IAEA Safety Standards

for protecting people and the environment

Classification of Radioactive Waste

General Safety Guide

No. GSG-1

IAEA

International Atomic Energy Agency

IAEA SAFETY RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards.

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The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at PO Box 100, 1400 Vienna, Austria.

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CLASSIFICATION OF RADIOACTIVE WASTE

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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world''.

IAEA SAFETY STANDARDS SERIES No. GSG-1

CLASSIFICATION OF RADIOACTIVE WASTE

GENERAL SAFETY GUIDE

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FOREWORD

The IAEA's Statute authorizes the Agency to establish safety standards to protect health and minimize danger to life and property — standards which the IAEA must use in its own operations, and which a State can apply by means of its regulatory provisions for nuclear and radiation safety. A comprehensive body of safety standards under regular review, together with the IAEA's assistance in their application, has become a key element in a global safety regime.

In the mid-1990s, a major overhaul of the IAEA's safety standards programme was initiated, with a revised oversight committee structure and a systematic approach to updating the entire corpus of standards. The new standards that have resulted are of a high calibre and reflect best practices in Member States. With the assistance of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its safety standards.

Safety standards are only effective, however, if they are properly applied in practice. The IAEA's safety services — which range in scope from engineering safety, operational safety, and radiation, transport and waste safety to regulatory matters and safety culture in organizations — assist Member States in applying the standards and appraise their effectiveness. These safety services enable valuable insights to be shared and I continue to urge all Member States to make use of them.

Regulating nuclear and radiation safety is a national responsibility, and many Member States have decided to adopt the IAEA's safety standards for use in their national regulations. For the contracting parties to the various international safety conventions, IAEA standards provide a consistent, reliable means of ensuring the effective fulfilment of obligations under the conventions. The standards are also applied by designers, manufacturers and operators around the world to enhance nuclear and radiation safety in power generation, medicine, industry, agriculture, research and education.

The IAEA takes seriously the enduring challenge for users and regulators everywhere: that of ensuring a high level of safety in the use of nuclear materials and radiation sources around the world. Their continuing utilization for the benefit of humankind must be managed in a safe manner, and the IAEA safety standards are designed to facilitate the achievement of that goal.

THE IAEA SAFETY STANDARDS

BACKGROUND

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. Radiation and radioactive substances have many beneficial applications, ranging from power generation to uses in medicine, industry and agriculture. The radiation risks to workers and the public and to the environment that may arise from these applications have to be assessed and, if necessary, controlled.

Activities such as the medical uses of radiation, the operation of nuclear installations, the production, transport and use of radioactive material, and the management of radioactive waste must therefore be subject to standards of safety.

Regulating safety is a national responsibility. However, radiation risks may transcend national borders, and international cooperation serves to promote and enhance safety globally by exchanging experience and by improving capabilities to control hazards, to prevent accidents, to respond to emergencies and to mitigate any harmful consequences.

States have an obligation of diligence and duty of care, and are expected to fulfil their national and international undertakings and obligations.

International safety standards provide support for States in meeting their obligations under general principles of international law, such as those relating to environmental protection. International safety standards also promote and assure confidence in safety and facilitate international commerce and trade.

A global nuclear safety regime is in place and is being continuously improved. IAEA safety standards, which support the implementation of binding international instruments and national safety infrastructures, are a cornerstone of this global regime. The IAEA safety standards constitute a useful tool for contracting parties to assess their performance under these international conventions.

THE IAEA SAFETY STANDARDS

The status of the IAEA safety standards derives from the IAEA's Statute, which authorizes the IAEA to establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection of health and minimization of danger to life and property, and to provide for their application.

With a view to ensuring the protection of people and the environment from harmful effects of ionizing radiation, the IAEA safety standards establish fundamental safety principles, requirements and measures to control the radiation exposure of people and the release of radioactive material to the environment, to restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation, and to mitigate the consequences of such events if they were to occur. The standards apply to facilities and activities that give rise to radiation risks, including nuclear installations, the use of radiation and radioactive sources, the transport of radioactive material and the management of radioactive waste.

Safety measures and security measures[1] have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

The IAEA safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. They are issued in the IAEA Safety Standards Series, which has three categories (see Fig. 1).

Safety Fundamentals

Safety Fundamentals present the fundamental safety objective and principles of protection and safety, and provide the basis for the safety requirements.

Safety Requirements

An integrated and consistent set of Safety Requirements establishes the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements are governed by the objective and principles of the Safety Fundamentals. If the requirements are not met, measures must be taken to reach or restore the required level of safety. The format and style of the requirements facilitate their use for the establishment, in a harmonized manner, of a national regulatory framework. The safety requirements use ‘shall’ statements together with statements of

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[1] See also publications issued in the IAEA Nuclear Security Series.

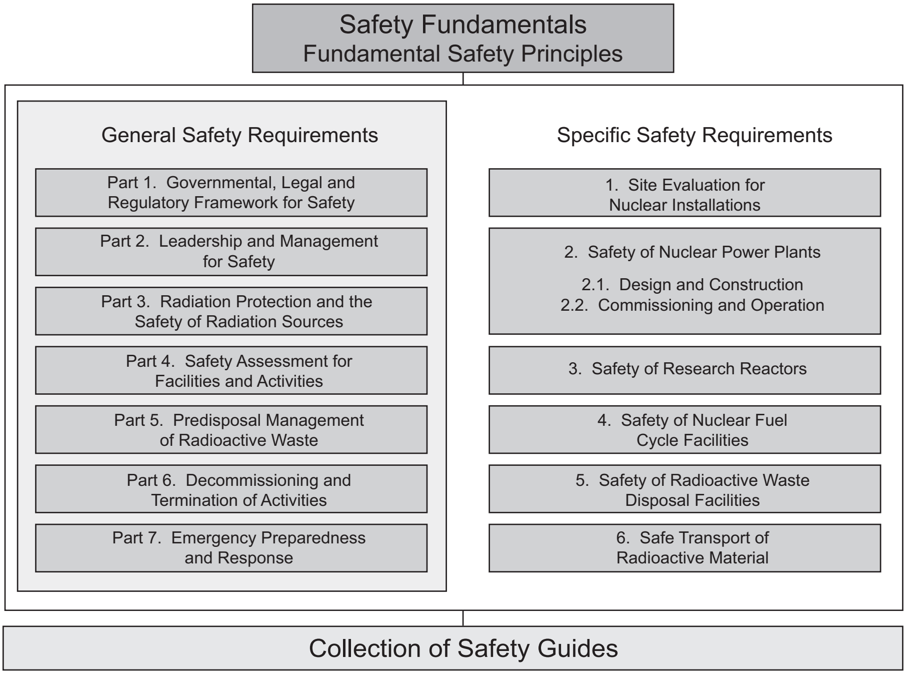

FIG. 1. The long term structure of the IAEA Safety Standards Series.

associated conditions to be met. Many requirements are not addressed to a specific party, the implication being that the appropriate parties are responsible for fulfilling them.

Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as ‘should’ statements.

APPLICATION OF THE IAEA SAFETY STANDARDS

The principal users of safety standards in IAEA Member States are regulatory bodies and other relevant national authorities. The IAEA safety standards are also used by co-sponsoring organizations and by many organizations that design, construct and operate nuclear facilities, as well as organizations involved in the use of radiation and radioactive sources.

The IAEA safety standards are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes and to protective actions to reduce existing radiation risks. They can be used by States as a reference for their national regulations in respect of facilities and activities.

The IAEA's Statute makes the safety standards binding on the IAEA in relation to its own operations and also on States in relation to IAEA assisted operations.

The IAEA safety standards also form the basis for the IAEA's safety review services, and they are used by the IAEA in support of competence building, including the development of educational curricula and training courses.

