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Predisposal Management of Radioactive Waste from Nuclear Reactors

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PREDISPOSAL MANAGEMENT OF

RADIOACTIVE WASTE FROM NUCLEAR REACTORS

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1 The production of electricity in nuclear power plants and the use of nuclear research reactors (including subcritical or critical assemblies) generate radioactive waste. Such radioactive waste arising from nuclear power plants and from research reactors is diverse and variable in nature and encompasses a broad range of radionuclides and levels of activity content. Typical waste from reactors includes, but is not limited to: spent ion exchange resins, filters, activated metals, liquid and gaseous effluents, irradiated experimental components, and spent fuel declared as waste. Because of the variability and diversity in the waste streams from these facilities, particular and constant attention has to be given to all steps of the management of the waste.

1.2 The importance of the safe management of radioactive waste for the protection of human health and the environment has long been recognized. The principles and requirements that govern the safety of the management of radioactive waste are presented in the Fundamental Safety Principles SF-1 [1], and in the following IAEA Safety Requirements publications: Governmental, Legal and Regulatory Framework for Safety (GSR Part 1) [2], Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (GSR Part 3) [3] and Predisposal Management of Radioactive Waste (GSR Part 5) [4].

1.3 GSR Part 5 [4] establishes requirements for the safe management of radioactive waste prior to its disposal. These requirements are derived from the safety principles established in the Safety Fundamentals publication SF-1 [1] and include requirements for the protection of human health and the environment and associated responsibilities. Recommendations on the fulfilment of these requirements are provided in this Safety Guide and several associated Safety Guides.

1.4 Predisposal management of radioactive waste, as the term is used in GSR Part 5 [4], encompasses all steps from waste generation up to (but not including) disposal, including processing (pretreatment, treatment and conditioning), storage and transport.

1.5 The generation of radioactive waste cannot be prevented entirely but is required to be kept to the minimum practicable ('waste minimization') as an essential objective of radioactive waste management. Waste minimization relates to type, volume and activity. Measures to prevent or minimize the generation of radioactive waste have to be put in place beginning during the design of facilities and the planning of activities that have the potential to generate radioactive waste. This step recognizes that the management of the activities that generate radioactive waste is the key to avoiding or minimizing quantities produced.

1.6 Pretreatment may include waste collection, segregation, chemical adjustment and decontamination. Treatment may include volume reduction, radionuclide removal and change of composition. Conditioning involves those operations that transform radioactive waste into a form suitable for subsequent activities such as handling, transport, storage and disposal; this may include immobilization of the waste, placing of the waste into containers and provision of additional packaging. Storage refers to the temporary placement of radioactive waste in a facility where appropriate isolation and monitoring are provided; it is an interim activity with the intent that the waste can be retrieved at a later date for clearance, processing and/or disposal at a later time, or, in the case of effluent, for authorized discharge.

1.7 In cases where no disposal facility is available for the waste, or the waste were to be stored over long periods of time, assumptions will have to be made regarding anticipated acceptance criteria or other anticipated future steps in order to provide guidance for its management.

1.8 In addition to its radiological hazard, the waste may present non-radiological hazards owing to its physical or chemical characteristics, as well as conventional health and safety issues, and these should also be taken into account.

OBJECTIVE

1.9 The objective of this Safety Guide is to provide operators[1] that generate and manage radioactive waste as well as regulatory bodies with recommendations on how to meet the requirements for the predisposal management of radioactive waste arising from nuclear power plants and research reactors (including subcritical or critical assemblies).

1.10 This Safety Guide supersedes those parts of the following IAEA Safety Standards that are concerned with the management of radioactive waste from reactors: WS-G-2.5 on predisposal management of low- and intermediate-level radioactive waste, WS-G-2.6 on predisposal management of high-level radioactive waste, NS-G-2.7 on Radiation Protection and Radioactive Waste Management in the Operation of Nuclear Power Plants, NS-G-1.13 on Radiation Protection Aspects of Design for Nuclear power Plants, and NS-G-4.6 on Radiation Protection and Radioactive Waste Management in the Design and Operation of Research Reactors.

1.11 This Safety Guide presents recommendations and guidance on how to meet the requirements established in the following IAEA Safety Requirements publications: Governmental, Legal and Regulatory Framework for Safety [2], International Basic Safety Standards [3], Predisposal

[1] The operator is the generators of radioactive waste, including organizations carrying out decommissioning activities, and operators of facilities for the predisposal management of radioactive waste[4].

Management of Radioactive Waste [4], Safety Assessment for Facilities and Activities [5] and The Management System for Facilities and Activities [6].

SCOPE

1.12 This Safety Guide applies to the predisposal management of radioactive waste of all types arising from nuclear power plants and research reactors (including subcritical and critical assemblies) during their commissioning, operation and decommissioning. It covers all the steps carried out in the management of radioactive waste following its generation up to (but not including) disposal, including its processing (pretreatment, treatment and conditioning), storage and transport.

1.13 While it is recognized that the recommendations in this publication are applicable to the generation of radioactive waste at nuclear reactors, operational activities at nuclear reactors are outside the scope of this Safety Guide.

1.14 This Safety Guide is not specifically intended to cover the storage of spent nuclear fuel as long as it remains a part of the operational activities of a nuclear power plant or research reactor. Storage of spent nuclear fuel in facilities that are collocated with a nuclear power plant or research reactor is addressed in Safety Guide SSG-15, Storage of Spent Nuclear Fuel [7].

1.15 Storage and transport of radioactive waste are not dealt with in detail in this Safety Guide. Recommendations on storage of radioactive waste are provided in Safety Guide WS-G-6.1 [8]. Transport of radioactive waste is subject to the requirements of SSR-6 [9].

1.16 Although this publication does not specifically address non-radiological hazards or conventional industrial health and safety issues, these issues also have to be considered by national authorities, both in their own right and in as much as they may affect radiological consequences.

1.17 The Safety Guide does not provide recommendations on the nuclear security of nuclear material, nuclear facilities or radioactive material. Recommendations and guidance on nuclear security at nuclear facilities and for radioactive material are provided in Nuclear Security Series No. 13 [10], No. 14 [11] and other publications in the IAEA Nuclear Security Series.

STRUCTURE

1.18 to be added later

2. PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

RADIOACTIVE WASTE MANAGEMENT

2.1 The safety objective and the fundamental safety principles established in [1] apply to all facilities and activities in which radioactive waste is generated, processed or stored for the entire lifetime of facilities, including planning, siting, design,, construction, commissioning, operation, shutdown and decommissioning, and the associated transport of radioactive waste.

2.2 The Safety Requirements, GS-R-3, The Management System for Facilities and Activities [6], requires both the regulatory body and the operator to establish a management system that integrates all elements of management, including safety, health, environmental, nuclear security, quality and economic requirements so that safety is not compromised. A key component of such a system in an organization is a robust safety culture.

2.3 In controlling the radiological and non-radiological hazards associated with radioactive waste, the following aspects are also required to be considered: conventional health and safety issues, radiation risks that may transcend national borders, and the potential impacts and burdens on future generations arising from long periods of storage of radioactive waste [1].

RADIATION PROTECTION

2.4 The BSS [3] states that the three general principles of radiation protection, which concern justification, optimization of protection and application of dose limits, are expressed in Safety Principles 4, 5, 6 and 10 stated in [1].

2.5 Requirements for radiation protection have to be established at the national level, with due regard to the BSS [3]. In particular, the BSS require radiation protection to be optimized for any persons who are exposed as a result of activities, with due regard to dose constraints, and require the exposures of individuals to be kept within specified dose limits.

2.6 National regulations will prescribe dose limits for the exposure of workers and members of the public under normal conditions. Internationally accepted values for these limits are contained in Schedule III of the BSS [3]. In addition to the provision for protection against the exposures that will arise from normal operations referred to in the preceding paragraphs, provision has to be made for protection against potential exposure from operations outside normal conditions, e.g. anticipated operational occurrences, incidents, or accidents. Requirements for protection against potential exposure are also established in the BSS [3]. They include management and technical requirements to prevent the occurrence of incidents or accidents and provisions for mitigating their consequences if they do occur.

2.7 When choosing options for the predisposal management of radioactive waste, consideration has to be given to both the short term and the long term radiological impacts on workers and members of the public (SF-1, ICRP 77, ICRP 81) [1, 12, 13].

2.8 Doses and risks associated with the transport of radioactive waste have to be managed in the same way as those associated with the transport of any radioactive material. Safety in the transport of radioactive waste is ensured by complying with the requirements in [9].

PROTECTION OF THE ENVIRONMENT

2.9 Requirements for protection of the environment have to be established by the relevant national regulatory bodies, with all potential environmental impacts that could reasonably be expected being taken into consideration [1, 3].

2.10 To achieve the fundamental safety objective of protecting people and the environment from harmful effects of ionizing radiation, measures have to be taken:

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

(b) To restrict the likelihood of events that might lead to a loss of control over source[s] of radiation; [and]

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

2.11 The operator has a duty in the area of radioactive waste management to take measures to avoid or to optimize the generation and management of radioactive waste, including consideration of requirements related to disposal, with the aim of minimizing the overall environmental impact. This includes ensuring that gaseous and liquid radioactive releases to the environment are in compliance with authorized limits, and to reduce doses to the public and effects on the environment to levels that are as low as reasonably achievable (optimization of protection).

2.12 Clearance (the removal of radioactive materials within authorized practices from any further regulatory control) and the control of discharges (on-going or anticipated releases to the environment within limits authorized by the regulatory body of liquid or gaseous radioactive material that originate from regulated nuclear facilities during normal operation) are addressed in IAEA Safety Standards Series Nos. RS-G-1.7, WS-G-2.3 and NS-G-3.2 [14, 15, 16] respectively.

3. ROLES AND RESPONSIBILITIES

LEGAL AND ORGANIZATIONAL FRAMEWORK

Requirement 1 (GSR Part 5, Ref. [4]): Legal and regulatory framework

The government shall provide for an appropriate national legal and regulatory framework within which radioactive waste management activities can be planned and safely carried out. This shall include the clear and unequivocal allocation of responsibilities, the securing of financial and other resources, and the provision of independent regulatory functions. Protection shall also be provided beyond national borders as appropriate and necessary for neighbouring States that may be affected.

Requirement 2 (GSR Part 5, Ref. [4]): National policy and strategy on radioactive waste management

To ensure the effective management and control of radioactive waste, the government shall ensure that a national policy and a strategy for radioactive waste management are established. The policy and strategy shall be appropriate for the nature and the amount of the radioactive waste in the State, shall indicate the regulatory control required, and shall consider relevant societal factors. The policy and strategy shall be compatible with the fundamental safety principles and with international instruments, conventions and codes that have been ratified by the State. The national policy and strategy shall form the basis for decision making with respect to the management of radioactive waste.

