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Predisposal Management of Radioactive Waste from Nuclear Fuel Cycle Facilities

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Draft Safety Guide

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PREDISPOSAL MANAGEMENT OF

RADIOACTIVE WASTE FROM

NUCLEAR FUEL CYCLE FACILITIES

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1 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) arises from a number of activities involving the use of radioactive material. The nuclear fuel cycle produces a wide range of radioactive waste, including inter-alia: high-level waste (e.g., vitrified waste from spent fuel reprocessing), intermediate-level waste that typically contains longer-lived radionuclides, and low-level waste that typically contains short lived radionuclides and limited quantities of long lived radionuclides. The approach to treating liquid and gaseous waste streams influences the amount of effluent generated for discharge, the approach to clearance and recycling influences the amount of waste for storage and disposal; therefore, the optimization of the overall radioactive waste management process (predisposal waste management and disposal) is very important. Thus, a key feature of predisposal management of radioactive waste at fuel cycle facilities is the interdependence between the steps of predisposal radioactive waste management as well as disposal within a national framework of waste management.

1.2 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]. Similar safety aspects and expectations for good practice have been set down in international legal instruments, such as the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention) [5].

1.3 GSR Part 5 [4] and NS-R-5 [6] require that measures to prevent or restrict the generation of radioactive waste are considered in the design of nuclear facilities and the planning of activities that have the potential to generate radioactive waste. This recognizes that the management of the material and processes that result in radioactive waste is the key to avoiding or minimizing quantities produced therefore minimizing the overall environmental impact.

1.4 Predisposal management of radioactive waste, as the term is used in GSR Part 5 [4], covers all steps in the management of radioactive waste from its generation up to (but not including) disposal, including waste processing (pretreatment, treatment and conditioning) as well as storage and transport. While the generation of radioactive waste at fuel cycle facilities is considered as part of normal operations, it is necessary to address the interdependences between the operational demands of each of the various steps in waste management. These activities include;

- Pretreatment may include waste assay and characterisation, 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 to retrieve the waste at a later date for clearance, processing and/or disposal at a later time, or, in the case of effluent, for authorized discharge.

1.5 The generation of radioactive waste cannot be prevented entirely but is required to be kept to the minimum practicable (‘waste minimization’). Waste minimization should form an essential component of a radioactive waste management strategy. Waste minimization relates to type, volume and activity. Measures to prevent or minimize the generation of radioactive waste have to be put in place at the 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 It may be that not all processing steps are necessary for particular categories of radioactive waste. The type of processing necessary will depend on the particular categories of waste, its form and characteristics, and the overall approach to its management, including consideration of the generation of secondary waste. Where appropriate, the waste material resulting from the pretreatment and treatment may be reused or recycled, or cleared from regulatory control in accordance with national regulations. Such activities limit the eventual challenge associated with waste management. The remaining radioactive waste from all sources that is not cleared, discharged or reused needs to be managed safely over its entire lifetime. Lifetimes of certain waste streams are such that management may fall outside the ability of the operating organization[1] to deliver or may be dictated by the availability of national assets (e.g. deep geological repository).

1.7 GSR Part 1 [2] requires the government to make provision for the safe management and disposal of radioactive waste arising from facilities and activities. These provisions should be included as essential elements of the governmental policy and the corresponding strategies over the

[1] The operating organization includes the generator of radioactive waste, operators of facilities for the predisposal management of radioactive waste, and organizations that carry out decommissioning activities, and [4].

lifetime of facilities and the duration of activities. Importantly there is also a requirement for the government to enforce continuity of responsibility between successive authorized parties.

1.8 In some instances, the predisposal waste management solution has to be found optimizing conflicting demands. Such considerations include the balancing of exposures of workers and/or those of members of the public, the short term and long term risk implications of different waste management strategies, the technological options available and the costs.

1.9 To select the most appropriate type of pretreatment, treatment and conditioning for the radioactive waste when no disposal facility has been established, reasonable assumptions have to be made about the likely disposal option. In cases where waste are to be stored for extended periods, conservative assumptions need to be made e.g. the time scale in which a disposal facility will be available. All assumption made that impact on the selection of pre-disposal management options should be properly justified. It is necessary to address the interdependences and the potential conflicts between the operational demands of each of the various steps in waste management, while ensuring that the waste is contained and stored in a passive, safe condition. In striking a balance between choosing an option and retaining flexibility, it is important to ensure that safety is not compromised.

OBJECTIVE

1.10 The objective of this Safety Guide is to provide operating organizations that generate and manage radioactive waste as well as regulatory bodies and Government bodies with recommendations on the predisposal management of radioactive waste generated by nuclear fuel cycle facilities (excluding nuclear power plants and research reactors and facilities for the mining or processing of uranium ores or thorium ores — both within larger facilities and at separate, dedicated waste management facilities, including centralized waste management facilities).

1.11 The Safety Guide presents recommendations and guidance on how to meet the requirements established in GSR Part 5 [4], as well as in GSR Part 1 [2], GSR Part 3 [3], NS-R-5 [6], and The Management System for Facilities and Activities (GS-R-3) [7].

1.12 Once published, this Safety Guide will supersede Safety Guides WS-G-2.5, Predisposal Management of Low and Intermediate Level Radioactive Waste [2]; and WS-G-2.6, Predisposal Management of High Level Radioactive Waste[3], both of which were issued in 2003.

SCOPE

1.13 This Safety Guide provides guidance on the predisposal management of all types of radioactive waste (including high level waste) generated by nuclear fuel cycle facilities (excluding

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of Low and Intermediate Level Radioactive Waste, IAEA Safety Standards Series No. WS-G-2.5, IAEA, Vienna (2003).
[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of High Level Radioactive Waste, IAEA Safety Standards Series No. WS-G-2.6, IAEA, Vienna (2003).

nuclear power plants, research reactors and facilities for the mining or processing of uranium or thorium ores). These facilities may be within larger facilities or at separate, dedicated waste management facilities (including centralized waste management facilities). It covers during all phases in their lifecycle of the facilities, including siting, design, construction, commissioning, operation, shutdown, and decommissioning. It covers all 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). It covers radioactive waste generated during normal operation and accident conditions. While the recommendations in this Safety Guide are applicable to the generation of radioactive waste throughout the entire lifecycle of nuclear fuel cycle, other operational activities at nuclear fuel cycle facilities are outside the scope of this Safety Guide. A classification scheme for radioactive waste and recommendations on its application to the various types of radioactive waste are provided in General Safety Guide GSG-1, Classification of Radioactive Waste [8].

1.14 While storage and transport are included in the definition of predisposal management of radioactive waste, they are not dealt with in detail in this Safety Guide. These are dealt with in the Safety Guides WS-G-6.1, Storage of Radioactive Waste [9] and SSG-15 [10]. Transport of radioactive waste is subject to the requirements of the Safety Requirements SSR-6 [11] and is not dealt with in detail in this Safety Guide. Spent fuel that is transferred to or destined for reprocessing facilities is not considered radioactive waste.

1.15 This publication is primarily targeted at complex situations that are typical in facilities for the predisposal management of radioactive waste arising from the nuclear fuel cycle and those wastes arising from facilities associated with medical isotopes produced from irradiation of nuclear materials. However, the regulatory body is required to adopt a graded approach, taking account of the hazards, the complexity and stage in the lifetime of the facilities and activities, and the characteristics of the waste, and should apply the requirements as necessary and as appropriate.

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 IAEA Nuclear Security Series No. 13 [12], No. 14 [13], 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 SF-1 [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. This includes the associated transport of radioactive waste.

2.2 The Safety Requirements GSR Part 1 [2] , GSR Part 5 [4], NS-R-5 [6] and GS-R-3 [7] provide requirements on management system that integrates, among others, all elements of management including safety, health, environmental, security, quality and economic elements so that safety is not compromised. A key component of such a system in an organization is a robust safety culture.

2.3 In the context of fuel cycle facilities, the control of events initiated by chemical hazards can have a significant bearing on achieving the fundamental safety objective. Events initiated by chemical hazards are required to be considered in the design, commissioning and operation of the facility. Activities at fuel cycle facilities may also include industrial processes that pose additional hazards to site personnel and the environment.

2.4 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, environmental impacts, radiation hazards that may transcend national borders, and the potential impacts and burdens on people of present and future generations and populations remote from present facilities and activities that give rise to radiation risks (SF-1) [1].

RADIATION PROTECTION

2.5 GSR Part 3 [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].

2.6 Requirements for radiation protection have to be established at the national level, with due regard to GSR Part 3 [3]. In particular, GSR Part 3 [3] requires radiation protection to be optimized for any persons who are exposed as a result of activities in the predisposal management of radioactive waste, with due regard to dose constraints, and require the exposures of individuals to be kept within specified dose limits.

2.7 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 GSR Part 3 [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 GSR Part 3 [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.

2.8 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, 14, 15].

2.9 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 SSR-6 [11].

PROTECTION OF THE ENVIRONMENT

2.10 Requirements for protection of the environment that are associated with predisposal management of radioactive waste have to be established by the relevant national regulatory bodies, with all potential environmental impacts that could reasonably be expected being taken into consideration (SF-1, GSR Part 3) [1, 3].

2.11 As stated in NS-R-5 [6] and GSR Part 3 [3] 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.

2.12 NS-R-5 [6] further states that the operator has a duty in the area of radioactive waste management to take measures to avoid or to minimize the generation of radioactive waste, including the consideration of requirements arising from disposal, with the aim of minimizing the overall environmental impact. This includes ensuring that gaseous and liquid radioactive discharges 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).

2.13 Clearance (the removal of radioactive material within authorized practices from any further regulatory control) and the control of discharges (on-going or anticipated releases to the environment of gaseous or liquid radioactive material that originate from regulated nuclear facilities during normal operation) are addressed in IAEA Safety Standards Series No. RS-G-1.7 [16] and WS-G-2.3 [17], 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 [1] 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 ensuring that a national policy and strategy are established for the management of radioactive waste. 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 stages 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 duties and 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 [5] and other relevant Directives and Conventions.

3.3 In order to implement the national policy and strategy, some Government responsibilities can be placed on a government institution. If more than one government institution is involved, effective arrangements should be made to ensure that their responsibilities and functions are clearly defined and coordinated, in order to avoid any omissions or unnecessary duplication. This should be organized in such a way as to achieve consistency and to enable the necessary feedback and exchange of information.

3.4 In relation to the predisposal management of radioactive waste, 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. It should be ensured that the regulatory framework takes this into account and delivers effective control.

3.5 The legal framework should ensure that the construction of facilities for the predisposal management of radioactive waste adjacent to an existing facility that could prejudice the safety of either facility is required to be monitored and controlled by means of planning requirements or other legal instruments.