International conventions contain requirements similar to those in the IAEA safety standards and make them binding on contracting parties. The IAEA safety standards, supplemented by international conventions, industry standards and detailed national requirements, establish a consistent basis for protecting people and the environment. There will also be some special aspects of safety that need to be assessed at the national level. For example, many of the IAEA safety standards, in particular those addressing aspects of safety in planning or design, are intended to apply primarily to new facilities and activities. The requirements established in the IAEA safety standards might not be fully met at some existing facilities that were built to earlier standards. The way in which IAEA safety standards are to be applied to such facilities is a decision for individual States.

The scientific considerations underlying the IAEA safety standards provide an objective basis for decisions concerning safety; however, decision makers must also make informed judgements and must determine how best to balance the benefits of an action or an activity against the associated radiation risks and any other detrimental impacts to which it gives rise.

DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

The preparation and review of the safety standards involves the IAEA Secretariat and four safety standards committees, for nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on Safety Standards (CSS) which oversees the IAEA safety standards programme (see Fig. 2).

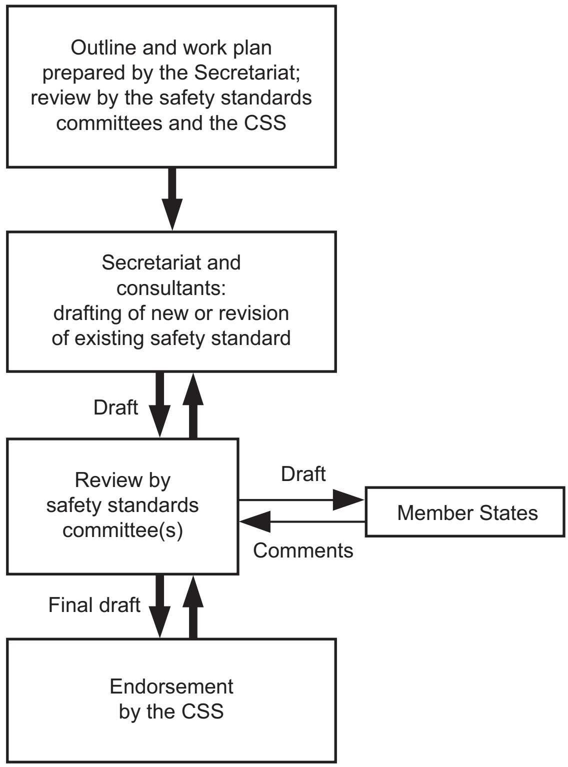

FIG. 2. The process for developing a new safety standard or revising an existing standard.

All IAEA Member States may nominate experts for the safety standards committees and may provide comments on draft standards. The membership of the Commission on Safety Standards is appointed by the Director General and includes senior governmental officials having responsibility for establishing national standards.

A management system has been established for the processes of planning, developing, reviewing, revising and establishing the IAEA safety standards. It articulates the mandate of the IAEA, the vision for the future application of the safety standards, policies and strategies, and corresponding functions and responsibilities.

INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

The findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the recommendations of international expert bodies, notably the International Commission on Radiological Protection (ICRP), are taken into account in developing the IAEA safety standards. Some safety standards are developed in cooperation with other bodies in the United Nations system or other specialized agencies, including the Food and Agriculture Organization of the United Nations, the United Nations Environment Programme, the International Labour Organization, the OECD Nuclear Energy Agency, the Pan American Health Organization and the World Health Organization.

INTERPRETATION OF THE TEXT

Safety related terms are to be understood as defined in the IAEA Safety Glossary (see http://www-ns.iaea.org/standards/safety-glossary.htm). Otherwise, words are used with the spellings and meanings assigned to them in the latest edition of The Concise Oxford Dictionary. For Safety Guides, the English version of the text is the authoritative version.

The background and context of each standard in the IAEA Safety Standards Series and its objective, scope and structure are explained in Section 1, Introduction, of each publication.

Material for which there is no appropriate place in the body text (e.g. material that is subsidiary to or separate from the body text, is included in support of statements in the body text, or describes methods of calculation, procedures or limits and conditions) may be presented in appendices or annexes.

An appendix, if included, is considered to form an integral part of the safety standard. Material in an appendix has the same status as the body text, and the IAEA assumes authorship of it. Annexes and footnotes to the main text, if included, are used to provide practical examples or additional information or explanation. Annexes and footnotes are not integral parts of the main text. Annex material published by the IAEA is not necessarily issued under its authorship; material under other authorship may be presented in annexes to the safety standards. Extraneous material presented in annexes is excerpted and adapted as necessary to be generally useful.

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. Radioactive waste is generated in a number of different kinds of facilities and it may arise in a wide range of concentrations of radionuclides and in a 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 to geological disposal.

1.2. The Safety Requirements publication, Predisposal Management of Radioactive Waste [1], requires that: "At various steps in the predisposal management of radioactive waste, the radioactive waste shall be characterized and classified in accordance with requirements established or approved by the regulatory body" (Requirement 9). This is to ensure that proper and adequate provision is made for the safety implications associated with the management and disposal of the waste.

1.3. Various schemes have evolved for classifying radioactive waste according to the physical, chemical and radiological properties that are of relevance to particular facilities or circumstances in which radioactive waste is managed. These schemes have led to a variety of terminologies, which may differ from State to State and even between facilities in the same State. In some instances, this has given rise to difficulties in establishing consistent and coherent national waste management policies and implementing strategies, and can lead to less than optimal levels of safety. It also makes communication on waste management practices difficult 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 [2]. Comparison of data published in the scientific literature is not straightforward, and difficulties can arise in trying to understand waste management programmes and practices both within and between States.

1.4. In order to address these issues, the classification of radioactive waste has been the subject of international standards on the safety of radioactive waste management. The first standard on the subject was published in 1970[1], and revisions were published in 1981[2] and 1994[3]. An explanation of the evolution of these standards is presented in Annex I. The classification scheme presented in this Safety Guide supersedes the classification schemes in the earlier standards.

1.5. 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 Ref. [3]. Nevertheless, apart from waste containing only short lived radionuclides, all other types of radioactive waste need to be eventually disposed of in a manner consistent with the Fundamental Safety Principles [4] and with safety requirements for the management of radioactive waste and for the disposal of radioactive waste.

1.6. The classification scheme developed previously[3] is not completely comprehensive in that it does not cover all types of radioactive waste, nor does it provide a direct linkage with disposal options for all types of radioactive waste. These aspects of the former classification scheme have been deemed limitations on its use and application.

1.7. The generic linkage between the different classes of waste and disposal options is addressed in this Safety Guide but, notwithstanding such generic linkage, 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 [5].

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[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Standardization of Radioactive Waste Categories, Technical Reports Series No. 101, IAEA, Vienna (1970).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Underground Disposal of Radioactive Waste: Basic Guidance, Safety Series No. 54, IAEA, Vienna (1981).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Classification of Radioactive Waste, Safety Series No. 111-G-1.1, IAEA, Vienna (1994).

OBJECTIVE

1.8. The objective of this Safety Guide is to set out a general scheme for classifying radioactive waste that is based primarily on considerations of long term safety, and thus, by implication, disposal of the waste. This Safety Guide, together with other IAEA safety standards on radioactive waste, will assist in the development and implementation of appropriate waste management strategies and will facilitate communication and information exchange within and among States. Disposal is considered the final step in the management of radioactive waste, as stipulated in Safety Requirements publications on predisposal management of radioactive waste and disposal of radioactive waste [1, 5].

1.9. The Safety Guide identifies the conceptual boundaries between different classes of waste and provides guidance on their definition on the basis of long term safety considerations. While the usefulness is recognized of classification schemes for the safe operational management of radioactive waste, including the transport of waste, such schemes are subject to different considerations and are not addressed in this Safety Guide.