3.1 The government is responsible for establishing a national policy and corresponding strategies for the management of radioactive waste [1, 2]. The policy and strategy, as well as the legal framework, should cover all types and volumes of radioactive waste, generated in the State, all waste processing and storage facilities located in the State, and waste imported or exported from it, with due account taken of the interdependences between the various steps of radioactive waste management, the time periods involved and the options available.

3.2 The management of radioactive waste should be undertaken within an appropriate national legal and regulatory framework that provides for a clear allocation of responsibilities, and that ensures the effective regulatory control of the facilities and activities concerned [1, 2]. The legal framework should also establish measures to ensure compliance with other relevant international legal instruments, such as the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [17], and the Convention on Nuclear Safety [18].

3.3 Where nuclear, environmental, industrial safety and occupational health aspects are separately regulated the regulatory framework should recognize that the overall safety is affected by the interdependences between radiological, industrial, chemical and toxic hazards and ensure that the regulatory framework identifies this and delivers effective control.

3.4 The legal framework should ensure that the construction of installations adjacent to an existing facility that could prejudice the safety of the facility are monitored and controlled by means of planning requirements or other legal instruments.

3.5 The management of radioactive waste may involve the transfer of radioactive waste from one operating organization to another organization or from one governmental region to another, or may even be processed in another State. Such transfers create interdependences in responsibilities as well as physical interdependences in the various steps in the management of radioactive waste. The legal framework should include provisions to ensure a clear allocation of responsibility for safety throughout the entire process, in particular with respect to interface with the storage of radioactive waste and its transfer between operating organizations.

3.6 The government is responsible for establishing a regulatory body independent from the owners of the radioactive waste or the operating organizations managing the radioactive waste, with adequate authority, power, staffing and financial resources to discharge its assigned responsibilities [2].

3.7 Responsibility for safety should be ensured by means of a system of authorization by the regulatory body. For transboundary transfers of radioactive waste between States, authorizations from the relevant national regulatory bodies are required [2].

3.8 The national and regulatory framework should incorporate clear definitions of the content and responsibilities for the management of the interdependences between the various steps in the predisposal management of radioactive waste.

3.9 A mechanism for providing adequate financial resources should be established to cover future costs, in particular, the costs associated with the storage of radioactive waste, decommissioning of the reactor facilities, waste management facilities and storage facilities, and also the costs of long-term management of radioactive waste, if applicable. The financial mechanism should be established before licensing and eventual operation, and should be updated as necessary. Consideration should also be given to provision of the necessary financial resources in the event of a premature shutdown of the waste management facility or an early dispatch of the waste to a disposal facility.

3.10 In order to facilitate the establishment of a national policy and strategy, the Government should establish a national inventory of the radioactive waste (current and anticipated, including waste generated during decommissioning and dismantling of facilities) and update it at regular time intervals. This inventory should take into account the Safety Guide on classification of radioactive waste [19].

3.11 There should be sufficient capacity to process all waste generated and the storage capacity should be sufficient to account for uncertainties in the availability of facilities for treatment, conditioning and disposal.

3.12 The government should consult interested parties on matters relating to the development of national policies and strategies that affect the management of radioactive waste, and should take due account of the concerns of the public.

3.13 The national policy and strategy should address the various waste classes as identified in Ref [19] or in the national waste classification scheme, taking into account the existing or likely disposal options; and their long-term management, both from a technical point of view as well as from a human and financial resources point of view.

RESPONSIBILITIES OF THE REGULATORY BODY

Requirement 3 (GSR Part 5, Ref. [4]): Responsibilities of the regulatory body

The regulatory body shall establish the requirements for the development of radioactive waste management facilities and activities and shall set out procedures for meeting the requirements for the various stages of the licensing process. The regulatory body shall review and assess the safety case [2] and the environmental impact assessment for radioactive waste management facilities and activities, as prepared by the operator both prior to authorization and periodically during operation. The regulatory body shall provide for the issuing, amending, suspension or revoking of licenses, subject to any necessary conditions. The regulatory body shall carry out activities to verify that the operator meets these conditions. Enforcement actions shall be taken as necessary by the regulatory body in the event of deviations from, or noncompliance with, requirements and conditions.

3.14 Regulatory responsibilities may include contributing to the technical input for the establishment of policies, safety principles and associated criteria, and for establishing regulations or conditions to serve as the basis for regulatory decisions. The regulatory body should also provide guidance to operating organizations on how to meet requirements relating to the safe management of radioactive waste.

3.15 The regulatory review of the safety case and initial decommissioning plans for radioactive waste management facilities should follow a graded approach, particularly considering the phases in the lifetime of the radioactive waste management facility or activities. At each phase in the lifetime of these facilities or activities, the safety case and initial decommissioning plan should be updated and reviewed by the regulatory body.

3.16 General recommendations for regulatory inspection and enforcement actions relating to radioactive waste management facilities are provided in Safety Guide GS-G-1.3, Regulatory Inspection of Nuclear Facilities and Enforcement by the Regulatory Body [20]. The regulatory body should periodically verify that the key aspects of the operation of the radioactive waste management facility

[2] The safety case is a collection of arguments and evidence in support of the safety of a facility or activity. This collection of arguments and evidence may be known by different names (such as safety report, safety dossier, safety file) in different States and may be presented in a single document or a series of documents (see Section 5).

meet the requirements of the national legal system and facility licence conditions, such as those relating to the keeping of records on inventories and material transfers, compliance with requirements for processing, storage, maintenance, inspection, testing and surveillance, operational limits and conditions, emergency preparedness and response. Such verification may be carried out, for example, by routine inspections of the radioactive waste management installations and audits of the operating organization. The regulatory body should verify that the necessary records are prepared and that they are maintained for an appropriate period of time. A suggested list of records is included in Safety Guide GS-G-1.4, Documentation for Use in Regulating Nuclear Facilities [21].

3.17 The regulatory body should follow a graded approach in informing interested parties about the safety aspects (including health and environmental aspects) of the radioactive waste management facility and about regulatory processes and should consult these parties, as appropriate, in an open and inclusive manner. The need for confidentiality, e.g. for nuclear security reasons, should be respected.

3.18 The regulatory body should consider the licensing strategy to be adopted, for example:

(a) A licence issued for the entire lifetime of the generation, processing and/or storage system and/or installation, which encompasses the entire anticipated operating period, including periodic review of safety assessments; or

(b) A licence issued for a specified time period with the possibility for its renewal after expiration.

(c) Possible long-term storage of radioactive waste after the reactor has been decommissioned.

3.19 If the regulatory body consists of more than one authority, effective arrangements should be made to ensure that regulatory responsibilities and functions are clearly defined and coordinated, in order to avoid any omissions or unnecessary duplication and to prevent conflicting requirements being placed on the operating organization. The regulatory functions of authorization, review and assessment, inspection, enforcement and development of regulations and guides should be organized in such a way as to achieve consistency and to enable the necessary feedback and exchange of information.

3.20 The regulatory review of the initial decommissioning plan for radioactive waste management facilities should follow a graded approach, particularly considering the phases in the lifetime of these facilities. The initial decommissioning plan should be conceptual and should be reviewed by the regulatory body for its overall completeness rather than for specific decommissioning arrangements, but should include specifically how financial and human resources and the identification and availability of the necessary information, including records from the design, construction and operational phases will be ensured for when the decommissioning takes place. At each phase in the lifetime of facilities or activities, the initial decommissioning plan should be updated regularly by the licensee and updates should be reviewed by the regulatory body. If a facility is shut down and no longer to be used for its intended purpose, a final decommissioning plan should be submitted to the regulatory body for review and approval (where appropriate within the legal framework) [22].

RESPONSIBILITIES OF THE OPERATING ORGANIZATION

Requirement 4 (GSR Part 5, Ref. [4]): Responsibilities of the operator
Operators shall be responsible for the safety of predisposal radioactive waste management facilities or activities. The operator shall carry out safety assessments and shall develop a safety case, and shall ensure that the necessary activities for siting, design, construction, commissioning, operation, shutdown and decommissioning are carried out in compliance with legal and regulatory requirements.

3.21 National policies and strategies and international cooperation in relation to safety of radioactive waste management can evolve over the lifetime of the facility. Policy decisions and technological innovations and advances can lead to fundamental changes in the overall radioactive waste management strategy. However, the operating organization retains its responsibility for the safety of facility and activities, and a continuous commitment by the organization remains a prerequisite to ensuring safety and the protection of human health and the environment.

3.22 The operating organization is responsible for the safety of all activities associated with the management of radioactive waste (including activities undertaken by contractors) in compliance with the principles contained in [1], and for the identification and implementation of the programmes and procedures necessary to ensure safety. The operating organization should demonstrate safety and maintain a robust safety culture. The operating organization should take measures to review and assess the safety culture periodically, and adopt and implement the necessary principles and processes in order to strengthen the safety culture.

3.23 In some instances, the operating organization may be the owner of the radioactive waste and in other cases the owner may be a separate organization or operating unit. In the latter case, the interface between responsibilities of the owner and the operating organization should be clearly defined, agreed and documented. Information about changes in ownership of the radioactive waste or changes in the relationship between the owner and the waste management organization should be provided to the regulatory body. For example, NPP operators or their surrogates who do not have complete responsibility for all aspects of predisposal management should coordinate and harmonize with the regulatory authority and commercial entities (where necessary) to ensure that the disposition of radioactive waste generated at their facility is appropriately planned and safely managed.

3.24 The responsibilities of the operating organization of a radioactive waste management facility typically include:

(a) Application to the regulatory body for permission to site, design, construct, commission, operate, modify or decommission a radioactive waste management facility;

(b) Conducting appropriate safety and environmental assessments in support of the application for a license and conducting periodic safety reviews;

(c) Operation of the radioactive waste management facility in accordance with the requirements of the safety case, the license conditions and the applicable regulations;

(d) Taking into consideration possible long-term storage of radioactive waste after the reactor has been decommissioned.

