GUIDE NO. AERB/NF/SG/RW-3

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GOVERNMENT OF INDIA

AERB SAFETY GUIDE

PREDISPOSAL MANAGEMENT OF HIGH LEVEL RADIOACTIVE WASTE

ATOMIC ENERGY REGULATORY BOARD

AERB SAFETY GUIDE NO. AERB/NF/SG/RW-3

PREDISPOSAL MANAGEMENT OF HIGH LEVEL RADIOACTIVE WASTE

Atomic Energy Regulatory Board
Mumbai-400 094
India

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Price:

Order for this guide should be addressed to:

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FOREWORD

Activities concerning establishment and utilisation of nuclear facilities and use of radioactive sources are to be carried out in India in accordance with the provisions of the Atomic Energy Act 1962. In pursuance of the objective of ensuring safety of members of the public and occupational workers, as well as protection of environment, the Atomic Energy Regulatory Board (AERB) has been entrusted with the responsibility of laying down safety standards and enforcing rules and regulations for such activities. The Board has, therefore, undertaken a programme of developing safety standards, safety codes and related guides and manuals for the purpose. While some of these documents cover aspects such as siting, design, construction, operation, quality assurance and decommissioning of nuclear and radiation facilities, other documents cover regulatory aspects of these facilities.

Safety codes and safety standards are formulated on the basis of nationally and internationally accepted safety criteria for design, construction and operation of specific equipment, structures, systems and components of nuclear and radiation facilities. Safety codes establish the safety objectives and set requirements that shall be fulfilled to provide adequate assurance for safety. Safety guides elaborate various requirements and furnish approaches for their implementation. Safety manuals deal with specific topics and contain detailed scientific and technical information on the subject. These documents are prepared by experts in the relevant fields and are extensively reviewed by advisory committees of the Board before they are published. The documents are revised when necessary, in the light of experience and feedback from users as well as new developments in the field.

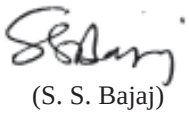
Operation of nuclear and radiation facilities may generate high-level radioactive waste. Management of this waste may involve long-term storage at various stages before its final disposal. This safety guide provides guidance for predisposal management of high-level radioactive waste to meet various safety requirements prescribed in the safety code on 'Management of Radioactive Waste'. In drafting this guide, extensive use has been made of the information contained in the relevant documents of International Atomic Energy Agency.

Consistent with the accepted practice, 'shall' and 'should' are used in the guide to distinguish between a firm requirement and a desirable option respectively. Approaches for implementation different to those set out in the guide may be acceptable, if they provide comparable assurance against undue risk to the health and safety of the occupational workers and the general public, and protection of the environment.

For aspects not covered in this safety guide, applicable national and international standards, codes and guides, acceptable to AERB should be followed. Non-radiological aspects such as industrial safety and environmental protection are not explicitly considered in this guide. Industrial safety is to be ensured through compliance with the applicable provisions of the Factories Act, 1948 and the Atomic Energy (Factories) Rules, 1996.

This guide has been prepared by specialists in the field drawn from the Atomic Energy Regulatory Board, Bhabha Atomic Research Centre, Nuclear Power Corporation of India Limited and other consultants. It has been reviewed by the relevant AERB Advisory Committee on Codes and Guides and the Advisory Committee on Nuclear Safety.

AERB wishes to thank all individuals and organisations who have prepared and reviewed the draft and helped in its finalisation. The list of persons, who have participated in this task, along with their affiliations, is included for information.



(S. S. Bajaj)
Chairman, AERB

DEFINITIONS

Acceptance Criteria

The standard or acceptable value against which the value of a functional or condition indicator is used to assess the ability of a system, structure or component to perform its design function or compliance with stipulated requirements.

Accident

An unplanned event resulting in (or having the potential to result in) personal injury or damage to equipment which may or may not cause release of unacceptable quantities of radioactive material or toxic/hazardous chemicals.

ALARA

An acronym for 'As Low As Reasonably Achievable'. A concept meaning that the design and use of sources**,** and the practices associated therewith, should be such as to ensure that exposures are kept as low as reasonably practicable, with economic and social factors taken into account.

Approval

A type of regulatory consent issued by the regulatory body to a proposal.

Atomic Energy Regulatory Board (AERB)

A national authority designated by the Government of India having the legal authority for issuing regulatory consent for various activities related to the nuclear and radiation facility and to perform safety and regulatory functions, including their enforcement for the protection of site personnel, the public and the environment against undue radiation hazards.

Authorisation

A type of regulatory consent issued by the regulatory body for all sources, practices and uses involving radioactive materials and radiation-generating equipment.

Competent Authority

Any official or authority appointed, approved or recognised by the Government of India for the purpose of the rules promulgated under the Atomic Energy Act, 1962.

Conditioning of Waste

The processes that transform waste into a form suitable for transport and/or storage and/or disposal. These may include converting the waste to another form, enclosing the waste in containers and providing additional packaging.

Contamination

The presence of radioactive substances in or on a material/the human body or other places in excess of quantities specified by the competent authority.

Decommissioning

The process by which a nuclear or radiation facility is finally taken out of operation in a manner that provides adequate protection to the health and safety of the workers, the public and the environment.

Decontamination

The removal or reduction of contamination by physical or chemical means.

Design

The process and results of developing the concept, detailed plans, supporting calculations and specifications for a nuclear or radiation facility.

Discharge (Radioactive)

Planned and controlled release of (gaseous or liquid) radioactive material into the environment.

Discharge Limits

The limits prescribed by the regulatory body for effluent discharges into atmosphere/ aquatic environment from nuclear/radiation facilities.