SCOPE

1.10. This Safety Guide provides guidance on the classification of the whole range of radioactive waste: from spent nuclear fuel, when it is considered radioactive waste, to waste having such low levels of activity concentration that it is not required to be managed or regulated as radioactive waste. This Safety Guide covers disused sealed sources, when they are considered waste, and waste containing radionuclides of natural origin. The recommendations in this Safety Guide are applicable to waste arising from all origins, including waste arising from facilities and activities, waste arising from existing situations and waste that may arise from accidents.

1.11. The classification scheme developed in this Safety Guide is focused on solid radioactive waste. However, the fundamental approach could also be applicable to the management of liquid and gaseous waste, with appropriate consideration given to aspects including the processing of such waste to produce a solid waste form that is suitable for disposal.

1.12. The Safety Guide does not give consideration to non-radioactive hazardous constituents of radioactive waste if they do not affect radiation safety. It will 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 this Safety Guide. In some States such waste is sometimes referred to as ‘mixed waste’.

1.13. It is important that the characteristics of any particular radioactive waste be known for decisions to be made on its processing, storage and disposal; however, approaches to and methods for the characterization of radioactive waste are not addressed in this Safety Guide.

STRUCTURE

1.14. This Safety Guide consists of two sections, an appendix and three annexes. The scheme for classification of radioactive waste is set out in Section 2. The Appendix expands on the general scope and objectives of classification schemes for radioactive waste. It discusses the purpose and limitations of the classification scheme described in this Safety Guide, and explains the approach adopted in the development of the scheme for classification of radioactive waste. The Appendix also discusses the criteria and waste management activities considered in the determination of waste classes. Annex I describes the evolution of the IAEA safety standards on classification of radioactive waste. Annex II discusses the various purposes of and approaches to waste classification as well as qualitative and quantitative methods for waste classification. Annex III describes various types of radioactive waste and illustrates the application of the waste classification scheme developed in this Safety Guide to these types of radioactive waste.

2. THE RADIOACTIVE WASTE CLASSIFICATION SCHEME

OVERVIEW

2.1. A number of elements of the classification scheme previously set out[3] have been retained. However, the scheme has been modified to address the shortcomings identified with the previous scheme (see para. 1.6) and to reflect experience gained in developing, operating and assessing the safety of disposal facilities. A comprehensive range of waste classes has been defined and general boundary conditions between the classes are provided. More detailed quantitative boundaries that take into account a broader range of parameters may be developed in accordance with national programmes and requirements. In cases when there is more than one disposal facility in a State, 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.

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

(1) Exempt waste[4] (EW): Waste that meets the criteria for clearance, exemption or exclusion from regulatory control for radiation protection purposes as described in Ref. [6].
(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 regulatory body, for uncontrolled disposal, use or discharge. This class includes waste containing primarily radionuclides with very short half-lives often used for research and medical purposes.
(3) Very low level waste (VLLW): Waste that does not necessarily meet the criteria of EW, but that does not need a high level of containment and isolation and, therefore, is suitable for disposal in near surface landfill type facilities 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 levels of activity concentration. Concentrations of longer lived radionuclides in VLLW are generally very limited.
(4) Low level waste (LLW): Waste that is above clearance 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. LLW may include short lived radionuclides at higher levels of activity concentration, and also long lived radionuclides, but only at relatively low levels of activity concentration.

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[4] The term ‘exempt waste’ has been retained from the previous classification scheme (see footnote 3) for consistency; however, once such waste has been cleared from regulatory control, it is not considered radioactive waste.

(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 no provision, or only limited provision, for heat dissipation during its storage and disposal. ILW may contain long lived radionuclides, in particular, alpha emitting radionuclides that will not decay to a level of 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, of the order of tens of metres to a few hundred metres.

(6) High level waste (HLW): Waste with levels of activity concentration 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 recognized option for disposal of HLW.

2.3. Quantitative values of allowable activity content for each significant radionuclide will be specified on the basis of safety assessments for individual disposal sites (which is outside the scope of this Safety Guide).

WASTE CLASSES

2.4. A conceptual illustration of the waste classification scheme is presented in Fig. 1. The vertical axis represents the activity content[5] of the waste and the horizontal axis represents the half-lives of the radionuclides contained in the waste. In some cases, the amount of 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.

2.5. Considering Fig. 1 vertically, the level of activity content can range from negligible to very high, that is, very high concentration of radionuclides or very high specific activity. The higher the level of activity content, the greater the

[5] The term ‘activity content’ is used because of the generally heterogeneous nature of radioactive waste; it is a generic term that covers activity concentration, specific activity and total activity.

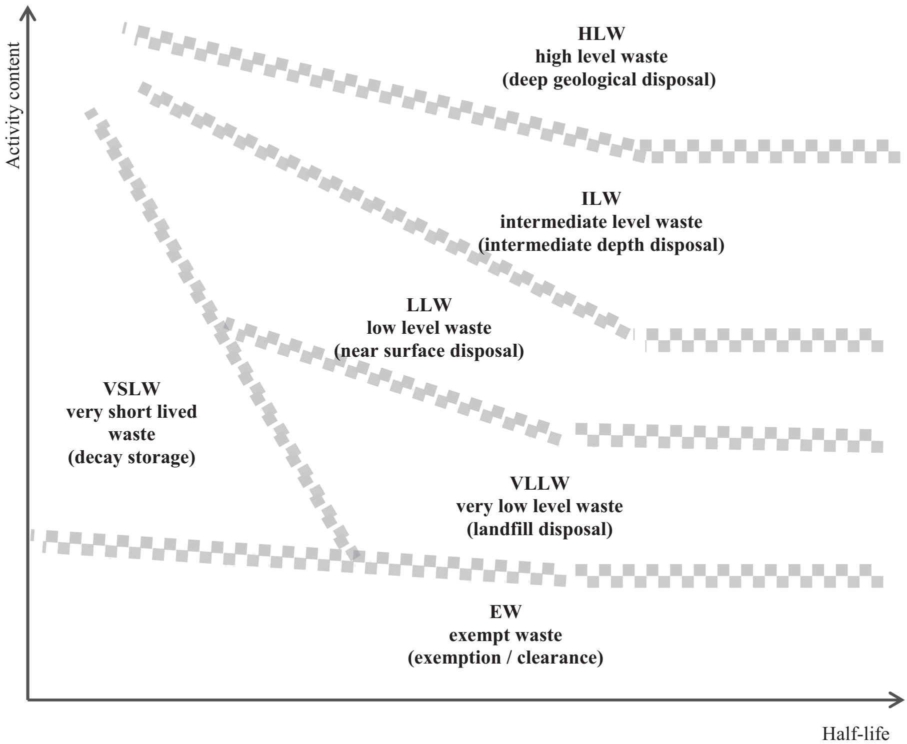

FIG. 1. Conceptual illustration of the waste classification scheme.

need to contain the waste and to isolate it from the biosphere. At the lower range of the vertical axis, below clearance levels, the management of the waste can be carried out without consideration of its radiological properties.

2.6. Considering Fig. 1 horizontally, the half-lives of the radionuclides contained in the waste can range from short (seconds) to very long time spans (millions of years). In terms of radioactive waste safety, a radionuclide with a half-life of less than about 30 years is considered to be short lived. It is beneficial to make such a distinction between waste containing mainly short lived radionuclides and waste containing long lived radionuclides because the radiological hazards associated with short lived radionuclides 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 mainly short lived radionuclides can be kept in place over such time frames. 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 on the particular radionuclides it contains.

2.7. A more detailed discussion of each waste class is presented in paras 2.8–2.31.

Exempt waste (EW)

2.8. 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 can be cleared from regulatory control and does not require any further consideration from a regulatory control perspective.