3.6 The management of radioactive waste may entail the transfer of radioactive waste from one operating organization to another and also from one national or governmental entity to another. Such transfers create interdependences in legal 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 (including provisions for regulatory control and authorization), in particular with respect to the interface with the storage of radioactive waste and its transfer between operating organizations.

3.7 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 (GSR Parts 1 and 5) [2, 4].

3.8 Responsibility for safety should be ensured by means of a system of authorization by the regulatory body. For transboundary transfers between States, authorizations from the relevent national regulatory bodies within the legal and regulatory frameworks of both States are required (GSR Parts 1 and 5) [2, 4].

3.9 A mechanism for providing adequate financial resources should be established to cover future costs; in particular, the costs associated with decommissioning of the fuel cycle facility and waste management facilities and also the costs of long term management of radioactive waste (including storage and disposal). The financial mechanism should be established at each stage of licensing and updated as necessary. Consideration should also be given to provision of the necessary financial resources in the event of a premature shutdown of the predisposal radioactive 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 (both current and anticipated, including waste generated during decommissioning and dismantling of facilities) and update it at regular time intervals. This inventory should address the various waste classes as identified in GSG-1 [8] or in the national waste classification scheme, taking into account their long term management including disposal; both from a technical point of view as well as from a human and financial resources point of view.

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 processing and disposal. In judging the sufficiency of capacity, account should be taken of process uncertainties, system reliability and availability and the possible need for redundancy.

3.12 The government should consult interested parties (i.e. those who are involved in or are affected by radioactive waste management activities) on matters relating to the development of policies and strategies that affect the management of radioactive waste, and should take due account of the concerns of the public. Communication with and involvement of the public is very important for decision making.

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[4] 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 licences, 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.

3.13 Regulatory body main responsibilities as related to the safe management of radioactive waste include the development of regulatory requirements; procedures for licensing, compliance verification and enforcement; and guidance to be followed by licensees. Responsibilities also include contributing to the technical basis and inputs for the establishment of policies, safety principles and associated criteria, and for establishing requirements or conditions to serve as the basis for regulatory decisions. The

[4] 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).

regulatory body should also provide specific guidance on how to meet requirements as related to the safe management of radioactive waste.

3.14 The regulatory review of the licensing documentation (safety case) for the predisposal management of radioactive waste at fuel cycle facilities should follow a graded approach, particularly considering the phases in the lifetime of the predisposal radioactive waste management facility or activities. At each phase in the lifetime of these facilities or activities (including decommissioning), the safety case should be updated by the operator and reviewed by the regulatory body.

3.15 General recommendations for regulatory inspection and enforcement actions relating to radioactive waste management facilities are provided in GS-G-1.3 [18]. The regulatory body should periodically verify that the key aspects of the operation of the radioactive waste management facility 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 facility 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 [19].

3.16 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.

3.17 The regulatory body should consider the licensing strategy to be adopted (in accordance with the national legal and governmental framework), for example:

(a) A licence issued for the entire lifetime of the generation, processing and/or storage system and/or facility, which encompasses the whole anticipated operating period, including periodic review of safety cases and safety assessments, as elaborated in Section 5; or

(b) A licence issued for a specified time period with the possibility for its renewal at or prior to expiration.

(c) Possible long term storage of radioactive waste after the fuel cycle facility has been shutdown and decommissioned.

3.18 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, as far as practicable, 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.

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.

3.19 The operating organization is responsible for developing site specific policies and strategies consistent with overall national policies and strategies. Furthermore 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.

3.20 The operating organization is responsible for the safety of all activities associated with the management of radioactive waste at its facilities (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 processes in order to strengthen the safety culture [7].

3.21 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. Ownership of the waste should always be clearly identified. Information about changes in ownership of the radioactive waste or changes in the relationship between the owner and the operating organization of the predisposal radioactive waste management facility should be provided to the regulatory body and, where required, to government institutions.

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

(a) Application to the regulatory body to obtain regulatory approval for the radioactive waste management facility or activity by providing an acceptable safety case;

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

(c) Development of operational limits, conditions and controls including waste acceptance criteria consistent with the safety case for approval by the regulatory body;

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

(e) Conducting all activities in accordance with the requirements of the safety case, the licence conditions and the applicable regulations;

(f) Taking into consideration possible long term storage of radioactive waste after the fuel cycle facility has been decommissioned;

(g) Ensuring that the information recorded at a particular step in the predisposal radioactive waste management process is aligned with the information required to demonstrate compliance with the downstream waste acceptance criteria, e.g. safety case for disposal.

(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 and any events that occur at the facility and which have to be reported to the regulatory body) and communicating with relevant interested parties and the general public.

(j) Ensuring operations are in compliance with criteria for either the removal or discharge of radioactive material as approved or authorized by the regulatory body;

(k) Limiting onsite contamination and occupational exposure;

(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 is appropriately processed to comply with the acceptance criteria for storage and disposal, as well as transport requirements. In situations where acceptance criteria for disposal are not yet available, ensuring that the management of radioactive waste is based on reasonable assumptions for the anticipated disposal option; and making provisions for relocating the radioactive waste for storage and/or disposal.

(n) Ensuring that spent fuel declared as waste is managed appropriately taking into account its higher activity, heat generation and potential for criticality (SSG-27) [20]. Appendix 1 provides a listing of the typical properties and characteristics that should be considered for waste packages and spent fuel declared as waste.

(o) Due consideration and decision making in the following cases:

- management of waste if no disposal option is available;
- management of waste that would need to be stored over long periods of time prior to disposal; or
- management of waste in case of decay storage with the purpose of clearance or reclassification.

3.23 The operating organization should develop a facility specific waste management programme, integrated with other relevant on site programmes (e.g. multi-facility sites), 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 radioactive waste management:

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. Processing of radioactive waste to ensure its safe storage and disposal.

More detailed guidance on facility-specific waste management programmes are provided in Appendix 2.

3.24 At the design stage, the operating organization is required to prepare an initial decommissioning plan The decommissioning plan should consider possible long term storage and disposal of radioactive waste after permanent shutdown of the facility[5]. For new facilities, features that will facilitate decommissioning should be taken into consideration at the design stage; such features should be included in the initial decommissioning plan together with information on

[5] The term 'permanent shutdown', as used in this publication, means that the reactor has ceased operation and will not be restarted, i.e. it will no longer be used for its intended purpose. Permanent shutdown is a state that is different from a planned shutdown (e.g. due to refueling outage, maintenance, inspection or refurbishment) or an unplanned shutdown (e.g. due to a scram), during which the reactor is not in operation

arrangements for how the availability of the necessary human and financial resources and information would be assured.

3.25 For existing facilities without a decommissioning plan, such a plan should be prepared by the operating organization as required by or agreed with the regulator. The decommissioning plan should be reviewed and updated at each phase in the lifetime of the facility. Requirements on decommissioning are established in GSR Part 6 [21] and recommendations are provided in WS-G-2.4 [22].

3.26 For fuel cycle facilities decommissioning plans need to consider the likelihood that high activity waste will be present and the need to avoid high doses to the workers during decommissioning, the availability of suitable reprocessing and storage facilities and the potential for criticality incidents.

3.27 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 nature of the radioactive waste being managed, the objectives of the radioactive waste management processes, the safety case, associated 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. Trained and qualified radiation protection officers should be appointed to oversee the application of radiation protection requirements.

3.28 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 assessment/case and with the safety requirements established by the regulatory body. A report summarizing the results of such these pre-operational and commissioning tests (inactive commissioning) should be prepared and submitted to the regulatory body for review and acceptance.

3.29 The operating organization should ensure that the removal of radioactive material within authorized practices from any further regulatory control and the control of discharges of radioactive and other potentially hazardous materials to the environment are in accordance with the conditions of licence or authorization, and limit on-site contamination and occupational exposure with account taken of the results of optimization of protection and safety.

3.30 Records should be maintained for discharges, clearance of materials from regulatory control, reuse or recycling of materials, as well as delivery of radioactive waste to an authorized disposal facility and transfers to other facilities. Such records should be retained until the facility has been fully decommissioned, or alternatively for a period of time after full decommissioning as agreed with the regulatory body.

3.31 The operating organization should develop and maintain a records system on the generation, processing, storage and transfer of radioactive waste (e.g. for further processing, storage or disposal), which should include among others the radioactive inventory, location and characteristics of the radioactive waste, and information on ownership, origin and transfer location [23]. Such records should be preserved and updated, to enable the implementation of the facility specific radioactive waste management programme. Such a records system should be managed by the operating organization as required by the national authority or regulatory body.

3.32 The operating organization should prepare plans and implement programmes for personnel area, and environmental monitoring. Such programmes should be evaluated periodically

3.33 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 which 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, further processing or disposal of radioactive waste.

3.34 As stated in GSR Part 5 [4], the operating organization is required to put in place appropriate mechanisms for ensuring that sufficient resources, including financial are available to undertake all necessary tasks throughout the lifetime of the facility, including its decommissioning, possible long term storage of radioactive waste at the site after the facility has been permanently shut down, and disposal (even when a disposal option is not yet available). In certain circumstances financial resources may need to be provided by the waste owner.

3.35 The operating organization should develop onsite emergency arrangements, including onsite emergency response plan for preparedness and response for a nuclear or radiological emergency on the basis of the hazards associated with the facility and activities within the site and the potential consequences of an emergency (GSR-2, GS-G-2.1, GSG-2) [24, 25, 26].

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.

Requirement 21 (GSR Part 5, Ref. [4]): System of accounting for and control of nuclear material
For facilities subject to agreements on nuclear material accounting, in the design and operation of predisposal radioactive waste management facilities the system of accounting for and control of nuclear material shall be implemented in such a way as not to compromise the safety of the facility.

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 and neither safety nor security is compromised.

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

4.3 When material needs to be accessed for waste management or safeguard purposes, all the requirements of radiation protection, waste management and nuclear security should be taken into account. Specific recommendations on nuclear security in the management of radioactive waste are provided in the publications of the IAEA Nuclear Security Series [12, 13].

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.

4.4 Interdependences exist among all steps in the management of radioactive waste, from the generation of the waste up to its disposal, discharge or clearance. 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 storage and disposal. At all times due consideration should also be given to the interdependency between safety and environmental protection as described in Chapter 2.

4.5 The following aspects in particular should be addressed:

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

(b) The establishment of, and the confirmation of conformance with acceptance criteria

4.6 A key feature of predisposal radioactive waste management within fuel cycle facilities is the nature of their interdependence and often their place within a national framework. Such interdependences create safety case interfaces, including waste acceptance criteria and operational limits and conditions and should be carefully managed along with any deviations that might occur for instance associated to those uncertainties Thus it is important to highlight that the interdependences should be taken into consideration to ensure that an integrated approach to safety is adopted; and that safety (within a waste management framework that also considers waste minimization via adoption of the waste management hierarchy) is optimized as required by the ALARA principle. All secondary wastes produced in the facility should undergo an approval process for further specific actions.