(e) Development and application of procedures for the receipt, storage and processing of radioactive waste

(f) Development and application of acceptance criteria as approved by the regulatory body;

(g) Ensuring that the waste acceptance criteria at a particular step acknowledges the information required to meet the downstream waste acceptance criteria;

(h) Management of the information required either to support the onward disposition/storage of any radioactive waste or to support the decommissioning of that facility, especially where the latter may be many decades after operations have ceased;

(i) Providing periodic reports as required by the regulatory body (e.g. information on the actual inventory of radioactive waste, any transfers of radioactive waste into and out of the facility, including material cleared from regulatory control, and any events that occur at the facility and which have to be reported to the regulatory body) and communicating with relevant interested parties;

(j) Derivation and implementation of limits, conditions and controls;

(k) Ensuring operations are conducted in compliance with the criteria for the effluent discharges from a radioactive waste management facility as approved or authorized by the regulatory body;

(l) Taking into consideration measures that will control the generation of radioactive waste, in terms of volume and radioactivity content, to the minimum practicable;

(m) Ensuring that radioactive waste generated is appropriately processed to comply with the acceptance criteria for storage and disposal as well as the transport requirements. If acceptance criteria for disposal are not yet available, ensuring that the management of radioactive waste is based on specific assumptions for the anticipated disposal option.

(n) Taking into consideration the decisions that would have to be made:

(1) in the management of waste if no disposal option is available,

(2) for waste that would need to be stored over long periods of time prior to disposal, or

(3) in case of decay storage (e.g., of activated large components) with the purpose of subsequent clearance.

3.25 In the case where waste is generated at the facility, the operating organization should develop a facility specific waste management programme that:

(a) implements the national waste management policy and strategy, as far as applicable;

(b) recognizes the connections between the sources of radioactive waste and the eventual discharge, disposal or onward disposition from that facility;

(c) recognizes the hierarchy of the following strategic options, which are applicable to predisposal management of radioactive waste:

(1) Keeping the generation of radioactive waste to the minimum practicable, in terms of type, activity and volume, by using suitable technologies;

(2) Possible reuse and recycling of materials; and

(3) Treating, retreating and conditioning radioactive waste to ensure safe storage and disposal.

More detailed guidance on facility-specific waste management programmes are provided in Appendix 1.

3.26 Prior to authorization of a radioactive waste management facility, the operating organization should provide the regulatory body with a safety case and supporting safety assessment that demonstrates the safety of the proposed activities and demonstrates that the proposed activities will be in compliance with the safety requirements and criteria set out in national laws and regulations. The operating organization should use the safety assessment to establish specific operational limits, conditions and operational controls. The operating organization may wish to set an operational target level below these specified limits to assist in avoiding any breach of approved limits and conditions.

3.27 At an early stage in the lifetime of a radioactive waste management facility, the operating organization should prepare preliminary plans for its eventual decommissioning, considering possible long term storage of radioactive waste after the reactor has been shut down. For new facilities, features that will facilitate decommissioning should be taken into consideration at the design stage; such features should be included in the decommissioning plan together with information on arrangements for how the availability of the necessary human and financial resources and information will be assured, for presentation in the safety case.

3.28 For existing facilities without a decommissioning plan, such a plan should be prepared as soon as possible. Requirements on decommissioning are established in the Safety Requirements, WS-R-5, Decommissioning of Facilities Using Radioactive Material [22], and recommendations are provided in Safety Guide WS-G-2.1, Decommissioning of Nuclear Power Plants and Research Reactors [23].

3.29 The operating organization should establish the requirements for training and qualification of its staff and contractors, including for initial and periodic refresher training. The operating organization should ensure that all staff members concerned understand the safety case, the nature of the radioactive waste, its potential hazards and the relevant operating and safety procedures to the extent required by their responsibilities. Supervisory staff should be competent to perform their activities and should therefore be selected, trained, qualified and authorized for that purpose. A radiation protection officer should be appointed to oversee the application of radiation protection requirements.

3.30 The operating organization should carry out pre-operational tests and commissioning tests to demonstrate compliance of the radioactive waste management facility and its activities with the requirements of the safety case and supporting safety assessment and with the safety requirements established by the regulatory body.

3.31 The operating organization should ensure that discharges of radioactive and other potentially hazardous materials to the environment are in accordance with the conditions of license or authorization, and limit on-site contamination and occupational exposure, with account taken of the results of optimization for protection and safety (e.g., considering limits for on-site contamination and occupational exposure).

3.32 Discharges, clearance of materials from regulatory control, reuse or recycling of materials, as well as delivery of radioactive waste to an authorized disposal facility or other transfers to other facilities should be documented. Such documents should be retained until the facility has been fully decommissioned, or alternatively by agreement with the regulatory body.

3.33 The operating organization should prepare plans and implement programmes for personnel monitoring, area monitoring, and environmental monitoring.

3.34 The operating organization should establish a process for authorization of modifications that includes evaluation of modifications to the radioactive waste management facility and activities, operational limits and conditions, or the radioactive waste to be processed or stored, using a graded approach that is commensurate with the safety significance of the modifications. The process of evaluating the potential consequences of such modifications should also consider potential consequences for the safety of other facilities and for the subsequent storage, reprocessing or disposal of radioactive waste.

3.35 The operating organization is required to put in place appropriate mechanisms for ensuring that sufficient financial resources are available to undertake all necessary tasks throughout the lifetime of the facility, including its decommissioning [2], and the possible long term storage of radioactive waste at the site after the reactor has been shut down.

3.36 The operating organization should develop and maintain a records system on the generation, processing and storage of radioactive waste, which should include the radioactive inventory, location and characteristics of the radioactive waste, and information on ownership and origin (Safety Guide GS-G-3.3, The Management System for the Processing, Handling and Storage of Radioactive Waste) [24]. Such records should be preserved and updated, to enable the implementation of the facility specific radioactive waste management plan. Such a records system should be managed as required by the national authority.

3.37 The operating organization should draw up emergency plans on the basis of the potential radiological impacts of accidents (GSR-2) [25] and should be prepared to respond to accidents at all times as indicated in the emergency plans.

4. INTEGRATED APPROACH TO SAFETY

SAFETY AND SECURITY

Requirement 5 (GSR Part 5, Ref. [4]): Requirements in respect of security measures

Measures shall be implemented to ensure an integrated approach to safety and security in the predisposal management of radioactive waste.

4.1 For a new facility, the site selection and design should take nuclear security into account as early as possible and also address the interface between nuclear security, safety and nuclear material accountancy and control to avoid any conflicts and to ensure that all three elements support each other.

4.2 The operator should assess and manage the interfaces between nuclear security, safety and nuclear material accountancy and control activities in a manner to ensure that they do not adversely affect each other and that, to the degree possible, they are mutually supportive.

4.3 When material is required to be accessed for waste management or safeguard purposes this should take account of requirements for radiation protection, and waste management as well as nuclear security considerations.

4.4 Specific recommendations on nuclear security in the management of radioactive waste are dealt with in the publications of the IAEA Nuclear Security Series [26, 27].

INTERDEPENDENCES

Requirement 6 (GSR Part 5, Ref. [4]): Interdependences

Interdependences among all steps in the predisposal management of radioactive waste, as well as the impact of the anticipated disposal option, shall be appropriately taken into account.

4.5 Interdependences exist among all steps in the management of radioactive waste, from the generation of the waste up to its disposal, or as far as practicable, authorized discharge or clearance from regulatory control. In selecting strategies and activities for the predisposal management of radioactive waste, planning should be carried out for all the various steps so that a balanced approach to safety is taken in the overall management programme and conflicts between the safety requirements and operational requirements are avoided. There are various alternatives for each step in the management of radioactive waste. For example, treatment and conditioning options are influenced by the established or anticipated acceptance requirements for disposal.

4.6 The following aspects in particular should be considered:

(a) The identification of interfaces and the definition of the responsibilities of the various organizations involved at these interfaces;

(b) The establishment of acceptance criteria, where necessary, and the confirmation of conformance with the acceptance criteria by means of verification tests or the examination of records.

4.7 Given that disposal is the final step in the management of radioactive waste that cannot be otherwise cleared, discharged or reused, the selected or anticipated disposal option also needs to be taken into account when any other upstream radioactive waste management activity is being considered. However, in many Member States disposal facilities are not yet available in general or only for specific types of waste. In this case, proper determination and documentation of the characteristics of waste form and waste package should be ensured. Independent of this, all radioactive waste arisings are required to be managed, requiring decisions on waste forms to be produced which, in this situation, have to be made before all radioactive waste management activities are finally established.

4.8 If no disposal facility is available for the waste, specific assumptions should be made on the requirements for the acceptance of the waste for disposal in order to provide guidance for its management. These assumptions should be justified and agreed upon by the waste generator, the operator of the waste management facility and the regulator.

4.9 Site and facility waste management programmes should identify all relevant interdependences and include arrangements to ensure that they are appropriately considered from the point of generation to the point of disposal. For example, the waste acceptance criteria for disposal should be known and appropriately considered when the waste is generated, recognizing that at the point of generation the controls and information associated with the waste will be aligned with the next stage of waste management and that of the disposal facility. Thus, the waste acceptance criteria for each step should be aligned with the waste acceptance criteria of the next waste management step ultimately up to the waste acceptance requirements of the disposal facility.

MANAGEMENT SYSTEM

Requirement 7 (GSR Part 5, Ref. [4]): Management systems

Management systems shall be applied for all steps and elements of the predisposal management of radioactive waste.

4.10 The requirements on management systems for all facilities are set in Ref. [6]. General guidance on the management systems for facilities and activities is given in Ref. [28], while specific guidance on the management systems for radioactive waste processing, handling and storage facilities is provided in Ref. [24].

4.11 An integrated management system (including safety, health, environmental, nuclear security, quality and economic elements) is required to be established, implemented, assessed and continually improved by the operating organization [6]. It should be aligned with the goals of the operating organization and should contribute to their achievement. Management systems should make provisions for siting, design, construction, commissioning, operation, maintenance and decommissioning of the facility. The management system should be designed to ensure that the safety of facilities are maintained, and that the quality of the records and of subsidiary information on radioactive waste inventories is preserved, with account taken of the duration of the management and storage periods and the consecutive management steps, for example, clearance, release, discharge, reprocessing or disposal. The management system should also include provision to ensure that the fulfilment of its goals can be demonstrated.

4.12 Managing radioactive waste involves a variety of activities that may extend over a very long period of time. These characteristics present a series of challenges to the development and implementation of effective management systems for a waste management programme, and give rise to the need for an integrated management system to deal with all matters that might affect the management of radioactive waste, including the financial provisions to carry it out.

4.13 For achieving and maintaining an integrated management system the following long term aspects should be considered:

(a) Preservation of technology and knowledge and transfer of such knowledge to people joining the operating organization in the future;

(b) Retention or transfer of ownership of radioactive waste and management facilities;

(c) Succession planning for the technical and managerial human resources;

(d) Continuation of arrangements for interacting with interested parties;

(e) Provision of adequate resources (the adequacy of resources for maintenance of facilities and equipment may need to be periodically reviewed over operational periods that may extend over decades); and

(f) Preservation of information, including but not necessarily limited to facility siting, design, operation, and safety case development.

