GUIDE NO. AERB/NF/SG/RW-5

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GOVERNMENT OF INDIA

AERB SAFETY GUIDE

MANAGEMENT OF RADIOACTIVE WASTE FROM MINING AND MILLING OF URANIUM AND THORIUM

ATOMIC ENERGY REGULATORY BOARD

AERB SAFETY GUIDE NO. AERB/NF/SG/RW-5

MANAGEMENT OF RADIOACTIVE WASTE FROM MINING AND MILLING OF URANIUM AND THORIUM

Atomic Energy Regulatory Board
Mumbai-400 094
India

August 2007

Price

Orders 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 framing 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, decommissioning of nuclear and radiation facilities, other documents cover regulation 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, systems, structures and components of nuclear and radiation facilities. Safety codes establish the objectives and set minimum 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 the experience and feedback from users as well as new developments in the field.

This safety guide provides guidance for ensuring safety in handling and disposal of radioactive waste generated from mining and milling of uranium and thorium. This guide is one of the series of guides, being prepared by AERB for the management of radioactive waste for nuclear and radiation facilities. It addresses administrative, legal and regulatory framework and radiation protection in the management of radioactive waste from mining and processing of uranium ore, monazite and thorium. It also provides guidance for the management of decommissioning waste of such facilities and monitoring and regulatory control during pre-operation, operation, closure and post-closure period.

Consistent with the accepted practice, ‘shall’ and ‘should’ are used in this guide to distinguish between a firm requirement and a desirable option respectively. Annexure and bibliography are included to provide further information on the subject that might be helpful to the user. 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.

This guide applies only for facilities built after the issue of the document. However during periodic safety review and life management (as brought out in the respective AERB guides) a review for applicability of current standards for existing facilities would be performed.

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 shall 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, the Bhabha Atomic Research Centre and the Indian Rare Earths Ltd. It has been reviewed by experts, relevant AERB Advisory Committee and the Advisory Committee on Nuclear Safety.

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

(S.K. Sharma)
Chairman, AERB

DEFINITIONS

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.

Assessment

Systematic evaluation of the arrangements, processes, activities and related results for their adequacy and effectiveness in comparison with set criteria.

Atomic Energy Regulatory Board (Regulatory Body)

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.

Authorised Limits
(See "Prescribed Limits")

Commissioning

The process during which structures, systems and components of a nuclear or radiation facility, on being constructed, are made functional and verified in accordance with design specifications and found to have met the performance criteria.

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.

Consentee

A person to whom consent is granted by the competent authority under the relevant Rules.

Controlled Area

A delineated area to which access is controlled and in which specific protection measures and safety provisions are, or could be, required for:

(a) controlling normal exposures or preventing the spread of contamination during normal working conditions; and

(b) preventing potential exposures or limiting their extent should they occur.

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.

Decontamination Factor

The ratio of initial level of contamination of radioactive material to residual level achieved through a decontamination process.

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.

Effluent

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

Emergency

A situation which endangers or is likely to endanger safety of the site personnel, the nuclear/radiation facility or the public and the environment.

Exemption

The deliberate omission of a practice, or specified sources within a practice, from regulatory control or from some aspects of regulatory control, by the regulatory body on the grounds that the exposures which the practice or sources cause or have the potential to cause are sufficiently low as to be of no regulatory concern.

Hazard

Situation or source, which is potentially dangerous for human, society and/or the environment.

Ingestion (of Radioactive Materials)

Intake of radioactive material by way of the gastro-intestinal system.

Inhalation (of Radioactive Materials)

Intake of radioactive material by way of the respiratory system.

Licence

A type of regulatory consent, granted by the regulatory body for all sources, practices and uses for nuclear facilities involving the nuclear fuel cycle and also certain categories of radiation facilities. It also means authority given by the regulatory body to a person to operate the above said facilities.

Limit

The value of a parameter or attribute (which is variable) used in certain specific activities or circumstances that must not be exceeded.

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.

Member of the Public

Any individual in the population except for one who is subject to occupational or medical exposures. For the purpose of verifying compliance with the annual dose limit for public exposure, the member of the public is the representative individual in the relevant critical group.

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.

Near Surface Disposal

Disposal of waste with/without engineered barriers, or below the ground surface with adequate final protection covering to bring the surface dose rate within prescribed limits.

Nuclear Fuel Cycle

All operations associated with the production of nuclear energy, including mining, milling, processing and enrichment of uranium or processing of thorium, manufacture of nuclear fuel, operation of nuclear reactors, reprocessing of irradiated nuclear fuel, decommissioning, and any activity for radioactive waste management and research or development activity related to any of the foregoing.

Occupier

One who has been given the ultimate control over the affairs of the installations.

Operation

All activities following and prior to commissioning performed to achieve, in a safe manner, the purpose for which a nuclear/radiation facility is constructed, including maintenance.

Prescribed limits

Limits established or accepted by the regulatory body.

Quality Assurance (QA)

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

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”).

Review

Documented, comprehensive and systematic evaluation of the fulfillment of requirements, identification of issues, if any.

Safety Analysis

Evaluation of the potential hazards (risks) associated with the implementation of a proposed activity.

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 with normal conditions and accident situations.

Safety Guide

A document containing detailed guidelines and various procedures/methodologies to implement the specific parts of a safety code, that are acceptable to regulatory body, for regulatory review. This is issued under the authority of regulatory body and is of non-mandatory nature.

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.

Site

The area containing the facility defined by a boundary and under effective control of the facility management.

Siting

The process of selecting a suitable site for a facility including appropriate assessment and definition of the related design bases.

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.

Unrestricted Use

Any release or use of materials, equipment, buildings or site without any restriction imposed by the regulatory body.

Waste Management

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

CONTENTS

1. INTRODUCTION

1.1 General

1.1.1 Wastes from the mining and milling of uranium and thorium ores pose potential environmental and public health hazards because of their radiological characteristics. These wastes are characterised by large volumes and low activity concentration of materials containing naturally occurring radionuclides with very long radioactive half-lives.

1.2 Objective

1.2.1 The objective of this safety guide is to provide guidelines for safe management of wastes generated from mining and milling of uranium and thorium for the protection of the workers, public and environment from the impacts resulting from these wastes.

1.3 Scope

1.3.1 This safety guide provides guidance on waste management activities associated with the mining and milling of uranium and thorium. Waste management includes the whole sequence of operations starting with the generation, treatment, disposal of waste and ending with closure and post-closure aspects.

1.3.2 The safety guide covers the administrative and technical aspects associated with the safe handling and management of radioactive waste. It explains the responsibilities of the waste generators/managers to protect workers, public and environment from impacts resulting from waste generated in uranium and thorium mining and milling. It provides guidelines for the protection of human health and the environment from the radiological hazards associated with the waste generated from these facilities.

1.3.3 Since generation, processing and disposal of waste are different for uranium and thorium facilities, these are dealt separately in this safety guide. It provides guidance on the classification and segregation of waste, storage and characterisation, processing, transport and disposal of radioactive waste. Special requirements related to the management of tailings from uranium milling have also been addressed. The wastes generated during the decommissioning operations are also considered. The guide specifies the details of environmental surveillance programme that should be put in place for various waste management facilities.

1.3.4 References to the hazards associated with non-radiological characteristics of the wastes that need to be addressed are also covered. However, detailed guidelines regarding non-radiological hazards are beyond the scope of this safety guide. The safety aspects on management of radioactive waste arising from other parts of nuclear fuel cycle or from other practices are also not covered.

2. RESPONSIBILITIES OF THE WASTE GENERATOR/MANAGER

2.1 General

This section sets out a recommended list of the specific responsibilities of the waste generator/manager of the U/Th mining and milling facility.

2.2 Responsibilities of the Waste Generator/Manager

(a) The waste generator/manager should submit the following information/documents:

(i) Characteristics and quantity of the waste generated and the proposed waste management scheme.

(ii) Programme of operational and post-operational studies of environmental impact, in comparison with baseline monitoring.

(iii) Assumptions and methods to be used for assessing the radiological impacts of operational and post-operational discharges and releases of radionuclides to the environment from the waste generated by the mining, milling and processing operation.

(iv) Technical and administrative measures to be adopted for the control and limitation of discharges.

(v) Programmes and methods for measuring and assessing releases of contaminants to the environment.

(vi) Securing the approval of the Atomic Energy Regulatory Board (AERB) for authorised limits for discharge and disposal under the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987.

(vii) Quality assurance programme.

(viii) Dose management of occupational workers.

(ix) Evaluation of the probabilities and consequences of unplanned events that may result in unacceptable impact on the environment. In studying potential unplanned events, it may be possible to implement design or operational changes that would significantly reduce the possibility or severity of such events.

(x) Emergency preparedness plans for remedial action to mitigate the consequences of unplanned events.

(xi) Plans for management of decommissioning waste.

(xii) Post-closure monitoring, surveillance and institutional control of the waste management facility.

(xiii) Safety analysis report during construction, operation, closure and post closure phases.

(b) Implementation of the programmes outlined in item 2.2 (a) as approved by AERB.

(c) Ensuring use of procedures approved by AERB for measurement and assessment of releases.

(d) Periodical review and updating of the waste management programmes and facilities.

(e) Intimation to AERB of any deviation from the approved programme and seeking approval.

(f) Seeking approval of AERB for any transaction of the land likely to be affected by the waste.

(g) Employing adequate qualified and trained staff.

(h) Ensuring adoption of approved work procedure by the contractor.

3. RADIATION PROTECTION AND ENVIRONMENTAL PROTECTION

3.1 General

3.1.1 The objective of radiation protection is to protect the workers, members of the public and the environment from the adverse effects of radiation while at the same time allowing the justified activities. The management of waste from U/Th mining and milling is part of a practice and radiation protection considerations are therefore governed by the principles of justification, optimisation and dose limitation as follows.