4.7 Compliance of the waste packages with the waste acceptance requirements of the chosen disposal option (or in the next step of the management process) should be considered and demonstrated; however, in the case that a disposal option has not been identified at a certain stage, reasonable assumptions should be made about the likely disposal options and these should be set down clearly.

4.8 For many programmes for the predisposal management of radioactive waste, decisions have to be made before the waste acceptance requirements for disposal are finalized. Decisions on the predisposal management of radioactive waste should be made and implemented so as ultimately to ensure compliance with the waste acceptance requirements for the selected or anticipated disposal option. In addition, in the design and preparation of waste packages for the disposal of radioactive waste, consideration should be given to the suitability of the packages for transport and storage, including retrieval, and to their suitability for handling and emplacement in a disposal facility on the basis of the anticipated waste acceptance requirements.

4.9 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 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, waste package and/or waste container should be ensured. Independent of this, all radioactive waste arisings are required to be managed. This requires decisions on waste forms to be produced which, in this situation, must be made before all radioactive waste management activities are finally established.

4.10 If there is no disposal facility yet available or defined, then an interim position should be defined such that either options are not foreclosed or all reasonably practicable steps have been taken to prepare waste for the anticipated disposal option. The interdependences between the waste generator, the radioactive waste management facility and the (existing or anticipated) disposal facility should also be defined.

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.

4.11 The requirements on management systems (safety, health, environmental, nuclear security, quality and economic elements) for all stages in the lifetime of a predisposal radioactive waste management facility are established in GS-R-3 [7]. General guidance on the management systems for facilities and activities is given in GS-G-3.1 [25], while specific guidance on a management system for the processing, handling and storage of radioactive waste is provided in GS-G-3.3 [23].

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 As stated in GS-R-3 [7], an integrated management system is required to be established, implemented, assessed and continually improved by the operating organization and it should be applied to all steps of the predisposal management of radioactive waste. Such an integrated system covers all aspects of management including arrangements for quality assurance and control. The management system should foster a safety culture that should be aligned with the goals of the operating organization and should contribute to their achievement. Management systems should make provision for siting, design, construction, commissioning, operation, maintenance and decommissioning of the predisposal radioactive waste management facility. Examples of key planning activities relevant to the lifecycle of a predisposal radioactive waste management facility are provided in Appendix 3.

4.14 For achieving and maintaining an integrated management system the following long term aspects (taking into account the duration of waste processing and storage periods) 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 predisposal 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 financial resources (the adequacy of resources for maintenance and eventual decommissioning of facilities and equipment may need to be periodically reviewed over operational periods that may extend over decades);

(f) Preservation and quality of records and information (e.g. details of radioactive waste inventories facility siting, design, operation, and safety case development); and

(g) Provision for review to ensure that the goals of the management system can still be met.

RESOURCE MANAGEMENT

4.15 Radioactive waste management activities will require financial and human resources and the necessary infrastructure. Senior management of all facilities involved in the generation and management of radioactive waste 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.

4.16 Management of radioactive wastes can take place over long timescales. In such circumstances the government, regulators, waste owners and site operators should address the sustainability of all the required resources to maintain safety and environmental protection in appropriate policies, strategies and plans.

PROCESS IMPLEMENTATION

4.17 In the design of radioactive waste management facilities to be operated over a long period (e.g. long term radioactive waste storage facilities that remain at the site after other facilities have been permanently shut down) consideration should be given to the incorporation of measures that will ease operation, maintenance of equipment and eventual decommissioning of the facility.

4.18 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 long term 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 that need to be retained for an extended period should be stored such that the likelihood and consequences of loss, damage or deterioration due to unpredictable events such as fire, flooding or other natural or human induced hazards are minimized (e.g. principle of redundancy). 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.

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 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 and guidance for the safety case for predisposal radioactive waste management at fuel cycle facilities are as follows:

(a) Requirements on the safety case and supporting safety assessment for predisposal management of radioactive waste are set in GSR Part 5 [4] and guidance is provided in GSG-3 [26];

(b) Requirements on the safety case and periodic safety reviews of fuel cycle facilities are set in NS-R-5 [6] and guidance are provided in SSG-5, SSG-6, and SSG-7 [27, 28, 29];

(c) Requirements on the safety assessment for all facilities and activities are set in GSR Part 4 [30].

5.2 The licensing documentation and the periodic safety reviews of fuel cycle facilities normally include the safety assessment and review of the radioactive waste management systems within the facility (NS-R-5, SSG-5, SSG-6, SSG-7) [6, 27, 28, 29]. This includes at a minimum a safety analysis report and operational limits and conditions that include:

(a) Description of the radioactive waste management structures, systems and components (SSCs) (waste generation and control, waste treatment and conditioning, storage);

(b) safety principles and criteria for the protection of operating personnel, the public and the environment;

(c) analysis of the hazards associated with the operation of the facility and assessment of accidents;

(d) demonstration of compliance with the regulatory requirements and criteria;

(e) identification of SSCs important to safety.

5.3 As stated in GSG-3, compliance with the requirements for the documentation of a safety case for the predisposal management of radioactive waste presents a number of challenges, due to the wide scope of safety concerns at various fuel cycle facilities, for example, associated with the management of large quantities of toxic and reactive chemicals. GSG-3 provides guidance on the use of criteria (e.g., safety significance, complexity and maturity of the facility or activity) on the application of the graded approach and to inform decisions regarding the amount of effort that should be taken into account, Greater attention should be paid to the facilities and processes involving significant chemical and physical processing, material transfer and human intervention.

5.4 For waste generated within a fuel cycle facility, the safety case should identify interfaces between the radioactive waste management facility and operational limits and conditions of the fuel cycle facility. In the event of a dedicated (centralized) waste management facility, the safety case and supporting safety assessment should demonstrate that consideration has been given to all steps in the generation and processing of the waste up to its disposal, including clearance of materials from regulatory control and authorized discharge of effluents, and to their overall compatibility. Thus, operational and long term safety aspects of waste management should be considered, as well as the possible need for future handling, processing and storage of the waste and the risks and doses that may be associated with these activities.

5.5 As predisposal management of radioactive waste within fuel cycle facilities is often a flow process with materials transferring directly from step to step, it is important to recognize the interdependences of these when considering data and models and their inputs and outputs.

5.6 The safety case should include identification of uncertainties in the performance of the waste at the waste management facility and related 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 by the regulator of the inputs and interdependences between the boundaries of interlinking safety cases. Guidance on the management of uncertainties is provided in GSG-3 [26].

5.7 Variation and uncertainty in the form and composition of the waste is a particular challenge for some types of legacy waste for which the accuracy and completeness of historical records may be limited. Safety assessments for the predisposal management of legacy waste should be performed in a comprehensive and detailed manner.

5.8 A description of the specific SSCS and activities associated with the generation and processing of radioactive waste at the fuel cycle facility is the basis from which the identification, characterization and quantification of the hazards may be determined (e.g. management of natural uranium versus irradiated materials). As described in [26], this description should include information about:

(f) A description of the facilities and equipment used for processing and storing radioactive waste, including location in relation to collocated or nearby facilities or activities, equipment, relevant design features, and expected lifetime(s);

(g) A description of the radioactive waste this is generated and processed, including data on the radioactive waste streams (e.g., origin of the waste; volume, mass and form of the waste; radionuclides of concern; radioactive content, presence of fissile materials; and other physical, chemical and pathogenic properties), including secondary waste streams and material that is cleared or discharged.

5.9 A description of the quantities, chemical and radiological characteristics of the waste are important in characterizing and assessing hazards associated with specific waste generation and processing activities, but these are facility-specific and thus should be considered within the framework of the decision making process, using a graded approach. The description should take into consideration additional hazards (e.g., fissile, thermal, physical, reactive) arising from activities or processes for its management, and should identify where initiating events (e.g., operational, external or natural phenomena) could create the potential for causing harm to human health and/or the environment.

5.10 In the case of centralized waste management facilities where one or more waste streams are received from separate sources the assessment should:

(a) Be carried out for all waste categories received and activities related to their specific processing

(b) Have regard to areas within the facility where there is a potential for individual wastes to interact

(c) Identify safety measures and engineering aspects for each waste category

(d) Review and consolidate the safety measures to determine the optimum safety measures and engineering aspects for the safety case for the overall facility. Optimization should ensure no conflicts or duplications occur.

(e) Identify consolidated operating limits and conditions as a basis for safe operation and to ensure compliance with the safety criteria.

5.11 Appendix 4 provides examples of hazards associated with typical activities for predisposal management of radioactive waste in fuel cycle facilities. Appendix 5 provides examples of hazards associated with dedicated waste management facilities. Appendix 6 identifies hazards associated with, or that could affect waste management at typical fuel cycle facilities. These examples are not exhaustive; rather, they are intended to assist in the identification and subsequent assessment of hazards. GSG-3 (Annex 1) provides further guidance on the identification and assessment of hazards and potential initiating events relevant to typical activities for predisposal management of radioactive waste.

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

5.13 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).

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 Management options such as clearance (including for recycling and reuse) 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 with preference given to recycling, reuse and clearance. The limitations and controls for clearance and the control of discharge activities should be set by the regulatory body [16, 17].

6.3 At various steps, when necessary, it should be verified that the waste complies with acceptance requirements. Therefore the waste should be characterized and classified at the various steps of its management, as necessary. Waste packages should have a system of identification that is unique, able to be linked to its associated records and that takes account of the need to be read in the long term future up to disposal.

6.4 The ultimate goal of predisposal management of radioactive waste that is not cleared, discharged or reused is to make the waste suitable for disposal (or for storage if no disposal facility is available). This implies that the final waste form and waste package have to comply with the waste acceptance requirements of the disposal facility as well as the operational safety requirements of the storage facility. In situations where acceptance criteria for disposal are not yet available, waste acceptance criteria should be based on reasonable assumptions for the anticipated disposal option.

6.5 Radioactive waste is handled and transported between and within the various steps in predisposal management of radioactive waste. Requirements and guidance on transport of radioactive waste can be found in SSR-6 [11] and TS-G-1.1 [31].