2.9. Liquid or gaseous effluents discharged to the environment under appropriate regulatory control are somewhat analogous to cleared waste, inasmuch as discharged material requires no further consideration from the perspective of radiation protection and safety. There are, however, some notable differences in the establishment of limitations on effluent quantities suitable for discharge and, in the case of discharge of effluents, confirmatory environmental monitoring is normally carried out [7].

2.10. Studies undertaken at the national and international levels have derived radionuclide specific levels of activity concentration for the exemption and clearance of solid material, and Ref. [6] provides explanation and guidance on the concepts of exclusion, exemption and clearance. Reference [6] gives values of activity concentration for radionuclides of both natural and artificial origin that may be used by the regulatory body for determining when controls over bulk amounts of solid material are not required or are no longer necessary.

2.11. The values of activity concentration for artificial radionuclides are derived on the basis of generic scenarios for the recycling and disposal of waste:

> "The primary radiological basis for establishing values of activity concentration for the exemption of bulk amounts of material and for

clearance is that the effective doses to individuals should be of the order of 10 μSv or less in a year. To take account of the occurrence of low probability events leading to higher radiation exposures, an additional criterion was used, namely, the effective doses due to such low probability events should not exceed 1 mSv in a year. In this case, consideration was also given to doses to the skin; an equivalent dose criterion of 50 mSv in a year to the skin was used for this purpose. This approach is consistent with that used in establishing the values for exemption provided in Schedule I of the BSS" [6].

For radionuclides of natural origin, a different approach was adopted: these values were determined on the basis of consideration of the upper end of the worldwide distribution of activity concentrations in soil [6].

2.12. Levels of activity concentration for exempt waste that are different from those recommended in Ref. [6] may be established by the regulatory body on a case by case basis, providing that consideration is given to specific national circumstances that will significantly influence exposure scenarios, or specific requirements or conditions are defined for the exemption or clearance of waste. Consideration should be given to any possible transboundary implications, if it is conceivable that the material in question might be exported. Levels of activity concentration established by the regulatory body will be highly dependent on the conditions under which exemption or clearance is granted.

2.13. An important aim of Ref. [6] is to provide a consensus on the boundary for unconditionally exempt or cleared material that may be transferred from one State to another (e.g. for recycling or reuse) without its being subject to regulatory control for the purposes of radiation protection. The existence of such consensus greatly simplifies procedures for exemption and clearance, and it is considered to contribute to an increased level of public confidence in the safety of practices.

Very short lived waste (VSLW)

2.14. Very short lived waste contains only radionuclides of very short half-life with activity concentrations above the clearance levels. Such waste can be stored until the activity has fallen beneath the levels for clearance, allowing for the cleared waste to be managed as conventional waste. Examples of very short lived waste are waste from sources using ^{192}Ir and ^{99m}Tc and waste containing other radionuclides with short half-lives from industrial and medical applications. Although this Safety Guide focuses 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.

2.15. The main criteria for the classification of waste as VSLW are the half-lives of the predominant radionuclides and the acceptability of the amounts of longer half-life radionuclides. Since the intent of storage for decay is to eventually clear the material, acceptable levels of concentration of long half-life radionuclides are set by the clearance levels. The boundary for the half-lives 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 half-lives of the order of 100 days or less.

2.16. The classification of waste as VSLW obviously depends on the point in time at which the waste is assigned a classification. Through radioactive decay, VSLW will move into the class of exempt 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)

2.17. Substantial amounts of waste arise from the operation and decommissioning of nuclear facilities with levels of activity concentration in the region of or slightly above the levels specified for the clearance 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, does require 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.

2.18. An adequate level of safety for VLLW may be achieved by its disposal in engineered surface landfill type facilities. This is the usual practice for waste from some mining operations and for other waste containing naturally occurring radionuclides from various operations involving minerals processing and other activities. Some States also use this disposal method for waste with low levels of activity concentration arising from nuclear installations [8, 9]. 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.

2.19. 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 using generic scenarios similar to those applied in the derivation of exemption and clearance levels in Ref. [6] or by undertaking a safety assessment for a specific facility in a manner approved by the regulatory body. The criteria derived will depend on the actual site conditions and on 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 Safety Guide. Nevertheless, it is expected that with a moderate level of engineering and controls, a landfill facility can safely accommodate waste containing artificial radionuclides with levels of activity concentrations one or two orders of magnitude above the levels for exempt waste, for waste containing short lived radionuclides and with limited total activity. This applies as long as expected doses to the public are within criteria established by the regulatory body. In general, for waste containing naturally occurring radionuclides, acceptable levels of activity concentration will be expected to be lower than those for waste containing artificial radionuclides, in view of the long half-lives of naturally occurring radionuclides. Depending on site factors and the design, it may still be possible to demonstrate the safety of waste with higher levels of activity concentration.

2.20. Another management option for some waste falling within this class, such as waste rock from mining operations, may be the authorized use of the material (e.g. for road construction). In this case, criteria can be derived by using approaches similar to those set out in Ref. [6] for the definition of general clearance values (see para. 3.1 of Ref. [6]).

Low level waste (LLW)

2.21. In previous classification schemes, low level waste was defined to mean radioactive waste that does not require shielding during normal handling and transport[6]. Radioactive waste that requires shielding but needs little or no provision for heat dissipation was classified as intermediate level waste[7]. A contact dose rate of 2 mSv/h was generally used to distinguish between the two classes of waste. Contact radiation dose rate is not used to distinguish waste classes in the present, revised classification scheme, which is based primarily on long term safety. However, it remains an issue that has to be considered in handling and transporting the waste, and for operational radiation protection purposes at waste management and disposal facilities, but is not necessarily a determining factor for the long term safety of a disposal facility.

2.22. In the classification scheme set out in this Safety Guide, low level waste is waste that is suitable for near surface disposal. This is a disposal option 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. It ranges from radioactive waste with an activity content level just above that for VLLW, that is, not requiring shielding or particularly robust containment and isolation, to radioactive waste with a level of activity concentration such that shielding and more robust containment and isolation are necessary for periods up to several hundred years.

2.23. Because LLW 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, and may involve disposal at varying depths, typically from the surface down to 30 m. They will depend on safety assessments and on national practices, and are subject to approval by the regulatory body.

2.24. Low concentrations of long lived radionuclides may be present in LLW. 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 LLW 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

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[6] See footnote 2.

[7] See footnote 3.

biosphere in the post-closure phase of a disposal facility) and inhalation (e.g. in the case of human intrusion into the waste). Thus, 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 time frames 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 [5].

2.25. In many States it is 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 exposed individuals after this period of institutional control. A special situation arises for waste from the mining and processing of uranium and other materials containing significant amounts of radionuclides of natural origin, for which the activity content will not decrease significantly over such timescales. Since the management of such waste in near surface facilities is in many cases the only practicable option, longer periods of institutional control have to be postulated, with periodic safety review of the facility.

2.26. A precise boundary between LLW and intermediate level waste (ILW) cannot be provided, as limits on the acceptable level of 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 and planning for the facility (e.g. engineered barriers, duration of institutional control, site specific factors). Restrictions on levels of activity concentration for long lived radionuclides in individual waste packages may be complemented by restrictions on average levels of activity concentration or by simple operational techniques such as emplacement of waste packages with higher levels of activity concentration at selected locations within the disposal facility. It may be possible for a regulatory body to provide bounding levels of activity concentration for LLW on the basis of generic site characteristics and generic facility designs, as well as specified institutional control periods and dose limits to individuals.