RESOURCE MANAGEMENT

4.14 Radioactive waste management activities will require financial and human resources and the necessary infrastructure. Senior management of the waste generating facility should be responsible for making arrangements to provide adequate resources for radioactive waste management activities, to satisfy the demands imposed by the safety, health, environmental, nuclear security, quality and economic aspects of the full range of activities involved in the management of radioactive waste and the potentially long duration of such activities.

4.15 Where the management of radioactive waste is anticipated to be multi-decade then the government has to ensure that there are national policies and plans to maintain the underpinned knowledge associated with management of radioactive waste via national education and training required to deliver safety and protection of the environment.

PROCESS IMPLEMENTATION

4.16 The management system should be periodically reviewed through the use of self-assessments, independent assessments, and management system reviews. It should accommodate the feedback of experience from implementation and from internal and external lessons learned. It should be flexible enough to accommodate changes in policy; in strategic aims; in safety, health, environmental, nuclear security, quality and economic considerations; and in regulatory requirements and other statutes.

4.17 Management systems should also be reassessed whenever the relationship between the owner of the radioactive waste and the operating organization of the facility changes (e.g. public organizations are privatized, new organizations are created, existing organizations are combined or restructured, responsibilities are transferred between organizations, operating organizations undergo internal reorganization of the management structure, or resources are reallocated).

4.18 In the design of facilities for long term radioactive waste management, consideration should be given to the incorporation of measures that will facilitate operation, maintenance of equipment and eventual decommissioning of the facility. For long term radioactive waste management activities, future infrastructural requirements should be specified to the extent possible and plans should be made to ensure that these will be met. In such planning, consideration should be given to the continuing need for support services, spare parts for equipment that may eventually no longer be manufactured and equipment upgrades to meet new regulations and operational improvements, and to the evolution and inevitable obsolescence of software. Consideration should also be given to the need to develop monitoring programmes and inspection techniques for use during extended periods of storage.

4.19 Consideration should be given to the possible need to relocate radioactive waste if problems arise after it has been placed in storage (e.g. threats to the integrity of containers or problems associated with criticality or decay heat). The availability of any specialized equipment that may be necessary over a long time period while radioactive waste is in storage or that may be necessary in the future should be assessed.

4.20 Records concerning the radioactive waste and its storage that need to be retained for an extended period should be stored in a manner that minimizes the likelihood and consequences of loss, damage or deterioration due to unpredictable events such as fire, flooding or other natural or human initiated occurrences. Storage arrangements for records should meet the requirements prescribed by the national authorities or the regulatory body and the status of the records should be periodically assessed. If records are inadvertently destroyed, the status of surviving records should be examined and the importance of their retention and their necessary retention periods should be re-evaluated.

5. SAFETY CASE AND SAFETY ASSESSMENT

GENERAL

Requirement 13 (GSR Part 5, Ref. [4]): Preparation of the safety case and supporting safety assessment

The operator shall prepare a safety case and a supporting safety assessment. In the case

of a step by step development, or in the event of the modification of the facility or activity, the safety case and its supporting safety assessment shall be reviewed and updated as necessary.

Requirement 14 (GSR Part 5, Ref. [4]): Scope of the safety case and supporting safety assessment

The safety case for a predisposal radioactive waste management facility shall include a description of how all the safety aspects of the site, the design, operation, shutdown and decommissioning of the facility, and the managerial controls satisfy the regulatory requirements. The safety case and its supporting safety assessment shall demonstrate the level of protection provided and shall provide assurance to the regulatory body that safety requirements will be met.

Requirement 15 (GSR Part 5, Ref. [4]): Documentation of the safety case and supporting safety assessment

The safety case and its supporting safety assessment shall be documented at a level of detail and to a quality sufficient to demonstrate safety, to support the decision at each stage and to allow for the independent review and approval of the safety case and safety assessment. The documentation shall be clearly written and shall include arguments justifying the approaches taken in the safety case on the basis of information that is traceable.

Requirement 16 (GSR Part 5, Ref. [4]): Periodic safety reviews

The operator shall carry out periodic safety reviews and shall implement any safety upgrades required by the regulatory body following this review. The results of the periodic safety review shall be reflected in the updated version of the safety case for the facility.

Requirement 22 (GSR Part 5, Ref. [4]): Existing facilities

The safety at existing facilities shall be reviewed to verify compliance with requirements. Safety related upgrades shall be made by the operator in line with national policies and as required by the regulatory body.

5.1 Requirements for the safety assessment for all facilities and activities are set in GSR Part 4 [5]. Requirements and guidance on the safety case and safety assessment for the predisposal management of radioactive waste is provided in GSR Part 5 [4] and in the Safety Guide GSG-3 [29], respectively.

5.2 The safety assessment and the periodic safety reviews of nuclear power plants and research reactors normally include the safety assessment and review of the radioactive waste management systems within the reactor facility (SSG-20, GS-G-4.1, SSG-25) [30, 31, 32]. This typically includes:

- Description of the design and operation of radioactive waste management systems (waste generation and control, waste treatment and conditioning, storage)
- Limits for releases to the environment

- Organizational responsibilities
- Management of safety and radiation protection, including operational limits and controls

5.3 For waste generated within a reactor, the safety case should identify interfaces between the radioactive waste management facility and limits and conditions of the reactor. The safety case and supporting safety assessment should demonstrate that consideration has been given to all steps in the management of the waste under consideration, from its generation to its disposal, and to their overall compatibility. Thus, short term, medium term and long term aspects of waste management should be considered, as well as the possible need for future handling and processing of the waste and the risks and doses that may be associated with these activities.

LONG TERM STORAGE AT THE REACTOR SITE

5.4 Long term storage of radioactive waste at the reactor site e.g. after the reactor has been decommissioned or shut down, requires special consideration in the safety case and safety assessment (GSR Part 4, WS-G-6.1, GSG-3) [5, 8, 29]. This includes the establishment of an ageing management programme, the assessment of passive safety features, package and packaging requirements, retention of records, emergency preparedness and response plans, decommissioning plan, and monitoring and inspection. The safety case should also consider degradation of engineered features and availability of maintenance and emergency response systems, changes to the stored waste and uncertainties in parameters and models used.

SAFETY CASE AND SAFETY ASSESSMENT

5.5 The safety case and supporting safety assessment should provide the primary input to the licensing documentation required to demonstrate compliance with regulatory requirements. An important outcome of the safety case and safety assessment is the facilitation of communication between interested parties on issues relating to the facility or activity, as well as substantiating the safety of the facility and contributing to confidence in its safety.

5.6 The safety case and supporting safety assessment should address the compatibility of the waste packages and unpackaged waste with the existing or anticipated disposal option; however, in the event that a disposal option does not exist, assumptions should be made about the likely disposal options and these should be set down clearly.

5.7 The safety case should include identification of uncertainties in the performance of the waste management activities, analysis of the significance of the uncertainties, and identification of approaches for the management of significant uncertainties. Such uncertainties should be a focus of an examination of the interdependences between the boundaries of interlinking safety cases.

5.8 Appendix 2 provides examples of hazards associated with typical predisposal management of radioactive waste activities within reactors. These examples are not exhaustive; rather, they are intended to assist in the identification and subsequent assessment of hazards. GSG-3 (Annex 1) also provides examples of hazards and potential initiating events relevant to typical waste management activities.

5.9 The safety case and supporting safety assessment are to be reviewed and updated periodically as necessary to reflect actual experience and increasing knowledge and understanding (e.g., knowledge gained through continuing scientific research), with account taken of any relevant operational feedback or other aspects that are relevant for safety (GSG-3) [29].

5.10 Facilities that were not constructed to present safety standards may not meet all the safety requirements. In assessing the safety of such these facilities, there may be indications that safety criteria will not be met. In such circumstances, reasonably practicable measures have are to be taken to upgrade the safety of the facility.

5.11 Although the focus of this Safety Guide is on radiological safety, non-radiological hazards (e.g. chemo-toxic, industrial) should also be addressed as specified in national requirements or as they may affect radiological safety (e.g. fires). Non-radiological hazards for which safety criteria exist can be assessed and modelled along with radiological hazards (e.g. hazards associated with the lifting and handling of waste containers).

5.12

6. GENERAL SAFETY CONSIDERATIONS

GENERAL

6.1 The steps involved in the predisposal management of radioactive waste are:

- Assessment of potential waste arisings and evaluation of options for disposition
- Waste generation and control
- Processing
  - Pretreatment
  - Treatment
  - Conditioning
- Storage
- Transport

6.2 At various steps it should be verified that the waste complies with acceptance criteria. Therefore the radioactive waste has to be characterized and classified throughout the steps of its predisposal management.

6.3 The ultimate goal radioactive waste processing is to make the waste suitable for disposal (or for storage if no disposal facility is available). This implies that the final waste form has to comply with the waste acceptance requirements of the disposal facility. At various steps it should be verified that the waste complies with applicable acceptance requirements. Therefore the waste has to be characterized and classified throughout the steps of its management.

6.4 Management options such as recycling, reuse, clearance and the control of discharges, and authorized disposal, in compliance with the conditions and criteria established by the regulatory body, should be used as far as practicable. The limitations and controls for clearance and the control of discharge activities should be set by the regulatory body [14, 15, 16].

6.5 Radioactive waste is handled and transported between and within the various steps. Requirements and guidance on transport of radioactive waste can be found in SSR-6 [9] and TS-G-1.1 [27, 33].

6.6 The on-site transport of radioactive waste may not need to meet all the requirements for off-site transport (SSR-6) [9], because transport is at all times under the control of the operator, who is responsible for the safety of on-site operations.

WASTE GENERATION AND CONTROL

Requirement 8: Radioactive waste generation and control

All radioactive waste shall be identified and controlled. Radioactive waste arisings shall be kept to the minimum practicable.

6.7 During the design of the reactor, consideration should be given to operational features for waste generation and control, including the following aspects:

(a) The careful selection of materials, processes and structures, systems and components for the facility;

(b) The selection of design options that favour waste minimization when the facility is eventually decommissioned;

(c) The use of effective and reliable techniques and equipment;

(d) The containment and packaging of radioactive material to maintain its integrity;

(e) Adequate zoning to prevent contamination;

(f) The decontamination of zones and equipment and the prevention of the spread of contamination.

6.8 The principle of waste generation and control should also be a factor for consideration in the selection of approaches to storage and processing. Examples of processing steps for which this principle should be considered include the selection of conditioning processes and the testing programme invoked to verify treatment and conditioning processes. For a conditioning process in which components become contaminated, equipment of proven longevity should be used.