Disposal (Radioactive Waste)

The emplacement of waste in a repository without the intention of retrieval or the approved direct discharge of waste into the environment with subsequent dispersion.

Documentation

Recorded or pictorial information describing, defining, specifying, reporting or certifying activities, requirements, procedures or results.

Dose Limit

The value of the effective dose or the equivalent dose to individuals from controlled practices that shall not be exceeded.

Effluent

Any waste discharged into the environment from a facility, either in the form of liquid or gas.

Emergency Plan

A set of procedures to be implemented in the event of an accident.

Environment

Everything outside the premises of a facility, including the air, terrain, surface and underground water, flora and fauna.

High Level Waste (HLW)

A type of waste, which contains any of the following:

(a) The radioactive liquid containing most of the fission products and actinides present in spent fuel, which forms the residue from the first solvent extraction cycle in reprocessing, and some of the associated waste streams.

(b) Solidified high level waste from above and spent reactor fuel (if it is declared a waste).

(c) Any other waste with similar radiological characteristics.

Maintenance

Organised activities covering all preventive and remedial measures, both administrative and technical, to ensure that all structures, systems and components are capable of performing as intended for safe operation of the plant.

Monitoring

The continuous or periodic measurement of parameters for reasons related to the determination, assessment in respect of structure, system or component in a facility or control of radiation.

Occupational Exposure

All exposures of personnel incurred in the course of their work.

Occupational Worker

Any person, working full time or part time in a nuclear or radiation facility, who may be employed directly by the consentee or through a contractor.

Off-site

Area in public domain beyond the site boundary.

Quality Assurance

Planned and systematic actions necessary to provide the confidence that an item or service will satisfy given requirements for quality.

Radiation Surveillance

Measures that may be specified by the competent authority to provide adequate protection either generally or in any individual case.

Radioactive Waste

Material, whatever its physical form, left over from practices or interventions for which no further use is foreseen: (a) that contains or is contaminated with radioactive substances and has an activity or activity concentration higher than the level for clearance from regulatory requirements, and (b) exposure to which is not excluded from regulatory control.

Records

Documents, which furnish objective evidence of the quality of items and activities affecting quality; they include logging of events and other measurements.

Regulatory Body

(See 'Atomic Energy Regulatory Board').

Safety Assessment

A review of the aspects of design and operation of a source which are relevant to the protection of persons or the safety of the source, including the analysis of the provisions for safety and protection established in the design and operation of the source and the analysis of risks associated both with normal conditions and accident situations.

Segregation (Radioactive Waste)

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

Storage (Radioactive Waste)

The placement of radioactive waste in an appropriate facility with the intention of retrieving it at some future time. Hence, waste storage is by definition an interim measure and the term interim storage should not be used.

Surveillance

All planned activities, viz. monitoring, verifying, checking including in-service inspection, functional testing, calibration and performance testing carried out to ensure compliance with specifications established in a facility.

Waste Form

The waste in its physical and chemical form after treatment and/or conditioning prior to packaging.

Waste Immobilisation

The conversion of radioactive waste into solid form (by solidification, or by embedding,

or encapsulating in a matrix material) to reduce the potential for migration or dispersion of radionuclides during transport, storage and disposal.

Waste Management

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

Waste Package

The product of conditioning that includes the waste form and any containers and internal barriers (e.g. absorbing materials and liner), as prepared in accordance with requirements for handling, transportation, storage and/or disposal.

Waste Treatment

Operations intended to benefit safety and/or economy by changing the characteristics of the wastes by employing methods such as

(a) volume reduction,

(b) removal of radionuclides, and

(c) change of composition.

After treatment, the waste may or may not be immobilised to achieve an appropriate waste form.

SPECIAL DEFINITIONS
(Specific for the Present Guide)

Low and Intermediate Level Waste (LILW)

Radioactive waste in which the concentration or quantity of radionuclides is above clearance levels established by the regulatory body, but with radionuclide contents below those of high level waste. Low and intermediate level waste is often separated into short lived and long lived waste.

CONTENTS

1. INTRODUCTION

1.1 General

Operation of nuclear fuel cycle and radiation facilities may generate high-level radioactive waste (HLW). A major stream of this waste is the aqueous radioactive waste generated from the first cycle extraction of the spent fuel processing. Also solid waste not suitable for disposal in near surface disposal facilities due to significant concentration of long-lived radionuclides or decay heat above the prescribed limits may also need to be regarded as high level waste.

1.2 Objective

Objective of this safety guide is to provide guidance on predisposal management of high-level radioactive waste to meet the safety requirements spelt out in the safety code on 'Management of Radioactive Waste' AERB/ NRF/SC/RW [1]. This safety guide provides recommendations to the waste generator/ manager at various stages in the predisposal management of high-level radioactive waste for ensuring safety of the occupational workers, public and the environment.

1.3 Scope

This safety guide applies to the predisposal management of HLW. It provides guidance on design, construction and operation of facilities for predisposal management of HLW including waste storage farm for liquid HLW. This safety guide also provides guidelines for predisposal management of high level waste generated during operation and decommissioning activities of nuclear and radiation facilities.

This safety guide may not be applicable for the management of low and intermediate level waste including the secondary waste generated during predisposal management of HLW. Guidance on management of low and intermediate level radioactive waste is provided in the AERB safety guide on 'Predisposal Management of Low and Intermediate Level Radioactive Waste' AERB/NRF/SG/RW-2 [2].

2. RADIATION PROTECTION AND ENVIRONMENTAL SAFETY

2.1 General

Predisposal management of HLW needs to be dealt in a manner that protects human health and the environment now and in the future without imposing undue burden on future generations [3]. A programme for monitoring and surveillance needs to be established to provide reasonable assurance that the relevant safety objectives are fulfilled while carrying out management activities of HLW.

