GUIDE NO. AERB/NRF/SG/RW-4

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GOVERNMENT OF INDIA

AERB SAFETY GUIDE

NEAR SURFACE DISPOSAL OF RADIOACTIVE SOLID WASTE

ATOMIC ENERGY REGULATORY BOARD

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NEAR SURFACE DISPOSAL
OF
RADIOACTIVE SOLID WASTE

Atomic Energy Regulatory Board
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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 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 the documents cover aspects such as siting, design, construction, operation, quality assurance and 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 internationally accepted safety criteria for design, construction and operation of specific equipment, structures systems and components of nuclear and radiation facilities. Safety codes establish the objectives and set minimum requirements that shall be fulfilled to provide adequate assurance for safety in nuclear and radiation facilities. 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. These 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 guidelines for near surface disposal of radioactive solid waste. It includes guidance on siting, design, construction and operation of near surface disposal facility (NSDF) to facilitate safe disposal of low and intermediate level radioactive solid waste. It brings out salient responsibilities of the Waste Generator/ Manager for safe disposal of radioactive waste. It also describes various types of near surface repositories, available options, acceptance criteria, safety assessment, radiation protection and site remediation activities in case of incidental/accidental radioactive contamination. In preparing this guide, extensive use has been made of the information contained in the relevant documents published by national/international agencies/ organisations.

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, references/bibliography and lists of participants 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.

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

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

AERB wishes to thank all individuals and organisations who have prepared and reviewed the 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

Acceptance Criteria

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

Accident

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

ALARA

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

Alpha-bearing Waste

Waste containing one or more alpha-emitting radionuclides in quantities and/or concentrations above clearance levels.

Anticipated Operational Occurrences

An operational process deviating from normal operation, which is expected to occur during the operating lifetime of a facility but which, in view of appropriate design provisions, does not cause any significant damage to items important to safety, nor lead to accident conditions.

Approval

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

Aquifer

A water-bearing formation (bed or stratum) of permeable rock, sand and gravel capable of yielding significant quantities of water.

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 (AERB)

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

Authorisation

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

Authorised Limits

Limits established or accepted by the regulatory body.

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.

Conditioning of Waste

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

Decommissioning

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

Decontamination

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

Design

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

Disposal (Radioactive Waste)

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

Documentation

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

Dose Limit

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

Emergency Plan

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

Environment

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

Exempt Waste

Waste, which is cleared from regulatory control in accordance with clearance levels. The designation should be in terms of activity concentration and/or total activity and may include a specification of the type, chemical/physical form, mass or volume of waste.

High Level Waste (HLW)

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

- The radioactive liquid containing most of the fission products and actinides present in spent fuel, which forms the residue from the first solvent extraction cycle in reprocessing, and some of the associated waste streams;
- Solidified high level waste from above and spent reactor fuel (if it is declared a waste);
- Any other waste with similar radiological characteristics.

Institutional Control (Radioactive Waste)

The process of controlling the radioactive waste site by an authority or institution designated under the laws of the country. This control may be active (monitoring, surveillance, remedial work) or passive (land use control) and may be a factor in the design of a nuclear/radiation facility.

Intermediate Level Waste (ILW)

Radioactive waste, in which the concentration or quantity of radionuclides is above that of low level waste but below that of high level waste (HLW), with the thermal power below that of HLW. It requires shielding during handling and transportation. Thermal power of ILW is below 2 kW/m^3. This is also termed as 'Medium Level Waste'.

Long-lived Wastes

Radioactive wastes containing long-lived radionuclides having sufficient radiotoxicity and/or concentrations requiring long time isolation from the biosphere. The term long-lived radionuclides refers to half lives usually greater than 30 years.

Low and Intermediate Level Waste (LILW)

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

Low Level Waste (LLW)

Radioactive waste in which the concentration or quantity of radionuclides is above clearance levels established by the regulatory body but with the radionuclide content below those of intermediate and high level wastes. It does not require shielding during handling and transportation.

Mathematical Model

A set of mathematical equations designed to represent a conceptual model.

Model

An analytical representation or quantification of a real system and the ways in which phenomena occur within that system, used to predict or assess the behaviour of the real system under specified (often hypothetical) conditions.

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, on or below the ground surface with adequate final protection covering to bring the surface dose rate within prescribed limits.

Prescribed Limits

Limits established or accepted by the regulatory body.

Pre-treatment (Radioactive Waste)

Any operation/conditioning of waste prior to final treatment before disposal.

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.

Radioactive Waste Management Facility

Facility specifically designed to handle, treat, condition, temporarily store or permanently dispose of radioactive waste.

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').

Repository

A facility where waste is emplaced for disposal. Future retrieval of waste from the repository is not intended.

Repository, geological

A facility for radioactive waste disposal located underground (usually more than several hundered metres below the surface) in a stable geological formation to provide long term isolation of radionuclides from the biosphere. Usually such a repository would be used for long-lived and/ or high level waste.

Repository, near surface

A facility for radioactive waste disposal located at or within a few tens of metres from the earth's surface. Such repository is suitable for the disposal of short-lived low and intermediate level waste.

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 both with normal conditions and accident situations.

Segregation (Radioactive Waste)

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

Sensitivity Analysis

A quantitative examination of how the behaviour of a system varies with change, usually in the values of governing parameters.

Short-lived Waste

Radioactive waste in quantities and/or concentrations, which will decay to activity levels considered acceptably low from the radiological point of view within the time period during which administrative controls are expected to last. Radionuclides in short-lived wastes will generally have half-lives shorter than 30 years.

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.

Solidification (Radioactive Waste)

Immobilisation of gaseous, liquid-like materials by conversion into solid waste form, usually with the intent of producing a physically stable material that is easier to handle and less dispersable. Calcination, drying, cementation, bituminisation and vitrification are some of the typical ways of solidifying liquid radioactive waste (See also 'Conditioning of Waste').