6.6 The on-site transport of radioactive waste may not need to meet all the requirements for off-site transport (SSR-6) [11], 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 (GSR Part 5, Ref. [4]): 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 Design features and operational procedures for waste generation and control at nuclear fuel cycle facilities should include the following aspect (NS-R-5, SSG-5, SSG-6, and SSG-7) [6, 27, 28, 29]:

(a) The careful selection of materials, processes and SSCs for the facility;

(b) The selection of design options, process and materials selection, construction methods, commissioning, and operational procedures that facilitate waste minimization throughout the facility facility’s entire lifecycle, including its final decommissioning;

(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 the spread of contamination;

(f) Provisions for the decontamination of zones and equipment to prevent the spread of radioactive 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, in order to minimize the generation of secondary radioactive waste. 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 the qualification of a conditioning process the programme should be designed in such a way that the number of test specimens using actual radioactive waste is minimized. 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 allow reclassification of the waste at a lower level or to enable regulatory control to be removed from the waste.

CHARACTERIZATION AND CLASSIFICATION OF WASTE

Requirement 9 (GSR Part 5, Ref. [4]): 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.

6.10 As stated in GSR Part 5 [4], radioactive waste is required to be characterized at various stages in its predisposal 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 waste.

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

(a) Origin, the waste type and the physical state of the raw waste (solid, liquid, gaseous);

(b) Criticality risk [31];

(c) Radiological properties (e.g. half-life, activity and concentration of nuclides, dose rates, heat generation);

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

(e) Chemical properties (e.g. composition of raw waste, water content, solubility, corrosion related properties, combustibility, gas generation properties, solubility, chemotoxicity);

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

(g) Intended methods of processing, storage and disposal

6.12 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, particularly with respect to facility decommissioning. Note that priority should be given to characterization of raw waste at the point of its generation.

6.13 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, including modelling, 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 accepted by the regulatory body in the authorization process.

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

6.15 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 processing, 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.

6.16 Details of the purpose, methods and approaches to the classification of radioactive waste are provided in GSG-1 [8]; Annex III of which also provides information on origin and types of radioactive waste, including waste arising from nuclear fuel cycle facilities. It should be noted that the classification scheme is based on the long term management (disposal) of the radioactive waste.

6.17 It should be borne in mind that most fuel cycle radioactive waste contains alpha emitting radionuclides. Flammable, pyrophoric, corrosive or other hazardous materials should also be given special attention. Care should be taken to avoid mixing waste of these types.

6.18 Liquid radioactive waste should be characterized 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.

6.19 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, thermal treatment or immobilization.

6.20 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.

6.21 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. 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, especially any exothermic reactions in order to avoid uncontrolled or unexpected reactions that could cause the unplanned release of volatile radionuclides or radioactive aerosols.

PROCESSING OF RADIOACTIVE WASTE

Requirement 10 (GSR Part 5, Ref. [4]): 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 both during normal operation and in accident conditions that could occur in the handling, storage, transport and disposal of waste.

6.22 The predisposal management of radioactive waste may include one or more processing steps, e.g. pretreatment, treatment and conditioning (see Appendix 7). These steps may take place in stationary or mobile facilities. The handling, storage and transport of the waste may be necessary within, between and after such steps.

6.23 Processing of radioactive waste can either facilitate the recycling and re-use of waste items, or produce conditioned waste suitable for subsequent handling, storage, transport and disposal. If reuse or recycling is not feasible, and no disposal facility is available, reasonable 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.

6.24 Radioactive waste should be processed as early as practicable taking into account different aspects, such as safety, security and economy in order to convert it into a passive form and to prevent its dispersal during storage and disposal. The balance between potential mobility of the waste, ALARA considerations and operational impact should be part of the consideration.

Pretreatment

6.25 Pretreatment operations such as waste collection, segregation, chemical adjustment and decontamination may result in a reduction in the amount of waste needing further treatment and conditioning, 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.

6.26 The first operation in the pretreatment of radioactive waste can be 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 waste containing long lived radionuclides. 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 discharged, either directly or after allowing for a decay period.

6.27 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 thermal treatment 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.

6.28 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.

6.29 While the volume of organic radioactive liquid waste is small relative to that of aqueous radioactive waste, the risk associated with its improper management may be high. Organic radioactive waste requires management steps that not only take account of its radioactivity, but also of the chemical organic content since this can also have detrimental effects on the environment. The "dilute and disperse" option applied for some aqueous and gaseous waste is inappropriate for organic liquid waste. Treatment of large amount of radioactive liquid organic is technology intensive as well costly. The treatment steps of organic liquid waste, incineration, emulsification to facilitate encapsulation into cement, absorption into matrix, distillation and wet oxidation.

6.30 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.

6.31 Mixing waste streams should be limited to those streams that are radiologically and chemically compatible. Mixed waste streams should be compatible with the waste acceptance criteria of the waste management facility (e.g., processing, storage, or disposal). If the mixing of chemically different waste streams is considered, an evaluation should be made of the chemical reactions that could occur, especially any exothermic reactions in order to avoid uncontrolled or unexpected reactions that could cause unplanned release of volatile radionuclides or radioactive aerosols. 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

6.32 The treatment of radioactive waste may include:

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

(b) The removal of radionuclides (e.g., evaporation or ion exchange for liquid waste streams and filtration of gaseous waste streams);

(c) Change of form or composition (e.g., chemical processes such as precipitation, flocculation and acid digestion as well as chemical and thermal oxidation);

(d) Change of the physical properties of the waste (e.g., solidification, sorption, encapsulation; common immobilization matrices include cement, bitumen and glass).

Solid waste

6.33 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.

6.34 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 thermal treatment.

6.35 Thermal treatment 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 used for thermal treatment and the nature of the radionuclides in the waste. Thermal treatment is also an advantageous technique for treating radioactive organic liquids because the products of complete combustion are ash, carbon dioxide and water. It should be noted that thermal treatment will result in the increase of the activity concentration levels in the ash which might result in a change of the waste class. In addition, 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 and concentration in residues of the gas cleaning system and those remaining in the ash, and to their further conditioning.

6.36 Releases of radionuclides to the environment are largely determined by the operational conditions of the incinerator, in particular through control of the temperature and the types and amounts of waste treated and its radionuclide content. 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 thermal treatment can include acids, polychlorinated biphenyls and various other materials presenting non-radiological hazards, which should be taken into account.

6.37 Compaction is a suitable method for reducing the volume of certain types of waste. This may include the compaction of ashes originating from thermal treatment. 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;

(e) Criticality safety considerations when waste that contains fissile material is compacted into a single waste package.

6.38 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.

6.39 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

6.40 Methods for the treatment of aqueous waste include evaporation, chemical precipitation, ion exchange, filtration, centrifugation, ultrafiltration, thermal treatment 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 [20]. Conditions of optimum moderation and reflection should be considered in the determination of safe configurations of radioactive waste and in the development of operating procedures.

6.41 Spent ion exchange resins are usually flushed out as slurry and subsequently managed as liquid waste until the resin can be separated from the carrier liquid, 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.

6.42 Liquids for discharge may be produced as a consequence of the treatment of waste. To the extent possible, liquid waste should be characterized on the basis of its radiological and chemical properties to facilitate collection and segregation. With proper characterization it may be possible to discharge the waste within authorized limits, provided that the non-radiological characteristics of the waste are appropriate.

6.43 All discharged liquids should be readily water soluble or 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.

6.44 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 [17].

6.45 Organic radioactive waste requires management steps that not only take account of its radioactivity, but also of the chemical organic content since this can also have detrimental effects on the environment. The “dilute and disperse” option applied for some aqueous and gaseous waste is inappropriate for organic liquid waste. The treatment steps of organic liquid waste that should be considered incineration, emulsification to facilitate encapsulation into cement, absorption into matrix, distillation and wet oxidation.

Gaseous waste and discharges

6.46 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. 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.

6.47 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 charcoal. 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.

6.48 For both liquid and gaseous discharges, the arrangements should be identified for dose assessment and any necessary workplace monitoring in relation to the exposures resulting from the accumulation of the waste, the discharge of the waste, and to any groups at particular risk as a result of the discharge.

Conditioning

6.49 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).

6.50 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.

6.51 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 or polymer for low- and intermediate-level waste or glass for high-level waste. Solidification may also be achieved without a matrix material, for example by drying. The product is then enclosed in a container.

6.52 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 micro-organisms.

6.53 The required characteristics of the form of the solid waste should be considered on a case by case basis. The required characteristics of the waste form as listed above apply to many types of solid waste. Some of the characteristics (in particular homogeneity and low voidage) do not apply for certain types of solid waste.

6.54 It should be taken into account that certain processes (e.g., bituminization) are exothermic and may present a fire and/or explosion hazard, depending on the material in the mix. It should also 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. In addition, some metal particles like zirconium can be flammable when the particle size/ surface area and environment are favourable. Chelating agents, organic liquids or oil and salt content in liquid waste may also be of concern in the conditioning process.

6.55 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.

6.56 The container 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 (GSR Part 5, Ref. [4]): 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 degradation of the waste containment.

6.57 Storage is an option that should be considered in the waste management strategy of a nuclear fuel cycle facility. Proper storage should be available at all stages in waste processing for isolation and environmental protection; it should also facilitate retrieval for subsequent steps. Guidance for the storage of radioactive waste and for the storage of spent fuel is dealt with extensively in WS-G-6.1 [9] and SSG-15 [10], respectively.

6.58 The design of storage facilities should take into consideration the type of radioactive waste, its characteristics and associated hazards, the radioactive inventory, and the anticipated period of storage. Provision has to be made for the regular monitoring, inspection and maintenance of the waste and of the storage facility to ensure their continued integrity.

6.59 Where necessary, provision should be made for containment in areas where radioactive effluent or radioactive waste is stored prior to its treatment and discharge. Provisions for the storage of waste in transit and for the removal of waste should also be considered.

6.60 Storage facilities and waste packages should take account of the waste form (i.e. solid, liquid or gas), radionuclide content and half-lives, activity concentrations, the total radioactive inventory, non-radiological characteristics and the expected duration of storage. The design features and facility operations should be such as to ensure that the waste can be received, handled, stored and retrieved without undue occupational and public radiation exposure or environmental impact.

6.61 Sufficient storage capacity should be provided for radioactive waste generated in normal operations with a reserve capacity for waste generated in any incidents or abnormal events. Extension of this capacity may be necessary in the event that the waste cannot be transferred off the site because, for example, a disposal facility is not available.

6.62 To the extent practicable, radioactive waste should be stored in a passive condition, (e.g., radioactive material is immobile, waste form and container are both physically and chemically stable and are resistant to degradation, containment is provided that uses a multi-barrier approach, safety functions are provided by passive systems and the need for active systems or maintenance are minimized, storage environment optimizes the lifetime of the waste container, etc.). The operator should ensure the integrity of the structures, equipment, waste forms and containers are maintained over the expected duration of storage. Consideration should be given to interactions between the waste, the containers and their environment (e.g. corrosion processes due to chemical or galvanic reactions). For certain types of waste (e.g. corrosive liquid waste) special precautions should be taken, such as the use of double walled containers and impervious liners.