Justification: No practice shall be adopted unless its introduction produces a positive net benefit.

Optimisation: All exposures shall be as low as reasonably achievable (ALARA), economic and social factors being taken into account.

Individual dose limitation: The dose equivalent to individuals shall not exceed the limits recommended by AERB.

Radiation protection considerations for workers and public and for siting are dealt in the following sections.

3.2 Radiological Protection of Workers

3.2.1 Workers at U/Th mines or mills may receive radiation doses from ores, concentrates, the product of milling process, associated airborne dust, process fluids, radon and thoron daughter products and radioactive wastes. All major pathways of radionuclides and ways of exposure should be considered and estimated so as to get a complete understanding of the resulting exposure. Radioactive waste from U/Th mines and mills are all unsealed sources. Hence protection of workers should account for the following exposure pathways- external gamma and beta irradiation including skin contamination, inhalation and ingestion. The facility should have in place a comprehensive radiological protection programme in accordance with the requirements of AERB. The radiation exposure of workers should not exceed the following dose limits prescribed by AERB (Table-1).

TABLE-1 : DOSE LIMITS AND CONSTRAINTS [1]

Category	Dose constraint			Annual effective dose limit (mSv)	Annual equivalent limit		
	Life time effective dose limit (Sv)	For medical review (Sv)	For consecutive 5 years (mSv)		Lens of eye (mSv)	Skin (mSv)	Extremities (mSv)
Radiation worker	1	0.5	100	30	150	500	500
Apprentices and Trainees	-	-	-	6	50	150	150
Temporary worker	-	-	-	15	75	250	250

3.3 Radiological Protection of the Public

3.3.1 The primary aim of radiological protection policy is to provide an appropriate standard of protection for people without unduly limiting the beneficial practices giving rise to radiation exposure. Wastes from the mining and milling of radioactive ores are potential sources of radiological impact, both for those working in the industry and for members of the public who may be exposed if wastes are dispersed in the environment. The radiation detriment due to a source relates to all human radiation exposures, both present and future, caused by the source during its lifetime. In the case of mining and milling wastes, there is also a need to consider exposures due to human intrusion into the waste at some future time. For example, mine and mill tailings will continue to present a potential hazard to human health even after closure, and therefore engineered/administrative measures should be provided for the protection of future generation. The principal dose limit for members of the public is 1 mSv in a year.

3.4 Siting Characteristics

3.4.1 Normally the waste management facilities are sited close to the mine/mill facility. The waste generator/manager should consider the following factors during site selection:

3.4.2 Climate and Meteorology

3.4.2.1 Precipitation and evaporation rates are important parameters for storage and disposal of waste. Consideration should be given to the distribution of the rainfall, both throughout the year and from year to year, to ensure that adequate freeboard in the waste retention system is available at all times.

3.4.2.2 If rainfall is unevenly distributed during the dry season the rivers or streams will dry up, so that effluents cannot be discharged to them. The rate of rainfall, the magnitude and frequency of floods should also be considered in the siting and design of a waste retention system. Wind direction and speed should be considered to assess wind erosion of wastes and dust transport.

3.4.2.3 Extreme meteorological conditions like wind, temperature and rainfall should be considered and computation methodology for these parameters are given in AERB safety guide on Extreme Values of Meteorological Parameters (AERB/NF/SG/S-3) [being published]. For long term storage facility a return period of 100 years is to be considered.

3.4.3 Geography, Geomorphology, Demography, Land and Water Use

3.4.3.1 These factors have a large influence on the waste management practices adopted at a particular site. For instance, the geomorphology of a site may not allow the siting of a waste retention system proximate to water bodies. Siting of the waste storage facilities should consider the drinking water sources and the adjacent population centres.

3.4.4 Geology and Seismicity

3.4.4.1 The geology of the area influences selection of the site for a large embankment, as suitable foundations are essential for stability. The seismicity of the area should be considered while siting and designing waste retention systems, as deformation and possible consequent liquefaction due to earthquake shocks can have serious structural consequences. Particular attention is to be given to the design of tailings embankments, thorium silos and other storage structures.

3.4.5 Geochemistry

3.4.5.1 Geochemical properties prevailing in the proposed sites should be considered to assess the final location and performance of the waste management facility. Chemical interactions of the wastes with the underlying strata of the site would influence the migration of the contaminants, with individual species being retained, retarded, or unaffected, depending on their specific chemical interactions.

3.4.6 Mineralogy

3.4.6.1 The mineralogy of soils and the subsurface of areas under considerations for mill sites and waste retention systems should be given greater attention. For example, an area with high limestone or dolomite wastes near the surface may prove unsatisfactory for a waste retention system if the wastes contain sulphides that may generate acid. Continuing acid percolation into the subsurface can dissolve carbonaceous rocks, opening channels for solution loss from the site, and also possibly affecting the stability of the waste retention system.

3.4.7 Hydrology and Flooding

3.4.7.1 The hydrology of the site should be taken into account as the wastes could contaminate either surface or ground water. Infiltration into the mine workings and in some cases into the waste retention system influences the composition of mine drainage and waste seepages and can affect their management.

3.4.8 Flora and Fauna

3.4.8.1 Distribution and abundance of important plant species and/or plant communities should be considered. Abundance, density, frequency (%), cover (%) of the plant species and dominant species should also be considered. Particular attention should be given to the animal species present, their location/ distribution, the nature and extent of their dependence on the site.

3.5 Non-radiological Considerations

3.5.1 Wastes from U/Th mining and milling will also give rise to non-radiological hazards to humans and the environment. Any release of contaminants to the receiving environment should comply with the criteria prescribed by the concerned statutory body.

3.5.2 Contaminants may be transported to the environment through seepage, surface runoff and mine effluents. Acid mine drainage is of particular concern with sulphidic ores. Acid generation can result in a reduction in the pH of adjacent water systems and an increase in the mobilisation of contaminants, particularly heavy metals that may adversely impact upon surface water ecosystem. In addition to chemical effects, sediments arising from the erosion of waste management facilities may increase turbidity or cause excessive silting in surface water systems within the catchment area and also transport radioactivity downstream.

3.6 Environmental Safety Assessment

3.6.1 In order to assess the impact that a proposed waste management facility would have on the environment, a pre-operational data collection and analysis programme incorporating the factors mentioned in siting characteristics (subsection 3.4) should be undertaken. In addition to the data mentioned above, programme requirements should include the collection and analysis of parameters such as:

- the concentration of important radioactive and non-radioactive components in environmental matrices,
- the local gamma radiation levels etc.

3.6.2 A properly designed sampling and monitoring programme should be established and implemented early. The purpose of the programme should be to provide data for site selection and modelling and later to calibrate and validate the models and thus provide a frame of reference for decommissioning.

4. MANAGEMENT OF RADIOACTIVE WASTE FROM MINING AND MILLING OF URANIUM ORE

4.1 General

For extraction of uranium from its ore a hydrometallurgical route is normally adopted. Mining and mineral extraction processes and wastes from mining and milling operations are given in Annexure I.

4.2 Management of Waste

4.2.1 Segregation of Waste

4.2.1.1 Solid Waste

Contaminated waste (metallic, non-metallic, flammable etc.) should be segregated for appropriate treatment and disposal. The mill tailings may be separated into sand and slime fraction if sand is required for mine backfilling purposes.

4.2.1.2 Liquid Waste

The mine water and the liquid waste from the mill should be monitored and segregated appropriately for suitable treatment and disposal.

4.2.2 Storage, Characterisation and Treatment of Radioactive Waste

4.2.2.1 Solid Waste

The large quantity of low active solid waste consisting of waste rocks should be preserved at mine site for back filling of the mines, embankment of tailings pond and eco-restoration.

The problem of storage, characterisation and disposal of tailing wastes from uranium milling operations is an unique one due to the large inventory of the waste associated with low levels of activity due to U (nat), ^{226}Ra and ^{230}Th and chemicals. This is dealt with in a separate section 4.2.3. Typical activity levels associated with solid waste from mining and uranium recovery process are given in Table I-4 of Annexure I.

4.2.2.2 Liquid Waste

Mine water containing low levels of activity may be used for milling operations. The effluent from the plant mostly acidic in nature should be monitored and neutralised. It should be treated appropriately at effluent treatment plant to ensure that the discharge to the environment is within the prescribed limit. Particular attention should be given for removal of ^{226}Ra in the effluent. Typical activity concentrations of liquid wastes from U mining and milling operations are given in Table I-5 of Annexure I.

4.2.2.3 Gaseous Waste

Gaseous releases from the mine should be exhausted in such a way as to ensure that the environmental doses are well within the prescribed limits. HEPA filters should be used for removal of long-lived radionuclides in the exhausts from mill equipment wherever necessary. Typical radioactivity levels in the mine exhaust are given in Table I-6 of Annexure I.

4.2.3 Treatment and Disposal of Uranium Tailings

Attempt should be made to deposit the tailings in mined out pits for passive design. In case underground disposal is not possible, the surface impoundment may be considered. The tailings treatment system should have appropriate design and operational features to ensure that the radiation exposure to the members of the public is within the prescribed limits. These features should include:

- Stable design of the tailings dam
- Provision of impermeable membrane or appropriate lining/barrier for the dam
- Provision of rock, soil and vegetation cover over the tailings pond
- Provision of proper fencing to prevent public access
- Provision of monitoring wells
- Seepage collection system

Site selection, design and engineering of the tailings impoundment should be considered in conjunction with the overall mining and milling operations, characteristics of the tailings residues and a preliminary closure plan.

4.2.3.1 Site Selection

The broad objective in siting and design decision is permanent isolation of tailings and associated contaminants by minimising disturbance and dispersion by natural forces, and to do so without ongoing maintenance.