2.2 Radiation Protection

Predisposal management of HLW may result in radiation exposure to occupational workers and members of the public. Design of the facility and operational practices for predisposal management of HLW should be aimed to control occupational radiation exposure and also exposure to members of the public.

Radiation exposure to the occupational workers and the public should be within the limits prescribed by the regulatory body [4]. The exposures should be maintained as low as reasonably achievable (ALARA) by implementing engineered and administrative controls.

2.3 Non Radiological Hazards

Non-radiological hazards associated with the predisposal management of HLW should also be taken into account in the design and operation of the facilities. Protection from the non-radiological hazards including chemical toxicity should be provided in accordance with relevant standards pertaining to industrial safety and environmental protection.

2.4 Protection Measures and Control

Following methods, as applicable should be used to control and limit radiation exposure:

(a) Design provision

(b) Zone classification for different areas of the facility as per the approved radiation protection procedures

(c) Remote handling techniques for operation and maintenance

(d) Work planning, training, administrative controls and mock-ups to minimize exposures during operation and maintenance activities

(e) Establishing activity limits for transfer of radioactive substance from areas of higher contamination/radiation level to areas of lower contamination/radiation level

(f) Provision of equipment for monitoring and control of contamination, radiation exposure of workers, public and the environment

(g) Estimation of possible intake of radionuclides by occupational workers and ways of reducing it

(h) Provision for future augmentation and decommissioning.

2.5 Safety Assessment

Safety assessment including environmental impact assessment of the predisposal HLW management facilities should be carried out to demonstrate safety of the workers and the public during normal operations and anticipated incidents/ accidents. It should be conducted prior to construction and operation of HLW management facility. It should also demonstrate that HLW packages adequately confine radionuclides under normal operations and anticipated incidents/accidents.

The safety assessment should address interalia the following:

(a) Identify and address of the relevant safety criteria

(b) Methods for collection and evaluation of data and information

(c) Identification of normal and abnormal operating conditions

(d) Consequences of incident/accident

(e) Formal list of postulated initiating events (PIE's) and design basis accidents (DBA) and design basis for protection.

For safety assessment, the following should be considered:

(a) Design basis of the plant

(b) Equipment and the activities involved in the handling of HLW, and the passive and active safety systems

(c) Physical and chemical properties of HLW, such as, volumes, toxicity and inventories of radionuclides and non-radioactive components

(d) Site characteristics which are necessary to assess possible environmental impact to be addressed during design and operation of the respective facility;

(e) Operating conditions or limits necessary to establish safety limits during normal operations

(f) List of PIE's for anticipated operational occurrences (AOO) and DBA should be prepared and provision to mitigate the consequences should be elaborated.

3. DESIGN, CONSTRUCTION AND OPERATION OF PREDISPOSAL MANAGEMENT FACILITIES OF HIGH LEVEL WASTE

3.1 General

The facilities for predisposal management of HLW need to be designed, constructed and operated in a manner that ensures safety to occupational workers, public and the environment now and in future.

3.2 Design

The design of HLW predisposal management facilities should ensure safe operation and maintenance and also facilitate replacement of system, structure and components as necessary. The following should be considered in the design of HLW predisposal management facility:

(a) Waste generation, its characteristics and possible variations

(b) Site characteristics

(c) Environmental safety

(d) Plant and personnel safety

(e) Waste acceptance criteria

(f) Operational safety

(g) Minimization of secondary waste and its management

(h) Maintenance

(i) In-service inspection

(j) Refurbishment and renovations

(k) Interfacility transfer of waste

(l) Life expectancy

(m) Decontamination and decommissioning

(n) Retrievability of stored waste

(o) Industrial and fire safety

(p) Physical protection and security

(q) General design features

(r) Corrosion (acidity, temperature).

3.2.1 Waste Tank Farm for High Level Liquid Waste Storage

The high level liquid waste (HLLW) generated from the spent fuel processing plants may be stored safely in specially designed waste storage tanks located in waste tank farm area for an interim period before it is taken up for treatment in waste management facility.

General design philosophy for HLLW storage system should be aimed at safe storage and transfer of HLLW by providing engineered safety, administrative procedures and surveillance to ensure safety during normal operation and off normal situations.

The HLLW storage tanks and the waste tank farm should be designed to ensure structural integrity and safety against possible damage resulting in leakage of waste to environment under all operational and accidental conditions. This should be achieved by applying the concept of containment with multiple barriers and leak detection system with remedial measures to prevent spread of activity. Waste storage tanks and related structure should be designed as per the applicable seismic code.

The tank farm vault should be lined with appropriate material as an additional barrier. The lined compartment should have properly sized sump. The sump should have provisions for remote surveillance, monitoring and emptying.

The storage capacity of HLLW tanks should be based on the waste generation rate and the interim period for which the liquid waste is to be stored before further processing. Appropriate redundancy for storage/tankage should be provided for handling of exigencies.

The HLLW storage tanks should have provisions for cooling of its contents to remove decay heat, for homogenization of its contents to avoid settling, for sampling and withdrawing the contents. The tanks should be designed for adequate negative pressure to minimise the spread of contamination. The system design should also ensure continuous in-service inspection (ISI) and surveillance monitoring of the tank parameters such as tank level, temperature and pressure.

