assessments;
- site specific conditions (e.g. for radioactive waste disposal, geological, hydrogeological and climatic characteristics may restrict the choice of a disposal site or of the type of radioactive waste that can be disposed of at the site);
- social or political aspects; and
- legal definitions and requirements.

These factors may restrict the degree of freedom for the choice and the development of a classification scheme and therefore have to be evaluated before the classification scheme can be derived.

Once the framework for classification has been set, the parameters to be used for classifying may be chosen in a third step. Starting from the radioactive waste itself, there are several properties that may be taken into account. Important parameters are given in Table 2.

The possible scenarios, design options and site-specific options have then to be evaluated in a fourth step to assess their suitability as classification parameters. For the case of LLW, examples are given in the IAEA publication WS-G-1.1 (IAEA 1999).

If a set of classification parameters has been chosen, intervals for numerical values or, as an alternative, qualitative characteristics are defined as limits for different classes. The practical step of assigning the considered types of radioactive waste to these classes will show whether or not an adequate scheme has been established.

Normally, the classification scheme results from an iterative procedure in which the steps described above are repeated until a satisfying result is reached.

Table 2. Important Parameters of Radioactive Waste that can be used as Criteria for Classification

- Origin;
- Criticality;
- Radiological properties:
  - Half-lives of radionuclides;
  - Heat generation;
  - Intensity of penetrating radiation;
  - Activity concentration of radionuclides;
  - Surface contamination;
  - Dose factors of relevant radionuclides;
  - Decay products.
- Physical properties:
  - Physical state (solid, liquid or gaseous);
  - Size and weight;
  - Compactability;
  - Dispersibility;
  - Volatility;
  - Miscibility;
  - Free liquid content.
- Chemical properties:
  - Chemical composition;
  - Solubility and chelating agents;
  - Potential chemical hazard;
  - Corrosion resistance/corrosiveness;
  - Organic content;
  - Combustibility and flammability;
  - Chemical reactivity and swelling potential;
  - Gas generation;
  - Sorption of radionuclides.
- Biological properties:
  - Potential biological hazards;
  - Bioaccumulation.
- Other factors:
  - Volume;
  - Amount arising per unit time;
  - Physical distribution.

Annex 3

Regulatory Authorities

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

COMMONWEALTH, STATE/TERRITORY	CONTACT
Commonwealth	Chief Executive Officer ARPANSA PO Box 655 Tel: (02) 9541 8333 Miranda NSW 1490 Fax: (02) 9541 8314 Email: info@arpansa.gov.au
New South Wales	Manager Hazardous Materials and Radiation Section Department of Environment and Climate Change PO Box A290 Tel: (02) 9995 5000 Sydney South NSW 1232 Fax: (02) 9995 6603 Email: radiation@environment.nsw.gov.au
Queensland	Director, Radiation Health Unit Queensland Health PO Box 2368 Tel: (07) 3328 9987 Fortitude Valley BC QLD 4006 Fax: (07) 3328 9622 Email: radiation_health@health.qld.gov.au
South Australia	Director, Radiation Protection Division Environment Protection Authority GPO Box 2607 Tel: (08) 8463 7814 Adelaide SA 5001 Fax: (08) 8124 4671 Email: radiationprotection@epa.sa.gov.au
Tasmania	Senior Health Physicist Radiation Protection Unit Department of Health and Human Services GPO Box 125B Tel: (03) 6222 7256 Hobart TAS 7001 Fax: (03) 6222 7257 Email: radiation.protection@dhhs.tas.gov.au
Victoria	Team Leader, Radiation Safety Department of Human Services GPO Box 4057 Tel: 1300 767 469 Melbourne VIC 3001 Fax: 1300 769 274 Email: radiation.safety@dhs.vic.gov.au
Western Australia	Secretary, Radiological Council Locked Bag 2006 PO Tel: (08) 9346 2260 Nedlands WA 6009 Fax: (08) 9381 1423 Email: radiation.health@health.wa.gov.au
Australian Capital Territory	Director Health Protection Service ACT Health Locked Bag 5 Tel: (02) 6205 1700 Weston Creek ACT 2611 Fax: (02) 6205 1705 Email: hps@act.gov.au
Northern Territory	Manager Radiation Protection Radiation Protection Section Department of Health and Families GPO Box 40596 Tel: (08) 8922 7152 Casuarina NT 0811 Fax: (08) 8922 7334 Email: envirohealth@nt.gov.au

Please note: This table was correct at the time of printing but is subject to change from time to time. For the most up-to-date list, the reader is advised to consult the ARPANSA web site (www.arpansa.gov.au).

For after hours emergencies only, the police will provide the appropriate emergency contact number.