The following site features which will contribute to such an objective, should be considered in selecting among alternative tailings disposal sites or judging the adequacy of existing tailings sites:

(a) Remoteness from populated areas

(b) Hydrological and other natural conditions as they contribute to continued immobilisation and isolation of contaminants from ground-water sources

(c) Potential for minimising erosion, disturbance, and dispersion by natural forces over the long term.

The site selection process should be optimised to maximise the benefits in terms of these features that can be reasonably achieved.

In general, desirable site characteristics for operational and post-operational performance are that the site should:

(i) be geologically stable and free from features such as caverns or geological formations that may react unfavourably with tailings liquid

(ii) have a minimum catchment area

(iii) have strata with low permeability

(iv) have foundation properties sufficient to support tailings impoundment without undue settling

(v) not be subject to flooding, fire or earth quakes.

In the selection of disposal sites, primary emphasis should be given to isolation of tailings or wastes, a matter having long-term impacts, as opposed to consideration only of short-term convenience or benefits, such as minimisation of transportation or land acquisition costs. While isolation of tailings will be a function of both site and engineering design, overriding consideration should be given to siting features given the long-term nature of the tailings hazards. Tailings should be disposed off in a manner that no active maintenance is required to preserve conditions of the site.

The following site and design criteria should be adhered to:

(a) Upstream rainfall catchment areas should be minimised to decrease erosion potential and the size of the floods, which could erode or wash out sections of the tailings disposal area.

(b) Topographic features should provide good wind protection.

(c) Embankment and cover slopes should be relatively flat after final stabilisation to minimise erosion potential and to provide conservative factors of safety assuring long-term stability.

(d) A full self-sustaining vegetative cover should be established or rock cover employed to reduce wind and water erosion to negligible levels.

(e) The impoundment should not be located near a capable fault that could cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand.

(f) The impoundment, where feasible, should be designed to incorporate features which will promote deposition.

4.2.3.2 Tailings Impoundment

The tailings impoundment system can be divided into six major elements, each of which has a number of associated systems.

(a) Physical Confinement

(Including natural and excavated basins, constructed embankments, water diversion channels, flood diversion dams and channels, spillways, access and haul roads)

Tailings should be covered after placement in the impoundments to prevent the transport of pollutants from the tailings to the environment. The choice of materials and the cover design should take into account local climatic conditions. These covers could be clay covers, native soil covers, riprap covers, water covers or surface vegetation. Sufficient longevity for a cover should be provided to minimise its rate of erosion.

(b) Seepage Control

(Natural and artificial liners, diversion trenches, foundation groutings, under-drainage, seepage collection systems, seepage return pumps and pipelines)

Seepage should be controlled either by providing low permeability barriers to keep water out of the confined tailings and/or ensuring that there is a low hydraulic head to drive such water into or through the impoundment. Appropriate liners singly or in combination should be used to reduce seepage from tailings impoundment. Permeability of such a barrier should be less than 10^{-9} ms^{-1}.

The liner should be

(i) constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients (including static head and external hydrogeological forces), physical contact with the waste or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation.

(ii) placed upon a foundation or base capable of providing support to the liner and resistance to pressure gradients above and below the liner to prevent failure of the liner due to settlement, compression, or uplift.

(iii) installed to cover all surrounding earth likely to be in contact with the wastes or leachate.

(iv) of low permeability as mentioned above.

(c) Tailings Transfer Operation

(Tailings delivery and distribution facilities, such as pipelines, conduits, drop boxes, spigots, cyclones, remote flow sensors and controls; water control and return facilities, such as decant systems, spillways, syphons, pumping barges and pipelines)

Tailings management systems should be designed for a specific site and mill system and give consideration to important parameters such as the physical state and moisture content of the tailings and the method of tailings placement. Tailings management system should take into account the following features:

(i) Distribution of tailings within the impoundment system.

(ii) Control of excess water in the impoundment during the mill operating period by the installation of drainage system to achieve consolidation of tailings. A water cover over the tailings adds significantly to the hydraulic gradient and to the potential seepage losses.

(iii) Control of freeboard in the impoundment.

Provisions should be made in the water management system to ensure that the embankment is not overtopped.

(iv) Control of density, compressibility, permeability and shear strength of the tailings within various impoundment zones.

(d) Stabilisation and Rehabilitation

(Capping or cover, embankment and surface contouring, permanent diversion facilities, erosion protection and re-vegetation)

After termination of the active operations at a mill and its associated tailings impoundment facility, a stabilisation, monitoring and closeout programme should be undertaken to ensure that the future performance of the closed facility will continue to meet the requirements of public health, safety and environmental protection.

The objectives of the work are to:

- ensure long term stability and integrity of the retaining structures and tailings mass;
- restrict the rates of future liquid, solid or gaseous releases to levels below limits prescribed by AERB;
- ensure that the undesirable effects of the facility decline with time to a state of minor concern;
- ensure that these safeguards will exist over the long term with as little human intervention as possible.-

(e) Effluent Treatment

Decant water contains most of the contaminants that are present in the tailings. The decant water, to the extent possible may return to the mill, reducing the use of fresh water. The balance should be treated and released to the environment. Treatment for pH adjustment and precipitation of dissolved radium and other metals should be followed. Preferably the treated water should be collected in a pond for analysis prior to its release.

In arid climates, the decant water management by evaporation ponds should be examined.

(f) Monitoring

(Monitoring systems for air, surface water and ground water, and migration of tailings solids, solutions and dissolved contaminants. Surveillance to identify degradation of protection measures. Long term programmes to measure uptake into environmental matrices)

Monitoring during the development and operational phases of the tailings impoundment should be undertaken to determine:

(a) the integrity of the confinement system;

(b) compliance with authorised criteria and release limits; and

(c) the validity of the models being used to predict the future confinement performance of the facility so that the stabilisation methods to be used at the close of mill operation can be planned and implemented.

To achieve these, monitoring of impoundment facility (confinement structure, controlled release, seepage and general facility) and nearby environment should be done. Monitoring after shutdown of the mill plant and stabilisation of the tailings should also be done to ensure extended protection of the environment.

4.3 Decommissioning Waste

4.3.1 Uranium Mining and Milling Plants

4.3.1.1 Solid Waste

Once the mining activity is suspended the mine should be suitably closed with back fill material and sealed. As the levels of activity associated with milling equipment are low, they can be cleaned with standard decontamination methods. Solid wastes generated from such operations should be disposed off in a near surface disposal facility as per the guidelines of AERB.

4.3.1.2 Liquid Waste

The liquid waste generated during decommissioning of mining and milling operations mainly consist of water used for washing and contain low radioactivity levels. They should be subjected to standard treatment procedures.

4.3.3.1 Gaseous Waste

No significant gaseous releases are envisaged during decommissioning of uranium mining and milling plants.

5. MANAGEMENT OF RADIOACTIVE WASTE FROM MINING, MINERAL SEPARATION AND PROCESSING OF MONAZITE AND THORIUM

5.1 General

The principal mineral ore of thorium abundant in India is monazite which contains approximately 9% thorium as ThO_2 and 0.35 % uranium as U_3O_8. The monazite content of the beach sands generally varies from <0.1 % to 2%. Mining, mineral separation and chemical processing of ores and concentrates of thorium generate wastes of different characteristics, which need careful management and regulatory control. Additional information on mining, mineral separation and chemical processing of monazite and the wastes generated is given in Annexure-II.

5.2 Characterisation and Storage of Radioactive Waste

5.2.1 Solid Waste

5.2.1.1 Mining and Mineral Separation

The large quantity of inactive solid waste consisting of topsoil, clay, silica sand, slime, organic waste (vegetation, trees, roots etc.), peat and screen-overs should be preserved at mine site for topping the refilled areas to facilitate eco-restoration. The mineral free sand from wet concentration and pre-concentration processes may be directly pumped to the mined out areas. The dry mill tailings should be stored appropriately prior to disposal. A composite sample of solid waste generated should be analysed for the radioactivity content to facilitate compliance with the categorisation of the waste. Table II-5 of Annexure II gives typical radioactivity levels associated with solid waste from mining and mineral separation.

5.2.1.2 Chemical Processing

Composite samples of the sludge produced during the chemical processing of monazite and thorium compound should be analysed and categorized. Table II-6 of Annexure II gives the radioactivity levels usually observed.

5.2.2 Liquid Waste

The tail water released after mining, pre-concentration and separation of minerals contains radioactivity levels comparable with levels normally encountered at the natural high background radiation areas (NHBRA). Typical activity concentrations are given in Table II-7 of Annexure II. Characteristics of the liquid waste from processing of monazite and thorium compound are given in Table II-8 of Annexure II. Acidic and alkaline effluents should be treated at effluent treatment plants. The treated effluent should be monitored before disposal.

5.2.3 Gaseous Waste

The main radioactive gaseous wastes are thorium particulates, ^{220}Rn, ^{222}Rn and their daughter products. The airborne releases from mining and mineral separation are insignificant. Chemical processing of monazite and thorium concentrate may result in release of low level of airborne activity in the immediate vicinity. Off gases from these processes should be monitored and treated if required.

5.3 Treatment of Radioactive Waste

5.3.1 Mining and Mineral Separation

5.3.1.1 Solid Waste

There is no processing required on the solid waste generated in pre-concentration stage and mineral separation. The mill tailings should be recycled along with fresh feed to the dry mill. The dry and wet solid tailings should be transported by mechanised means such as pumping, conveyors, covered trucks and dump trucks/ bins to the disposal site.

5.3.1.2 Liquid Waste

The water from the operations does not carry any enhanced radioactivity levels and hence does not need any processing other than settling in settling ponds for recycling purpose. Water used for mineral concentration may be pumped /drained to the settling ponds.