2.27. The regulatory body should establish limits for the disposal of long lived radionuclides on the basis of the safety assessment for the particular disposal facility. A limit of 400 Bq/g on average (and up to 4000 Bq/g for individual packages) for long lived alpha emitting radionuclides has been adopted in some States [10–12]. For long lived beta and/or gamma emitting radionuclides, such as ^{14}C, ^{36}Cl, ^{63}Ni, ^{93}Zr, ^{94}Nb, ^{99}Tc and ^{129}I, the allowable average activity concentrations may be considerably higher (up to tens of kilobecquerels per gram) and may be specific to the site and disposal facility.

Intermediate level waste (ILW)

2.28. 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 is provided by near surface disposal. Disposal in a facility at a depth of between a few tens and a few hundreds of metres is indicated for ILW. 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 the disposal system are selected properly. 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, in comparison 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 application of institutional controls.

2.29. As stated in para. 2.26, the boundary between the LLW class and the ILW class cannot be specified in a general manner with respect 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 ILW, the regulatory body may determine that certain waste constitutes LLW or ILW on the basis of generic safety cases.

High level waste (HLW)

2.30. High level waste is defined to be 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. Such containment and isolation is usually provided by the integrity and stability of deep geological disposal, with engineered barriers. HLW generates significant quantities of heat from radioactive decay, and normally continues to generate heat for several centuries. Heat dissipation is an important factor that has to be taken into account in the design of geological disposal facilities.

2.31. HLW typically has levels of activity concentration[8] in the range of 10^4–10^6 TBq/m^3 (e.g. for fresh spent fuel from power reactors, which some States consider radioactive waste). HLW includes conditioned waste arising from the reprocessing of spent fuel together with any other waste requiring a comparable degree of containment and isolation. At the time of disposal, following a few decades of cooling time, waste containing such mixed fission products typically has levels of activity concentration of around 10^4 TBq/m^3. For the purposes of communication pending the establishment of disposal facilities for HLW, national authorities may determine that certain waste constitutes ILW or HLW on the basis of generic safety cases.

ADDITIONAL CONSIDERATIONS

2.32. If the classification scheme is used, the specific types and properties of radioactive waste should be taken into account. The precise criteria according to which waste is assigned to a particular waste class will depend on the specific situation in the State 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 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 and the different regulatory approaches that have been adopted. Annex III 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 2 is a logic diagram illustrating the use of the classification scheme to assist in determining disposal options, explained further in Annex III.

2.33. Although heat generation is a characteristic of HLW, 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 (e.g. half-life, decay energy, activity concentration and total activity). Furthermore,

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[8] The previous classification system (see footnote 3) quoted a corresponding thermal power of 2–20 kW/m^3. A level of thermal power is not specified in this Safety Guide as it is a matter for detailed consideration in the demonstration of the safety of a geological disposal facility.

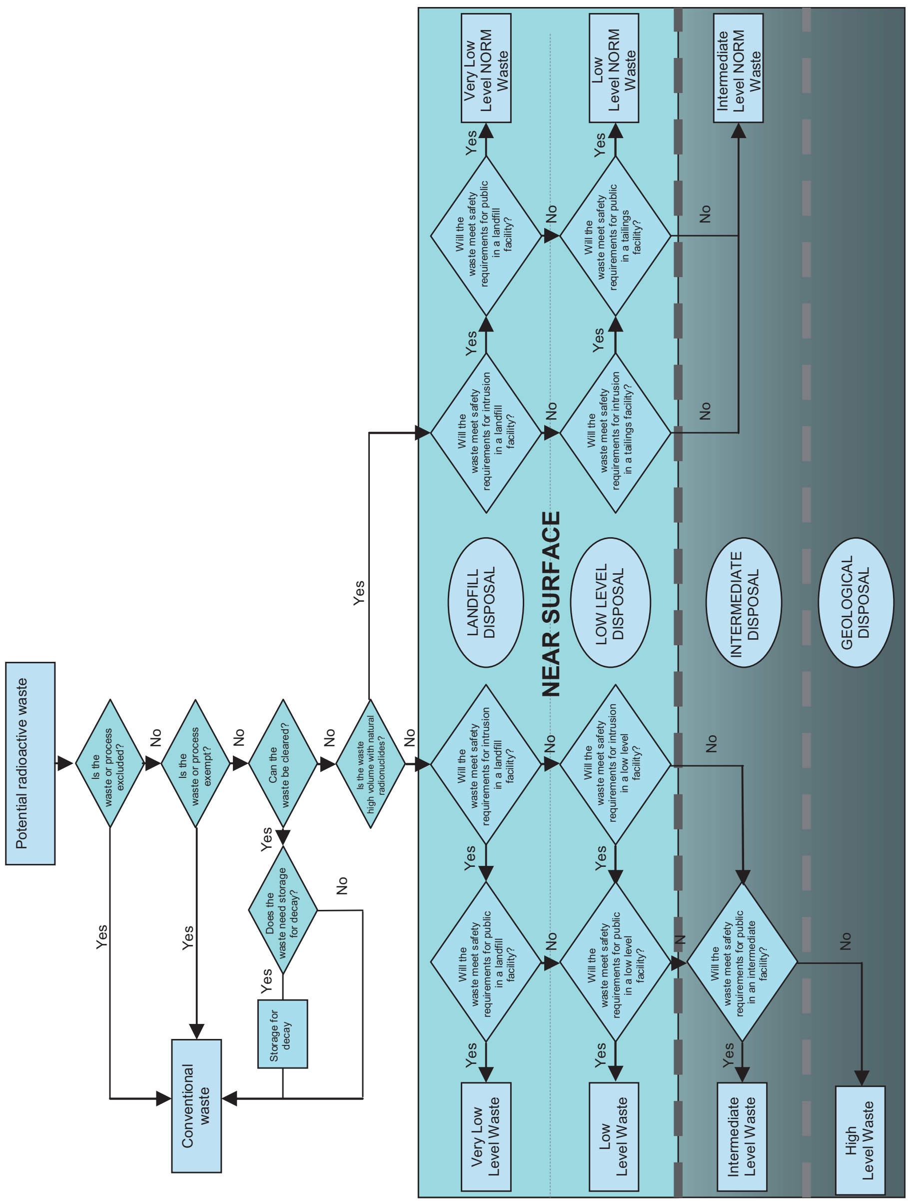

FIG. 2. An illustration of the use of the classification scheme.

consideration of heat removal is very important (e.g. thermal conductivity, storage geometry and ventilation). Therefore, the significance of heat generation cannot be defined by means of a single parameter value. The impact of heat generation can vary by several orders of magnitude, depending on the influencing factors and the methods in place for heat removal. Management of decay heat should be considered if the thermal power of waste packages reaches several Watts per cubic metre. More restrictive values may apply, particularly in the case of waste containing long lived radionuclides.

Appendix

THE CLASSIFICATION OF RADIOACTIVE WASTE

A.1. Schemes for the classification of radioactive waste may be developed from different bases, such as operational or long term safety, the demands of process engineering, the availability of management or disposal facilities or the source of generation of the waste. A discussion of different purposes of and approaches to classification schemes for radioactive waste is provided in Annex II. In this Safety Guide, consideration is given primarily to the long term safety of waste management, since this is overriding in most cases involving its extended storage and disposal. This approach does not preclude the consideration of other aspects, such as occupational safety, that are pertinent in operational waste management.

A.2. 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;
  - In assigning radioactive waste to a particular conditioning technique or disposal facility.

— At the legal and regulatory level:
  - In the development of legislation;
  - In the establishment of regulatory requirements and criteria.

— At the operational level:
  - By defining operational activities and in organizing the work to be undertaken with the waste;
  - By providing a broad indication of the potential hazards associated with the various types of radioactive waste;
  - By facilitating record keeping.

— 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.