Storage (Radioactive Waste)

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

Surveillance

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

Technical Specifications for Operation

A document approved by the regulatory body, covering the operational limits and conditions, surveillance and administrative control requirements for safe operation of the nuclear or radiation facility. It is also called 'operational limits and conditions'.

Topography

The configuration of a terrain giving general description of physical features like hills, valleys, slopes, water bodies and other man-made structures.

Uncertainty Analysis

An analysis to estimate the uncertainties and error bounds of the quantities involved in, and the results from, the solution of a problem.

Validation

The process of determining whether a product or service is adequate to perform its intended function satisfactorily.

Validation (Computer Code)

The evaluation of software at the end of the software development process to ensure compliance with the user requirements. Validation is therefore 'end-to-end verification'.

Verification

The act of reviewing, inspecting, testing, checking, auditing, or otherwise determining and documenting whether items, processes, services or documents conform to specified requirements.

Waste Form

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

Waste Immobilisation

The conversion of radioactive waste into solid form (by solidification, or by embedding, or encapsulating in a matrix material) to reduce the potential for migration or dispersion of radionuclides during transport, storage and disposal.

Waste Management

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

Waste Package

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

Waste Treatment

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

(a) volume reduction,

(b) removal of radionuclides,

(c) change of composition.

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

CONTENTS

1. INTRODUCTION

1.1 General

Low and intermediate level radioactive solid and solidified waste generated from nuclear and radiation facilities are generally disposed in near surface disposal facilities. It is necessary to ensure that the near surface disposal of radioactive solid waste does not cause undue hazard to human and the environment for a few hundred years.

1.2 Objective

Objective of this safety guide is to provide guidelines for safe disposal of radioactive solid waste in near surface disposal facilities (NSDFs) complying with the requirements specified by the regulatory body [1,2,3].

1.3 Scope

1.3.1 Scope of this safety guide is to provide guidelines for siting, design, construction, operation, closure, surveillance and safety assessment of near surface disposal facilities. The document also discusses the responsibilities of waste generator/manager and their inter-dependency during pre-operational, operational, closure and post-closure phases of the disposal facility.

1.3.2 This safety guide is applicable to the near surface disposal of low and intermediate level radioactive solid and solidified waste.

1.3.3 This safety guide does not apply to the disposal of high-level radioactive solid waste or the disposal of waste containing significant quantities of long-lived radionuclides.

2. IMPORTANT SAFETY CONSIDERATIONS FOR NEAR SURFACE DISPOSAL OF SOLID WASTE

2.1 General

Radioactive solid waste needs to be managed safely to ensure protection of human health and the environment during disposal without imposing undue burden on future generations. Waste generator/manager ensures compliance with the safety requirements at various stages of operation of the facility [4].

2.2 Radiation Protection of the Occupational Workers

2.2.1 Radiation dose to the occupational workers at any stage of operation of the NSDF should not exceed the limit prescribed by the regulatory body [5]. Radiation dose to the occupational workers should be kept below the prescribed limits by:

(a) adhering to radiation protection procedures;

(b) adopting ALARA principle on radiation exposures;

(c) preventing incidental/accidental radiation exposures; and

(d) mitigating the consequences of radiation exposure due to any incident or accident.

2.2.2 To achieve the objective of radiation protection in respect of the occupational workers, the waste generator/ manager should provide:

(a) appropriate instrument for radiation, personnel, contamination and area monitoring;

(b) adequate shielding, remote handling, operating and administrative procedure for handling radioactive waste;

(c) appropriate protective clothing; and

(d) personnel decontamination facilities.

2.2.3 Radiation dose to the occupational workers should be governed by the concepts of justification, optimisation and dose limitation. In case of intervention, the radiological exposure to the occupational workers should be optimised and all exposures above the prescribed limits should be justified.

2.3 Radiation Protection of the Public

2.3.1 Radiation dose to the critical group or the general public from all exposure pathways of NSDF should not exceed the limits (50 μSv/y) prescribed by the regulatory body.

2.3.2 To restrict the radiation dose to the public, the waste generator/manager should:

(a) dispose radioactive solid waste within the authorised limit;

(b) control the release of radionuclides from the disposal facility to the environment;

(c) establish environmental monitoring and surveillance programme to ensure compliance with the regulatory requirements; and

(d) maintain all monitoring and surveillance records.

2.4 Protection of the Environment

At every stage of operation of the NSDF, the concentration of radioactive and non-radioactive contaminants in the environment should not exceed the limits prescribed by the regulatory body or statutory bodies. Approved operating procedures, quality assurance and waste acceptance criteria should provide acceptable levels of protection of the environment from all radiological and non-radiological effects.

2.5 Land and Ownership Requirements

2.5.1 Before designing of NSDF, the waste generator/manager should acquire sufficient land for its development to accommodate the estimated quantity of waste including decommissioning and augmentation requirements.

2.5.2 The NSDF land should have clear ownership title and should be free from encumbrances.

2.6 Safety Assessment

2.6.1 Before designing and construction of NSDF, the waste generator/manager should perform a comprehensive and systematic safety assessment of the proposed disposal facility for a reasonable time frame based on the peak concentration and important safety significant scenarios.

2.6.2 Radiological impact assessment of NSDF should be based on habitat and behavior of the critical group that get exposed in the event of the release of radionuclides from the disposal facility.

2.7 Licensing

Waste generator/manager should obtain license or authorisation from the regulatory body for siting, designing, construction, operation and closure of the disposal facility [6].

2.8 Physical Protection and Access Control

Waste generator/manager should prevent intrusion of human and animals into the NSDF site during operational and closure phases. Only designated persons should have access to the NSDF site. Necessary provisions should be made to prevent persons from carrying out unauthorised activities.