5.3.1.3 Gaseous Waste

The emissions should be controlled by suitable filtration/scrubbing systems. Stack heights should be adequate to ensure that ground level concentrations are below the regulatory limits.

5.3.2 Chemical Processing

5.3.2.1 Solid Waste

Monazite Insolubles

The waste sludge containing unattacked mass of monazite and traces of thorium and radium should be neutralised and filtered. The filter should be mechanically (hydraulic or otherwise) operated and the filtered cake should be filled into suitable containers for disposal/storage.

Mixed Cake of PbS and Ba(Ra) SO_4

The cake slurry in water should be collected in designated storage tanks prior to disposal. Direct pumping to the disposal site should be adopted for radioactive solid waste in slurry form.

ETP Cake

The solid sludge produced at the effluent treatment plant should be suitably packed prior to land disposal.

Calcium Oxalate Cake

The active waste produced in the processing of thorium oxalate should be suitably packed prior to disposal.

The solid waste filled containers/bags, and contaminated waste (scrap etc.) should be transported by mechanised methods such as fork lift/covered vehicle to the disposal site. The inner surface of the transport vehicle should be provided with FRP lining for corrosion prevention and ease of decontamination.

5.3.2.2 Liquid Waste

Monazite and Thorium Processing

Acidic effluents and alkaline effluents after adequate settling should be treated at effluent treatment plant to remove the activity content. The sludge should be filtered and disposed off ensuring compliance with disposal limits. The filtrate should be collected in post-treatment tanks and should be disposed off after monitoring and ensuring compliance with discharge limits.

5.3.2.3 Gaseous Waste

The exhausts from reaction vessels should be discharged to the atmosphere after passing through suitable scrubbers. The stack height should be decided on the basis of the local meteorological parameters and the permitted ground level concentrations of the discharged pollutants.

5.4 Disposal of Radioactive Waste

5.4.1 Mining and Mineral Separation

5.4.1.1 Solid Waste

The tailings sand generated in dredge and wet concentration process contain insignificant concentrations of radioactivity and may be pumped to mined area as back fill.

The dry mill waste tailings from mineral separation plants should be dumped in dredge mining area for recycling along with fresh raw sand being mined. In places where surface mining/beach washings collection only is practiced, the dry mill tailings may be stored in earthen trenches or other suitable storage. The earthen trenches should be provided with adequate soil topping so that the radiation level is less than 0.2 mGy/h. The trenches should be in controlled areas well demarcated by appropriate barriers to prevent public access.

Dry mill tailings containing unrecovered minerals including monazite should not be directly disposed into sea or public domain without the approval of AERB.

5.4.1.2 Liquid Waste

Pumping to settling ponds for settling and recirculation, disposal to water bodies (canal, sea) after settling are the methods of disposal recommended for the water used for mining and mineral separation.

5.4.2 Chemical Processing

5.4.2.1 Solid Waste

Insolubles:

The waste filled containers/bags should be disposed in RCC trenches/ engineered structures. The design of the structure should take into consideration the local conditions (rains, acidity, water table, flooding, earthquakes etc.) and radiation shielding requirements and meet the regulatory requirements. The trenches should be provided with top concrete slab after filling.

Solid waste containing very low levels of activity (such as ETP cake) should be disposed in controlled areas in engineered barriers taking into account the characteristic of the waste and soil. The earthen trenches should be provided with adequate soil topping so that the radiation level is less than 0.2 mGy/h. The area should be stabilised by re-vegetation with natural invaders. The disposal site should be well demarcated, fenced and identified with suitable caution boards.

Contaminated scrap should be disposed in engineered structures as above or decontaminated and disposed depending on the radioactivity content.

5.4.2.2 Liquid Waste

The treated effluents conforming to regulatory requirements may be discharged to water bodies like river, canal or sea.

5.5 Decommissioning Waste

5.5.1 Mining and Mineral Separation Plants

5.5.1.1 Solid Waste

The sand containing monazite present in the bins and machinery should be disposed as solid waste as specified in subsection 5.4. As mining and mineral separations involve no chemical processing, the potential for radioactive contamination of surfaces and equipment is minimal. The contaminated equipment and plant surfaces should be washed with water. The solid waste resulting from decommissioning of mining and mineral separation plants should be considered as inactive.

5.5.1.2 Liquid Waste

The liquid waste generated during decommissioning of mining and mineral separation mainly consists of water used for washing and contains activity levels usually encountered in NHBRA.

5.5.1.3 Gaseous Waste

There are no gaseous releases during decommissioning of mining and mineral separation plants.

5.5.2 Chemical Processing Plants

5.5.2.1 Solid Waste

Radioactive sludge accumulated in tanks should be analysed for radioactivity content and disposed off in RCC trenches/earthen trenches/engineered structures depending on the activity content.

Surface contaminated equipment like large tanks should be decontaminated and the contamination free material shall be disposed off as inactive scrap. Other contaminated equipment like filters, electrical fittings, pipelines etc. should be decontaminated by washing and reused or disposed off. Contaminated structural parts and floor/wall cement plaster chipping should be disposed off in RCC trenches/earthen trenches depending on the radionuclides, activity content and radiation fields.

5.5.2.2 Liquid Waste

All the effluents generated should be directed to ETP after settling at the respective hold up tanks near to the sites of generation of the effluents and shall be neutralised and treated at ETP and treated effluents should be discharged to the water body after ensuring compliance with the stipulated limits.

5.5.2.3 Gaseous Waste

The gaseous releases encountered during the decommissioning are insignificant and do not warrant separate treatment and disposal.

6. MONITORING AND REGULATORY CONTROL

6.1 General

6.1.1 In order to ensure that the design and operation of the waste management system are being implemented in a manner that protects the health of public and environment, it is important to put in place an appropriate monitoring and regulatory control regime. The monitoring and regulatory procedures will be governed by the process involved, site parameters, nature of risks etc. Some of the important aspects of monitoring and regulatory control with respect to handling of wastes associated with mining and milling of uranium and thorium industries are discussed in the following subsections.

6.2 Solid Waste Disposal

6.2.1 The solid waste generated should be analysed for activity content. The authorised activity limits (concentration and quantity), and radiation field limits should be complied with. Integrity of containers and structural integrity of the repositories (trenches/disposal structures) should be monitored and ensured. Necessary preventive maintenance works should be carried out when required. Radiation monitoring of the disposal site should be carried out periodically (at an appropriate frequency as approved by AERB). Proper inventory of the radioactivity content and quantity of solid waste disposed should be maintained.

6.2.2 Sufficient number of monitoring bore wells should be provided in consultation with experts around trenches and other disposal areas. Water samples collected from monitoring wells provided around the storage trenches and other disposal areas should be analysed (at an appropriate frequency as approved by AERB) for activity to detect breach of containment and seepage of activity if any. The water samples should be analysed for suspended solids, dissolved solids, pH and radioactivity.

6.3 Liquid Waste

6.3.1 Sampling and analysis of different streams of effluents should be carried out before and after effluent treatment to ensure compliance with regulatory requirements. Where effluents are released on a controlled basis, routine monitoring should be done for flow and concentrations of radionuclides, toxic metals and other components, including those arising from the process chemicals to ensure that the releases do not affect the use of the water now and in future. Authorised limits for release of activity (activity concentration and total activity) and effluent volume should be adhered to. Proper inventory of the radioactivity content and effluent volumes discharged should be maintained. Monitoring is required to determine the existence and extent of seepage from the facility.

6.4 Tailing Waste from Milling of Uranium

6.4.1 Monitoring during the development and operational phases of the tailings impoundment should be undertaken to determine

- the integrity of the confinement systems,
- compliance with authorised criteria and release limits, and
- the validity of the models being used to predict the future confinement performance of the facility so that the stabilisation methods to be used at the closure of mill operation can be planned and implemented.

6.4.2 Physical Monitoring of the Facility

Quality assurance on dam construction materials and the methods of dam construction should be ascertained to ensure that adequate factors of safety are maintained. The saturated surface through the impoundment embankments should be monitored and the results used for re-evaluating the stability of the embankment. These data may be used to estimate seepage flows through the embankment. The performance of the liners and drainage systems should be monitored. Dams should be visually inspected on a routine basis to check the integrity.

6.4.3 Monitoring after shutdown of the mill/plant and stabilisation of the tailings and post closure monitoring should be carried out to ensure extended protection of the environment.

6.5 Gaseous Waste

6.5.1 Sampling and analysis of stack emissions should be carried out as per regulatory requirements. The stack discharge limits should be complied with and an inventory of the releases and volumes discharged should be maintained. Population exposures from the gaseous wastes from the mine, mill and tailing ponds should be ensured to be within the limits prescribed by the AERB.

6.6 Institutional Control

6.6.1 Institutional control consists of those actions, mechanisms, and arrangements implemented to maintain control of a waste management site after closure, as required by AERB. This control should be active (for example, monitoring, surveillance, remedial work) or/and passive (for example, land use control).

6.6.2 Establishing the requirements for institutional control should be part of the optimisation of the design for closure. The design should minimise the need for dependence on active institutional controls.

6.6.3 The programme for institutional control should be reviewed by AERB to ensure that it would be effective. The design of the programme should be based on the safety assessment that considers the impact on human health and the environment over an appropriate time into the future. The safety assessment should consider scenarios describing human intrusion, failure of engineered structures, systems and components and evolution of the environment.

6.6.4 As part of an institutional control programme, all relevant records of the location and characteristics of the closed waste management facilities, restrictions on land use and ongoing monitoring/surveillance requirements should be maintained in accordance with applicable requirements.

7. ENVIRONMENTAL SURVEILLANCE

7.1 General

7.1.1 In order to confirm that the exposures to the members of the public are within the limits prescribed by the regulatory authorities, the waste generator/manager should carry out a comprehensive environmental surveillance programme. Such a programme should cover not only the operational phase but also the pre-operational and post-operational phases. The important components of the surveillance programme are covered in the following sections.