A.3. To satisfy all these purposes, an ideal radioactive waste classification scheme should meet a number of objectives, namely:

— Cover the full range of radioactive waste types;
— Be of use at all steps of radioactive waste management and be able to address the interdependences 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 characterizing waste by all parties, including regulators, operators and other interested parties;
— Be as widely applicable as possible.

A.4. 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 will be needed to ensure simplicity, flexibility and broad applicability of the scheme. In developing a classification scheme:

— The definition of waste classes should be developed on a sound technical basis, should be clear and should be easily understandable;
— The general nature and applicability of the classification scheme should be clearly understandable;
— The number of classes should be such as to achieve a balance between the desired differentiation among waste types and the ease of handling of the classification scheme.

A.5. The classification scheme developed in this publication is intended to provide a framework for defining waste classes within national waste management strategies and to serve as a tool for facilitating communication on radioactive waste safety. 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 in each State (Ref. [12] provides an example). 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, from which specific criteria should be derived for different types of waste. Also of relevance is when and how material is declared to be waste, that is, material for which no further use is foreseen, and arrangements and procedures related to such a declaration should be subject to approval by the regulatory body.

A.6. The classification scheme developed in this publication is mainly based on long term safety considerations and can be applied for all waste management activities. The assignment of waste to a particular waste class does not depend on the actual activities being performed, except when disposal is being considered. However, for certain waste management steps (e.g. processing, transport and storage), more detailed classification may be required. This could be expressed in terms of subclasses 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 activities are discussed in Annex II.

A.7. The classification scheme is not intended to — and cannot — replace the specific safety assessment required for a waste management facility or activity. 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.

A.8. 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 made on the basis of the characteristics of the practice or source, with account taken of the magnitude and likelihood of exposures.

A.9. The parameters used in the classification scheme are the levels of activity content of the waste and the half-lives of the radionuclides contained in the waste, with account taken of the hazards posed by different radionuclides and the types of radiation emitted. Activity levels may be expressed in terms of total activity of the waste, activity concentration or specific activity, depending on the type of waste considered. 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.

A.10. 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 level of activity concentration that would be suitable for bulk amounts of waste will, in general, not be adequate to classify disused sealed 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.

A.11. 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 may be developed on the basis of considerations of optimization 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.

A.12. The classification scheme presented in this publication is based on the safety aspects of waste management, in particular the safety aspects of disposal. However, the importance of security aspects of the management of radioactive waste is recognized. Although security is not explicitly addressed in the determination of the waste classes, safety and security aspects of waste management are in general compatible inasmuch as waste with higher activity concentrations and longer lived radionuclides is subjected to disposal options providing a greater degree of containment and isolation. However, a substantial difference in safety and security aspects of waste management could 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.

A.13. 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 or clearance;
- Storage for decay;
- 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;
— 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 as established in Ref. [5] will apply.

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Annex I

THE EVOLUTION OF IAEA STANDARDS ON RADIOACTIVE WASTE CLASSIFICATION

I–1. Publications on classification of radioactive waste have been issued previously by the IAEA in 1970[9] and 1981[10]. Generally, radioactive waste was divided into three classes: (1) high level waste (HLW); (2) intermediate level waste (ILW); or (3) low level waste (LLW). Within the ILW and LLW classes, the latter publication also differentiated between waste containing short lived radionuclides and waste containing long lived radionuclides, as well as waste containing alpha emitting radionuclides. That classification scheme proved to be useful for general purposes; nevertheless, limitations were identified with the scheme. In particular, the classification scheme lacked a completely coherent linkage to safety aspects in radioactive waste management, especially disposal.

I–2. To address these limitations and to provide for improved communication, a modified classification scheme was published by the IAEA in 1994[11]. Three major classes of waste were identified and used as the basis for the scheme:

— Waste that contains such a low concentration of radionuclides that it can be exempted from regulatory control, as the associated radiological hazard is negligible.
— Waste that contains such an amount of radioactive material that it requires actions to ensure the protection of workers and the public, either for short periods or for long periods of time. This class covers a very wide range of radioactive waste, ranging from radioactive waste just above exemption levels that will not require shielding or particular containment, to radioactive waste that contains such high levels of activity that shielding and possibly provision for heat dissipation may be required. A range of disposal methods may be postulated for such waste.
— Waste that contains such high levels of radioactive material that a high degree of isolation from the biosphere, usually by means of geological disposal, is required for long periods of time. Such waste normally requires both shielding and provision for heat dissipation.

[9] See footnote 1.
[10] See footnote 2.
[11] See footnote 3.

Annex II

METHODS OF CLASSIFICATION

II–1. Classification schemes for radioactive waste may be developed from different bases, such as safety or regulatory related aspects or process engineering demands. This annex provides a discussion of the various purposes of and approaches to classification schemes for radioactive waste.

II–2. Radioactive waste classification schemes can be set up at different levels and for various purposes. A classification scheme may be defined at the international level, at the national level or at the operator level. Its perspective and purpose will differ accordingly, addressing, for example, safety related aspects, the origin and characteristics of the waste, engineering demands or regulatory control.

II–3. The approach to classification will depend on the purpose of the radioactive waste classification scheme. One basic approach to classification is a straightforward qualitative description of the individual classes, whereby the general characteristics of the radioactive waste are used as the main criteria for the classification. Nevertheless, even for this qualitative approach to classifying, numerical values to characterize broad bands or orders of magnitude may also be helpful. Another basic approach to classification is by the use of quantitative criteria, whereby numerical values are specified for the definition of waste classes.

II–4. The approach described in Section 2 of this Safety Guide is based mainly on the long term safety aspects of waste disposal, but can be used in the various stages of waste management. It is reasonable to use disposal as a basis for a classification scheme in order to maintain compatibility and coherence through the different stages of waste management.

II–5. A clear distinction has to be made between a classification scheme and a set of regulatory limits. The purpose of classification is to ensure that waste is managed 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 activity. Therefore, the development of precise limits has to be carried out within the regulatory framework of licensing or authorizing specific radioactive waste management activities and facilities. The regulatory body of a State will establish actual limits on quantities or concentrations for the classification of radioactive waste.

While a 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 characterization of radioactive waste.

QUALITATIVE CLASSIFICATION

II–6. There exist 'natural' classification schemes, for example, classification of waste according to its origin. An example of such a qualitative classification scheme is given in Annex III. While such a scheme is convenient for record keeping and notification to the regulatory body, it fails to meet many of the objectives listed in para. A.3 of the Appendix. Moreover, the characteristics relating to safety of the waste in a given class may vary widely, and waste within the same class may require different types of processing.

II–7. Another 'natural' classification scheme is the differentiation of radioactive waste according to its physical state, that is, solid, liquid or gaseous. This scheme stems from the process engineering needs for the processing of different waste streams, and the scheme is often refined to correspond to individual waste processing systems. A classification scheme of this type follows technical needs and possibilities and will therefore generally be specific to the individual facility. It may, however, incorporate safety considerations such as the radiation protection measures necessary for radioactive waste classes with higher radiological hazard potential.

II–8. The classification scheme proposed in 1994[11] had three principal waste classes: exempt waste, low and intermediate level waste (subdivided into short lived waste and long lived waste), and high level waste. The boundaries between waste classes were presented in terms of orders of magnitude of activity levels.

II–9. Different States use different classification schemes. In the United States of America, for example, the low and intermediate level class of waste is divided into four subclasses [II–1]. Some States have a class of very low level radioactive waste [II–2, II–3]. In many States, further distinction is made on the basis of half-lives of radionuclides in the waste, the physical state of the waste and other factors [II–4].