The monitoring provision should be made for HLLW storage facilities to ensure operability of safety related systems, for example, ventilation, cooling and level detection systems. Consideration should be given for providing redundant monitoring. In addition, measures should be provided to monitor physical and chemical parameters of the waste as required by the safety assessment, for example, temperature, pressure, and concentration of constituents, radiolytic decomposition of aqueous solutions and buildup of potentially flammable or explosive substances during normal operation and blackout condition. Measures should also be provided for maintaining these parameters within acceptable limits, as well as to ensure discharge of airborne and liquid effluents below regulatory limits.

Shielding of waste storage tank farm should be designed as per the prevailing regulatory requirements.

Primary and secondary containments of the storage system (i.e., storage tanks and vault) should be designed as per the applicable seismic classification to ensure that the storage system remains safe even during a maximum potential earthquake for specific site.

Adequate monitoring and surveillance provisions such as bore wells should be provided in the surrounding areas of the waste storage facility to detect the activity leakages, ingress water and radionuclide migration, if any.

3.2.2 Waste Transfer

Depending on the characteristics of the waste solution, especially the solid contents, the transfer mode should be reliable and near-maintenance-free with adequate redundancies. The number of interfacility wastes transfer lines should be optimised.

The facility should preferably be based on hot-cell concepts with adequate ventilation. The storage vessels containing HLLW and transfer devices should be housed in separate cells with provision of inspection and monitoring of leakages and ingress water.

Inter-facility pipelines should have adequate shielding and provision for leak detection. The transfer system should have multiple engineered barriers to ensure containment of radioactive liquid. Pipe-in-pipe concept should be used as primary and secondary containment. Provision should be made for monitoring annular space of the HLLW transfer line for timely detection of loss of primary containment of the line. Provision should also exist for monitoring ingress water into the waste pipe-line trench and draining of water and management scheme for the same.

The layout of the piping and the location of the facility should be such that there is no hold up after the transfer operation. Siphoning of the liquid should be avoided by design. Provision should be made for decontamination of the waste transfer lines.

Process interlocks should be incorporated to facilitate the safe transfer operations with respect to level, pressure and temperature of the source and destination tanks involved in the HLLW transfer.

3.2.3 Sampling System

Treatment and conditioning of HLLW involves various stages where radio-chemical analysis of the waste is important for assessing the activity and characteristics of the liquid. Sampling system should employ passive components. Provision should be made to provide homogenous and

representative samples, ensure fail-safe operation with minimum spread of contamination and avoid cross contamination. The sampling system should be connected to an off-gas treatment system to provide sufficient negative pressure in the system. Decontamination and maintenance facilities should exist in sampling systems.

3.2.4 HLLW Processing

HLLW processing involves treatment of the waste and conditioning in suitable matrix to produce vitrified waste product of desired properties for safe transportation, storage and disposal. This is achieved by providing engineered safety features, administrative procedures and surveillance to ensure safety during normal operation and off-normal situations. The design of the HLLW processing systems, operational practices and the maintenance of facility should result in minimum radiological exposure. A defense-in-depth concept should be used in the design of HLLW predisposal management facilities. Administrative controls should also be included to enhance the safety of the facility.

The design of predisposal management facilities for HLLW should include features (engineering controls) to maintain containment, removal of decay heat and avoid criticality, especially when concentrating HLLW to reduce total volume.

Integrity and safety of the primary and secondary containments against possible failure should be ensured. Sufficient redundancy and diversity for normal operation as well as off-normal conditions should be incorporated in the design.

HLLW transfer lines should be for a dedicated application and should not have inter connection with any transfer lines of other type/categories of waste.

Independent modes of feeding for melters, evaporators and all other equipment for critical processes should be ensured. Liquid transfer for forward routing or recycling should be incorporated in the design to achieve necessary operational flexibility. Such flexibility is useful to tackle the conditions that may arise if the waste streams produced during processing do not comply with the stipulated limits for discharge or to meet the process requirements. Cross contamination of stream should be avoided.

All the equipment involved in processing should be connected to off gas treatment system capable of maintaining adequate negative pressure. This system should also ensure the proper flow of the off-gases generated. Adequate number of filtration cycles and dilution should be provided before the off-gases are discharged to the atmosphere. Off-gas cleaning system should aim for removal of condensibles, entrained liquids and particulate activities.

Layout of the facility should be planned to provide segregation of active and inactive services. Multiple cell concepts may be adopted and layouts of the equipment are to be segregated in such a way that the maintenance on these equipment involves minimum radiological exposure. Individual cell may have multiple compartments.

Important parameters such as temperature, pressure and level of all the processing equipments should be monitored and adequate facilities should be available for their continuous monitoring since such parameters indicate the operational conditions.

Design of treatment and conditioning equipments should be based on the following basic parameters:

(a) Process conditions such as chemical kinetics, high temperature, void fraction in the solid bed, foaming characteristics, amount of corrosive components

(b) Waste processing rate

(c) Waste characteristics (acidity, total solid content, activity-alpha, beta, gamma, detailed elemental analysis, sulphate content, fluoride content, actinide content, total oxide content)

(d) Decay heat of the immobilised product and cooling requirement during storage and transportation

(e) Compatibility of the waste with matrix

(f) Waste acceptance criteria covering the properties such as chemical durability, thermal stability, mechanical properties and radiation stability

(g) Radiolytic decomposition and resultant gas generation involved in any stage of the process

(h) Consideration of secondary waste generation

(i) Suitability of the conditioned waste packages for transportation including retrieval and emplacement in a repository.

The waste concentration system which includes the waste concentration and acid recovery (HLLW being acidic) may contain soluble fractions and entrained organics, which may lead to explosive reactions. In order to avoid such occurrences safety provisions should be adequately incorporated. Volatilization of certain radionuclides such as ruthenium during evaporation should be taken into account in the design and accordingly off-gas treatment to be engineered. Material of construction should be chosen taking into account the presence of high concentration of acid and corrosion enhancing species present in the waste in evaporators/fractionators.