7.2 Pre-operational Surveillance

7.2.1 A comprehensive pre-operational environmental survey should be carried out to establish the baseline radiation/radioactivity levels in the environment. The survey should cover one year ideally with appropriate frequency.

- Baseline radiation data:
  - Background radiation fields
  - Radioactivity in water, soil, vegetation, food, identification of indicator organisms
  - Identification of critical pathways of population exposure
  - Identification of critical groups

  The background radiation exposure received by the population residing in the area where the plant is proposed should be estimated based on the pre-operational monitoring data.

  It should also include

- Site characteristics data
  - Site geology
  - Soil characteristics
  - Water table and ground water data
  - Rainfall
  - Wind data
  - Humidity
  - Temperature
  - Earth quakes
  - Floods
  - Cyclones

- Population data
- Land use pattern
- Water use pattern (irrigation, crops, drinking water)
- Dietary survey of the population nearby

7.3 Operational Surveillance

7.3.1 During the operational phase of the waste management facility also environmental surveys covering all the parameters specified should be carried out at the specified frequency to assess the environmental impact of the operations and to ensure compliance with regulatory requirements.

Environmental surveillance programme should include monitoring of the following parameters at an appropriate frequency:

- Radiation fields
- Air activity
- Dust concentrations in air
- Radioactivity in ground water, soil, vegetation, food, indicator organisms.

Radiation exposure to critical groups should be assessed based on the surveillance data to ensure compliance with the dose limits for exposure to members of the public.

7.4 Post-operational Surveillance

7.4.1 The objectives of the post-operational surveillance are to ensure that the exposures to the public are well within the prescribed limits and to detect any breach of containment of the waste repositories, environmental impact of the storages and to take timely remedial action if required.

7.5 Special Requirements with respect to Uranium Tailing Storage Ponds

7.5.1 A programme of environmental monitoring should be put in place primarily to determine any impacts that the tailings facility may have on the public health and the environment. To evaluate the changes in the environmental levels during and after operation of an uranium mill, pre-operational measurements of the radionuclide levels in the environment should be carried out. Of particular importance are measurements of ^{222}Rn concentrations in air and ^{226}Ra levels in surface waters and sediments in the area. The mill operators should prepare an integrated contingency plan in advance covering all aspects of monitoring, likely scenarios for releases and areas which are most likely to be affected. An important part of this planning is the documentation of the placement of the sampling wells and procedures and a knowledge of which geological pathway each well is monitoring. The main objective should be to obtain information necessary to assess the situation and to decide on the need and specific actions for intervention. Periodic surveillance and environmental monitoring after decommissioning of the mill and stabilisation of the tailings should be carried out to ensure that successful rehabilitation has been achieved.

8. SAFETY ASSESSMENT

8.1 General

8.1.1 A safety assessment document should be prepared and updated as necessary by the operator in support of applications to AERB for approvals to develop, operate or modify facilities for managing waste from mining and milling of uranium or thorium. The safety assessment should indicate how the waste management facilities have been designed to provide optimum protection for workers, public and the environment.

8.1.2 The safety assessment should cover the design, operational, closure and post-closure phases of the facility. The scope and extent of the assessment should be commensurate with the site-specific issues that need to be addressed. The results of the initial safety assessment should be factored into the choice of site and the design of the overall mining, milling and processing facilities. The assessment should consider all significant ways by which workers, the public and the environment may be impacted by radiological and non-radiological hazards. Where possible, and warranted by the significance of the impacts, this assessment should be quantitative. The scope and level of details should be sufficient to identify and evaluate all relevant risk components over the relevant time periods of the facilities' life. The models and methods used should allow the impacts from the different hazards of the various management options to be compared in a consistent manner.

8.1.3 In the safety assessment all the waste management facilities at the site should be considered together with those features of the mine and mill and any other nearby facilities that may influence the methods available for managing the waste.

8.2 Safety Assessment Methodology

8.2.1 The steps in deciding the management of the waste from uranium or thorium mining and milling should include

(a) identifying and characterising the site options;

(b) defining the criteria for human health and environmental protection;

(c) characterising the waste;

(d) identifying and characterising the waste management options including engineering controls;

(e) identifying and describing options for institutional control;

(f) identifying and describing potential institutional and engineering control failures;

(g) estimating the radiological and other consequences for each combination of options being considered ('safety analysis');

8.2.2 Criteria should be defined for the radiological protection of workers and the public during operations and of the public after closure for the releases that occurred during operations and that are expected to occur after closure. The criteria for the protection of the environment from radiological and non-radiological hazards should also be defined.

8.2.3 Identifying and Characterising Site Options

8.2.3.1 Potential sites for locating mining and milling waste facilities should be selected based on the considerations outlined in Section 3. The characteristics of the potential sites determine the generation and transport of contaminants from the sites. These characteristics should be determined and appropriate source term and contaminant transport models and associated parameters be defined.

8.2.3.2 Baseline environmental data should be collected before operation of the waste management facility. These measurements should be used, as appropriate, for the calibration and validation of models and as reference levels for monitoring and surveillance activities during all phases in the life of the waste management facility. The average value and the range of background levels for radioactive and non-radioactive contaminants at and around the sites of the proposed waste management facility should be determined.

8.2.3.3 If the facilities are currently in operation, a characterisation of the site and surrounding environment should be performed as soon as possible. The main characteristics that will be evaluated should be similar to those for the baseline survey.

8.2.4 Characterising the Waste

The waste that will be generated during the mining and milling operations should be properly defined based on the operating process and the characteristics of the site. Items that should be considered to include the type of waste, volumes expected, chemistry, minerals in the waste etc.

8.2.5 Identifying and Characterising Options for Waste Management, including Engineering Controls

Potential options for managing the waste should be identified. It is particularly important that a broad range of options should be considered for the initial analysis. The behaviour of the various options for managing the waste should be modeled and appropriate model parameters determined.

8.2.6 Identifying and Describing Options for Institutional Control

The waste generator/manager should provide means of institutional controls as applicable after closure of the waste management facility and describe their key characteristics including the period during which they may be assumed to remain effective.

8.2.7 Identifying and Describing Potential Failures of Institutional and Engineering Control

8.2.7.1 In order to estimate potential exposures, future events that can give rise to increased risks should be considered. These include failures of institutional and engineering controls and fall into the following categories:

(a) human activities (for example intrusion, farming, building a house on waste management areas, unauthorised diversion and use of radioactive waste);

(b) natural processes and events which may affect the integrity of containment structures (for example erosion, flooding, earthquakes); and

(c) internal processes (for example acid generation, weathering, differential settlement).

8.2.7.2 Institutional controls will prevent human intrusion and the inappropriate use of the land for a period of time. For engineering controls, the period for which they remain effective should be based on a technical assessment taking into account relevant matters such as erosion, seismology, hydrology, hydrogeology, acid generation and other physical and chemical interactions which may affect the integrity of engineered structures or the release of radionuclides from the waste to the environment. Appropriate models describing these failures should be defined for input into the safety analysis.

8.2.8 Safety Analysis

8.2.8.1 Safety analysis should be carried out to estimate occupational exposures, public exposures and environmental impacts. For public exposures, the safety analysis should quantify the incremental exposures that arise from the waste above natural background. There should be iterations of these analyses not only for evaluating the options for siting and management but also for refining the institutional and engineering controls. A safety analysis will involve, as appropriate:

- the consideration of all relevant radionuclides, chemicals and physical concerns, pathways and exposure scenarios to provide the basis for comparisons with dose and risk constraints, and environmental protection criteria;

- the consideration of events including their probabilities that could lead to a release of radionuclides or other contaminants, or that could affect the rates at which they are released or transported through the environment;

- the estimation of the radiation doses likely to be received by workers during operations; and
- the estimation of the radiation doses and risks to members of the public and the risks to the environment during operation and after closure.

8.2.8.2 For exposures during operation and after closure, scenarios should be assumed that are based on the lifestyles and living conditions of individuals currently residing in the general vicinity of the waste management facilities.

9. QUALITY ASSURANCE

9.1 To ensure that radiological and non-radiological protection will be maintained during the operation of the waste management facilities and to enhance confidence after their closure, a quality assurance programme should be implemented through out the design, construction, operation and closure of the facilities.

9.2 The quality assurance programme should include the following elements.

- Organisational responsibilities should be defined and understood
- Design and construction should be with proven technology that conforms to regulatory requirements.

9.3 Regular auditing of the design, its implementation and the operation of the waste management facilities should be undertaken to ensure that they are designed, constructed and operated as intended, and that deficiencies can be corrected. Models and codes used in the safety assessment should be validated and verified to the extent possible

9.4 A feedback process should be established so that the results of the safety assessments are appropriately taken into account during the design. Close co-operation among all parties involved in the waste management facilities should be developed to reach the optimum solution and the system should contain

(a) Personnel involved in the design, construction, commissioning, operation, and closure of the waste management facilities whose performance could affect safety should be trained to an appropriate and verified level.

(b) A system of record keeping and document handling should be established so that construction details and appropriate operating details, including monitoring data are retained and changes in operations can be controlled.

(c) Periodic assessment of the effectiveness of the protection achieved in the management of the wastes should be carried out.

10. RECORDS AND DOCUMENTATION

10.1 The waste generator/manager should establish a procedure for maintaining adequate documentation and records on the safe handling and management of radioactive waste. The scope and detail of the records should depend on the hazard and/or complexity of the proposed operation and is subject to approval by AERB.