6.63 In facilities in which significant volumes of liquid waste are generated, collecting tanks should be the preferred container for liquid waste. The tanks should be constructed of chemically resistant material such as stainless steel, plastic, rubber lined carbon steel or fibreglass. Secondary containment should be provided around the tank to prevent the spread of contamination in the event of leakage. The provision of adequate shielding should also be considered.

6.64 Radioactive waste containing short-lived radionuclides may be collected and stored to allow its radioactivity to decay to levels that permit authorized discharge, authorized use or removal of regulatory control. Storage may also be necessary for operational reasons; for example, to permit off-site transfer at specified time intervals.

6.65 Radioactive waste should be stored in a segregated manner such that it can be retrieved for further treatment, transfer to another storage facility or disposal. Radioactive waste should be stored separately from nonradioactive waste to avoid cross-contamination and accidental removal from control. Special attention may need to be given to storage of fissile materials, to avoid storage configurations which could lead to criticality concerns.

6.66 A tracking system for waste packages should be developed and implemented. The system should provide for the identification of waste packages and their locations and an inventory of waste stored. The sophistication of the waste tracking system required (e.g. including labelling and bar coding) will depend on the number of waste packages, the anticipated duration of storage of the waste and the hazard associated with it.

Storage of liquid high level waste

6.67 Surveillance should be provided to ensure the operability of safety related systems such as systems for ventilation, cooling and fluid level detection. Consideration should be given to providing redundant capabilities for the monitoring and indication of the measured values. In addition, measures should be provided to monitor the key physical and chemical parameters of the waste (e.g. temperature and pressure, subcriticality and the concentrations of key constituents, the degree of the radiolytic decomposition of aqueous solutions and levels of potentially flammable or explosive substances). Means should also be provided for maintaining these parameters within acceptable operational limits, as well as for maintaining the discharge of airborne and liquid effluents within the regulatory limits.

6.68 Care should be taken to ensure that liquid high level waste is chemically compatible with the process chemistry used for its conditioning and with the structural materials of vessels, pipes and other structures and components. Design features should include double walled pipes and vessels, containment bunds and sumps for waste holding tanks and active ventilation systems that ensure that air flows from areas of lower contamination to areas of higher contamination. Collection and recovery systems for leaks or spills, such as cell lining and sump systems and liquid recycling systems, should be provided. Measures should also be in place to maintain solids in suspension in order to promote adequate cooling and to prevent their buildup on cooling surfaces.

6.69 Protection against the hazards associated with the storage of liquid HLW should be provided by engineered safety features that make use of redundant active or passive safety systems. This should include, as a minimum, shielding and containment as well as provisions to prevent, by cooling the liquid HLW and ventilating the gases that may be generated, the uncontrolled generation of explosive gases or rises in temperature and pressure.

6.70 Storage facilities for liquid HLW should be provided with off-gas systems that employ appropriate filtration systems to control the release of airborne effluents.

RADIOACTIVE WASTE ACCEPTANCE CRITERIA

Requirement 12 (GSR Part 5, Ref. [4]): Radioactive waste acceptance criteria

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

6.71 Criteria are to be developed for the acceptance of radioactive waste in the facilities for predisposal management of radioactive waste. Account should be taken of all relevant operational limits and conditions of the facility for predisposal management of radioactive waste (consistent with the safety case) and also of the future disposal facility. In fact, an important objective of the predisposal management of radioactive waste 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 criteria 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 criteria should be anticipated as far as possible. The waste acceptance criteria may be met by providing an overpack that is tailored to the specific conditions at the repository site and to the characteristics of the waste and the engineered components of the disposal facility.

6.72 Appendix 1 provides a listing of the typical properties and characteristics that should be considered for waste packages. To ensure the acceptance of waste packages for disposal, a programme should be established, as an element of the management system, to develop a process for conditioning that is approved by the regulatory body. 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 compliance with the waste acceptance criteria of the disposal facility.

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

6.74 Establishment of waste acceptance criteria enable the effective interlinking of facilities and processes where material is transferred, being held for storage or transported to a disposal facility.

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

6.76 The operator should put contingency measures in place for in the event waste packages whose characteristics do not comply with the acceptance criteria are received. Such measures may include after placing the waste package into a safe and secure quarantine area, the return of the waste package to the facility that generated the waste or sending it to an alternative treatment facility.

LIFETIME SAFETY CONSIDERATIONS

Siting and design

Requirement 17 (GSR Part 5, Ref. [4]): 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.

6.77 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 [32], SSG-9 [33], SSG-18 [34], SSG-21 [35] and DS433 [36].

6.78 Facilities for the predisposal management of radioactive waste on any particular site should be located in the same area, to the extent practicable, to reduce the need for the transport of waste between locations for processing and for storage.

6.79 Facilities for predisposal management of radioactive waste should be designed:

(a) To prevent dispersion of radioactive material (confinement, cooling, measures against accumulation of explosive gas mixtures)

(b) To prevent external radiation exposure (shielding)

(c) To prevent t criticality

The design assessment should consider internal and external hazards (Annex 1 of [6]).

6.80 In the design of the nuclear fuel cycle facility and waste management facility, due consideration should be given to the need for:

(a) Criticality safety;

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

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

(d) Waste characterization and inventory control;

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

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

(g) The control of liquid and gaseous effluents;

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

(i) Maintenance work and eventual decommissioning;

6.81 Measures considered in the design for the management of gaseous radioactive 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 points;

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

6.82 Measures considered in the design for the management of liquid radioactive waste and liquid effluents 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;

(d) Provisions for decay storage to minimize discharges of radioactive material;

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

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

(g) Provisions as necessary for storing spent ion exchange resins and evaporation of liquid waste;

(h) Provisions for filtration in liquid waste collection lines to prevent the discharge of solids."

6.83 Measures considered in the design for the management of solid radioactive waste should include, when appropriate, the following:

(a) Provisions for segregating waste by type (physical form, volume, mass, isotopic composition and activity concentration) or by area of origin;

(b) The handling, packaging and storage of solid low level and very low level radioactive waste, such as contaminated cleaning equipment, clothing, paper and tools;

(c) The handling, packaging and storage of solid intermediate level radioactive waste, such as waste arising from ion exchange resins, ventilation filters and charcoal beds that are associated with higher dose rates;

(d) Areas and tools for handling, temporary storage and loading of waste;

(e) Equipment and tools for radiation protection;

(f) Provisions as necessary for handling and storing of filters, resins and residues from liquid waste evaporation;

(g) 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.

6.84 Facilities should be designed to prevent material interactions that may compromise the containment of the waste or safety at the facility.

6.85 The predisposal management of radioactive waste may also entail the management of non-radioactive hazardous material. 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.

6.86 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.

6.87 The design and operation of predisposal radioactive waste management facilities should be carried out in such a way as to ensure subcriticality in both operational states (i.e. normal operation and anticipated operational occurrences) and under accident conditions (i.e. design basis accidents) by means of safe geometrical configurations, limitations on concentrations and inventories of fissile material or the use of neutron poisons. Conditions of optimum moderation and reflection should be considered in the determination of safe configurations of radioactive waste and the development of operating procedures. An appropriate limiting neutron multiplication factor, with suitable safety factors for mass, concentration and other characteristics taken into account, should be selected in the design for the purpose of ensuring criticality safety, depending upon the conditions mentioned above. Additional organizational and administrative arrangements that may be necessary in the operation of such a facility to ensure subcritical conditions should be considered [20].

6.88 The design of a facility for the predisposal management of high-level (heat generating) radioactive waste should incorporate systems (e.g. a system for monitoring and controlling the temperature) that are capable of maintaining the temperature of the waste or the waste form within acceptable limits in all stages of predisposal management of radioactive waste, both in operational states (e.g., normal operation and anticipated operational occurrences) and under accident conditions (e.g., design basis accidents). 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 the forced circulation of coolant is used, the system should be highly reliable. Examples of features that enhance the reliability of the cooling system 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 should be put in place to deal with such contingencies.

Construction and commissioning

Requirement 18 (GSR Part 5, Ref. [4]): 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.

6.89 Guidance for the construction of nuclear installations is dealt with in DS441 [37].

6.90 For modular storage systems, most of the commissioning should 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 [10].

Facility operation

> **Requirement 19 (GSR Part 5, Ref. [4]): 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 [24].**

6.91 Instructions and procedures should be prepared for normal operations of the facility, and under accident conditions. Instructions and procedures should be prepared to be readily available when needed for the designated responsible person.

6.92 Measures for preventing and limiting potential exposure associated with radioactive waste during normal operations should include:

(a) Provisions for the isolation of radioactive waste from site personnel and the public, including access control, e.g., zoning the facility in accordance with the potential for radioactive contamination and radiation exposure;

(b) Provisions for detection, collection and treatment of liquid spills;

(c) Provisions for the decontamination of personnel and equipment;

(d) Provisions for handling radioactive waste arising from decontamination activities.

6.93 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 type and class of the waste to be stored;

(b) Geometries necessary to ensure subcriticality;

(c) Dependence of subcriticality on neutron absorbers

(d) Conditions of optimum moderation and reflection

(e) Waste form and waste packages;

(f) Handling operations;

(g) The potential for abnormal operation; and

(h) Defense in depth analysis.

6.94 Protection and safety considerations that should be taken into account in the development of operating procedures and contingency and emergency arrangements are addressed in GS-G-2.1 and

GSG-2 [38, 39]. When developing emergency arrangements, the operating organization should consider, but not be limited to, events such as the following:

(a) Failure of handling systems, including severe crane failure, dropping of loads, falling waste packages;

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

(c) Explosions (e.g., 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).

6.95 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

6.96 Operational limits and conditions should be developed on the basis of the following:

(a) Design specifications and operating parameters and the results of commissioning tests;

(b) The sensitivity of items important to safety and the consequences of events following the failure of items, the occurrence of specific events or variations in operating parameters;

(c) The accuracy and calibration of instrumentation equipment for measuring safety related operating parameters;

(d) Consideration of the technical specifications for each item important to safety and the need to ensure that such items continue to function in the event of any specified fault occurring or recurring;

(e) The need for items important to safety to be available to ensure safety in operational states including maintenance;

(f) Specification of the equipment that should be available to enable a full and proper response to postulated initiating events or design basis accidents;

(g) The minimum staffing levels needed to operate the facility safely.

6.97 Operational limits and conditions should be kept under review and may also have to be revised as necessary in accordance with the national regulatory framework for the following reasons:

(a) In the light of operating experience;

(b) Following modifications made to the facility and/or the type of radioactive waste;

(c) As part of the process of periodically reviewing the safety case (including as part of periodic safety review) for the facility;

(d) In case of relevant changes in legal or regulatory conditions

Maintenance

6.98 In general, the maintenance schedule should be derived from the requirements of the safety assessment and 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.