In addition to the above, the design of conditioning system should ensure the following:

(a) Suitable material of construction during conditioning taking into account high processing temperature and highly corrosive environment

(b) Adequate redundancy for temperature measurement and its control by proper interlocks to avoid overheating of the melter

(c) Monitoring of off gas line with provisions of flushing/dechoking and remote replacement when necessary

(d) Off-gas to have consistent clean up system to take care of entrained particulates and volatile species

(e) Provision for minimizing spread of radioactivity during conditioned waste product draining

(f) Incorporation of safety provisions to avoid unplanned draining of active glass, overflow from the storage vessel and containment in case of failure of the melter

(g) Design provisions and safety considerations for processing/ conditioning of HLLW other than glass matrix.

3.2.5 Plant Ventilation System

The design of the ventilation system should be based on the zoning concept and should ensure adequate air changes, flows patterns and prevent reverse flow in normal as well as blackout condition. The exhaust air should be filtered through absolute filter before discharge to atmosphere through stack. The exhaust fans should be provided with stand-by and emergency power supply.

3.2.6 Off-gas System

The objective of the clean-up system should be to remove volatiles, condensables, entrained liquids and particulate activities from the off-gas stream. The off-gas cleaning system should be available during all plant conditions including shutdown.

The design of off gas system should ensure the following:

(a) Keep the release of particulate activity through gaseous route within specified limits by providing high efficiency filtration

(b) Maintain process equipment and storage vessels under suitable negative pressure

(c) Avoid build up of condensible liquid in the off-gas filters which could impair the filter efficiency

(d) Minimise particulate activity of the off-gases to levels as to avoid contamination of equipment such as blowers, fans etc.

(e) Incorporation of adequate measures to remove volatile components like ruthenium, which substantially pose problem in the off-gases during operation

(f) Redundancy of critical equipment like fans, blowers and filters with provision of emergency power supply

(g) Isolation of blowers and filter with adequate shielding

(h) Location of the blowers and filters so that their maintenance/ replacement are done with minimum exposure

(i) Adequate instrumentation for critical parameters

(j) Adequate sampling points for measurement of the filter efficiencies

(k) Provision for testing the performance of the off-gas system.

3.2.7 Surveillance and Monitoring

Monitoring of the HLLW storage tanks on a continuous basis should typically include level, density, temperature and negative pressure. Monitoring of sump level and sampling in case of liquid collection should be a part of surveillance. The cooling water flow, inlet and outlet temperatures, radiation level at the outlet by means of installed area gamma monitor (AGM) should be monitored on a continuous basis and sampling of cooling water should be done in case of any abnormality. The monitoring of the radiological condition of the storage vault, operating cells and access areas of the facility should be done on continuous basis. Checklist of the surveillance should also include the access control and the physical protection systems.

Provisions should be identified for the ingress of water, collect such water at suitable location, sample it and transfer it to a desired process vessel for its further treatment.

Environmental monitoring provisions such as bore wells, infiltration galleries should be provided around the HLLW predisposal management facilities.

3.2.8 Auxiliary Service System

The utility and service systems should be designed and engineered to ensure safety during their operation as well as under off-normal situations. The utility and service systems should be designed conforming to the relevant code and standards of industrial safety. Additional consideration should be given for those streams, which have potential of contamination such as primary cooling water system and steam condensate. These streams should have provision of interim storage and should be subjected to adequate monitoring before discharge.

3.3 Construction

HLW predisposal management facilities should be constructed as per approved design and relevant codes. These include safety during civil constructions, equipment and piping installation. The areas should be well identified with respect to hazard during construction phase and necessary industrial safety gadgets/wears should be used.

3.4 Commissioning

During commissioning stage, all equipment, piping and associated system should be tested for their design intent. Emergency plans should be prepared for handling abnormal conditions.

Records generated during design, construction and commissioning should be verified and kept available in updated form. Quality assurance of all the systems should be carried out. This should include preparation of as-built drawings, documentation of all relevant test/checks carried out and their certificates.

Visual inspection and continuity checks, flushing of equipment, pneumatic/ hydrostatic test as applicable by the codes and procedures should be carried out. Individual equipment, related to various systems, should be tested and system wise operation should also be checked along with the utilities and services. Integrated testing and commissioning of all the systems involved in different processing and conditioning should be carried out.

Calibration of equipment, transfer modes, system performance on qualitative and quantitative manner should be included in commissioning trials. All the individual process interlocks are to be checked under operating conditions and simulated condition

3.5 Operation and Maintenance

Approved procedures should be used for operation and maintenance (O & M) of the facility. The facility should be operated as per the design intent. Documents such as safety reports, operating procedure, technical specifications, operation and maintenance manuals, should be available. Records of the operation parameters should be maintained. In-plant training and auditing of the safety procedures of the facility should be adopted. During operation and maintenance, following safety aspects should be considered.

(a) Radiological safety of the O & M personnel

(b) Industrial safety of the plant and O & M personnel

(c) Operation of the plant with laid-down approved procedures

(d) Operation of the plant within the technical specifications

(e) Maintenance of the equipment as per the design intent

(f) Secondary waste generation and its management

(g) Control of the discharges to the environment with respect to chemical and radioactive species.

3.6 Waste Characterisation

The HLLW should be characterised to ensure proper predisposal management. The objective of characterisation is to obtain the information regarding the properties of HLLW for ensuring final product quality and to verify critical process parameters. Various steps involved in characterisation include withdrawal of representative sample and subjecting the same to detailed physical and radiochemical analysis.