10.2 Records will have varying periods of usefulness. Some records, which relate to the waste management facility, the waste and the disposal criteria, will have a long period of utility and should include:

(a) waste characterisation data;

(b) treatment, packaging and conditioning process control records;

(c) procurement documents for containers required to provide confinement for a certain period;

(d) waste package specifications and records for individual containers and packages;

(e) trends in operating performance;

(f) non-compliances with the specifications and the actions taken to rectify the situation;

(g) monitoring records;

(h) the results of safety assessments;

(i) written operating procedures;

(j) safety related unusual occurrences; and

(k) any additional data requested by AERB.

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 (activity concentration, total activity, radionuclides present and their proportions);

(e) classification of waste; and

(f) any chemical, biological or other hazards associated with the waste and the concentrations of hazardous material.

10.3 Reporting

The waste generator/manager should submit a periodic report to AERB, regarding the operator's compliance with all the regulatory requirements in accordance with a schedule established by AERB. A routine report should give a clear idea of waste management operations during the reporting period and the current situation at the time of reporting. In general, the report should summarise:

(a) the waste received, including secondary waste from processing of the primary waste and waste from maintenance or decommissioning of any components, equipment or structures at the facility;

(b) the processing of waste, as well as details of the processes used;

(c) any waste released by transfer, by clearance, by authorised discharge or for authorised use;

(d) an overview to determine trends in the inventory of waste generated, processed, stored and transferred at the facility, as well as trends in safety performance;

(e) an estimate of the resulting impacts, in terms of radiation exposure of the workers and the public; and

(f) generation of waste non-conforming to the specified waste.

ANNEXURE - I

ADDITIONAL INFORMATION ON URANIUM MINING AND MILLING

I .1 Mining and Mineral Extraction Process

I.1.1 Uranium ore extracted and brought from the mines initially undergoes crushing, screening and wet grinding operations at the mill. The next step in the process is leaching of uranium ore in sulphuric acid in the presence of pyrolusite mineral (MnO_2). The uranium rich liquor obtained by filtration is further purified and concentrated employing ion exchange resins. After precipitating sulphate and ferric ions by addition of lime slurry, magnesia slurry (MgO) is added to the pure liquor to precipitate uranium as magnesium diuranate known as yellow cake. However, depending on the nature of the ore and nature of the desired end product, alternate process can be employed.

I .2 Waste from Mining Operations

(a) Solid waste: Rocks below 0.03% U_3O_8 content are considered as waste. About 10% of the rocks mined out constitute the waste.

(b) Liquid waste: Large quantities of water are encountered in mines. The inventory of this waste depends on the geohydrological features of the mine. Typically the quantities of the mine water are in the range of 500 m^3/day. Water from the drilling and ore pile wetting operations and rain water run off from exposed waste rocks also add to the liquid wastes.

(c) Gaseous waste: Mine air from different operating levels containing radon, ore dusts, blasting gases and diesel fumes constitute the gaseous wastes.

I .3 Waste from Milling Operations

(a) Solid waste : The bulk of the ore processed in the mill emerges as waste or tailings after the leaching of uranium. These are separated into sands which are coarse particles and slimes which are fine particles made up of clay, silt and other very fine materials. Contaminated equipment, scrap, machinery and material from the mill generated during plant operation/maintenance are also treated as waste. Yet another source of solid waste is the effluent treatment plant cake carrying low levels of radioactivity.

(b) Liquid waste : Barren solutions from ion exchange recovery process and other process waters such as supernatants from diurnate precipitation, leakages, filter back washings etc. constitute the major liquid wastes. Other waste streams include runoff water from ore yard, overflow waters from the tailings pond and floor drains from plant areas.

(c) Gaseous waste : Gaseous waste from milling operation are characterised by very low radioactivity in the air route during ore handling, crushing and grinding operations.

I.4 Classification and Segregation of Waste

I.4.1 The radioactive waste is classified as solid, liquid and gaseous wastes. The solid wastes are categorised, depending on the radiation dose on the surface dose rates. Liquid wastes and gaseous wastes are categorised on the basis of the radioactivity content.

TABLE I-1 : SOLID WASTE CATEGORISATION
(Adapted from AERB Document, AERB/NPP/SG/O-11 [2])

Waste details	Radionuclides content	Surface dose rate (typical values)	Category
Waste rock from mining operations	U (nat), ^{226}Ra, ^{230}Th	<2 μGyh^{-1}	I Low level waste
Tailings from mill operations	U (nat), ^{226}Ra, ^{230}Th	<5 μGyh^{-1}	I Low level waste
Contaminated equipment and decontamination waste	U (nat), ^{226}Ra, ^{230}Th	<10 μGyh^{-1}	I Low level waste

TABLE I-2 : LIQUID WASTE CATEGORISATION

Waste details	Radionuclides content	Radioactivity level (typical values Bq.m^{-3})	Category
Mine water	U (nat), ^{226}Ra	U 1x10^{4} ^{226}Ra 500	I
Floor washings from mill area	U (nat), ^{226}Ra	U 3x10^{3} ^{226}Ra 400	I
Acidic effluent from uranium recovery process	U (nat), ^{226}Ra	U 1x10^{3} ^{226}Ra 400	I

TABLE I-3 : GASEOUS WASTE CATEGORISATION

Waste details	Radionuclides content	Radioactivity level (typical values $Bq.m^{-3}$)	Category
Gaseous waste from Mining operations	^{222}Rn and daughter products	7×10^3	II
Ore handling operations	U (nat) and ^{226}Ra	0.01	I
Uranium recovery process	U (nat)	0.1-1	I

TABLE I-4 : TYPICAL ACTIVITY IN SOLID WASTE: U MINING AND MILLING OPERATIONS

Solid waste	Gross alpha ($Bq.g^{-1}$)	Gross beta ($Bq.g^{-1}$)
Waste rock	15	10
Tailings pond waste	50	40

TABLE I-5 : TYPICAL ACTIVITY CONTENT OF LIQUID WASTE: MINING AND MILLING OPERATIONS

	Gross alpha ($Bq.l^{-1}$)	Gross beta ($Bq.l^{-1}$)	U (nat) ($Bq.l^{-1}$)	Ra-226 ($Bq.l^{-1}$)
Mine water	1 - 10	1- 10	1 - 5	0.5 - 1.0
Floor washings from mill area	–	–	2.5 - 10	0.2 - 0.5
Discharge from ETP	0.5 – 2.5	0.5 – 1.5	0.02 - 0.2	0.01 – 0.03

TABLE I-6 : TYPICAL ACTIVITY LEVEL IN THE URANIUM MINE/MILL EXHAUST

Stream	Radon - 222 ($kBq.m^{-3}$)
Mine exhaust	1 - 8
Mill exhaust	negligible

I .5 Treatment and Disposal of Uranium Waste

I. 5.1 Solid Waste

I.5.1.1 Waste rocks from the mine having insignificant radioactivity content are used for back filling of the mine areas or embankment of the tailing ponds. They can also be disposed off in identified areas owned by the plant management. The treatment and disposal of tailing waste are discussed in section I.5.4.

I..5.2 Liquid Waste

I.5.2.1 As the mine water has insignificant levels of radioactivity, it is used as process water for milling operations. All the effluents from the mill including those from the tailing ponds should be treated in an effluent treatment plant (ETP). The treated effluents should be monitored for pH and radioactivity and chemical contents before release into environmental streams.

I.5.3 Gaseous Waste

I.5.3.1 Major gaseous waste from uranium mining and milling operations is the mine air from different operating levels containing radon and ore dusts. The radioactivity content in the gaseous waste from the milling operations are insignificant. Off gases from the MDU section are exhausted through HEPA filters.

I.5.4 Treatment and Disposal of Uranium Tailings

I.5.4.1 Treatment and disposal of tailings from the uranium milling operation should be carried out with great care in view of the very large inventory of the material and the associated radionuclides and chemical pollutants. After uranium leaching, the entire ore is rejected as solid waste. These tailings are first neutralised with lime and then segregated as sand and slimes with the help of hydrocyclones. The typical constituents of the waste are sands (the heavier, coarse particles) and the slimes (the finer particles in the tailings in the micron/ submicron range and made up of the clays, silts and other very fine particles). Sand and gravel are used as back fill materials for the exhausted mines and the slimes are transferred to the tailing impoundment area/ponds. Both slimes and sands may contain chemical residues and precipitates from the mill process and a variety of heavy metal contaminants.

I .5.4.2 On acid treatment, only a small fraction of the total radionuclides present in the ore finds its way in the leach solutions and major portion remains associated with the solids. Approximately 0.5 % of the total radium inventory gets dissolved during leaching process. Similarly 5-10% of ^{230}Th and a significant amount of ^{210}Pb are found in the leach solutions. The sand fraction of the solids contains relatively very small amounts of radioactive pollutants (12-16% of total ^{226}Ra) and the major quantities remain with the slime fraction.

I 5.4.3 Neutralisation of the tailings with lime helps in precipitating most of the radioactive and chemical pollutants. In the pond they settle along with other solids and remain confined. Although radium and heavy metal toxins are also confined to an appreciable extent, their concentration in the effluent water if discharged in the public domain should be within the regulatory limits. Due to certain insitu reactions in the pond resulting in change in pH conditions, some of the radioactive and chemical pollutants may be solubilised from the solid phase of the tailings. Neutralisation by atmospheric carbon dioxide with the soluble lime is one of the major factors responsible for fall in pH value. In addition, bacterial action, particularly for sulphide bearing tailings contributes substantially to this effect. At some of the sites, the water flowing out of the tailing ponds may become acidic. The production of free acid in the tailings brings about dissolution of the contaminants and impart mobility thus endangering the environmental safety. Neutral or alkaline conditions should be maintained in the pond by periodic addition of suitable chemicals for stabilisation of radionuclides and metal toxins.