6.82 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.

Radiation protection programme

6.83 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 the potential for contamination. The area classification allows for access control in accordance with area class specific requirements. The programme should include the monitoring and control of all relevant radiological hazards in the facility and should include provision to ensure that radiation exposures of personnel working in the facility are assessed, recorded, optimized and kept below dose limits. A programme of work planning should also be put in place to ensure that radiological exposure is kept as low as reasonably achievable.

Emergency planning and response

6.84 Emergency plans and procedures should be developed and documented, and made available to the personnel concerned. These plans and procedures should be subject to periodic review and revision as necessary in light of past experience and any changes that may impact emergency arrangements. Personnel concerned should be qualified and trained in the implementation of these plans and procedures. Emergency arrangements should be tested in exercises on a regular basis and feedback obtained should be incorporated in the emergency arrangements as necessary. The quality management programme should be in place to ensure that equipment, supplies, communication systems and other resources necessary for an emergency response are available and in working order when needed. (GS-R-2, GSG-2.1) [24, 39]

Decommissioning

Requirement 20 (GSR Part 5, Ref. [4]): Shutdown and decommissioning of facilities

The operator shall develop, in the design stage, an initial plan for the shutdown and decommissioning of the predisposal radioactive waste management facility 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.

6.85 The key elements that should be considered for the decommissioning of facilities for the predisposal management of radioactive waste, as specified in GSR Part 6 [21], include:

(a) The development of a decommissioning plan;

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

(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;

(e) Allocation of decommissioning funds or financial instrument to cover decommissioning costs.

6.86 An initial version of the decommissioning plan should be prepared during the design of the facility in accordance with requirements and recommendations on decommissioning (GSR Part 6, WS-G-2.4) [21, 22].

6.87 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 fuel cycle facility has been permanently shut down, or delivery of radioactive waste to an authorized facility for storage or disposal in compliance with transport requirements;

(f) Availability of disposal options; and

(g) Cost estimates, financial provisions, and update of decommissioning funds based on characterization data and safety case updates.

6.88 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-2.4) [22].

APPENDIX 1. DEVELOPMENT OF SPECIFICATIONS FOR WASTE PACKAGES

Specifications for conditioned radioactive waste are established to ensure that the waste package satisfies the relevant acceptance criteria for storage or disposal, as well as transport requirements. The radiological characteristics are identified at an early stage. Other waste package specifications may be divided into four main topics: chemical and physical properties, mechanical properties, containment capacity and stability. This last topic, robustness, concerns the capacity of the waste package to retain radionuclides over extended periods of time.

RADIOLOGICAL PROPERTIES

The radiological characteristics of the waste could include:

(a) radionuclide-specific activities and half-lives;

(b) total radioactivity content (alpha, beta/gamma) and activity concentration levels;

(c) dose rate;

(d) Heat output.

CHEMICAL AND PHYSICAL PROPERTIES

The chemical and physical properties of the waste form include:

(a) chemical composition;

(b) density, porosity, permeability to water and permeability to gases;

(c) homogeneity and the compatibility of the waste with the matrix;

(d) thermal stability;

(e) percentage of water incorporated, exudation of water under compressive stress, shrinkage and curing;

(f) leachability and corrosion rate.

The chemical and physical properties of the container include:

(a) materials;

(b) porosity, permeability to water and permeability to gases;

(c) thermal conductivity;

(d) solubility and corrosion in corrosive atmospheres or liquids such as water or brines.

The physical properties of the waste package include:

(a) number of voids in the container (which are to be minimized);

(b) characteristics of the lidding and sealing arrangements;

(c) sensitivity to changes in temperature.

MECHANICAL PROPERTIES

The mechanical properties of the waste form include its tensile strength, compressive strength and dimensional stability.

The mechanical properties of the waste package include its behaviour under mechanical (static and impact) or thermal loads.

CONTAINMENT CAPABILITY

The containment capability of the waste package concerns:

(a) diffusion and leaching of radionuclides in an aqueous medium;

(b) release of gas under standard atmospheric conditions or the conditions in a repository;

(c) diffusion of tritium under standard atmospheric conditions or conditions in a repository;

(d) capability for the retention of radionuclides;

(e) water-tightness and gas-tightness of the package sealing device.

LONG TERM PERFORMANCES and DURABILITY

Long term performances and durability of the waste package concerns:

(a) behaviour under temperature cycling;

(b) sensitivity to elevated temperatures and behaviour in a fire;

(c) behaviour under conditions of prolonged radiation exposure;

(d) sensitivity of the matrix to water contact;

(e) resistance to the action of micro-organisms;

(f) corrosion resistance in a wet medium (for metal containers);

(g) porosity and degree of gas tightness;

(h) potential for swelling due to the internal buildup of evolved gases.

APPENDIX 2. FACILITY SPECIFIC WASTE MANAGEMENT PROGRAMME

The content of a facility specific waste management programme could include:

(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) The limits and conditions necessary for the waste to be managed safely;

(d) A comprehensive list of the current and anticipated waste arisings and inventories for the facility;

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

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

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

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

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

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 (conditioned and unconditioned) and an additional reserve storage capacity;

(f) Ensuring that the radioactive waste can be retrieved at any time within the anticipated storage period;

(g) Techniques and suitable procedures available for the retrieval of stored radioactive waste;

(h) Processing radioactive waste to comply with waste acceptance requirements and to ensure safe storage and disposal;

(i) Safe handling and transport of radioactive waste;

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

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

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

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

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

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

(p) Recording and reporting of a systematic evaluation of operating experience and events at the facility;

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

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

(s) Emergency preparedness and response[6].

[6] Although emergency preparedness and response is mentioned under this programme, it may be part of the overall emergency arrangements for the entire facility. In this case, the programme should make reference to the overall emergency arrangements.

APPENDIX 3. EXAMPLES OF KEY PLANNING ACTIVITIES RELEVANT TO THE LIFECYCLE OF A PREDISPOSAL RADIOACTIVE WASTE MANAGEMENT FACILITY

DESIGN PHASE ASPECTS

5.1. Commence when a decision is made to carry out operations involving the management of radioactive materials.

(a) Review of government policies to establish national expectations and fit into national strategic waste strategy

(b) Establish the location of the facility to take into account safety and radioactive waste management aspects i.e. distance from populations centres and availability of transport links from the facility to waste treatment /disposal sites and recognizing decommissioning will also impact on populace.

(c) Establish an integrated waste strategy and Integrated Waste Management programme

(d) Establish / upgrade waste management inventory

(e) Establish steps in the management of the radioactive materials and related radioactive wastes.

(f) Evolve the waste management inventory to incorporate all wastes identified

(g) Establish initial waste disposal criteria, onward disposition criteria, storage criteria

(h) Establish links with upstream and downstream facilities

(i) Establish Integrated waste strategy and apply the waste management hierarchy to develop optimal waste management at particular design and build stage level

(j) Build additional requirements into the design of the facility and the records management

(k) Set down research and development requirements to establish the gaps in knowledge that requires filling to achieve optimal waste management

(l) Interface with regulators and government to establish and inform all requirements set down

(m) Repeat a to l through concept, development, detailed design and build stages growing the database of information, future requirements of information and auditable trail of decisions

OPERATIONAL PHASE ASPECTS

Commence when radioactive materials are introduced into the plant.

(a) Review of government policies to establish how operational needs and experience are influenced by national expectations and fit into local as well as national strategic waste strategy

(b) Establish / upgrade waste management inventory with operational data

(c) Register and record all normal waste arisings as well as those outside the normal arisings

(d) Establish and monitor the behaviour of radioactive waste in the steps in the management of the radioactive materials and related radioactive wastes.

(e) Evolve the waste management inventory to incorporate all wastes identified

(f) Evolve via links established earlier waste disposal criteria, onward disposition criteria, storage criteria

(g) Improve and add detail to the Integrated waste strategy and plan and apply the waste management hierarchy to develop optimal waste management as information evolves from the facility

(h) Build additional requirements into the operation of the facility and the records management

(i) Develop the design and construction of the facility as it is modified during the operational phase to deal with where possible the gaps in knowledge that require filling to achieve optimal waste management

(j) Interface with regulators and government to establish and inform all requirements set down and interface with the national waste strategy and plan

(k) Repeat a to j through the commissioning, operation and shutdown phases growing the database of information, future requirements of information and auditable trail of decisions

DECOMMISSIONING PHASE ASPECTS

Commence when radioactive materials are removed from the plant.

(a) Review of government policies to establish national expectations and fit into national strategic waste strategy

(b) Establish / upgrade waste management inventory via techniques including monitoring

(c) Utilize the waste management inventory to establish the scope and condition of the waste remaining within the facility

(d) Establish and monitor the behaviour of radioactive waste in the steps in the management of the radioactive materials and related radioactive wastes by selection of appropriate methods and equipment that deliver optimal waste minimization.

(e) Evolve the waste management inventory to incorporate all wastes identified

(f) Evolve via links established earlier waste disposal criteria, onward disposition criteria, storage criteria

(g) Improve and add detail to the Integrated waste strategy and plan and apply the waste management hierarchy to develop optimal waste management as information evolves from the facility

(h) Build additional requirements into the operation of the decommissioning process and the records management

(i) Interface with regulators and government to establish and inform all requirements set down and interface with the national waste strategy and plan

(j) Repeat (a) to (i) through the decommissioning and interim storage phases growing the database of information, future requirements of information and auditable trail of decisions

APPENDIX 4: EXAMPLES OF HAZARDS ASSOCIATED WITH WASTE MANAGEMENT ACTIVITIES AT FUEL CYCLE FACILITIES

Waste management activities	Waste materials	Characteristics	Hazards (radiological)	Hazards (non-radiological)
Uranium conversion (natural): • Post Dissolution insoluble solids treatment • Solvent washing effluent management • Fluoride related gaseous scrubbing particulate scrubbing • Particulate filtration • Scrubber Liquid effluent management • General Solid waste management including collection, size reduction and packaging	• UOC insolubles	• U and NORM concentration • U compound properties • Impurities (e.g. V, Cr)	• Alpha bearing materials • Radiation dose (internal/external)	Heavy metal toxicity
	• Uranium excess / Fluoride ash	• Concentration of short lived progeny (Th, Pa) • U Concentration • Uranium compound properties • Fluorine content • Particulate size and dispersibility • Temperature and thermal capacity	• Alpha bearing materials Radiation dose (internal/External) • Additional beta dose rates due to concentration of short lived radionuclides)	• Fire • Fluoride toxicity (acute/chronic) • Heavy metal toxicity • Thermal burns
	• KOH liquors including test liquors	• Liquids containing uranium and fluorides and alkali chemicals • Low uranium concentration	Uranium impact on environment	• Alkali and fluoride chemical handling • Chemical impact on environment • Chemical impact on operators
	• Carbonate and hydroxide liquors from solvent washing including test liquors	• Contamination with solvent • Possible colloids formation • U compound properties • Impurities (e.g. V, Cr) • Variable concentrations of test chemicals and uranium and decay products	Uranium and decay product impact on environment	• Alkali and fluoride chemical handling • Chemical impact on environment • Solvent impact on environment • Chemical impact on operators
	• PPE and other compressible solids	Varying levels of surface contaminated materials	• Alpha bearing materials • Radiation dose (internal/external)	Heavy metal toxicity
	• Contaminated filters	• Varying levels of activity • Uranium • Uranium compound properties	• Alpha bearing materials • Radiation dose (internal/external)	Heavy metal toxicity