2.9 Monitoring and Surveillance

Waste generator/manager should establish appropriate monitoring and surveillance programme during operational and post-closure phases of the NSDF. This programme should include:

(a) surveillance of the NSDF and its surrounding; and

(b) measurement of system parameters to confirm that the performance of the isolation system is as expected.

2.10 Continuity of Disposal Facility Operation

Waste generator/manager should maintain documents and records of the disposal facility operation to comply with the regulatory requirements. If the responsibility of a disposal site is transferred to any other agency, the previous agency should supply the succeeding agency with all pertinent information needed to continue satisfactory operation and to complete all possible post-closure measures of the NSDF. The succeeding agency should review the pertinent information and obtain approval from the regulatory body to take over the responsibility of the disposal site.

3. RESPONSIBILITIES OF WASTE GENERATOR/MANAGER

3.1 General

3.1.1 To achieve the objective of safe disposal of radioactive solid waste, the responsibilities of agencies involved in the near surface disposal of radioactive solid waste should be clearly defined and identified .

3.1.2 Waste generator/manager is responsible for safe management of radioactive solid waste in compliance with all regulatory requirements. In case, the waste generator and the waste manager are two separate and independent agencies, the role and responsibilities among these agencies and their interdependency in the management of radioactive solid waste need to be clearly defined and approved.

3.2 Responsibilities of Waste Generator/Manager

Waste generator/manager should:

(a) ensure that generation of radioactive solid waste (volume and activity) is minimum practicable;

(b) collect, monitor, categorise, segregate, characterise, and transport radioactive waste as per the approved procedure;

(c) characterise solid waste based on volume, specific activity, total activity, radionuclide content and physico-chemical characteristics;

(d) provide treatment and conditioning of the waste for safe disposal;

(e) establish and implement acceptance criteria for solid waste conditioning, handling, storage, transport and disposal;

(f) develop quality assurance programme for waste conditioning, handling, storage, transport and disposal to meet the regulatory requirements;

(g) provide appropriate shielding and containment of the waste stored;

(h) ensure safety, security and retrievability of the waste stored;

(i) develop procedure for storage/disposal of non-conforming waste packages;

(j) ensure emplacement and disposal of waste as per the authorised procedure;

(k) develop and implement procedure for remedial actions in case of waste container failure or failure of waste disposal system;

(l) provide facilities to handle exigencies;

(m) ensure monitoring and surveillance of the NSDF; and

(n) maintain documents and records pertaining to radioactive waste generated, stored, transferred and disposed off complying with the regulatory requirements.

3.3 Interdependency in Safe Disposal of Radioactive Solid Waste

3.3.1 Operation of NSDF including waste handling, conditioning, storage and disposal are interdependent. Variance in methodology for solid waste management may result in non-conforming waste, which may require special conditioning for storage or disposal. Therefore, decisions relating to various steps on waste management by different agencies involved should be taken with due consideration of the impacts on other aspects of waste management.

3.3.2 Safe disposal of radioactive solid waste with the participation of interdependent agencies should be achieved by:

(a) delineation of responsibilities of concerned agencies;

(b) establishing co-ordination between agencies involved in the waste management activities; and

(c) review and exchange of information between agencies involved in waste management.

4. SITE SELECTION

4.1 General

4.1.1 A suitable site for near surface disposal of radioactive solid waste exhibits salient characteristics to:

(a) host radioactive waste matrix in the engineered system for a desired time period;

(b) retain radionuclides within the system under all foreseen conditions; and

(c) limit radionuclides release or migration to the biosphere.

4.1.2 Based on the policy and programme adopted, NSDFs may be of the following types:

(a) central disposal facility (for disposal of radioactive solid waste received from various nuclear installations located at different sites); and

(b) co-located disposal facility with nuclear waste generating units (for disposal of radioactive solid waste received from various nuclear installations located at that particular site).

4.1.3 Site selection process commences with the collection of regional information and concludes with the site confirmation. Basic requirements for the selection of central or co-located NSDF remain the same [7]. The scale may, however, vary with site characteristics and waste parameters. In co-located disposal facilities the site selection process is mostly limited to the site characterisation (refer section 4.4.4).

4.1.4 Typical site characteristics of various near surface disposal facilities are provided in the Annexure.

4.2 Basic Consideration of Natural Events for Selection of Near Surface Disposal Site

Basic factors to be considered for the selection of a near surface disposal site generally include tectonics and seismicity, geology, geo-hydrology, geo-chemistry, environmental and socio-economic factors.

4.2.1 Tectonics and Seismicity

NSDF should be located in an area of low tectonic and seismic activity. Preference should be given to area or site where potential for adverse tectonic, volcanic and seismic events are sufficiently low so that the NSDF meets safety requirements of structural integrity and stability.

4.2.2 Geology

The geological characteristics of the near surface disposal site should provide adequate isolation of the waste and limit the release of radionuclides to the biosphere. It should also contribute to the stability of the disposal system and provide suitable lithological, mineralogical, structural and geotechnical properties for NSDF construction. Preferred host medium should be uniform, homogenous (free from open joint, fracture, bedding planes, dykes), with low porosity, permeability and high sorption of radionuclides to provide long migration pathways.

4.2.3 Geo-hydrology

The geo-hydrological setting of the site should provide sufficiently deep groundwater table, low groundwater velocity and long flow paths in order to retard the transport of radionuclide through the geo-hydrological media.

4.2.4 Geochemistry

The geochemistry of geological media should retard and arrest the migration of radionuclides from the NSDF. The geochemical characteristics of the disposal site should not reduce the longevity of engineered barriers. The geochemical condition of the site should promote high sorption and precipitation/co-precipitation of radionuclides potentially released from the disposal system and inhibit the formation of easily transportable radionuclide compounds.