QUANTITATIVE CLASSIFICATION

II–10. Frequently, classification of radioactive waste is related to the safety aspects of the management of the waste in question. Such a classification scheme therefore provides a link between the characteristics of the waste and safety objectives that have been established by a regulatory body or the operator of a waste management facility. As safety criteria are generally formulated in terms of numerical values, a quantitative approach to classification will be necessary. Quantitative criteria for a radioactive waste classification scheme may be presented in terms of levels of activity concentration, half-lives of the radionuclides in the waste, heat generated by the waste and/or dose or dose rate. To derive a quantitative classification scheme, a procedure such as that outlined in paras II–11 to II–17 should be used.

II–11. The first step in developing a quantitative classification scheme is a definition of the purpose of the classification scheme, since a given classification scheme can only address a particular aspect of radioactive waste management. The decision as to the purpose of the classification scheme will be based on such aspects as:

— Type of radioactive waste;
— Facility or activity under consideration;
— Processing options available;
— Safety objectives to be met;
— Related social and economic factors;
— Need for communication.

II–12. The second step is the definition of the aspects to be considered in the scheme, for example:

— Exposure of personnel;
— Exposure of members of the public;
— Contamination of the environment;
— Safety from criticality;
— Normal conditions or accidents;
— Heat generated by the waste;
— Process engineering aspects.

II–13. For some of the aspects listed in para. II–12, regulatory or technical constraints may exist that have to be taken into account. Examples of such constraints are:

— Limits and requirements set by the regulatory body;
— The characteristics of the waste itself, that is, the annual amount arising, the total volume of generation, and the spectrum of radionuclides and their concentrations;
— Facility specific conditions (e.g. waste forms or waste packages accepted, engineering design);
— Operational limits;
— Pathways or scenarios prescribed for safety assessments;
— Site specific conditions (e.g. for waste disposal, the geological, hydrogeological and climatic characteristics of a site may restrict the choice of a disposal site or of the type of waste that can be disposed of at the site);
— Social or political aspects;
— Legal definitions and requirements.

These factors may place restrictions on the choice and the development of a classification scheme and therefore their effect has to be evaluated before the classification scheme can be derived.

II–14. Once the framework for classification has been set, the third step involves selection of the parameters to be used for classifying the waste. Important characteristics of waste that may be used as parameters for classification are given in Table II–I.

II–15. Possible scenarios, design options for the facility and site specific options then have to be evaluated in a fourth step to assess their suitability as classification parameters. For the case of LLW, a discussion of possible scenarios is provided in Ref. [II–4].

II–16. When a set of classification parameters has been chosen, intervals for numerical values or, alternatively, qualitative characteristics are specified as limits for different classes. Assignment of the waste to these classes will indicate whether the classification scheme that has been established is adequate.

II–17. Normally, the steps described in paras II–11 to II–16 are repeated in an iterative manner until a satisfactory result is reached.

TABLE II–I. IMPORTANT CHARACTERISTICS OF RADIOACTIVE WASTE THAT MAY BE USED AS PARAMETERS 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
- — Compactibility
- — 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
- — Bio-accumulation

Other factors:
- — Volume
- — Amount arising per unit of time
- — Physical distribution

REFERENCES TO ANNEX II

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Annex III

ORIGIN AND TYPES OF RADIOACTIVE WASTE

III–1. Many activities involving the use of radionuclides and the production of nuclear energy, including all the steps in the nuclear fuel cycle, result in the generation of radioactive waste. Radioactive waste may also be generated by other activities such as the medical or industrial use of radioisotopes and sealed radiation sources, by defence and weapons programmes, and by the (mostly large scale) processing of mineral ores or other materials containing naturally occurring radionuclides, which in some cases have to be managed as radioactive waste. Examples of the last include the processing of phosphate ore and oil or gas exploration. Radioactive waste also arises from intervention activities, which are necessary after accidents or to remediate areas affected by past practices.

III–2. The radioactive waste that is generated is as varied in form, activity concentration and type of contamination as it is in type of generating activity. It may be solid, liquid or gaseous. Levels of activity concentration range from extremely high levels associated with spent fuel and residues from fuel reprocessing to very low levels associated with radioisotope applications in laboratories, hospitals, etc. Equally broad is the spectrum of half-lives of the radionuclides contained in the radioactive waste.

III–3. This annex briefly and qualitatively describes the major waste generating activities and the types of radioactive waste generated by each. The descriptions and the numerical values given are based on Ref. [III–1]. This annex also illustrates the application of the classification scheme developed in this Safety Guide to some of the types of radioactive waste described.

WASTE FROM MINING AND MINERALS PROCESSING THAT CONTAINS ELEVATED LEVELS OF NATURALLY OCCURRING RADIONUCLIDES

III–4. 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, such as radium, may also be separated from the ores for a variety of applications. Mining activities lead to the extraction of ore that is sufficiently rich to justify processing, and also of relatively large amounts of materials that contain uranium or thorium in such small quantities that further processing is not economically justified. The mined materials not subjected to further processing constitute the mine tailings generally accumulated as waste piles, usually in proximity to the mines. Mine tailings resulting from the mining of uranium and thorium ores generally contain elevated levels of naturally occurring radionuclides and are required to be managed as radioactive waste for radiation protection purposes and safety reasons.

III–5. The richer ores from which uranium or thorium are to be separated are sent to mills for processing, which generally entails crushing and chemical processing. After removal of the uranium, the residues (the mill 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 daughter products may be more susceptible to leaching and emanation from the tailings than from the original ore. In addition, tailings from processing 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.

III–6. 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 2 of this Safety Guide. 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 TENORM) and that 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.

III–7. The classification scheme described in Section 2 of this Safety Guide 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 levels of activity concentrations. These may necessitate the management of waste such as LLW or, in some cases, ILW. Volumes of such waste, however, are generally very limited.

WASTE FROM NUCLEAR POWER PRODUCTION

III–8. Nuclear power production gives rise to the generation of several kinds of radioactive waste, including spent fuel (if it is declared waste), other high level waste (HLW) that is generated mainly from the chemical reprocessing of spent fuel, and very low level waste (VLLW), low level waste (LLW) and intermediate level waste (ILW) that is generated as a result of reactor operations, reprocessing, decontamination, decommissioning and other activities in the nuclear fuel cycle.

High level waste (HLW)

III–9. Spent nuclear fuel contains significant amounts of fissile materials, other actinides and fission products. It generates significant heat when freshly removed from the reactor, and is usually placed in storage pools, generally located within the reactor building. Eventually the spent fuel will be removed and subjected to a management option chosen from among a few possibilities:

- Reprocessing: In this case the fuel is dissolved and treated to separate the remaining fissile components from the fission products and activation products. Reprocessing operations generate solid, liquid and gaseous radioactive waste streams. Solid waste such as fuel element cladding hulls, hardware and other insoluble residues is generated during fuel dissolution. This waste may contain activation products, as well as some undissolved fission products, uranium and plutonium. The principal liquid waste stream is the nitric acid solution, which contains both high levels of activity concentration of fission products and actinides in high concentrations. The principal gaseous waste stream is the off-gas, which contains rare gases and volatile fission products that are released from the spent fuel during the dissolution process. After solidification, HLW arising from reprocessing of spent fuel requires disposal in geological disposal facilities providing sufficient isolation and containment over long time periods.
- Disposal: A number of States have decided that spent fuel should not be reprocessed and consider it to be waste, therefore requiring disposal. The disposal option generally under consideration is emplacement in geological disposal facilities.
- Long term storage: If reprocessing is not carried out, and as long as geological disposal facilities are not operational, storage of spent fuel is obviously unavoidable. Most States that do not reprocess spent fuel are making plans for its extended storage. Long term storage may take place at reactor sites or in storage facilities remote from the reactor.

III–10. Liquid HLW is generally stored in tanks prior to its eventual solidification (vitrification is the approach currently used). While there is general agreement that liquid HLW needs to be transformed into a solid, there are a number of sites where liquid HLW has been stored in tanks for time periods now extending to several decades. Most liquid HLW subjected to such long term storage has been generated by activities in defence programmes (see para. III–21).