Waste management activities	Waste materials	Characteristics	Hazards (radiological)	Hazards (non-radiological)
	• Non-ferrous and ferrous Metals components	• Varying levels of activity • Uranium • Uranium compound properties	• Alpha bearing materials • Radiation dose (internal/external)	• Heavy metal toxicity • Environmental impact
	• Organic / plastic process components e.g. PTFE	• Varying levels of activity • Uranium • Uranium compound properties • Impurities of organics	• Alpha bearing materials • Radiation dose (internal/external)	• Fire • Heavy metal toxicity • Hydrogen Fluoride • Fluorine
	• Contaminated electrolyte	• Uranium • Uranium compound properties • HF/KF electrolyte in solid and liquid forms • Gaseous HF • Fluorine • hydrogen	Potential of exposure to: • Alpha bearing materials • Radiation dose (internal/external)	• Fire and explosion • Heavy metal toxicity • Hydrogen Fluoride • Fluorine • Fluoride toxicity (acute/chronic) • Heavy metal toxicity • Chemical burns
	• Non-compressible Solids e.g. building rubble	• Varying levels of activity concentration levels	• Alpha bearing materials • Radiation dose (internal/external)	Heavy metal toxicity
	• Organic Liquids e.g. Kerosene, TBP	• Varying levels of activity • Uranium • Uranium compound properties • Organic properties	• Alpha bearing materials • Radiation dose (internal/external) • Environmental impact	• Fire • Heavy metal toxicity • Environmental impact
	• Gases and aerosols	• Varying levels of activity e.g. uranium, uranium decay products and their compounds • Varying levels of chemical composition e.g. UF6 , UO2F2, HF, F2, NH3	• Alpha bearing materials • Radiation dose (internal/external) • Environmental impact	• Heavy metal toxicity • Environmental impact
Uranium conversion (irradiated): • Same processes as Natural Uranium Conversion. • Additional considerations from irradiated feedstock	Feedstocks, products, and wastes	• Concentration of fission and nuclear reaction products e.g. U232 and Pu isotopes • Ingrowth of radionuclides during processing • Elevated radioactivity concentration levels	• Alpha bearing materials • Elevated dose rates	

Waste management activities	Waste materials	Characteristics	Hazards (radiological)	Hazards (non-radiological)
Uranium Enrichment (centrifuge): • Particulate filtration • Cylinder decontamination • Waste cylinder size reduction • General Solid waste management including collection, size reduction and packaging • General liquid waste management e.g. cooling water, steam condensates disposal • Refrigerants and glycol disposal	Used Cylinders including those requiring long term management prior to disposal	• Varying levels of activity from buildup of uranium and uranium decay products and impurities • Potential for presence of residual washings • Potential for unknown contents both mass and composition • Hydrogen • HF	• Alpha bearing materials • Radiation dose (internal/external) • criticality • Environmental impact	• Heavy metal toxicity • Corrosive chemicals • Explosion • overpressurization • Environmental impact
	Spent cylinder washings	• Varying levels of activity from buildup of uranium and uranium decay products and impurities • Variable and potential unknown chemical composition • Hydrofluoric acid content	• Alpha bearing materials • Radiation dose (internal/external) • Criticality • Environmental impact	• Heavy metal toxicity • Corrosive chemicals • Hydrofluoric acid • Explosion • Overpressurization • Environmental impact
	Cooling water and condensates	Potential uranium contamination	• Alpha bearing materials • Radiation dose (internal/external)	• Heavy metal toxicity • Environmental impact
	Ferrous and non-ferrous metals	• Varying levels of activity • Uranium	• Alpha bearing materials • Radiation dose (internal/external)	• Heavy metal toxicity • Environmental impact
	PPE and other compressible solids	• Varying levels of Surface contaminated materials	• Alpha bearing materials • Radiation dose (internal/external)	• Heavy metal toxicity • Environmental impact
	Gases and aerosols	• Varying levels of activity • Varying levels of chemical composition e.g. UF6 , UO2F2, HF	• Alpha bearing materials • Radiation dose (internal/external)	• Heavy metal toxicity • Hydrogen Fluoride • Environmental impact
	Process filters	• Varying levels of activity • Uranium	• Alpha bearing materials • Radiation dose (internal/external)	Heavy metal toxicity
	Particulate filtration	• Varying levels of activity • Uranium	• Alpha bearing materials • Radiation dose (internal/external)	Heavy metal toxicity
	Non-compressible Solids e.g. building rubble	• Varying levels of activity concentration levels	• Alpha bearing materials • Radiation dose (internal/external)	Heavy metal toxicity

Waste management activities	Waste materials	Characteristics	Hazards (radiological)	Hazards (non-radiological)
Uranium fuel fabrication: • Dissolution and solvent extraction • Treatment and discharge of liquid effluents to the environment	Liquid effluents	• Concentrations of Uranium compounds as radioactive materials in waste • Characteristics of the Uranium as UF6 as a soluble compound • Characteristics of the uranium as UO2 as an insoluble compound	• Criticality • Alpha bearing materials • Radiation dose (internal/external) • Environmental impact	• Hydrogen • Hydrofluoric acid • High temperature processes • Concentrations of Uranium as heavy metals in the waste • Pyrophoric properties of Uranium metal
Mixed oxide fuel fabrication: • Interim storage of waste • Collection and transport of waste to central waste management area • Interim and long term storage • Filtration and discharge of gaseous effluents	Solid waste, waste contaminated with plutonium, floor sweepings, waste and residues from decontamination	• Concentrations of Uranium and transuranics as radioactive materials in waste (e.g. americium ingrowth) • Characteristics of the uranium and transuranics insoluble compounds • Plutonium dust and contamination (Importance of maintaining process integrity and cleanliness)	• Criticality • Alpha bearing materials • Radiation dose (internal/external) • Environmental impact	• Radiolytic properties of plutonium (flammable gas generation and material breakdown) • Heat generating (amounts of plutonium with even mass numbers and those of americium) • Plutonium physical properties (hardness and ability to act as a grinding medium) • High temperature processes
Spent fuel reprocessing • Collection, segregation and management of process residues • Treatment and conditioning of waste materials • Vitrification of high level liquid waste • Bituminization of process sludges and other materials • Cementation or Supercompaction of hulls and end-caps	Cemented or compacted hulls and end caps	• Residual concentrations of Uranium and transuranics as radioactive materials in waste • Characteristics of the uranium and transuranics insoluble compounds • Concentration of fission products and minor actinides • Chemical Reagents and reaction products (including hydrogen and nitrogen oxides)	• Elevated dose rates • Ingrowth of radionuclides during processing • Elevated radioactivity concentration levels • Criticality (particularly in effluent precipitation processes and solvent washing)	• The possibility of an explosive reaction • Chemical processes that generate effluent and gaseous emissions • High temperature processes • Chemically Reactive metals (e.g. Zirconium)
	Magnesium and graphite wastes		• Alpha bearing materials • Radiation dose (internal/external) • 14C concentrations	• Risk of fire/explosion from graphite dust
	Vitrified, separated fission products and minor actinides	• High activity concentration • Heat generation	• Alpha bearing materials • Radiation dose (internal/external)	

Waste management activities	**Waste materials**	**Characteristics**	**Hazards (radiological)**	**Hazards (non-radiological)**
	Contaminated equipment/technological wastes	• Surface contamination	• Alpha bearing materials • Radiation dose (internal/external)	
	Bituminized process sludges	• Potential for radiolysis	•	• Hydrogen (explosion or deflagration) • Risk of fire/explosion from bituminization process/ products
	personal protective equipment and other compressible solids	• Varying levels of surface contaminated materials	• Alpha bearing materials • Radiation dose(internal/external)	• Heavy metal toxicity
	Gases and aerosols	• Varying levels of activity • Varying levels of chemical composition depending on process used	• Alpha bearing materials • Radiation dose (internal/external) • Environmental impact	• Heavy metal toxicity • Environmental impact
	Process filters	• Varying levels of activity	• Alpha bearing materials • Radiological Dose (internal/external)	• Heavy metal toxicity

APPENDIX 5: EXAMPLES OF HAZARDS ASSOCIATED WITH CENTRALIZED WASTE MANAGEMENT FACILITIES

Facility description	**Activities**	**Hazards (radiological)**	**Hazards (non-radiological)**
Centralized facility that receives low alpha compactible, solid waste in drums from a medical isotope processing facility and produces waste packages for disposal	• Receiving waste and verifying WAC including sampling	• External radiation • Internal radiation (via contamination or release)	• Chemical / Toxic materials • Industrial including handling of sharps • Chemical reactions of / between waste compounds • Fragile materials
	• Compaction of the received drums	• External radiation • Internal radiation (via contamination or release) • Release of radioactive liquids including oils • Release of radioactive dusts • Release of radioactive gases	• Generation of liquids • Generation of dusts • Chemical reactions • Pressure bursts • explosions • industrial including handling of sharps
	• Transfer, sorting and collection and drying of pucks	• External radiation • Internal radiation (via contamination or release)	• Industrial including handling of sharps • Chemical / Toxic materials
	• Placement of pucks into waste container	• External radiation • Internal radiation (via contamination or release)	• Industrial including handling of sharps • Chemical / Toxic materials
	• Waste container grouted to produce a waste package	• External radiation • Internal radiation (via contamination or release)	• Industrial • Chemical materials (grout)
	• Waste package cleaning, Surveillance, Monitor and Transfer to interim Store	• External radiation • Internal radiation (via contamination)	• Industrial

APPENDIX 6: WASTE SPECIFIC SAFETY CONSIDERATIONS OF FUEL CYCLE FACILITIES

The following is a list of hazards associated with, or that could affect waste management at typical fuel cycle facilities. Where appropriate certain features are highlighted that require specific attention when considering radioactive waste management. This list is not exhaustive. Rather, it provides indicators for the safety assessor to produce the equivalents of the tables in Appendices 1 and 2 for the specific facility under consideration.