4.2.5 Surface Processes

The probability and intensity of surface process such as flooding, landsliding and erosion of the disposal site should be very low and their occurrence should not affect the disposal system to meet safety requirements. Accumulation of water in upstream drainage areas due to precipitation, snow melt, failure of water control structures, channel obstruction or landsliding should be evaluated and minimised to decrease the amount of runoff, which could erode or inundate the facility. Preference should be given to areas or sites with suitable topographical and hydrological features where the potential for flooding does not exist. A gently sloping land with good runoff should be preferred.

4.2.6 Meteorology

The meteorology should be characterised and the potential for extreme meteorological events should be evaluated. The effect of unexpected extreme meteorological conditions such as high rainfall, occurrences of tornadoes, cyclone and tsunami should be adequately considered in site selection process of the disposal facility.

4.3 Basic Consideration of Man-induced Events for Selection of Near Surface Disposal Site

4.3.1 The site should be located such that activities of present and future generations in and around should not affect the isolation capability of the disposal system. The near surface disposal facilities should be kept at adequate distance from the potentially hazardous facilities, airports and transport routes which may carry significant quantities of hazardous materials.

4.3.2 Transportation of Waste

The location of disposal site should be at optimum transport distance and allow the transportation of waste with a minimum radiological risk to the public. Parameters including cost, radiation exposure and accident potential associated with the transportation of waste to the disposal site should be taken into account while selecting the site.

4.3.3 Land Use, Population Distribution and Socio-economic Factors

4.3.3.1 The site should be located such that the potential of radiological exposure to the present and the future population should be within the limits prescribed by the regulatory body.

4.3.3.2 Areas having high population density and abundant in natural resources should be avoided for locating near surface solid waste disposal. The land and groundwater utilisation point of the public should have adequate distance from the disposal system to reduce the potential of radiological risk.

4.3.3.3 NSDFs are generally located/ co-located within the exclusion zone and various parameters are considered to keep the radionuclides migration to a minimum in controlled zone of the nuclear facility.

4.4 Stages of Siting

Siting process of NSDF consists of the following stages:

(a) conceptual planning;

(b) data collection and collation;

(c) area survey;

(d) site characterisation; and

(e) site confirmation.

4.4.1 Conceptual and Planning Stages

Objective of the conceptual and planning stages are to develop an overall plan for site based on waste characteristics, projected waste quantities, radionuclide content and the regulatory requirements. On the basis of this information, a generic design concept of the disposal facility should be developed. This forms the basis for the preliminary survey of the site.

4.4.2 Data Collection and Collation

The siting of centralised near surface disposal facility begins with acquisition of regional data to identify suitable areas for further narrowing down the choice of candidate sites. Generally, data on various aspects, mainly on meteorology, soil types, geological and geo-hydrological systems, surface water bodies, drainage pattern, demography, transport and communication facilities, power availability and socio-economics of the region is collected by procurement of available maps on larger scales and published reports, through various organisations or agencies. In case of co-located disposal facility, these aspects are considered along with site selection process of the nuclear facility itself.

4.4.3 Area Survey

The purpose of area survey is to identify one or more potential sites having favourable tectonic, seismic, geological, structural, hydrological, geo-hydrological, geochemical and climatic features. This may include:

(a) study of regional maps;

(b) satellite and aerial survey; and

(c) land based reconnoitary survey.

4.4.4 Site Characterisation

The identified candidate sites are further characterised to demonstrate that they meet all regulatory requirements. This stage requires site-specific information to establish the characteristics and ranges of parameters of a site with respect to the location of the intended disposal facility. This stage also involves on-site investigations, laboratory studies, safety assessment and comparative evaluation among the candidate sites to establish the suitability for the construction of the disposal facility. Site characterisation requires detailed data acquisition of desirable parameters and macro-level site investigation to select the most suitable site amongst the candidate sites, based on score points and weightage.

4.4.5 Site Confirmation

4.4.5.1 Site confirmation stage consists of detailed and micro-level field investigations and laboratory studies of the most preferred site and its surroundings, prior to the construction of the facility. Extensive laboratory studies, in-situ testing and detailed safety and environmental impact assessment should be performed at this stage.

4.4.5.2 The investigations include geological mapping, close grid shallow geo-physical surveys, trenching and pitting for soil/rock sampling, borehole drilling for lithological and aquifer characterisation, groundwater flow and fluctuation characteristics and sorption parameters. Laboratory studies involve determination of physico-chemical, mineralogical, petrological and radionuclide sorption properties with soil and rock.

4.5 Clearance from Regulatory Body

Clearance for the selected site should be obtained from the regulatory body before construction of NSDF. The data collected at various stages of site selection should be submitted to the regulatory body for review.

5. WASTE ACCEPTANCE CRITERIA

5.1 General

5.1.1 Radioactive wastes have different physico-chemical characteristics and contain variable amount of radionuclides with different half-lives and toxicities. The waste may also contain non-radioactive components with degradable or non-degradable characteristics. Due to some of these characteristics the waste may not be amenable for direct disposal in near surface disposal facilities and may require suitable conditioning.

5.1.2 Improved waste form, engineered barrier, depth of the disposal facility and institutional control period have very little effect on lowering the hazard potential of long lived radionuclides. Specific activities of such radionuclides determine the criteria for disposal in NSDF.

5.2 Waste Acceptance Criteria for Disposal

5.2.1 The acceptance of waste should take into account both radioactive and non-radioactive components and their associated hazards. The waste acceptance criteria are generally applied to waste packages and are established on the basis of safety assessment, site characteristics, NSDF design, engineered barrier, backfill material, and other factors including anticipated institutional controls.

5.2.2 Waste generator/manager should establish waste acceptance criteria for the near surface disposal of radioactive solid waste based on the safety assessment of the entire disposal system comprising of waste form characteristics, engineered barriers, overall NSDF design and site characteristics.

5.2.3 Waste acceptance criteria, as approved by the regulatory body for safe disposal of radioactive solid waste in NSDF should include the following parameters:

(a) radiological;

(b) physico-chemical; and

(c) micro-biological.