6.9 Pretreatment operations including segregation should be carried out so as to minimize the amount of radioactive waste to be further treated, conditioned, stored and disposed of. Decontamination and/or a sufficiently long period of storage to allow for radioactive decay should be used where appropriate to enable regulatory control to be removed from the waste.

Radioactive waste from power reactors

Gaseous radioactive waste

6.10 Although the sources of gaseous radioactive waste differ according to the type of reactor, possible sources include: leakage from the coolant, the moderator systems or the reactor itself; degasification systems for the coolant; condenser vacuum air ejectors or pumps; the exhaust from turbine gland seal systems; and activated or contaminated ventilated air. In all cases, spent fuel in storage or in handling operations is a potential source of gaseous radioactive waste.

Liquid radioactive waste

6.11 The primary coolant in water cooled reactors and water from the fuel storage pools are major sources of liquid radioactive waste since some of their radioactive content may be transported to the liquid radioactive waste stream via process streams or leakages. Although the composition of the liquid radioactive waste may vary appreciably according to reactor type, contributions to the stream may derive from reactor coolant let-down, evaporator concentrates, equipment drains, floor drains, laundry waste, contaminated oil and waste arising from the decontamination and maintenance of facilities and equipment.

Solid radioactive waste

6.12 Solid radioactive waste results from the operation, maintenance, and decommissioning of the nuclear power plant and its associated processing systems for gaseous and liquid radioactive waste. The nature of such waste varies considerably from plant to plant, as do the associated levels of activity. Solid radioactive waste may consist of: spent ion exchange resins (both bead and powder); cartridge filters and pre-coat filter cake; particulate filters from ventilation systems; charcoal beds; tools; contaminated metal scrap; core components; debris from fuel assemblies or in-reactor components; and contaminated rags, clothing, paper and plastic.

Radioactive waste from research reactors

Gaseous radioactive waste

6.13 The typical sources of gaseous radioactive waste generated during the operation of research reactors include:

(a) Gaseous radioactive elements or compounds from the pools, coolant systems, irradiation facilities and experimental facilities;

(b) Airborne radioactive material produced in ancillary facilities, including fume cupboards and decontamination areas.

Liquid radioactive waste

6.14 The typical sources of liquid radioactive waste generated during the operation of research reactors include:

(a) Cooling water draw-off;

(b) Primary system drains (in the case of light water reactors);

(c) Liquid waste from the demineralized water plant;

(d) The drain of the ventilation water system;

(e) Demineralized waste water recovered from the drainage of large equipment in maintenance operations;

(f) Washbasin and shower liquids;

(g) Floor drain liquids;

(h) Liquids from laboratories (these can be radioactive or non-radioactive).

Solid radioactive waste

6.15 The typical sources of solid radioactive waste generated during the operation of research reactors include:

(a) Irradiated target cans;

(b) Used irradiation rigs and reactor components (e.g. thermocouples);

(c) Neutron beam guide tubes;

(d) Used control rods;

(e) Waste arising from the pool service area;

(f) Ventilation system waste (charcoal filters, HEPA filters);

(g) Spent ion exchange resins;

(h) Cleaning materials and used personal protective items;

(i) Laboratory waste (gloves, tissue paper, disposable glassware, etc.);

(j) Contaminated items arising from maintenance and other works.

CHARACTERIZATION AND CLASSIFICATION OF WASTE

Requirement 9: Characterization and classification of radioactive waste

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.

6.16 Radioactive waste is required to be characterized at the various stages in its management to obtain information on its properties for use in controlling the quality of the products, verifying the process and thus facilitating the subsequent steps for safely processing and finally disposing of the radioactive waste.

6.17 For the purposes of determining arrangements for the handling, processing and storage of radioactive waste, consideration should be given to:

(a) Its origin;

(b) Criticality risk [34];

(c) Its radiological properties (e.g. half-life, activity and concentration of nuclides, dose rates);

(d) Other physical properties (e.g. size and mass, compactibility, solubility);

(e) Chemical properties (e.g. composition of raw waste, water content, residual moisture, corrosion resistance, combustibility, gas generation properties, chemical toxicity);

(f) Biological properties (e.g. biological hazards);

(g) Intended methods of processing, storage and disposal.

6.18 The characterization process should include the measurement of physical and chemical parameters, the identification of radionuclides and the measurement of activity content. Such measurements are necessary for monitoring the history of the radioactive waste or waste packages through the stages of processing, storage and disposal and for maintaining records for the future.

6.19 The data requirements for characterization and methods for collecting data will differ depending on the type and form of the radioactive waste. When waste streams are processed, characterization may be performed by sampling and analysing the chemical, physical and radiological properties of the waste. The quality of waste packages may be investigated by non-destructive and, infrequently, also by destructive methods. However, it may be possible to apply indirect methods of characterization based on process control and process knowledge instead of or in addition to sampling and the inspection of waste packages in order to avoid undue occupational exposure. The methods of characterization in the processing of the waste should be approved by the regulatory body in the authorization process.

6.20 An important objective of radioactive waste processing is to produce waste packages that can be handled, transported, stored and disposed of safely. In particular, radioactive waste should be conditioned to meet the acceptance requirements for its disposal. In order to provide reasonable assurance that the conditioned waste can be accepted for disposal, although there may not yet be any specific requirements, options for the future management of radioactive waste and the associated waste acceptance requirements should be anticipated as far as possible. The waste acceptance requirements may be met by providing an overpack that is tailored to the specific conditions of the disposal facility and to the characteristics of the radioactive waste and the engineered components of the disposal facility.

6.21 To ensure the acceptance of waste packages for disposal, a programme should be established to develop a process for conditioning that is approved by the regulatory body. The features adopted for waste characterization and process control should provide confidence that the properties of waste packages will be ensured.

6.22 The categorization and classification of radioactive waste assists in the development of management strategies and in the operational management of the waste. Segregation of waste with different properties will also be helpful at any stage between the arising of the raw waste and its conditioning, storage, transport and disposal. To make the appropriate segregation of waste, it will be necessary to know its properties and, hence, it will be necessary to characterize the waste at various stages of its processing. Documented procedures should be followed for the characterization of radioactive waste and its segregation, and for assigning the waste to a particular class.

6.23 Details of the purpose, methods and approaches to the classification of radioactive waste are provided in GSG-1 [19]. Annex III of [19] also provides information on origin and types of radioactive waste, including waste from nuclear power production. The classification scheme is based on the long-term management (disposal) of the radioactive waste.

6.24 It should be borne in mind that certain types of radioactive waste contain alpha emitting radionuclides, which could arise from degraded or failed nuclear fuel[3]. Inflammable, pyrophoric, corrosive or other hazardous materials should also be given special attention. Care should be taken to avoid mixing waste of these types.

[3] The terms ‘degraded fuel’ or ‘failed fuel’ can cover a broad range of conditions, ranging from minor pinholes to cracked cladding to broken fuel pins. The nature and extent of failure is an important consideration.

6.25 Gaseous radioactive waste should be classified for treatment purposes into waste arising directly from the primary coolant systems of the reactor and waste arising from the ventilation of plant areas.

6.26 Liquid radioactive waste should be classified for processing purposes according to its activity concentration and its content of chemical substances. For instance, radioactive waste containing boric acid or organic matter may need special treatment. Non-aqueous radioactive waste such as oil should be segregated for separate treatment.

6.27 Solid radioactive waste should be classified according to its radionuclide content (type and half-life) and activity concentration, taking into account the existing or likely disposal options, and segregated according to treatment and conditioning process. For instance, sludge, cartridge filters, contaminated equipment and components, ventilation filters and miscellaneous items (such as paper, plastic, towels) may be segregated in accordance with the type of treatment and conditioning process, such as compaction, incineration or immobilization.

6.28 The segregation of radioactive waste into appropriate categories should be carried out as near to the point of generation as practicable. The waste should be segregated in accordance with written procedures. Mixing of waste (e.g., concentration averaging) at the generating source may be allowed by certain State regulatory authorities in order to achieve specific waste acceptance requirements.

PROCESSING OF RADIOACTIVE WASTE

Requirement 10: Processing of radioactive waste

Radioactive material for which no further use is foreseen and with characteristics that make it unsuitable for authorized discharge, authorized use or clearance from regulatory control shall be processed as radioactive waste. The processing of radioactive waste shall be based on appropriate consideration of the characteristics of the waste and of the demands imposed by the different steps in its management (pretreatment, treatment, conditioning, transport, storage and disposal). Waste packages shall be designed and produced so that the radioactive material is appropriately contained during both normal operation and in accident conditions that could occur in the handling, storage, transport and disposal of waste.

6.29 The processing radioactive waste may include one or more steps (e.g. pretreatment, treatment and conditioning). These steps may take place in stationary or mobile facilities. The handling, storage and transport of the waste will be necessary within, between and after such steps.

6.30 The objective of processing is to produce packages of conditioned radioactive waste suitable for safe handling, transport, storage and disposal. If no disposal facility is available, assumptions should be made on the requirements for the acceptance of the waste for disposal in order to provide guidance for its processing, which may include provisions for long-term storage.

6.31 Radioactive waste should be processed as early as practicable in order to convert it into a passively safe state and to prevent its dispersal during storage and disposal.

Pretreatment

6.32 Pretreatment operations such as waste collection, segregation, chemical adjustment and decontamination may result in a reduction in the amount of waste needing further processing, storage and disposal. Actions can be performed to adjust the characteristics of the waste, to make it more amenable to further processing, and to reduce or eliminate certain hazards posed by the waste owing to its radiological, physical and chemical properties.

6.33 The first operation in the pretreatment of radioactive waste is to collect waste materials, segregating them as necessary on the basis of their radiological, physical and chemical properties. Radioactive waste containing predominantly short-lived radionuclides should not be mixed with long lived waste. In the segregation of waste, it should also be taken into account whether regulatory control can be removed from the waste or whether it can be recycled or released, either directly or after allowing for a decay period.

6.34 To facilitate further treatment and enhance safety, solid waste should be segregated according to the facility specific waste management programme and the available facilities. Segregation is based on consideration of the following waste properties:

(a) Combustible or non-combustible, if incineration is a viable option;

(b) Compressible or non-compressible, if compaction is a viable option;

(c) Metallic or non-metallic, if melting is a viable option;

(d) Fixed or non-fixed surface contamination, if decontamination is a viable option.

6.35 Special care should be taken in segregating materials and objects that are fissile, pyrophoric, explosive, chemically reactive or otherwise hazardous, or that contain free liquids or pressurized gases.

6.36 A number of decontamination processes remove surface contamination using a combination of mechanical, chemical and electrochemical methods. Care should be taken to limit the amount of secondary waste generated and to ensure that the characteristics of the secondary waste are compatible with subsequent steps in the waste management process.