NATURAL URANIUM CONVERSION

- Concentrations of Uranium compounds and uranium decay products as radioactive materials in waste
- Concentrations of Uranium as heavy metals in the waste
- Characteristics of the Uranium compounds e.g. solubility
- Concentrations of contaminants in the waste streams including heavy metals such as chromium and vanadium
- Chemical corrosive materials e.g. Hydrogen fluoride, sulphuric acid
- Chemical toxic materials e.g. Ammonia
- Fire consideration from reagents including Fluorine and hydrogen
- Chemical processes that generate effluent and gaseous emissions

IRRADIATED URANIUM CONVERSION

- As for Natural Uranium Conversion
- In addition
- Concentration of fission and nuclear reaction products e.g. U232 and Pu isotopes
- Elevated dose rates
- Ingrowth of radionuclides during processing
- Elevated radioactivity concentration levels

URANIUM ENRICHMENT FACILITIES

- Concentrations of Uranium compounds as radioactive materials in waste
- Concentrations of Uranium as heavy metals in the waste
- Characteristics of the Uranium as UF6 and as a soluble compound
- Presence of HF as a reaction product
- Bulk Depleted Uranium generation and accumulation as a corrosive fluoride e.g. (Preference for passive stable uranium storage of depleted uranium for long term management e.g. Uranium hexafluoride versus Uranium Oxide)

- Criticality in waste management processes which include techniques / chemical reactions such as precipitation
- Failure rate of process equipment (Optimizing the replacement frequency of enrichment stages where the enrichment stage is a contaminated waste metal)

URANIUM FUEL FABRICATION FACILITIES

- Concentrations of Uranium compounds as radioactive materials in waste
- Concentrations of Uranium as heavy metals in the waste
- Characteristics of the Uranium as UF6 as a soluble compound
- Characteristics of the uranium as UO2 as an insoluble compound
- Pyrophoric properties of Uranium metal
- Criticality
- Hydrogen
- Hydrofluoric acid
- High temperature processes
- Maintenance of tight manufacturing tolerances (Operator inspection requirements, fuel manufacturing failures generating waste streams)

MIXED OXIDE FUEL FABRICATION FACILITIES

- Concentrations of Uranium and transuranics as radioactive materials in waste (e.g. americium ingrowth)
- Characteristics of the uranium and transuranics insoluble compounds
- Plutonium physical properties (hardness and ability to act as a grinding medium)
- Radiolytic properties of plutonium (self-heating)
- Plutonium dust and contamination (importance of maintaining process integrity and cleanliness)
- Criticality
- Hydrogen
- High temperature processes
- Maintenance of tight manufacturing tolerances (Operator inspection requirements, fuel manufacturing failures generating waste streams)

REPROCESSING FACILITIES

- Radiological characteristics of spent fuel (burnup and cooling, effects on handling equipment)
- Physical characteristics of spent fuel (fragility)
- Concentrations of uranium and transuranics as radioactive materials in waste
- Characteristics of the uranium and transuranics insoluble compounds

- Concentration of fission and nuclear reaction products
- Elevated dose rates
- In-growth of radionuclides during processing
- Elevated radioactivity concentration levels
- Criticality (particularly in effluent precipitation processes and solvent washing)
- Chemical reagents and reaction products (including hydrogen, nitrogen oxides and organic materials)
- High temperature processes
- Chemically reactive metals (e.g. zirconium)
- Chemical processes that generate effluent and gaseous emissions
- Chemical processes that generate explosive gaseous mixtures in the off-gas system

CENTRALIZED WASTE MANAGEMENT FACILITY

Liquid waste treatment

- Presence of all contaminants as addressed above
- Presence of dissolved contaminants and particulates within liquid streams
- Physical concentration that generates precipitates of radioactive material including fissile material
- Chemical reactions that generate precipitates of radioactive material including fissile material
- Criticality
- Chemical reagent (non-radiological hazards and environmental impact)
- Environmental impact due to discharges
- Generation of secondary radioactive waste and requirements for its predisposal management e.g. accumulation of spent radioactive ion exchange media (elevated external dose rate levels)

Gaseous waste treatment

- Presence of all contaminants as addressed above
- Presence of particulates and aerosols within gaseous effluent streams (Condensation / deposition within gaseous effluent lines)
- Environmental impact due to emissions / discharges (Effective, representative characterization and monitoring techniques are needed)
- Generation of secondary waste and their pre-disposal waste management requirements e.g. accumulation of used HEPA filters (elevated external dose rate levels), liquid wastes
- Accumulation of short lived isotopes on adsorption media (E.g. Iodine 131 on activated carbon columns)

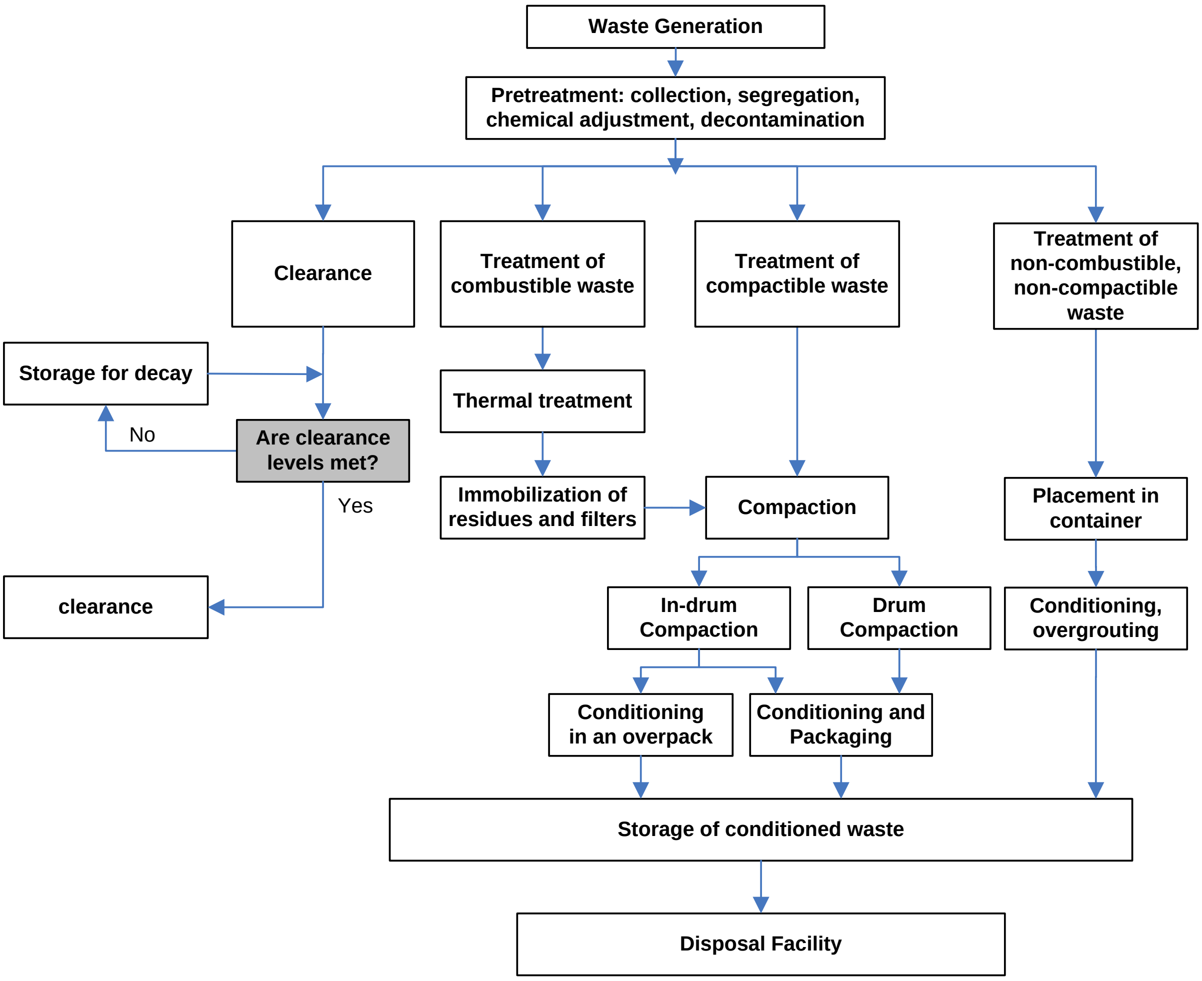
Evaporation and thermal treatment

- Concentration of radioactive materials including fissile materials within the waste
    - Increased dose rates
    - Criticality
    - Ability to dispose of the material
- High temperatures
- Fire
- Chemical reagents
- Chemical reactions of particularly contaminations or inadvertent arisings (e.g. solvents within aqueous streams)
- Presence of all contaminants as addressed above
- Presence of particulates and aerosols within gaseous effluent streams (Condensation / deposition within gaseous effluent lines)
- Environmental impact due to emissions / discharges (Effective, representative characterization and monitoring techniques are needed)
- Generation of secondary waste and their pre-disposal waste management requirements e.g. accumulation of used HEPA filters (elevated external dose rate levels), liquid wastes

Vitrification

- Concentration of radioactive materials including fissile materials within the waste
    - Increased dose rates
    - Criticality
    - Ability to dispose of the material
- High temperatures
- Corrosive liquids and vapours (e.g. nitric acid, nitrogen oxides)
- Chemical reactions of particularly contaminations or inadvertent arisings (e.g. solvents within aqueous streams)
- Presence of all contaminants as addressed above
- Presence of particulates and aerosols within gaseous effluent streams (Condensation / deposition within gaseous effluent lines)
- Environmental impact due to emissions / discharges (Effective, representative characterization and monitoring techniques are needed)
- Generation of secondary waste with significant radioactivity levels and their pre-disposal waste management requirements e.g. accumulation of used HEPA filters liquid wastes, highly contaminated process equipment - resulting in elevated external dose rate levels)
- Corrosive effects of molten glass (generation of highly contaminated spent material)

APPENDIX 7: MANAGEMENT FLOW DIAGRAM FOR SOLID RADIOACTIVE WASTE



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CONTRIBUTORS TO DRAFTING AND REVIEW

Abu-Eid, B.	Nuclear Regulatory Commission, United States of America
Baekelandt, L.	Federal Agency for Nuclear Control (FANC), Belgium
Blundell, N.	Office for Nuclear Regulation, United Kingdom
Boyden, F.	Private consultant, United Kingdom
Doughty, P.	Nuclear Safety Commission, Canada
Fass, T.	Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH, Germany
Geupel, S.	Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH, Germany
Kinker, M.	International Atomic Energy Agency
Leroyer, V.	Institute for Radiological Protection and Nuclear Safety, France
Selling, H.	Ministry of Economic Affairs Agency, Netherlands
Visagie, A.	South African Nuclear Energy Corporation, South Africa