I 5.4.4 The basic design and operating objectives for the impoundment of the uranium mill tailings are to:

(a) provide an impoundment which is both physically and chemically stable, and

(b) control the movement of radioactive as well as other toxic elements to the environment to acceptable levels.

I 5.4.5 Risk of environmental contamination is mainly due to escape of the pollutants from the impoundment systems. The different factors that are responsible for the transport and spread of contamination from a tailings pond are as follows:

- Wind borne erosion and transport
- Water borne erosion and transport
- Ground water dissolution and transport
- Radon emanation
- Intrusion by ecological agents
- Man made intrusion

Thus, composition of the tailings, geochemical, geohydrological climatic and socioeconomic conditions of the region are some of the important factors that determine the behaviour of contaminants and their spread into the environment. The important considerations concerning the effectiveness of tailings impoundment relate to both site selection and design of impoundment systems.

I 5.5 Tailings Impoundment

I. 5.5.1 Physical Confinement

I.5.5.1.1 This section describes options that are being used for physical confinement of uranium mill tailings. The choice of impoundment location and system are the most important decisions to be made. The basic types of impoundment facilities may be valley dam, ring dyke, mine pit, specially dug pit, underground mine [3].

I .5.5.1.2 Primary aims of a cover are limiting the access of people and animals, restricting the infiltration of water and reducing the escape of radon and direct radiation to acceptable levels.

I. 5.5.2 Seepage Control

I. 5.5.2.1 Seepage from a tailings impoundment may initially occur because of the tailings liquid which accompanies the solids when placed. In the longer term, however, seepage control is usually a matter of preventing water from seeping into the tailings repository to prevent further movement of contaminants as the water moves through and out of the tailings.

I .5.5.2.2 Where natural geological formations, such as low permeability soil or rock strata, exist on the tailings impoundment site they are usually effective in providing an economical seal. Because of their thickness and stability under site conditions, their long-term effectiveness is generally reliable. In their natural form they usually seal only part of the impoundment basin, such as the floor and the portions of the containment walls, and are therefore frequently used in combination with other liner types. Their integrity, i.e. the absence of substantial permeable faults or joint systems, should be established or such features accounted for in the engineering design.

I .5.5.2.3 There are generally three basic groups of liners that are applicable for seepage control.

(a) Geological liners (formed by natural geological formations)

(b) Clay and other compacted soil liners

(c) Synthetic liners including synthetic membrane, pneumatically applied mortar and concrete, asphaltic concrete, or sprays.

I .5.5.2.4 Clay, either from site-derived clay or imported materials (e.g. bentonite), has long been used to construct effective liners. Hydraulic conductivities of 10^{-9} $m.s^{-1}$ and lower are attainable with these materials. Soils with a large fraction of material coarser than clay fraction can, when adequately compacted at the optimum moisture content, form effective liners with conductivities between 10^{-7} and 10^{-8} $m.s^{-1}$. Lower permeabilities may still be obtained by adding bentonite. Hydraulic conductivities of 10^{-11} to 10^{-12} $m.s^{-1}$ are applicable to the various types of synthetic membranes.

I. 5.5.3 Tailings Operation

I .5.5.3.1 Tailings management system are concerned with the treatment and handling of tailings. They include the systems for tailings management during mill operation, including the various pumps, pipelines and tailings distribution systems, and the manner in which the systems handle tailings from the time they leave the mill until they are placed in the impoundment.

(a) Saturated Management

In saturated management the tailings are transported, distributed and maintained in a saturated state at all times. This is also commonly known as 'subaqueous deposition'.

(b) Wet Management

Wet management indicates placement methods resulting in tailings that have substantial saturated zones, but a total tailings impoundment that is not necessarily saturated. In this system the tailings slurry (typically, about 40% by weight) is pumped to the impoundment and discharged by either a point or line discharge at the periphery of the impoundment area, frequently along the upstream face of the dam.

(c) Semi-dry Tailings Management

Semi-dry tailings management usually refers to a system of periodic deposition of comparatively thin layers (typically 50-150 mm) of thickened tailings slurry onto a gradually sloping beach of tailings maintained above the saturated water level. The tailings are left to dry, by drainage and evaporation, for sometime before subsequent deposition of further layers on the same area.

(d) Dry Management

Dry management refers to deposition methods in which the moisture content is too low for the solids to be handled as a slurry. Dry tailings can be produced either by evaporative drying in layers or by mechanical dewatering in the mill.

I. 5.5.4 Stabilisation and Rehabilitation

I .5.5.4.1 Stabilisation and Rehabilitation include the following actions:

(a) general preparations such as bringing together miscellaneous wastes into the main tailing pile;

(b) dewatering of the pile if necessary;

(c) engineering work to ensure the long term stability of major structural components such as the dam embankments, water diversion structures, etc;

(d) general modification of the land form and contours to reduce erosion, direct runoff and possibly to promote vegetation or meet some aesthetic requirement;

(e) construction of engineered cover and/or liner systems to limit seepage, radon emissions, surface gamma dose, and achieve erosion control;

(f) construct further diversion systems, drainage channels, flood control structures, etc. if required; and

(g) possibly revegetate all or parts of the site.

I. 5.5.5 Effluent Treatment

I .5.5.5.1 Where climatic conditions require the controlled release of tailings water to surface water or ground water, treatment for pH adjustment and precipitation of dissolved radium and other metals should be required. Even when water is not to be released, neutralisation of acid tailings will reduce the levels of many potential contaminants in seepage from the tailings impoundment and is likely to be required for that purpose. Control of the pH value of the tailings water discharge to about neutral 7 usually ensures the precipitation of radioisotopes. When the precipitates settle the only potentially significant radiological hazard associated with the liquid discharge will be that of ^{226}Ra. It should be co-precipitated before discharge and running it into settling ponds or lagoons.

Reporting of radioactive waste disposal/transfer should be as per the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, GSR-125, (1987).

ANNEXURE - II

ADDITIONAL INFORMATION ON THORIUM MINING AND MILLING

II .1 General

II.1.1 The principal mineral ore of thorium abundant in India is monazite which is found along with other heavy minerals like ilmenite, zircon, rutile, garnet and sillimanite in beach sands of certain locations in coastal regions of peninsular India and some inland placer deposits. Xenotime, another ore of lesser abundance containing thorium is also available in limited quantities.

II.2 Mining and Mineral Separation

II.2.1 Mining, mineral separation and chemical processing of ores and concentrates of thorium generate wastes of different characteristics, which need careful management and regulatory control.

Surface mining, collection of beach washings and dredge mining are the common modes of mining process. Mineral separation process makes use of the differences in the electrical and magnetic properties and differences in specific gravity of the constituent minerals to separate them. The dried concentrates are passed through a series of high-tension electric separators and magnetic separators of varying intensities. Fine separation of some minerals is also carried out by air tabling, wet tabling and froth floatation.

II.3 Chemical Processing of Monazite and Thorium Concentrate.

II.3.1 Monazite, an orthophosphate of thorium and rare earth elements (RE), is chemically processed by caustic soda digestion and selective extraction with HCl to separate the thorium and rare earths (RE). Thorium is purified by solvent extraction and converted to thorium oxalate. Part of the thorium oxalate is utilised for production of mantle grade thorium nitrate. The uranium present in the thorium fraction is recovered by solvent extraction and converted to ammonium di-uranate (ADU).

II.4 Production of Thorium Nitrate (Chemical Processing of Thorium Oxalate)

II.4.1 Thorium oxalate is normally converted to thorium hydroxide by caustic soda treatment. Filtered thorium hydroxide is dissolved in commercial nitric acid. From the filtered and conditioned nitrate solution of thorium and rare earths, thorium is extracted by solvent extraction. The thorium nitrate solution is evaporated, crystallised and centrifuged to get the final product. A part of the thorium is converted to thorium oxide by calcination.

II .5 Waste from Mining and Pre-concentration

II.5.1 Surface mining of beach washings and inland placers as well as dredge mining generate large volumes of overburden which include topsoil, clay, silica sand, slime, peat, organic waste (vegetation, trees, roots etc.), screen-overs and shells.

II.5.2 Solid tailings of silica sand, shells and organic waste (shreds of roots etc.) and screen-overs from trommel operations are the major solid wastes generated in the pre-concentration and concentrate upgradation operations. These two operations account for major part of the solid waste generated in the mining and mineral process industry and contain very low amounts of radioactivity. The volume of waste generated depends on the heavy mineral concentration in the raw sand and the recovery effected in the processes. Typically 600 kg to 700 kg of tailings are generated per ton of raw sand mined.

II.5.3 The water used for pre-concentration and concentrate upgradation containing slime and suspended particulate matter is recirculated after settling.

II.6 Waste from Mineral Separation

II.6.1 The sand tailings from the mineral separation plant containing un-recovered minerals and silica sand constitute the solid wastes. The tailings sand generated in the mineral separation plant varies from 70 kg to 100 kg per ton of concentrated feed sand processed in the plant. The water used for wet concentration of minerals also carries solid tailings. The crude monazite concentrate also requires appropriate management. The gaseous releases are mainly the exhausts from the driers which may contain suspended particulate matters, SO_2 etc.

II.7 Waste from Chemical Processing of Monazite and Thorium Concentrate.

II.7.1 Solid Waste

Chemical processing of monazite and thorium concentrate results in the following solid wastes:

II.7.1.1 Monazite Insolubles

The monazite insolubles contain un-reacted monazite from the monazite caustic soda reaction. In addition to un-reacted monazite, this waste also contains traces of RE, Th, Ra and U. Approximately 80-100 kg of insolubles are produced per ton of monazite processed. Yet another source of insolubles is the process for the recovery of uranium and conversion of thorium hydroxide to thorium oxalate. The quantity generated amounts to nearly 500 kg per ton of thorium concentrate processed.