5.3 Radiological Parameter

5.3.1 The radiological acceptance criteria of the waste should ensure adequate protection to occupational workers, public and the environment to the levels prescribed by the regulatory body. Acceptance criteria should be established based on following aspects:

(a) radionuclide content;

(b) surface dose rate; and

(c) surface contamination.

5.3.2 Acceptance criteria of the waste should be established based on the radionuclide content, surface dose rate and specific activity. Concentration of fissile isotope, alpha and long-lived pure beta emitting radionuclides present in the waste should not exceed the limit prescribed for near surface disposal. External surface of the waste package or container should be free from radionuclide contamination. Basic limits on acceptability of waste for disposal in near surface facility include specific activity and total quantities of radionuclides in the waste as determined by site-specific safety analysis.

5.3.3 The surface dose rate of waste packages should be such that the occupational exposures are kept below acceptable level. The exposure should be minimised by shielding and remote handling.

5.3.4 The surface contamination of the waste package should be well below the prescribed limit to prevent personnel contamination and its spread through contact.

5.4 Physical Parameter

(a) Physical form : The moisture content of the waste/waste product accepted for near surface disposal should not affect or compromise the safety of the disposal facility.

(b) Density: : Waste should be densified to minimise the voids, surface area, volume and radionuclide mobility.

(c) Thermal stability : The waste form should have resistance to degradation by heat generated due to decay of radionuclides present in the waste.

(d) Packaging : The weight, volume, shape and dimensions of all packages should be compatible with the planned handling and emplacement during disposal operations.

(e) Mechanical stability : The waste packages should have sufficient mechanical strength to keep their shapes and withstand handling and storage

(f) Dispersibility : Dispersible materials such as dry powder, ashes should be immobilised and contained using proper packaging to prevent spread of contamination.

5.5 Chemical Parameter

(a) Chemical stability : Waste should not contain strong oxidants, corrosive or reactive agents.

(b) Chemical compatibility	:	Consideration should be given to the chemical content of waste which may degrade waste form characteristics or affect the integrity of engineered barrier.
(c) Complexing agent	:	The presence of stable complexing agents used in decontamination may increase the mobility of radionuclides by interfering with sorption process and hence should be minimised.

5.6 Micro-biological Parameter

The amount of organic waste disposed in NSDF should be controlled to limit the microbial degradation of the waste matrix and the structural material of the disposal system.

5.7 Non-conforming Waste

The waste packages not conforming to the acceptance criteria should be segregated, reconditioned and disposed off as per the approved procedures.

6. DESIGN AND CONSTRUCTION

6.1 General

NSDF needs to provide adequate isolation of radioactive solid waste from the biosphere and contain radioactive waste within the system under all foreseen conditions. To achieve this objective, engineered multi-barrier disposal systems are used for the disposal of low and intermediate level solid waste. The design of the engineered barriers take into account the site specific conditions and waste/waste form characteristics.

6.2 Design Consideration

Design of NSDF should consider waste and waste form characteristics, package characteristics, land requirements, layout, size of the disposal facility, engineered barriers, biological shields, backfill material, post-operational sealing and water proofing, monitoring provisions, auxiliary services systems and anticipated institutional controls.

6.3 Waste Form Characteristics

Waste forms usually employed and found to be satisfactory for low and intermediate level waste are waste immobilised in inorganic or organic matrices. Waste form should consider the following aspects and meet the acceptance criteria:

(a) radionuclide inventory;

(b) fissile isotopic content ;

(c) surface dose rate;

(d) surface contamination levels;

(e) weight and volumes;

(f) leach rates;

(g) free liquid content;

(h) compressive strength and impact resistance;

(i) special features (attractiveness due to value, special materials etc.);

(j) chemical stability (combustibility, thermal resistance, degradation and gas generation etc);

(k) explosive and pyrophoric fractions;

(l) volatile fractions; and

(m) toxic and corrosive contaminants.

6.4 Waste Container/Package

Waste containers used for low and intermediate level waste should provide primary containment to facilitate handling and prevention of spread of contamination. The following types of containers may be used singly or in combinations:

(a) PVC bag or plastic bag;

(b) mild steel drum/container;

(c) steel lined concrete high integrity container (HIC); and

(d) concrete bins.

6.5 Land Requirements

Land required for the development of NSDF should be estimated and acquired on the basis of:

(a) waste generation;

(b) anticipated operating life of the facility;

(c) requirements of intended waste volume due to anticipated operational occurrences;

(d) decommissioning needs of the nuclear facility; and

(e) requirements for augmentation and future expansion of the facility.

6.6 Layout

Layout of the disposal site should take into consideration:

(a) approachability;

(b) drainage of surface run off;

(c) access control and zoning;

(d) equipment layout; and

(e) physical protection.

6.7 Optimisation of Size of the Disposal Facility

Size of the disposal facility should be optimised by considering:

(a) stability of the engineered structure;

(b) ease of operation;

(c) size of the waste consignments;

(d) requirements of biological shields; and

(e) limiting radionuclide releases in case of structural failure of a disposal module.

6.8 Engineered Barrier

6.8.1 The engineered disposal facilities commonly in use for low and intermediate level waste are:

(a) earth trenches, brick/stone lined trenches;

(b) reinforced cement concrete structure; and

(c) tile holes.

6.8.2 Engineered barriers should be designed to:

(a) minimise the release of radionuclides from the waste disposal system to biosphere;

(b) restrict ingress of water;

(c) protect waste packages from degradation and physical deformation;

(d) provide long term structural stability;

(e) control erosion of the surface;

(f) facilitate monitoring; and

(g) reduce potential for intrusion.