Low level waste and intermediate level waste from operations

III–11. The manufacture of reactor fuel generates waste from purification, conversion and enrichment of uranium and the fabrication of fuel elements. This waste includes contaminated filter materials from off-gas systems, lightly contaminated trash, and residues from recycling or recovery operations. This waste generally contains uranium and, in the case of waste from the manufacture of mixed oxide fuel, also plutonium.

III–12. In the operation of nuclear power plants, waste arises from the processing of cooling water and storage pond water, from equipment decontamination and from routine facility maintenance. Waste from the operation of nuclear power plants is normally contaminated with fission products and activation products. Waste generated from routine operations includes contaminated clothing, floor sweepings, paper and plastic. Waste from processing of primary coolant water and the off-gas system includes spent resins and filters as well as some contaminated equipment. Waste may also be generated from the replacement of activated core components such as control rods or neutron sources.

Waste from decommissioning of nuclear installations

III–14. 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 activities involved in decontamination and dismantling of a nuclear facility and the cleanup of the site will lead to the generation of radioactive waste that may vary greatly in type, level of activity concentration, size and volume, and may be activated or contaminated. 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 INSTITUTIONAL ACTIVITIES

III–15. Institutional uses of radioactive materials include activities in the fields of research, industry and medicine. Such activities, particularly in the field of research, are very varied and result in the generation of waste of different classes. As in the nuclear sector, institutional waste can be generated in gaseous, liquid or solid form. Most institutional waste is in solid form and is generally handled in a comparable way to waste generated within the nuclear fuel cycle.

Waste from research reactors

III–16. The waste generated by research reactors and from some disused radioactive sources is particularly significant because, owing to its level of activity concentration and to the half-lives of the radionuclides, it does not meet the waste acceptance criteria of near surface disposal facilities.

Waste from research facilities

III–17. Research facilities (e.g. hot cell chains, glovebox chains) or pilot plants for checking fuel fabrication processes (particularly the fabrication of mixed uranium plutonium oxides, known as MOX), for fuel reprocessing (particularly advanced schemes), and for post-irradiation examinations, as well as their analytical laboratories, generate types of waste that, often, are different from the typical waste generated by industrial plants. Owing to the presence of non-negligible amounts of long lived alpha emitters, waste from research facilities generally belongs to the ILW class and even, in some circumstances, to the HLW class. Research activities take place at facilities such as research reactors and accelerators, and include laboratory activities. The type and volume of waste generated by research activities is dependent on the research conducted.

Waste from the production and use of radioisotopes

III–18. The production and use of radioisotopes generate smaller quantities of waste than fuel cycle activities:

- 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 activities is small but the levels of activity concentration may be significant.

— 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 other nuclear facilities

III–19. Nuclear facilities within the institutional sector will also require decommissioning. The waste generated will be similar to that arising from the decommissioning of nuclear installations (in particular in the case of decommissioning of research reactors); however, the volumes of waste generated will be substantially smaller.

Disused sealed sources

III–20. A particular type of waste is disused sealed radioactive sources. Sealed sources are characterized 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 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 radionuclide is 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.

III–21. Sources may be described according to the activity and half-life of the radionuclide they contain. Sources containing radionuclides with half-lives of less than 100 days (e.g. ^{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 III–1 (from Ref. [III–2]).

WASTE FROM DEFENCE PROGRAMMES AND WEAPONS PRODUCTION RELATED WASTE

III–22. Large quantities of waste from defence programmes and waste relating to the production of nuclear weapons were generated in the early days of the development and testing of nuclear weapons. The most mobile HLW in this context is that in storage while awaiting solidification. Decommissioning of nuclear weapons typically involves blending the highly enriched uranium and/or plutonium with natural uranium to produce UO_2 and/or mixed uranium–plutonium fuel for commercial power reactors or storing this material for future disposal in geological disposal facilities with HLW or spent fuel.

RADIOACTIVE MATERIAL IN THE ENVIRONMENT

III–23. Radioactive residues have been deposited on the Earth's surface as a result of a variety of activities. These include residues from nuclear weapon testing, accidents at nuclear facilities and past practices such as uranium mining that 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 be either stabilized in situ or disposed of in appropriate disposal facilities [III–3].

EXAMPLE OF THE USE OF THE WASTE CLASSIFICATION SCHEME

III–24. An example of the use of the classification scheme described in this Safety Guide to waste not deriving from nuclear activities is given in Fig. III–1. It shows the waste classes into which different types of sealed sources as defined in Table III–1 and waste containing naturally occurring radionuclides typically will fall. Waste containing naturally occurring radionuclides can vary considerably in its characteristics and could hence fall into a number of classes for disposal. As indicated, some waste could have very low levels of activity concentration 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, where specific radionuclides may have been concentrated, may require disposal at greater depth than is 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.

TABLE III–1. DISUSED SEALED RADIOACTIVE SOURCES

Example in Fig. III–1	Half-life	Activity	Volume	Example
i	<100 d	100 MBq	Small	Y-90, Au-198 (brachytherapy)
ii	<100 d	5 TBq	Small	Ir-192 (brachytherapy)
iii	<15 a	<10 MBq	Small	Co-60, H-3 (tritium targets), Kr-85
iv	<15 a	<100 TBq	Small	Co-60 (irradiators)
v	<30 a	<1 MBq	Small	Cs-137 (brachytherapy, moisture density detectors)
vi	<30 a	<1 PBq	Small	Cs-137 (irradiators) Sr-90 (thickness gauges, radioisotope thermoelectric generators (RTGs))
vii	>30 a	<40 MBq	Small, but may be large numbers of sources (up to tens of thousands)	Pu, Am, Ra (static eliminators)
viii	>30 a	<10 GBq		Am-241, Ra-226 (gauges)

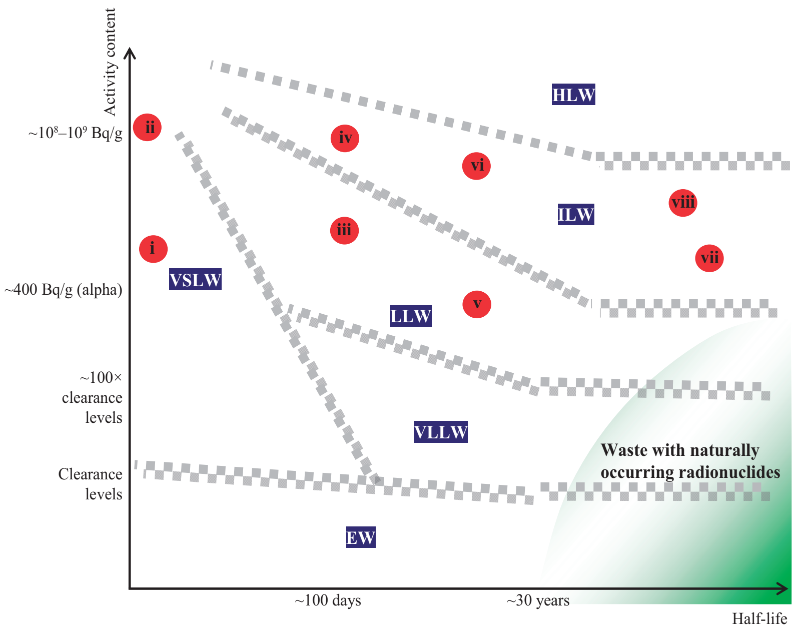

FIG. III–1. Illustrative example of the application of the waste classification scheme. The numbers refer to examples of disused sealed sources set out in Table III–1 (see para. 2.2, para. 2.27 and Fig. 1).

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