Conditioning of high-level liquid waste results in the immobilisation of the waste oxides in stable and inert solid matrix. Depending on the waste characteristics, matrix composition should be selected. The waste should take into account various aspects, like compatibility of waste component and container, extent of phase separation and non-homogeneity of the conditioned product. The processes available should be fully explored for getting the conditioned product of the desired characteristics. The conditioning process should also be compatible and adaptable for the particular HLLW.

Stable and inert solid form of this waste should have following characteristics:

(a) Good thermal, chemical, mechanical and radiation stabilities

(b) Insensitive to loss of services

(c) Better form from environmental safety point of view

(d) Ease of transportation

(e) Amenability to interim storage and ultimate disposal

(f) Readily available raw material and simple to manufacture.

Liquid HLW processing facilities should incorporate features to deal with nonconforming waste packages. Example includes separate storage areas and additional engineered barrier for non-conforming HLW packages. Contingency plan to deal with such situation should exist in the facility.

The conditioned waste product should be characterized for its chemical durability, thermal stability, radiation stability and mechanical strength and other physical properties such as density and homogeneity.

Operating parameters, which are essential to yield waste packages within the acceptable limits, should be identified and verified during operations.

3.7 Specific Safety Aspects of HLLW Concentration System

(a) Presence of organics in the HLLW may lead to pressure surges due to fast reaction of nitrates or nitric acid with the organics during evaporation. The operating procedure should incorporate safety provisions in order to avoid such occurrences. The temperature of the heating medium should be restricted to safe values, so that it can be ensured that the initiation of any such effect is avoided. Proper sampling and analysis should provide necessary information to ensure the acceptable composition of the contents for safe operation.

(b) Sufficient free board should be maintained in the evaporator. Necessary interlocks should be provided to avoid pressurisation in the evaporator.

(c) The concentration of waste should be carried out in such a way that it does not lead to high rate of Ru volatilisation and corrosion of equipment. This may be achieved by controlling the molarity of acid by means of proper process interlocks and selection of proper material of construction.

(d) For measurement of all critical parameters adequate redundancies should be provided.

(e) Adequate safety control and proper procedure should be adopted for acid denitration.

3.8 Material Handling and Remotisation System

Processing of HLLW should be carried out remotely in shielded cells. The conditioning process and the related equipment, decontaminations required for the storage vessel of conditioned waste product, welding of the canisters/ overpacks and their removal out of the cell and transportation to interim storage facility and the material handling inside the shielded areas require remote handling systems/gadgets. Adequate gadgets should be provided for remote handling of melters, other equipment and product transfer trolleys. In-cell crane required for material handling, welding facility for carrying out welding of the lids to product canisters and overpacks, product removal and transportation cask, manipulators for assisting remote handling services inside the conditioning and other related cells, radiation resistant cameras, radiation shielding window for viewing the cells should be incorporated. These equipment should be operated remotely and should also be rugged enough requiring minimum maintenance and should also be able to withstand the high radiation inside the cells. Material of construction should be so chosen to allow easy decontaminations. All the equipment/gadgets should have emergency handling operability. All the lubricants of gears should be radiation resistant type. The remote handling equipment should be such that the units

can be taken-out/replaced without cell entry. Provisions should be made so that the material handling/gadgets for remote operation can be parked in relatively lower radioactive areas to avoid unnecessary exposure. The design of the viewing instruments such as windows should take care of shielding. In the event of worst possible accident leading to the failure of cover glass of viewing windows, the effective shielding achievable after the complete draining of oil should be sufficient. Proper handling of cask should be ensured with all necessary interlocks and administrative controls. The grapplers should be of rugged construction, longer expected life, high maintainability and fail-proof operation and should be made of corrosion resistant materials compatible with cell atmosphere. All the remote handling gadgets should be operated with proper interlocks, administrative controls and operational procedures.

3.9 HLW from Nuclear and Radiation Facilities

Nuclear and radiation facilities including nuclear power plants and research reactors may generate high level waste during operation, decontamination and decommissioning of reactor components. This waste should be properly characterized and, if required, properly stored to enable its subsequent treatment and conditioning to minimize volume and meet product acceptance criteria for final disposal.

3.10 Decommissioning

Predisposal management facilities for HLW have a definite useful life and will need to be decommissioned. Therefore, the decommissioning aspects should be considered at the design stage itself. The provisional decommissioning plan should include anticipated waste generation during decommissioning and their management scheme [5].

4. STORAGE OF SOLID AND SOLIDIFIED WASTE PRODUCT

4.1 General

Interim storage of solidified HLLW product is an important step in predisposal management of HLW. The interim storage period may be few decades till the decay heat and resultant temperature profile are within the limits of transportation and emplacement in the repository. Interim storage may also be needed for solid / solidified alpha contaminated waste products including cladding hulls before their ultimate disposal.

Interim storage facility needs to be designed, constructed and operated taking into account thermal aspects due to decay heat and applicable seismic standards in view of large radionuclide inventory.

The facility should be above highest flood level for the site and in addition there should be provisions for detection of water ingress and pumping out the same for monitoring and/or treatment.

4.2 Surveillance and Monitoring of Storage Facility

Monitoring of canister temperature, exhaust air and underground water around the facility for radioactivity should be carried out regularly to ascertain the integrity of the waste canister and the safety of the storage facility. Surveillance of storage unit may also be carried out by physical and / or remote inspection using video camera or any other suitable devices.

4.3 Heat Removal

The design of predisposal HLW management facilities should incorporate measures (for example, a temperature monitoring and control system) capable of maintaining HLW temperatures within acceptable limits during all steps of predisposal management under both normal and accident conditions. Such temperature limits should be based on the properties of the waste and waste packages, taking into account material properties of the container, containment structures, and the waste form during all processing steps, including storage.