6.37 To the extent possible, liquid waste should be characterized on the basis of its physical, radiological and chemical properties to facilitate processing. With proper characterization it may be possible to release the waste within authorized limits, provided that the non-radiological characteristics of the waste are appropriate. To the extent possible, liquid waste should be processed and conditioned (e.g., adsorption, immobilization, etc.) to promote safe handling and disposal.

6.38 Mixing waste streams should be limited to those streams that are radiologically and chemically compatible. If the mixing of chemically different waste streams is considered, an evaluation should be made of the chemical reactions that could occur in order to avoid uncontrolled or unexpected reactions. Organic liquid waste needs different treatment owing to its chemical nature and should be segregated and kept separate from aqueous waste streams. Organic liquid waste may also be flammable and its collection and storage should incorporate provisions for adequate ventilation and fire protection.

Treatment

6.39 The treatment of radioactive waste may include:

(a) The reduction in volume of the waste (by incineration of combustible waste, compaction of solid waste and segmentation or disassembly of bulky waste components or equipment);

(b) The removal of radionuclides (by evaporation or ion exchange for liquid waste streams and filtration of gaseous waste streams); and

(c) Change of composition (by chemical processes such as precipitation, flocculation and acid digestion as well as chemical and thermal oxidation).

Solid waste

6.40 Solid radioactive waste may be heterogeneous. Special consideration should be given to representative sampling before processing so as to confirm compatibility with the intended process, and appropriate arrangements should be made for this as far as practicable. Arrangements should also be made for systematic control of the final products to verify compliance with established requirements and recommendations.

6.41 A great number of processes are available for producing acceptable waste packages. Such processes should be selected on the basis of the characteristics of the waste concerned. If possible, processes with high volume reduction factors should be applied with the use of proven techniques such as compaction or incineration.

6.42 Incineration of combustible solid waste normally achieves the highest volume reduction as well as yielding a stable waste form. After combustion, radionuclides from the waste will be distributed between the ash, the products from cleaning the exhaust gases and the stack discharges. The distribution will depend on the design and operating parameters of the incinerator and the nature of the radionuclides in the waste. Incineration is also an advantageous technique for treating radioactive organic liquids because the products of complete combustion are ash, carbon dioxide and water. Other constituents in the waste may yield acid gases and corrosive combustion products, and the effects of corrosion of the incinerator’s components and of acid releases to the atmosphere should therefore be considered. Off-gas scrubbing to prevent the discharge of radioactive and non-radioactive hazardous materials may be necessary and should be considered. Attention should be paid to radionuclides accumulating in residues of the gas cleaning system and those remaining in the ash, and to their further conditioning. It should be noted that incineration will result in the increase of the activity concentration which might result in a change of the waste class.

6.43 For incinerators processing significant amounts of radioactive waste, the operator should monitor the radionuclides in the stack discharge by appropriate measures to ensure that the concentrations and amounts discharged are within the limits specified by the regulatory body and are consistent with the parameters modelled in the safety assessment. The products of incineration can include acids, polychlorinated biphenyls and various other materials presenting non-radiological hazards, which should be taken into account.

6.44 Compaction is a suitable method for reducing the volume of certain types of waste. This may include the compaction of ashes originating from incineration. The characteristics of the material to be compacted and the desired volume reduction should be well defined and controlled. Consequences of compaction that should be given consideration in selecting or designing and operating a compactor include the following:

(a) The possible release of volatile radionuclides and other airborne radioactive contaminants;

(b) The possible release of contaminated liquid during compaction;

(c) The chemical reactivity of the material during and after compaction;

(d) The potential fire and explosion hazards due to pyrophoric or explosive materials or pressurized components.

6.45 Segmentation or disassembly and other size reduction techniques may be used before conditioning waste that is bulky or oversize in relation to the intended processing (e.g. worn out components or structures). Processes to achieve this typically use cutters with high temperature flames, various sawing methods, hydraulic shearing, abrasive cutting and plasma arc cutting. Means of preventing the spread of particulate contamination should be considered in the choice of method and in the operation of the equipment.

6.46 For non-combustible and non-compressible solid waste, for which delay and decay or decontamination is not a viable option, direct conditioning without prior treatment should be considered. Melting metal scrap, with resultant homogenization of the radioactive material and its accumulation in the slag, may be considered as a means of achieving authorized reuse or removal of regulatory control.

Liquid waste and discharges

6.47 Methods for the treatment of aqueous waste include evaporation, chemical precipitation, ion exchange, filtration, centrifugation, ultrafiltration, incineration and reverse osmosis. In each case, process limitations due to corrosion, scaling, foaming and the risk of fire or explosion in the presence of organic material should be carefully considered, especially with regard to the safety implications of operations and maintenance. If the waste contains fissile material, the potential for criticality should be evaluated and eliminated to the extent practicable by means of design features and administrative safety measures [34].

6.48 Spent ion exchange resins are usually flushed out as slurry and subsequently managed as liquid waste, although some operators retain the resins as a dry solid. When resins are flushed out as slurry, care should be taken to prevent blockages of the flow as these may cause radiation hot spots and necessitate special maintenance. Special care should also be taken with their prolonged storage while awaiting conditioning, because of the potential for radiolysis or chemical reactions generating combustible gases or causing physical degradation or exothermic reactions.

6.49 Liquids for discharge may be produced as a consequence of the treatment of waste. All discharged liquids should be readily dispersible in water. If the liquid contains suspended materials, it may need to be filtered prior to discharge. Waste that is immiscible with water should be completely excluded from discharge. Acidic or alkaline liquids should be neutralized prior to discharge. If the waste also contains toxic or other chemicals that could adversely affect the environment or the treatment of sewage, the waste should be treated prior to discharge in accordance with the regulations in respect of health and safety and protection of the environment.

6.50 For routine discharges of liquids to the environment, the main types of control options are to provide either storage facilities, so that short lived radionuclides can decay before release, or treatment facilities that remove radionuclides from the effluent stream for disposal by other means. Within these two broad categories there may be a number of different options available. The limitations and controls for such releases should be set by the regulatory body [15].

Gaseous waste and discharges

6.51 In the operation of treatment systems for gaseous radioactive waste, consideration should be given to: the amount of gas to be treated; the activity; the radionuclides contained in the gas; the concentrations of particulates; the chemical composition; the humidity; the toxicity; and the possible presence of corrosive or explosive substances.

6.52 Noble gases with short half-lives should be retained in hold-up tanks or other delay systems that allow the radionuclides to decay to an acceptable activity or activity concentration before release.

6.53 Radioactive particulates and aerosols in gaseous effluents may be removed by filtration using high efficiency particulate air (HEPA) filters. Iodine can be removed by charcoal filters and noble gases can be delayed by sorption beds charged with activated carbon. The use of scrubbers for the removal of gaseous chemicals, particulates and aerosols from off-gases should be considered. Where required by the regulatory body, or if the reliability of the system is fundamental to the achievement of safety, redundant systems such as two filters in sequence should be used in case one fails. Additional components of the off-gas system that should be considered for detecting problems include those that ensure proper operation of the filters, such as pre-filters or roughing filters, and temperature and humidity control systems, as well as monitoring equipment such as gauges that show pressure differentials.

Conditioning

6.54 Conditioning of radioactive waste consists of those operations that produce a waste package suitable for safe handling, transport, storage and disposal. Conditioning may include the immobilization of liquid waste or dispersible waste, the enclosure of the waste in a container and the provision of an overpack (as necessary).

6.55 Waste packages produced by conditioning should satisfy the respective acceptance criteria. Therefore, the regulatory body and organizations operating or planning to operate transport services and storage and disposal facilities should be consulted in deciding which types of pretreatment, treatment and conditioning will be necessary.

6.56 Liquid waste is often converted into a solid form by solidifying it in a suitable (in accordance with the waste acceptance criteria) matrix such as cement, bitumen, glass or polymer. Solidification may also be achieved without a matrix material, for example by drying. The product is then enclosed in a container.

6.57 To the extent practicable the solidification process for liquid waste should produce a waste form with the following characteristics and properties:

(a) Compatibility (physical and chemical) of the waste, any matrix materials and the container;

(b) Homogeneity;

(c) Low voidage;

(d) Low permeability and leachability;

(e) Chemical, thermal, structural, mechanical and radiation stability for the required period of time;

(f) Resistance to chemical substances and microorganisms.

6.58 Solid waste should be considered on a case by case basis. The characteristics of the waste form as listed above apply for many types of solid waste. Some of the characteristics (in particular homogeneity and low voidage) do not apply for certain types of solid waste. For example, core components are enclosed in thick-walled waste containers without immobilization.

6.59 It should be taken into account that certain metals, such as aluminium, magnesium and zirconium, could react with, for example, the alkaline water of cement slurry or water diffused from a concrete matrix, to produce hydrogen. Chelating agents, organic liquids or oil and salt content in liquid waste may also be of concern in the conditioning process.

6.60 The waste and its container should be compatible. Depending on the waste characteristics and the method of handling, transport and storage, the container may also need to provide shielding for direct radiation. In selecting materials for the container and its outer surface finish, consideration should be given to the ease of decontamination. If a waste package is not initially designed to meet the relevant acceptance criteria for transport, storage or disposal, an additional container or an overpack will be necessary to meet the acceptance criteria. Care should be taken to consider the compatibility of the waste package and the overpack with respect to the waste acceptance criteria and transport requirements.

6.61 The conditioned waste package should provide integrity during the anticipated storage period prior to disposal and should be capable of allowing for:

(a) Retrieval at the end of the storage period;

(b) Enclosure in an overpack, if necessary;

(c) Transport to and handling at a disposal facility;

(d) Meeting acceptance requirements of the disposal facility.

STORAGE OF RADIOACTIVE WASTE

Requirement 11: Storage of radioactive waste

Waste shall be stored in such a manner that it can be inspected, monitored, retrieved and preserved in a condition suitable for its subsequent management. Due account shall be taken of the expected period of storage, and, to the extent possible, passive safety features shall be applied. For long term storage in particular, measures shall be taken to prevent the degradation of the waste containment.

6.62 Guidance for the storage of radioactive waste and for the storage of spent fuel is dealt with extensively in WS-G-6.1 [8], SSG-15 [7] and NS-G-1.4 [35].

RADIOACTIVE WASTE ACCEPTANCE CRITERIA

Requirement 12: Radioactive waste acceptance criteria

Waste packages and unpacked waste that are accepted for processing, storage and/or disposal shall conform to criteria that are consistent with the safety case.