Annex 4

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 14.3	Safety Guide for Radiation Protection in Radiotherapy (2008)

RPS 15	Safety Guide for Management of Naturally Occurring Radioactive Material (NORM) (2008)
RPS 16	Safety Guide for the Predisposal Management of Radioactive Waste (2008)
RPS 17	Code of Practice and Safety Guide for Radiation Protection in Veterinary Medicine (2009)
RPS 18	Safety Guide for the Use of Radiation in Schools Part 1: Ionizing Radiation (2009)

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

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 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 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 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

ARPANSA 2002. *Recommendations for Limiting Exposure to Ionizing Radiation (1995)* and *National Standard for Limiting Occupational Exposure to Ionizing Radiation (republished 2002)*. Radiation Protection Series No. 1.

ARPANSA 2004. *National Directory for Radiation Protection – Edition 1.0*. Radiation Protection Series No. 6.

ARPANSA 2005. *Code of Practice and Safety Guide for Radiation Protection and radioactive Waste Management in Mining and Milling Processing*. Radiation Protection Series No. 9.

ARPANSA 2007. *Code of Practice for the Security of Radioactive Sources (2007),* Radiation Protection Series No. 11.

ARPANSA 2008. *Safety Guide for the Predisposal Management of Radioactive Waste (2008),* Radiation Protection Series No. 16.

ASN 2005, Authorité de Sûreté Nucléaire, *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management: Second National Report on Implementation by France of its Obligations under the Convention*, ASN, Paris (2005).

IAEA 1994, *Classification of Radioactive Waste*, Safety Series No. 111-G-1.1, IAEA, Vienna (1994).

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Glossary

Activity

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

Activity, *A*, is a measure of the amount of a radioactive material given by:

$$A = \frac{dN}{dt}$$

where *dN* is the expectation value of the number of spontaneous nuclear transitions which take place in the time interval *dt*.

The SI unit of activity is s^{-1} with the special name becquerel (Bq).

Activity concentration

the activity of a radionuclide per unit mass (or per unit volume) of a material

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 containers and, if necessary, provision of an overpack[2].

Decay chain

a series of radionuclides, each of which (except for the first, or parent) is formed as a result of the radioactive decay of the previous member of the chain.

NORM

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

Packaging

preparation of radioactive waste for safe handling, transport, storage and/or disposal by means of enclosing it in a suitable container.

Processing

any operation that changes the characteristics of waste, including pre-treatment[3], treatment and conditioning.

Radioactive material

any material that emits ionizing radiation spontaneously.

Radionuclide

a radioactive species of atom characterised by its mass number, atomic number and sometimes its nuclear energy state (provided that the mean lifetime of that state is sufficiently long for the species to be observed).

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[2] A secondary (or additional) outer container for one or more waste packages, used for handling, transport, storage and/or disposal.

[3] Any or all of the operations before waste treatment, such as collection, segregation, chemical adjustment and decontamination.

Relevant regulatory authority

the radiation protection authority or authorities designated, or otherwise recognised, for regulatory purposes in connection with protection and safety relating to medical applications of ionizing radiation.

Representative person

an individual receiving a dose that is representative of the more highly exposed individuals in the population. This term is the equivalent of, and replaces, 'average member of the critical group' described in ICRP Recommendations before ICRP 101.

Reprocessing

a process or operation, the purpose of which is to extract radioactive isotopes from spent fuel for further use.

Safety case[4]

a collection of arguments and evidence in support of the safety of a facility or practice. This will normally include the findings of a safety assessment and a statement of confidence in these findings. For a repository, the safety case may relate to a given stage of development. In such cases, the safety case should acknowledge the existence of any unresolved issues and should provide guidance for work to resolve these issues in future development stages.

Sealed radioactive source

radioactive material that is permanently sealed in a capsule or closely bonded in a solid form.

Segregation

an action where types of waste or material (radioactive or exempt) are separated or are kept separate on the basis of radiological, chemical and/or physical properties, to facilitate waste handling and/or processing.

Spent fuel

Nuclear fuel that has been irradiated in and permanently removed from a reactor core and that is no longer usable in its present form because of depletion of fissile material, poison build-up or radiation damage.

Tailings

the residues resulting from the processing of ore to extract uranium series or thorium series radionuclides, or similar residues from processing ores for other purposes.

Treatment

an operation intended to benefit safety and/or economy by changing the characteristics of the waste. Three basic treatment objectives are:

- volume reduction[5];
- removal of radionuclides from the waste; and

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[4] In these Recommendations, the safety case only refers to radiological considerations of the safety of the facility or practice.

[5] A method that decreases the physical volume of a waste and typically includes mechanical compaction, incineration and evaporation. Volume reduction should not be confused with waste minimisation.

- change of composition.

Treatment may result in an appropriate waste form.

Waste management facility

any facility specifically designated to handle, treat, condition, temporarily store, or permanent dispose of radioactive waste.

Waste management practice

all administrative and operational activities involved in the handling, pre-treatment, treatment, conditioning, transport, storage and disposal of radioactive waste.

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