To the extent possible, cooling systems for conditioned HLLW storage facilities should be passive and should require minimum maintenance. Where forced circulation of air is used, a highly reliable system is needed. An induced draft air-cooling with HEPA (High Efficiency Particulate Air) filter installation for filtration of exhaust air of appropriate capacity should be provided as stand by. Design should provide sufficient margin to avoid dust deposit. Examples of features that enhance the reliability of the cooling system are the ability to deal with the settling of solids and buildup on surfaces, which

affects efficiency of heat removal. The design of the storage facility itself should be capable of accommodating temporary loss of cooling without damage to the stored waste. In addition, other mitigating measures should be in place to deal with this kind of contingency.

4.4 Transportation of Waste Packages

Transportation of radioactive waste packages requires appropriate systems for safe handling at consignor and consignee's premises. This also involves specifying procedures and control measures, including documentation of waste packages. The solid radioactive material should be transported in a packaged form taking into account the following aspects:

(a) Containment

(b) Shielding

(c) Heat dissipation (to maintain temperatures within permissible limits).

4.4.1 On-site Transportation of HLW Packages

On-site transport of HLW packages should be as per the approved procedure. Precautions to be taken while transporting solid waste on-site depend mainly on the activity, the packing and surface contamination. Adequate packaging, shielding and supervision should be provided to keep the exposure of site personnel to a minimum in accordance with the ALARA principle and to minimize the potential of the release of activity in the event of an accident during transportation.

Prior to the dispatch of package or the departure of the vehicle carrying packaged material, the consignor should ensure that the radiation levels and surface contamination are within the limits prescribed by regulatory body.

4.4.2 Off-site Transport of HLW Packages

Off-site transport of solid radioactive waste should be as per the approved procedures meeting the requirements of the AERB safety code AERB/SC/TR-1 [6].

Prior to the dispatch of package or the departure of the vehicle carrying packaged material, the consignor should ensure that the radiation levels and surface contamination are within the limits prescribed by regulatory body.

4.5 Safety Aspects of other Solid Waste Requiring Geological Disposal

Solid waste containing significant quantities of alpha and long-lived radionuclides (e.g. hulls) or waste not suitable for near surface disposal should be stored in interim storage facilities for a period till its final disposal. Appropriate treatment/conditioning should be provided for such waste to minimize the volume and to meet the acceptance criteria for storage, transportation and final disposal.

5. RESPONSIBILITIES OF WASTE GENERATOR/ MANAGER

5.1 General

Predisposal management of HLW needs to take place within the regulatory framework. A clear delineation of responsibilities in the entire predisposal management of HLW including the transfer of such waste needs to be ensured [7].

The waste manager needs to decide the mode of treatment depending on the processes and facilities available. It may also require development of process for treatment of non-conforming waste.

5.2 Responsibilities of Waste Generator/ Manager

Waste Generator/Manager should:

(a) Ensure provision for suitable and sufficient storage capacity on an appropriate time-scale

(b) Perform safety and environmental impact assessments of HLW predisposal waste management facilities and activities

(c) Ensure adequate radiation protection of the workers, the general public and the environment

(d) Ensure that suitable staff, equipment, facilities, training and operating procedures are available

(e) Establish and implement a quality assurance programme at all stages

(f) Establish and keep records of the generation, processing, storage and disposal of radioactive waste

(g) Provide surveillance and control as required by the regulatory body

(h) Use operational experience to improve waste management safety

(i) Address issues related to decommissioning and management of resulting radioactive waste

(j) Assume complete responsibility in case of delegation of any work to a different agency

(k) Establish emergency preparedness

(l) Ensure effective organisation structure

(m) Obtain necessary approval from the regulatory body for all aspects of waste management (viz.waste segregation, classification, treatment

and conditioning, safety criteria for processes/operation, acceptance criteria for waste packages, waste discharge/disposal and decommissioning).

(n) Ensure discharges/ disposal of radioactive waste to the environment within the authorized limits and at an authorised destination

(o) Meet requirements of regulatory body with respect to normal/off-normal discharges and corrective action if any.

6. QUALITY ASSURANCE PROGRAMME (QAP)

6.1 General

The facility needs to have an approved QAP based on the prevalent QA codes and practices to meet the safety requirements.

6.2 QAP for Predisposal Management of HLW

The QA programme should address the management elements necessary for its implementation, including planning, scheduling of activities, and resource considerations. It should be documented in the quality assurance programme plan (or description) and the results of these activities should be recorded. The responsibilities and authority of personnel and organisations involved should be clearly delineated in the approved plan.

Safety related components and systems should be managed according to their importance for HLW containment and safe operation of HLW predisposal management facilities. The necessary level of QA controls design, selection of material, fabrication, piping etc. and installation of such components and systems should be assigned accordingly.

It is important to assure that the waste packages are prepared in a manner that will meet waste acceptance requirements, in order to ensure acceptance at a storage facility/ repository. Prevention of non-conformances in waste packages should be emphasized, particularly for those activities that, if not performed properly, could lead to an irreversible non-conformance. This may be achieved through implementation of a QA programme, including implementing procedures, for the following activities:

(a) HLW characterisation

(b) Approval of the HLW conditioning process

(c) Development of the HLW package specifications

(d) Review of quality control records

(e) Verification of the HLW package characteristics.

For HLW, a characterisation programme is necessary to assess the suitability of pretreated/treated HLW for the conditioning process, as well as to optimise the composition of the solidified waste (waste form). Establishing a reference composition of the waste form (with bandwidths) is recommended which should include the characteristics to be determined. Proposals for deviations from this reference composition and the characterisation programme should be assessed to determine their effect on waste package quality.