6.63 Criteria are to be developed for the acceptance of radioactive waste. Account should be taken of all relevant operational limits and conditions of the reactor and the waste management facility (consistent with the safety case) and also of the future disposal facility. In fact, an important objective of processing is to produce waste packages that can be handled, transported, stored and disposed of safely. In particular, waste should be conditioned to meet the acceptance requirements for its disposal. In order to provide reasonable assurance that the conditioned waste can be accepted for disposal, although there may not yet be any specific requirements, options for the future management of radioactive waste and the associated waste acceptance requirements should be anticipated as far as possible. The waste acceptance requirements may be met by providing an overpack that is tailored to the specific conditions for disposal and to the characteristics of the waste and the engineered components of the disposal facility.

6.64 Appendix 3 provides a listing of the typical properties and characteristics that should be considered for waste packages and spent nuclear fuel declared as waste. To ensure the acceptance of waste packages for disposal, a programme should be established, as an element of the management system as described in GS-G-3.3 [24], to develop a process for conditioning that is approved by the regulatory body. In addition to that, a programme for quality assurance and control of waste packages should be developed and included in the management system. Subsequent to approval by the regulatory body, this programme should be implemented as a measure to confirm fulfilment of the waste acceptance requirements of the disposal facility.

6.65 The operator should ensure that the radioactive waste accepted in his facility (and installations) complies with the set criteria. Procedures for acceptance should be included in the management system.

6.66 Adequate techniques need to be in place to identify the characteristics of the material to demonstrate that it meets the waste acceptance criteria.

LIFETIME SAFETY CONSIDERATIONS

Siting and design

Requirement 17: Location and design of facilities

Predisposal radioactive waste management facilities shall be located and designed so as to ensure safety for the expected operating lifetime under both normal and possible accident conditions, and for their decommissioning.

6.67 Criteria for siting and methods that could be used in a graded approach in the siting of nuclear installations are dealt with in NS-R-3 [38], SSG-9 [39], SSG-18 [40] SSG-21 [41], and DS433 (in preparation) [42].

6.68 Waste management facilities should be located in the same area as the reactor, to the extent practicable, to reduce the need for the transport of waste between locations for processing and for storage.

6.69 In the design of the reactor and waste management facilities, due consideration should be given to the need for:

(a) The control of access to areas for waste processing and storage and the control of movement between radiation zones and contamination zones;

(b) The retrieval of stored waste (including waste generated during operation);

(c) Waste characterization and inventory control;

(d) The inspection of the waste and its containment;

(e) Dealing with waste and waste packages that do not meet specifications;

(f) The control of liquid and gaseous effluents;

(g) Managing waste giving rise to non-radiological hazards;

(h) Maintenance work and eventual decommissioning;

6.70 Measures considered in the design for the management of gaseous and liquid waste and effluents should include the following:

(a) Provision for radioactive gases to be channelled through proper ducting as appropriate and brought to monitored release point(s);

(b) Provision of means, such as stacks for the discharge of authorized gaseous radioactive waste, and of methods for sampling and monitoring those releases.

6.71 Measures considered in the design for the management of liquid radioactive waste should include the following:

(a) Collection of radioactive liquid effluents to a common point such as a holding tank;

(b) The potential for re-concentration downstream in the environment of some released radionuclides in relation to the collection of liquid radioactive waste with low levels of activity and the methods of monitoring such releases;

(c) The management and control of liquid radioactive waste with higher levels of activity, such as waste that might arise from planned major shutdowns of research reactors of some types;

(d) Provisions for decay devices to minimize releases of radioactive material;

(e) Provisions for sampling from and monitoring retention tanks prior to the release of liquid content, preferably at the point of release;

(f) Provisions for treating liquid radioactive waste either for reuse (e.g. treatment using resins) or because the activity levels are too high for their release to the environment.

6.72 Measures considered in the design for the management of solid radioactive waste should, as far as applicable, include the following:

(a) Provisions for segregating waste by type (amount, form, volume, isotopic composition and activity concentration);

(b) The packaging, handling and storage of solid radioactive waste with low level and very low level activity (e.g., contaminated cleaning equipment, clothing, paper and tools);

(c) The packaging, handling and storage of solid radioactive waste with intermediate level activity (e.g., waste arising from ion exchange resins, ventilation filters and charcoal beds);

(d) The packaging, handling and storage of solid radioactive waste with high level activity (e.g., fuel element cladding hulls, hardware);

(e) Areas and tools for handling and loading waste;

(f) Equipment and tools for radiation protection;

(g) Provisions as necessary for storing resins and dehydrating liquid waste;

(h) Provisions for filtration in liquid waste collection lines to prevent the release of solids;

(i) Provisions for ensuring that the removal of radioactive material within authorized practices from any further regulatory control and the control of discharges are within authorized limits.

6.73 The reactor and waste management facilities should be designed to prevent material interactions that may compromise the containment of the waste or safety at the facility.

6.74 The management of radioactive waste may also entail the management of nonradioactive hazardous material. Material should be selected and other measures should be taken so as to ensure that its management is in compliance with the applicable regulations relating to hazardous material and to take account of potential interactions between radioactive and non-radioactive constituents.

6.75 Depending on the characteristics of the waste concerned, protection may be provided solely by a container or by a container supplemented by the safety systems of the facility, such as those for heat removal (either passive or active).

6.76 For the conditioning of waste, all relevant characteristics of the waste form need to be considered and provided for in the design of the waste package. The waste package should provide adequate containment, shielding and heat removal properties.

6.77 The design of the reactor and waste management facility of heat generating waste should incorporate systems (e.g. a system for monitoring and controlling the temperature) that are capable of maintaining the temperature of the waste within acceptable limits in all stages of predisposal management of radioactive waste, both in operational states and under accident conditions. Such temperature limits should be based on the properties of the waste and waste packages, with account taken of the material properties of the container, the containment structures and the waste form in all steps of management, including storage. To the maximum extent practicable, the cooling systems for storage facilities for conditioned high-level waste should be passive and should need minimal maintenance. If forced circulation of coolant is used, the system should be highly reliable and redundant (robust). Examples of features that enhance the reliability of cooling systems are the capability of dealing with the settling of solids and with build-up on surfaces that affects the efficiency of heat removal. The storage facility itself should be designed to be capable of experiencing temporary loss of cooling events without damage to the stored waste. In addition, means of mitigation or recovery should be put in place to deal with such contingencies.

Construction and commissioning

Requirement 18: Construction and commissioning of the facilities

Predisposal radioactive waste management facilities shall be constructed in accordance with the design as described in the safety case and approved by the regulatory body. Commissioning of the facility shall be carried out to verify that the equipment, structures, systems and components, and the facility as a whole perform as planned.

6.78 Guidance for the construction of nuclear installations is dealt with in [36].

6.79 For modular storage systems, most of the commissioning will have been completed on loading of the first storage module. Some of the commissioning processes may become a part of regular operation as new modules are brought into service. However, a change in module design may require some of the commissioning steps to be repeated for the new design.

Facility operation

Requirement 19: Facility operation

Predisposal radioactive waste management facilities shall be operated in accordance with national regulations and with the conditions imposed by the regulatory body. Operations shall be based on documented procedures. Due consideration shall be given to the maintenance of the facility to ensure its safe performance. Emergency preparedness and response plans, if developed by the operator, are subject to the approval of the regulatory body.

6.80 Instructions and procedures should be prepared for normal operations of the facility, anticipated operational occurrences and design basis accident conditions. Instructions and procedures should be prepared so that the designated responsible person can readily perform each action in the proper sequence. Responsibilities for approval of any deviations from operating procedures that may be necessary for operational reasons should be clearly specified [24].

6.81 The operating organization should ensure that operating procedures relating to the maintaining of subcriticality are subjected to rigorous review and compared with the safety requirements of the design. This may include confirmatory analysis and review by the regulatory body. Some of the factors that should be considered in this review include:

(a) The nature of the waste to be stored;

(b) Geometries necessary to ensure subcriticality;

(c) Waste form and waste packages;

(d) Handling operations;

(e) The potential for abnormal operation;

(f) Dependence of subcriticality on neutron absorbers.

6.82 There are other safety considerations that should be taken into account in the development of operating procedures and contingency and emergency arrangements (GS-G-2.1) [36]. It should be noted that many events would be addressed either as anticipated operational occurrences or as design basis accidents. However, some of these events could also lead to severe accidents, which are beyond the design basis. Whilst the probability of such design extension conditions occurring is extremely low, in the preparation of operating procedures and contingency plans the operating organization should consider events such as the following:

(a) Failure of handling systems, such as severe crane failure or dropping of loads;

(b) Loss of safety related facility process systems such as supplies of electricity, process water, compressed air and ventilation;

(c) Explosions, including those due to the build-up of gases generated by radiolysis;

(d) Fires leading to the damage of items important to safety;

(e) External natural hazards, such as extreme weather conditions and earthquakes;

(f) External human induced hazards (airplane crash, sabotage, and other malicious acts).

6.83 Operating experience and events at the facility and reported by similar facilities should be collected, screened, analysed and/or reviewed in a systematic way. Conclusions should be drawn and implemented by means of an appropriate feedback procedure. Any new standards, regulations or regulatory guidance should also be reviewed to check for their applicability for safety at the facility. This feedback should be taken for both design and operation.

Operational limits and conditions

6.84 Operational limits and conditions are developed on the basis of the facility design, its safety assessment and the result of its commissioning, and usually comprise the minimum staffing requested for safety during operational stage.

Maintenance

6.85 In general, the maintenance schedule should take into account:

(a) analysis of maintenance requirements on the basis of previous experience or other applicable data (such as manufacturers' recommendations);

(b) work planning in relation to the availability of skilled personnel, tools and materials (including spare items);

(c) the monitoring programme for radiation protection and industrial safety;

(d) the potential for a loss of containment;

(e) impact to operating facilities/maintenance.

6.86 Suitably qualified and experienced operating personnel should be deployed in the approval and implementation of the maintenance, inspection and testing programme and in the approval of associated working procedures and acceptance criteria.

Radiation protection programme

6.87 An operational radiation protection programme should be put in place that ensures that areas of the facility are classified according to the radiation levels and that access control is in place in accordance with the level of classification. It should cover the monitoring of radiation levels in the facility and should include provision to ensure that personnel working in the facility are provided with appropriate dosimetry. A programme of work planning should also be put in place to ensure that radiation exposure is kept as low as reasonably achievable.

Emergency planning and response

6.88 Emergency response procedures should be documented, made available to the personnel concerned and kept up to date. The need for exercises should be assessed. If there is such a need, exercises should be held periodically to test the emergency response plan and the degree of preparedness of the personnel. Inspections should be performed regularly to ascertain whether equipment and other resources necessary in the event of an emergency are available and in working order.