6.8.3 Design of engineered barrier should take into account;

(a) all foreseen disruptive events like earthquake, flooding and landslide. The design of the rafts and other load bearing structure should be commensurate with total load of the facility after emplacement of waste, capping, water proofing and the load bearing capacity of the substratum;

(b) location above the water table as far as possible and the bouncy forces, if any, due to the water table and its seasonal fluctuation;

(c) provision for collection of ingress water and dewatering system;

(d) the radiological and chemical characteristics of the waste and waste form;

(e) each of construction to eliminate defects and enhance the integrity of the facility;

(f) proper capping, sealing, waterproofing;

(g) safe and easy placement of pre-cast shielding slabs after emplacement of the waste packages;

(h) minimum disruption to the substratum; and

(i) economic and effective usage of land and resources.

6.9 Biological Shielding

The trenches/ vaults and tile-holes should be provided with appropriate earthen embankments to ensure:

(a) adequate shielding to keep the radiation fields well below the acceptable levels prescribed by the regulatory body during operation and closure of the facility;

(b) sufficient working space around the facility; and

(c) stable slope to minimise erosion.

6.10 Backfill Materials

6.10.1 Backfill material should be interposed between the waste and the engineered/ natural barriers to prevent or retard the migration of radionuclide from the disposal system to the biosphere. Backfill material should have:

(a) adequate ion exchange capacity for retention of radionuclides;

(b) minimum permeability; and

(c) acceptable amount of swelling.

6.10.2 Selection of the backfill material should be optimised based on:

(a) waste and waste form characteristics;

(b) radionuclide composition;

(c) geochemistry; and

(d) effects of backfill material on engineered structure.

6.11 Post Operational Sealing and Ingress Water Monitoring

Design of engineered structure should ensure provision for sealing, capping and water proofing after emplacement of waste in the disposal facility (earthen trenches, RCC trench, vault and tile hole). The design of caps, covers and water proofing should ensure:

(a) stability over a period of time;

(b) minimisation of water ingress;

(c) self drainage slopes to facilitate quick drainage of rain water;

(d) sufficient strength and support to withstand subsidence and sinking of emplaced waste in the facility;

(e) ingress monitoring and dewatering system;

(f) sufficient chemical and mechanical stability; and

(g) radiation markers and caution board.

6.12 Surveillance and Monitoring Provision

6.12.1 Design of the disposal facility should provide monitoring and surveillance provision to monitor health and integrity of the disposal facility. Surveillance and monitoring provisions in the design should include:

(a) groundwater monitoring; and

(b) inspection and dewatering of disposal modules.

6.12.2 Groundwater monitoring should include:

(a) provision for borewells based on groundwater flow pattern;

(b) catchment basin around the facility; and

(c) cut-off drains in the down stream of the facility.

6.13 Auxiliary Services

Adequate space and provision should be provided in the design for auxiliary facilities like administration, security, waste receipt, loading and unloading, waste conditioning, treatment, transit storage, laboratories for quality control and environmental monitoring, decontamination, health physics, change room, parking space for waste transport vehicle and handling equipment, general services such as water supply, electricity, emergency light, ventilation system, fire fighting equipment and system, hot cells and pumps.

6.14 Construction

6.14.1 Construction of a NSDF should start only after the regulatory body approves the design. The construction should proceed as per the approved safety report ensuring compliance with all the conditions imposed by the regulatory body. Construction of disposal facility includes:

(a) site preparation;

(b) initial excavation;

(c) erection of building structures;

(d) construction of disposal modules; and

(e) installation of monitoring system.

6.14.2 Construction of engineered concrete structure should be in accordance with the approved design and national/international codes and standards. The construction should ensure:

(a) minimal thermal stress;

(b) absence of cold joints; and

(c) quality control as per quality assurance programme.

7. OPERATION OF DISPOSAL FACILITY

7.1 General

Operation of near surface disposal facility needs to be planned and carried out to achieve all regulatory requirements. Prior to normal and routine operations of the repository, the waste disposal agency needs to establish operating steps and procedures for safe operation of the facility. The operating manual of NSDF covers the procedures for normal and anticipated operational occurrences during waste disposal activities.

7.2 Operational Requirements

7.2.1 Operational requirements of NSDF should include:

(a) approved operation and maintenance manuals;

(b) license or authorisation for operation;

(c) qualified staff;

(d) approved quality assurance programme; and

(e) physical protection and security arrangements.

7.2.2 Waste generator/manager should establish waste acceptance criteria and limiting conditions to ensure safe operation of the disposal facility in compliance with regulatory requirements. The approved operating procedures or manual should include:

(a) procedures for radiation protection to the occupational workers and members of the public;

(b) procedures for receipt and disposal of solid waste;

(c) criteria and procedures for receipt and disposal of non-conforming waste;

(d) assumptions and limit specified in the safety assessments;

(e) waste acceptance criteria and limits for different types of near surface repositories; and

(f) authorised disposal limit for waste volume and activity.

7.3 Commissioning

7.3.1 Waste generator/manager should formulate a commissioning programme approved by the regulatory body prior to regular operation of the facility to ensure that the disposal facility and its installed equipment function as envisaged in the approved design. The commissioning activities should include:

(a) equipment test;

(b) engineered barrier integrity test; and

(c) experimental or trial operation.

7.3.2 Equipment test should cover testing of all operational equipment whose malfunction may result in abnormal radiological exposures to operating personnel or may affect the integrity of the disposal facility. The test results should be compared with quality assurance data to build up confidence.

7.3.3 Integrity test should be carried out to verify the isolation capacity of the disposal facility. The integrity of disposal module should be checked by water-fill test using suitable tracers. The test should be carried out for the individual module of the battery at a time.

7.4 Waste Receipt

7.4.1 Conditioned waste received for near surface disposal should be verified for the following information provided by the waste generator:

(a) volume (m^3);

(b) radiation dose rate (Gy/hour);

(c) radionuclides present and their concentration (Bq/g);

(d) presence of alpha or long lived pure beta emitters, wherever applicable;

(e) total activity content (MBq);

(f) description of the waste form; and

(g) description of the waste package or container.