The HLW package specification should be defined to meet waste acceptance requirements for handling, transportation, storage and anticipated disposal. The operator should develop a conditioning process that results in production of waste packages within the specified limits. In the conditioning process, critical parameters should be identified and controlled.

For each conditioned HLW package, quality records should be established and maintained. These records should be reviewed against the specification to determine the acceptability of the waste package. A record should be made of the results of the review and retained for a specified period of time. Should a waste package not meet the specifications/waste acceptance requirements, the nature of the nonconformity be recorded and the decisions taken to carry out appropriate corrective actions.

Records generated at all stages of predisposal HLW management may be important for demonstrating compliance of the waste package with the defined specifications. Such records should ensure traceability of waste characteristics from receipt through processing and storage. A documentation system that includes the development of such records should be set up. Examples of the contents of such records include, characterisation of the waste/waste package:

(a) Key process parameters for the HLW during pretreatment, treatment and conditioning

(b) Characterisation of the waste form, the associated canister/container, e.g. material certificates of the container including lids, and welds or seals etc.

(c) Significant monitoring parameters.

Lack of availability of treatment and conditioning facilities may necessitate storage of HLW for long periods before treatment or conditioning. There may also be a long period of storage before disposal if a suitable disposal facility is not available, or if time must be allowed for the decay of thermal power. In such cases, the QA programme should be designed to ensure that the quality and integrity of the product are sustained, and the quality of the records, as well as the marking and labeling of waste packages are maintained and preserved.

An audit programme should be developed that includes provisions for self-assessments and independent assessments (audits). Such assessments should determine if the predisposal HLW management programme and plans meet the respective requirements, that activities are covered by procedures, and that the implementation of the programme is adequate. Process audits are necessary for verifying that processes under the QA programme are being operated within specified parameters, in compliance with safe operating procedures and the requirements established by the regulatory body in a license or other type of authorisation.

6.3 Training and Qualification

The plant organisation should establish a programme for training of the plant personnel to meet the requirements.

The staff employed in the plant should also undergo training of appropriate duration at regular intervals for updating their knowledge and skills.

7. DOCUMENTATION AND RECORDS

7.1 General

Documents and records are the primary requirements of the plants meant for predisposal management of HLW. These include project proposal, design basis report, safety analysis reports, etc., which are generated during establishment of the facility. Other reports/records constitute the operation and maintenance reports of the facility which are generated during operation of that facility.

7.2 Types of Documents and Records

The waste generators/managers of radioactive waste management facilities should maintain documentation and records consistent with the regulatory requirements and their own needs. The records relevant to the facility should be kept in custody such that these can be referred to and understood by people different from those who generated the records. The facility should take responsibility for the retention of the records important from long-term considerations.

Documentation and records should include relevant details of items such as:

(a) An inventory of radioactive waste, including origin, location, physical and chemical characteristics, and, as appropriate, a record of radioactive waste transferred or disposed from a facility

(b) Site plans, engineering drawings, specifications and process descriptions

(c) Data resulting from operation and maintenance of the plant

(d) Data resulting from quality assurance and quality control procedures and from operating activities

(e) Radiation exposure and health of the workers

(f) Safety and environmental assessment methods and computer codes

(g) Results of safety and environmental assessments

(h) Effluent and environmental monitoring

(i) Radioactive waste package identifications

(j) Major deviations/incidents/accidents and their corrective actions

(k) Operation and maintenance manuals and technical specifications

(l) Design basis reports and the safety report.

The waste manager/generator should establish a procedure for maintaining adequate documentation and records. Various records are waste receipt records, waste characterisation records, operational records and storage/ disposal records. The QA record should also be maintained in accordance with approved QAP. The scope and details of the record will depend on the hazard and/or complexity of the proposed operation.

7.3 Operational Records

The records should include:

(a) Waste inventory

(b) Waste characterisation

(c) Treatment, packaging and conditioning process

(d) Container/canister/overpack documents

(e) Waste package specifications and audit records for individual container/canister/overpack and packages

(f) Trends in operating performance

(g) Non-compliances with the specifications and the action taken to rectify the situation

(h) Monitoring records.

7.4 Waste Characterisation Records

A waste characterisation record should contain the following information pertaining to the waste:

(a) Source or origin

(b) Physical and chemical form

(c) Amount (volume and/or weight)

(d) Radiological characteristics (radio-activity concentration, total activity, radionulcides present and their proportions)

(e) Classification in accordance with the waste classification systems

(f) Data pertaining to chemical, biological and radiological hazards.

7.5 Waste Package Records

The records of each waste package should constitute the following:

(a) Waste characterisation record - chemical and radiological constituents

(b) Waste loading

(c) Unique identification of all the canisters and over pack

(d) Composition of immobilised waste form

(e) Properties of immobilised waste form

(f) Interim storage records

(g) QA details of canisters and over pack including details of the lid welding performed.

7.6 Reports

(a) Waste generator/manager should submit a periodic report to the regulatory body, in accordance with authorisation

(b) Waste generator/manager should submit a report on significant events, if any, to the regulatory body in the prescribed format.

7.7 Accessibility and Retention of the Records

All the records should be preserved in multiple forms and in different places to ensure their availability. Retrieval of data/records should be available only to the authorised person.

7.8 Record Keeping

The period of record keeping may vary from few months to the several hundreds of years. The record keeping should be consistent with the safety and regulatory requirements.

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PROVISIONAL LIST OF SAFETY CODES AND SAFETY GUIDES ON RADIOACTIVE WASTE MANAGEMENT

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