II.7.1.2 PbS-Ba(Ra)SO_4 Mixed Cake

The mixed cake of PbS and Ba(Ra)SO_4 results from the lead elimination and deactivation of RE chloride. The $BaSO_4$ carries along with it Ra as $RaSO_4$. This waste contains traces of uranium, thorium and rare earth (RE) also. 60 kg to 100 kg of this cake is generated per ton of monazite processed.

II .7.1.3 Calcium Oxalate Sludge

Calcium oxalate sludge from the non-nitrate stream of process effluents (oxalate removal) and precipitation from nitrate waste (rare earth recovery) containing sodium nitrate, rare earth fraction and thorium along with traces of Ra and $BaSO_4$ are the two main solid wastes generated in the production of thorium nitrate. The quantity typically generated amounts to 800 kg per ton of thorium concentrate.

II.7.1.4 Solid Waste from Effluent Treatment (ETP Cake)

The phosphate sludge results from the neutralisation and calcium phosphate precipitation of acidic and alkaline effluents generated during the processing of monazite. The ETP cake mainly contains phosphate and carries low levels of radioactivity. The quantity of this waste generated amounts to approximately 100 kg per ton of monazite processed.

II.7.1.5 Contaminated Equipment

Surface contaminated scrap (metallic, non-metallic, flammable etc.) are generated during routine maintenance/modifications etc.

II.7.1.6 Decontamination/Decommissioning Waste

Decontamination/decommissioning of plants (especially chemical plants) generate large quantities of solid waste, which require proper segregation, treatment and storage/disposal. The wastes include contaminated floor and cement plaster, left over active sludge, contaminated equipment, combustible waste and debris from demolished buildings.

II.7.2 Liquid Waste

II.7.2.1 Acidic and alkaline effluents from the processing plants and water and chemicals used for decontamination constitute the liquid waste in monazite processing. Nearly 15 m^3 of effluents are generated per ton of monazite/thorium concentrate processed.

II.7.2.2 Liquid waste generated during production of thorium nitrate consist of filtrate from oxalate conversion, aqueous washings from thorium solvent extraction, filtrate from rare earths recovery containing mainly nitrates, evaporator condensate, plant washings and water and chemicals used for decontamination.

The total volume of liquid waste is related to time and inventory and is approximately 30 m^3 (Nitrate = 10 m^3, non-nitrate = 20 m^3) per ton of thorium concentrate processed.

II.7.3 Gaseous Waste

II.7.3.1 Exhausts from plants consisting of suspended particulate matters, flue gases, Th, ^{220}Rn and its progeny, drier/furnace exhausts, H_2S and HCl are the constituents of the gaseous releases from chemical processing of monazite and thorium compounds.

II.8. Segregation of Waste

II.8.1 Solid Waste

The topsoil from mining areas should be preserved for site restoration. Mineral free sand from dredge and wet concentration process should be used for back filling the mined out areas. The dry and wet tailings and the contaminated waste (metallic, non-metallic, flammable etc.) should be segregated for appropriate treatment and disposal.

II.8.2 Liquid Waste

The liquid waste streams should be segregated into acidic and alkaline streams and appropriately stored for suitable treatment, monitoring and disposal.

II.9. Decommissioning Waste

II.9.1 Chemical Processing Plant

II.9.1.1 Solid Waste

II.9.1.1.1 Considerable quantity of solid waste like radioactive sludge accumulated in tanks, surface contaminated equipment, tanks, filters, motors, pumps, pipelines, electrical fittings, contaminated structural materials, wall cement plaster, floor/wall chipping etc. are generated during the decontamination of chemical processing plants. The solid waste generated during decontamination should be segregated into combustible/non combustible and compressible/non compressible wastes. Classification of these wastes into various categories should be done as per Table II-2 and based on the radionuclide content/contamination levels.

II.9.1.2 Liquid Waste

II.9.1.2.1 Liquid waste generated during decommissioning consist of decants from sludge tanks, wash water and water used for decontamination of equipment. Wastes generated should be segregated into different streams depending on their acidity/alkalinity and radioactivity content. Classification of the different streams should be done on the basis of the radioactivity content [Ref. Table II-3].

TABLE II-1 : TYPICAL ACTIVITY CONTENT OF MONAZITE AND BEACH SANDS

	^{232}Th (Bq.g^{-1})	^{238}U (Bq.g^{-1})	Radiation field (infinite spread) (mGy.h^{-1})
Raw sand	0.3 - 6.0 (80 - 1600 ppm)	0.04 - 0.70 (3 - 60 ppm)	0. 5 - 35
Monazite	350 - 400 (80000 - 95000 ppm)	35 (3000 ppm)	180 - 250

Th chain activity (equilibrium) = 10 times ^{232}Th activity
U chain activity (equilibrium) = 14 times ^{238}U activity

TABLE II-2 : SOLID WASTE CATEGORISATION
(Adapted from AERB Document, AERB/NPP/SG/O-11 [2])

Waste details	Radionuclides content	Surface dose rate	Category
Tailings sand from mining and mineral separation	Th (nat) and U (nat) in equilibrium	50 µGyh^{-1}	I Low level waste
Solid wastes from chemical processing of monazite, monazite insolubles, mixed cake and ETP cake, and solid waste from Th oxalate processing.	Th (nat), ^{228} Ra, U (nat)	<2 mGyh^{-1}	I Low level waste
Contaminated equipment and decontamination waste	Traces of Th (nat), ^{228} Ra and U (nat)	<2 mGyh^{-1}	I Low level waste

TABLE II-3 : LIQUID WASTE CATEGORISATION

Waste details	Radionuclides Content	Radioactivity level ($Bq.m^{-3}$)	Category
Mining and mineral separation-water	Th (nat) and U (nat) in equilibrium	Back ground	-
Aqueous alkaline and acidic effluent from chemical processing of monazite and Th oxalate	Th (nat), ^{228}Ra and traces of U (nat)	$< 3.7 \times 10^4$ (after treatment)	I

TABLE II-4 : GASEOUS WASTE CATEGORISATION

Waste details	Radionuclides content	Radioactivity level ($Bq.m^{-3}$)	Category
Gaseous waste from Mining and mineral Separation	Th (nat) and U (nat) in equilibrium	Back ground	-
Chemical processing of monazite and Th oxalate	^{220}Rn and daughter products, traces of Th (nat)	< 3.7	I

TABLE II-5 : TYPICAL ACTIVITY IN SOLID WASTE FROM MINING AND MINERAL SEPARATION

Solid waste	Gross alpha ($Bq.g^{-1}$)	Gross beta ($Bq.g^{-1}$)	Radiation field ($mGy.h^{-1}$)
Mining tails	0.5	5	0.5
Pre-concentration tails	0.8	4	0.4
Mineral separation plant tails	80	300	50

TABLE II-6 : TYPICAL ACTIVITY IN SOLID WASTE, CHEMICAL PROCESSING

Solid waste	Gross alpha ($Bq.g^{-1}$)	Gross beta ($Bq.g^{-1}$)	^{228}Ra ($Bq.g^{-1}$)	Radiation field ($mGy.h^{-1}$)
Monazite insolubles	800 - 2500	800 - 3000	400 - 1000	60 - 100
Mixed cake	2000 - 4000	3000 - 7000	2000 - 5000	400 - 600
ETP cake	300 - 500	300 - 600	25 - 100	2 - 3
Ca oxalate cake	500 - 1000	1200 - 2500	800 - 1000	80 – 100

TABLE II-7 : TYPICAL ACTIVITY CONTENT OF LIQUID WASTE, MINING AND MINERAL SEPARATION

	Mining	Pre-concentration	Mill
Gross alpha ($Bq.l^{-1}$)	0.04	0.01	0.05
Gross beta ($Bq.l^{-1}$)	0.04	0.03	0.09

TABLE II-8 : CHARACTERISTICS OF THE LIQUID WASTE FROM PROCESSING OF MONAZITE AND THORIUM COMPOUND PRE-TREATMENT LEVELS

Effluent	pH	Gross alpha ($Bq.l^{-1}$)	Gross beta ($Bq.l^{-1}$)	^{228}Ra ($Bq.l^{-1}$)
Monazite processing:				
Acidic effluent	1.6 - 2.0	100 – 300	400 – 600	150 – 200
Alkaline effluent	12 – 13	600 - 900	900 - 1000	300 - 400
Th oxalate processing:				
Non-nitrate effluent	1 – 3	20 – 30	100 – 110	25 – 40
Nitrate effluent	1 - 3	20 - 70	200 - 700	25 – 30

Reporting of radioactive waste disposal/transfer should be as per Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, GSR-125, 1987.

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PROVISIONAL LIST OF SAFETY CODE AND GUIDES ON RADIOACTIVE WASTE MANAGEMENT

Safety Series No.	Title
AERB/NRF/SC/RW	Management of Radioactive Waste.
AERB/SG/RW-1	Classification of Radioactive Waste.
AERB/SG/RW-2	Pre-disposal Management of Low and Intermediate Level Radioactive waste.
AERB/SG/RW-3	Pre-disposal Management of High Level Radioactive Waste.
AERB/SG/RW-4	Near Surface Disposal of Radioactive Solid Waste.
AERB/NF/SG/RW-5	Management of Radioactive Waste from Mining and Milling of Uranium and Thorium.
AERB/RF/SG/RW-6	Management of Spent Radiation Sources and Radioactive Waste Arising from the use of Radionuclides in Medicine, Industry and Research including Decommissioning of such Facilities.
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AERB/SG/D-13	Liquid and Solid Radwaste Management in Pressurised Heavy Water Reactor Based Nuclear Power Plants.

AERB SAFETY GUIDE NO. AERB/NF/SG/RW-5

Published by : Atomic Energy Regulatory Board
Niyamak Bhavan, Anushaktinagar
Mumbai - 400 094
INDIA.

BCS