7.4.2 Transferable contamination on the waste package or container should be monitored to avoid cross contamination and undesirable personnel exposures. If any contamination is detected, it should be either decontaminated or provided with appropriate over pack before further handling. The waste transport vehicle should also be checked for contamination and decontaminated appropriately if observed, before leaving the site.

7.5 Waste Handling and Storage

7.5.1 Waste handling equipment include forklift, hoist, travelling crane and remote handling devices. Waste handling equipment should be selected based on the radiation dose rate, weight and size of the waste package.

7.5.2 Solid waste packages difficult to handle manually due to volume, size and radiation dose should be handled by:

(a) lift truck;

(b) locally controlled overhead crane with package hook clamp; or

(c) remote controlled crane.

7.5.3 Waste handling and storage area of the disposal facility should be located at sufficient distance from inactive material storage and working area. The handling and storage area should be free from contamination and provision should be available for decontamination, re-packaging, retrieval and re-location of waste. Adequate security provision should be made to prevent unauthorised access. Waste handling and storage area should have sufficient ventilation and provision for gas dissipation.

7.5.4 Waste stored in transit or interim storage area should:

(a) have appropriate labeling of waste packages;

(b) not contain any pyrophoric or inflammable material;

(c) be free from loose contamination;

(d) have proper segregation and adequate shielding for high dose rate waste packages;

(e) be tidy and planned for minimum handling; and

(f) have sufficient space to facilitate safe storage and retrieval.

7.6 Waste Disposal

Radioactive solid waste should be disposed in earth trenches or in engineered structures based on the following criteria:

Disposal Facility	Criteria
Earth, stone /brick lined trenches	suspected or low radioactive solid waste having very low radiation field (up to 0.02 mGy/h), radionuclides concentration and total activity
R.C.C. trenches/vault	radioactive solid waste having a dose rate of upto 0.5Gy/h and concentration of alpha and long lived pure beta emitting radionuclides below the prescribed limits.
Tile holes or HIC	radioactive solid waste having a dose rate of above 0.5 Gy/h and concentration of alpha and long lived pure beta emitting radionuclides below the prescribed limits.

7.7 Backfilling and Sealing of Disposal Facility

7.7.1 To restrict the release of radionuclide from the NSDF to the biosphere, it should be backfilled and sealed to prevent the ingress of water. The backfill materials generally used are:

(a) native soil having good sorption capacity;

(b) sand and clay mixtures (bentonite, kaolin etc);

(c) vermiculate; and

(d) cement grout.

7.7.2 Backfilling of the disposal module should be done by providing sufficient margin for swelling/expansion to avoid any adverse effect on the integrity of the disposal module. The filled disposal module after backfilling should be covered with an impermeable cap to prevent the ingress of water. Additional barriers/water-proofing should be provided on the cap to prevent the ingress of water during the interim and final closure of the disposal facility. Vegetation growth should be avoided on or around the module.

7.8 Surveillance and Monitoring

7.8.1 To verify the integrity of NSDF, periodic sampling and monitoring should be carried out on soil, water, air, vegetation and radiation field in and around the facility.

7.8.2 The periodicity of sampling and the methodology of analysis should be established to ensure compliance with regulatory requirements.

7.9 Emergency Preparedness

Approved emergency preparedness plan of the NSDF should separately exist unless it is covered by the emergency preparedness plan of the facility. The plan should:

(a) cover spillage of waste due to anticipated operational occurrences;

(b) have the procedure to mitigate abnormal releases from the disposal facility;

(c) provide remedial measures to prevent or minimise spread of contamination;

(d) limit occupational/public exposures in the event of unusual occurrences; and

(e) include handling and disposal of waste generated from anticipated operational occurrences.

7.10 Organisation and Training of Personnel

7.10.1 Waste disposal agency should clearly define and implement organisational structure, functional responsibility, authority and communication channel. Adequate number of staff, necessary qualification and training programme should be determined at each level of operation of the disposal facility. The training programme should cover:

(a) commissioning and operational requirements;

(b) decontamination and remediation procedures;

(c) fire prevention and fire fighting; and

(d) review and update of curricula.

7.10.2 The training programme should specify the extent of theoretical and practical aspect to each level and discipline. Procedures for qualification and certification of operating personnel should be established at each level to meet the requirements of safe operation of the repositories.

7.10.3 Training programme should be oriented to develop safety consciousness at all levels of the organisation. Retraining programme should be established to maintain proficiency of the operating staff.

7.10.4 All temporarily employed persons in the operation of NSDF should be trained to the extent necessary in radiological protection and access control to minimise the occupational exposure.

7.11 Security of Disposal Facility

Physical protection and system of safe guarding should be established to prevent human and animal intrusion during operational and post closure phase of the disposal facility. The security system should consider providing:

(a) boundary wall with anti-climb arrangements; and

(b) intrusion detection and alarm system (manual or automatic).

7.12 Review and Modification

7.12.1 Periodic and systematic review of the NSDF performance should be carried out based on the operating experience and the regulatory requirements. The review plan should include:

(a) operation of the disposal facility;

(b) evaluation of the environmental impact; and

(c) radiation exposure to the occupational workers and public.

7.12.2 Modification plans based on review and updates should be submitted to the regulatory body for approval.

7.13 Site Remediation

7.13.1 Operations of near surface waste repositories may result in contamination of soil, ground/surface water and air due to:

(a) spillage of radioactivity; and

(b) leaching and migration of radionuclides due to disposal facility degradation or failure.

7.13.2 The potential impact of the contaminated media on the human and the environment should be minimised by remedial measures. Remediation plan should contain:

(a) identification and quantification of source;

(b) corrective action for controlling source;

(c) safety assessment of the problem;

(d) selection of treatment method of the contaminated media; and

(e) monitoring programme.

7.13.3 Contaminated media should be brought to the level acceptable to the regulatory body by reducing the concentration of radionuclides in the contaminated media by approved methods.