Decommissioning

Requirement 20: Shutdown and decommissioning of facilities

The operator shall develop, in the design stage, an initial plan for the shutdown and decommissioning of predisposal radioactive waste management facilities and shall periodically update it throughout the operational period. The decommissioning of the facility shall be carried out on the basis of the final decommissioning plan, as approved by the regulatory body. In addition, assurance shall be provided that sufficient funds will be available to carry out shutdown and decommissioning.

6.89 The key elements that should be considered for the decommissioning of reactors , as specified in Ref. [23] (WS-G-2.1), include:

(a) The selection of a decommissioning option in which the radionuclides in the secondary waste, technical factors, costs, schedules and institutional factors are taken into account;

(b) The development of a decommissioning plan;

(c) The specification of the critical tasks involved in their decommissioning; in particular decontamination, dismantling, demolition, surveillance and conducting a final radiological survey;

(d) The management functions important for their decommissioning, such as training, organizational control, radiological monitoring, planning and the control of waste management, nuclear security, safeguards and quality assurance.

6.90 An initial version of the decommissioning plan should be prepared during the design of the facility in accordance with requirements and recommendations on decommissioning (WS-R-5, WS-G-2.1) [22, 23].

6.91 During the operation of the facility, the initial decommissioning plan should be periodically reviewed and updated and should be made more comprehensive with respect to:

(a) Technological developments in decommissioning;

(b) Possible natural and human induced hazards of external events;

(c) Modifications to systems and structures affecting the decommissioning plan;

(d) Amendments to regulations and changes in government policy;

(e) Possible long term storage of radioactive waste at the site once the reactor has been shut down.

(f) Cost estimates and financial provisions.

6.92 A comprehensive decommissioning strategy should be developed for sites also having other facilities to ensure that interdependences are taken into account in the planning for individual facilities (WS-G-2.1) [23].

APPENDIX 1. FACILITY SPECIFIC WASTE MANAGEMENT PROGRAMME

The content of a facility specific waste management programme should include, as appropriate:

(a) The description of the processes in which the radioactive waste is generated by the facility;

(b) A description of the radioactive waste streams and the efforts to avoid and minimize them;

(c) A comprehensive list of waste categories and anticipated arisings and inventories, including historic and legacy waste;

(d) Definition of the facility specific waste management principles and objectives;

(e) Identification of waste management options and associated steps as well as interdependences between waste management steps;

(f) Justification of the selection of appropriate management options based on the above and international good practices;

(g) Demonstration that the facility specific waste management programme is compatible with national policy and strategy;

(h) Demonstration, if necessary, of how the safety case is affected by the waste management programme, e.g. modification of the programme to incorporate longer storage than originally designed for would be a safety case impact.

The programme should include provisions for:

(a) Keeping the generation of radioactive waste to the minimum practicable, in terms of type, activity and volume, by using suitable technologies;

(b) Possible reuse and recycling of materials;

(c) Appropriate classification and segregation of waste, and maintenance of an accurate inventory for each radioactive waste stream, with account taken of the available options for clearance and disposal;

(d) Collection, characterization and safe storage of radioactive waste;

(e) Adequate storage capacity for the radioactive waste expected to be generated, and an additional reserve storage capacity;

(f) Ensuring that the radioactive waste can be retrieved at the end of the anticipated storage period, by means of suitable techniques and procedures;

(g) Treating, retreating and conditioning radioactive waste compatible with waste acceptance criteria to ensure safe storage and disposal;

(h) Safe handling and transport of radioactive waste;

(i) Adequate control of discharges of effluents to the environment;

(j) Monitoring of sources (of effluent discharges) and the environment, for the demonstration of regulatory compliance;

(k) Maintaining facilities and equipment for the collection, processing and storage of waste to ensure safe and reliable operation;

(l) Monitoring the status of the containment for the radioactive waste in the storage location;

(m) Monitoring changes in the characteristics of radioactive waste by means of inspection and regular analysis, in particular, if storage is continued for extended periods;

(n) Initiating, as necessary, research and development activities to improve existing methods for processing radioactive waste or to develop new

(o) Systematic evaluation of operating experience and events at the facility;

(p) Adoption and implementation of corrective actions on the basis of the results of monitoring and operating experience feedback;

(q) Emergency preparedness and response.

APPENDIX 2: EXAMPLES OF HAZARDS ASSOCIATED WITH WASTE MANAGEMENT ACTIVITIES AT NUCLEAR REACTORS

Waste management activities	Waste materials	Characteristics	Hazards (radiological)	Hazards (non-radiological)
Nuclear power plants				
• Normal operation, maintenance, and decommissioning of the plant and its associated processing systems for gaseous and liquid radioactive waste	Solid waste: • spent ion exchange resins; cartridge filters and pre-coat filter cake; particulate filters from ventilation systems; charcoal beds; tools; contaminated metal scrap; core components; debris from fuel assemblies or in-reactor components; contaminated rags, clothing, paper and plastic. Liquid waste: • primary coolant in water cooled reactors and water from the fuel storage pools • reactor coolant let-down, evaporator concentrates, equipment drains, floor drains, laundry waste, contaminated oil and waste arising from decontamination and maintenance o Gaseous waste: • leakage from the coolant, the moderator systems or the reactor itself; • degasification systems for the coolant; • condenser vacuum air ejectors or pumps; • exhaust from turbine gland seal systems; • activated or contaminated	• Mostly activated solids from structural, moderator, and coolant materials • corrosion products • fission product contamination arising from the fuel	• Criticality • Alpha bearing materials • Elevated dose rates • Elevated radioactivity concentration levels • Radiation dose (internal/external)	• Radiolysis or chemical reactions generating combustible gases or causing physical degradation or exothermic reactions • Heat generating (amounts of plutonium with even mass numbers and those of americium) • Heavy metal toxicity • Environmental impact

Waste management activities	Waste materials	Characteristics	Hazards (radiological)	Hazards (non-radiological)
	ventilated air; • spent fuel in storage or in handling operations			
Research reactors				
• Normal operation, maintenance, and decommissioning of the plant and its associated processing systems for gaseous and liquid radioactive waste	Solid waste: • Irradiated target cans; • Used irradiation rigs and reactor components (e.g. thermocouples); • Neutron beam guide tubes; • Used control rods; • Waste arising from the pool service area; • Ventilation system waste (charcoal filters, HEPA filters); • Spent ion exchange resins; • Cleaning materials and used personal protective items; • Laboratory waste (gloves, tissue paper, disposable glassware, etc.); • Contaminated items arising from maintenance and other works. Liquid waste: • Cooling water draw-off; • Primary system drains (in the case of light water reactors); • Liquid waste from the demineralized water plant; • The drain of the ventilation water system; • Demineralized waste water recovered from the drainage of large equipment in maintenance operations; • Washbasin and shower liquids;	• Mostly activated solids from structural, moderator, and coolant materials • corrosion products • fission product contamination arising from the fuel	• Alpha bearing materials • Elevated dose rates • Elevated radioactivity concentration levels • Radiation dose (internal/external)	• Radiolysis or chemical reactions generating combustible gases or causing physical degradation or exothermic reactions • Heavy metal toxicity • Environmental impact

Waste management activities	Waste materials	Characteristics	Hazards (radiological)	Hazards (non-radiological)
	• Floor drain liquids; • Liquids from laboratories (these can be radioactive or non-radioactive). Gaseous waste: • Gaseous radioactive elements or compounds from the pools, coolant systems, irradiation facilities and experimental facilities; • Airborne radioactive material produced in ancillary facilities, including fume cupboards and decontamination areas.			

APPENDIX 3. KEY PROPERTIES AND CHARACTERISTICS OF WASTE PACKAGES AND SPENT NUCLEAR FUEL DECLARED AS WASTE

Properties and characteristics	Radioactive waste [4]	Unconditioned fuel	Conditioned fuel
Radiological data: number and types of radionuclides, half-life and activity for each radionuclide, total radioactivity content, activity concentrations, heat output	√		
Fuel data: type, power history, initial fissile content, burn-up and cooling time		√	√
Activity: β–γ and α activity by radionuclide for the major contributors to activity	√	√	√
Criticality safety: geometrical configuration, concentration and inventory of fissile material (e.g. U-233, U-235, Pu-239, Pu-241), presence of neutron poisons and demonstration of non-criticality	√	√	√
Dose rate: neutron and γ dose rate at the surface and at a distance of 1 m	√	√	√
Surface contamination: levels of β–γ and α contamination	√		√
Thermal properties: thermal power, thermal conductivity and predicted maximum temperatures (with and without cooling by engineered systems)		√	√
Physical properties: density; porosity; permeability to water and gases; thermal stability; homogeneity and compatibility with the matrix; percentage of water incorporated, exudation of water under compressive stress, shrinkage and curing; leachability and corrosion rate, tensile strength, compressive strength and dimensional stability	√	Density only	
Chemical properties: pH, main chemical species and compounds, toxic substances and corrosive compounds		√	

[4] Not all elements may be required; the relevant acceptance requirements will define the specific elements required

Properties and characteristics	Radioactive waste [4]	Unconditioned fuel	Conditioned fuel
Mass of waste and/or waste package: total mass (mass of waste form and canister, if applicable)	√	√	√
Quality of canister/container: material specification, tare weight, dimensions, corrosion resistance, characteristics of lidding and seal arrangements, quality of seal weld, material certifications from manufacture; quality assurance records from conditioning process; compatibility with the waste form			√
Quality of waste package: diffusion and leaching of radionuclides in an aqueous medium; release of gas under standard atmospheric conditions or the conditions for acceptance; diffusion of tritium under standard atmospheric conditions or conditions for acceptance; capability for the fixation and retention of radionuclides; water-tightness and gas-tightness of the package sealing device	√		
Stackability and handling: number of packages stackable without deformation, results of package drop tests and requirements for lifting packages (e.g. lifting features)	√		√
Package labelling: unique permanent identification	√		√
Quality of matrix material: certification and quality assurance records for matrix material	√		√
Mass fractions of waste form: fractions of waste, fixation materials and additives	√		√
Robustness of the waste package: behaviour under temperature cycling; sensitivity to elevated temperatures and behaviour in a fire; behaviour under conditions of prolonged radiation exposure; sensitivity of the matrix to water contact; resistance to the action of micro-organisms; corrosion resistance in a wet medium (for metal containers); porosity and degree of gas-tightness; potential for swelling due to the internal build-up of evolved gases.	√		
Stability of the package: corrosion and/or leaching behaviour in relevant atmospheres or aqueous solutions, data on long term corrosion and data extrapolation, influence of surface area and solubility of radionuclides in relevant aqueous solutions		√	√

Properties and characteristics	Radioactive waste [4]	Unconditioned fuel	Conditioned fuel

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