8. CLOSURE AND SURVEILLANCE OF DISPOSAL FACILITY

8.1 General

8.1.1 Near surface disposal facility is closed down when the authorised/designed capacity is exhausted. The closure programme of repositories essentially consists of the following:

(a) interim closure of different modules in the disposal facility; and

(b) final closure of the entire disposal facility.

8.1.2 During the institutional control period, the disposal site may be released for limited use and thereafter for unrestricted use.

8.2 Prerequisite for Closure

8.2.1 Closure of a NSDF may fall into following categories:

(a) design basis;

(b) operational basis; and

(c) abnormal and accidental conditions.

8.2.2 The design basis should be activated when the disposal facility is filled to its authorised quantity of radioactive waste or its capacity is exhausted. The operational condition depends on the recommendations of the safety assessment, which is being carried out during the operational phase using intensive site characterisation data collected during this phase. The abnormal and accidental closure condition may occur because of severe deviations from the design basis and practical conditions. This may be caused by a severe event, either natural or man-induced, that changes the character of the disposal facility to the extent that it is no longer a safe receptor for radioactive waste. The abnormal condition may also arise due to unexpected serious flaws in the integrity of the disposal facility.

8.3 Closure

The objective of closure is to ensure the long-term protection of the environment from radioactive contamination by preventing water infiltration into the disposal facility and by restricting plant, animal and human intrusion into the disposal facility. The interim and final closure may require different approaches and considerations.

8.4 Interim Closure

Interim closure is applicable to different modules in the disposal facility under design basis or operational closure conditions during the operational phase of the disposal facility. Interim closure is limited to a disposal module when it is filled with the approved quantity of radioactive waste. The basic objective of interim closure is to ensure the structural integrity of the module. The filled module should be closed with sufficiently thick concrete slab. Efficient waterproofing should be provided to prevent infiltration of water. The top layer should be designed to provide self drainage of water. Any vegetation growth over the module should be avoided. The boundaries of the module should be clearly identified with visible markers.

8.5 Final Closure

8.5.1 The basic objective of final closure is to provide additional protection to the disposal system to minimise migration of radionuclides to the environment upto the institutional control period. This objective can be achieved by:

(a) stabilization of the surface; and

(b) preventing erosion from water and wind, infiltration of water, intrusion of deep rooted vegetation, animal and human.

8.5.2 Individual filled modules should be integrated with one or more protective systems. Components used for closure of the disposal facility include:

(a) a cap with or without a low permeability (resistive) layer;

(b) cut-off wall designed to minimise lateral migration of the leachate out or groundwater into disposal facility;

(c) drainage features to conduct surface and sub-surface water and potential leachate away from a disposal facility; and

(d) markers to indicate the presence of a closed disposal facility to future generations.

8.5.3 The disposal site should be secured by providing fences on all sides and appropriate and prominent warning signs displayed to indicate the radiological hazard of the disposal facility.

8.6. Post-closure Surveillance

8.6.1 Surveillance includes all the activities needed to ensure the continued integrity of the disposal site such as monitoring, restriction of access, maintenance, keeping of records and possible remedial actions. Post-closure surveillance of a disposal facility should be under the control of designated authority. The purpose of post-closure surveillance is to:

(a) maintain topography of the area and drainage systems;

(b) prevent intrusion of man, animal, deep-rooted vegetation and habitation of deep-burrowing animals;

(c) maintain radiation field in and around the disposal site within the prescribed limits; and

(d) monitor and control migration of radionuclides to the environment.

8.6.2 Periodic survey and physical inspection of the closed disposal facility should be carried out to detect and take remedial action in case of barrier failures, breaches of drainage system, damage to concrete structure, protective layer, intrusion of vegetation etc.

8.6.3 Monitoring requirements of the closed disposal facility are same as the operating disposal facility except in the intensity and frequency of monitoring. Post-closure monitoring programme should meet the specific needs of any abnormal situation and include all significant exposure pathways.

8.6.4 After institutional control period, review of the condition of the disposal facility should be carried out based on the monitoring data collected over the years to ascertain that the residual activity present in the disposal facility reaches an acceptable level prescribed by the regulatory body for unrestricted use.

9. SAFETY ASSESSMENT

9.1 General

9.1.1 Safety assessment is carried out for evaluating the performance of disposal facility as a whole and its components individually for predicting the potential radiological impact on public and the environment. This exercise delivers a reasonable assurance of safety of the NSDF in terms of radiation dose or risk to members of the public. The safety assessment of NSDF during the operational and post-closure phase provides reasonable assurance that the NSDF meets the design objective, intended performance and the regulatory requirements.

9.1.2 The safety assessment methodology considers the disposal facility and its environment as a system. This takes into account waste inventory, features of engineered and geological barriers, time frame, uncertainty in the parameters and modeling.

9.2 Elements of Safety Assessment

9.2.1 Safety assessment of NSDF involves the following elements:

(a) identification of features, events and processes (FEP);

(b) scenario generation, screening and analysis;

(c) identification of radiological pathways;

(d) data acquisition;

(e) development of model and software;

(f) presentation of the results of analysis;

(g) QA in safety assessment; and

(h) safety indicator.

9.2.2 Based on the objective of the analysis, relevant data, all significant features, events and processes should be identified for the safety assessment.

9.3 Identification of Features, Events and Processes(FEPs)

This step identifies all relevant features of the site, geo-sphere, biosphere, engineered barriers, events and processes, which might affect the long term isolation of the waste and cause the radionuclides to migrate. The list of FEPs should be used to construct scenarios, pathways and development of associated model. Available generic list of scenarios may also be used for inter-comparison and for checklisting.

9.4 Scenario Generation, Screening and Analysis

9.4.1 The purpose of scenario generation is to ensure that all relevant and important mechanisms have been considered for release of radionuclide from the NSDF. The scenario should adequately cover operational, closure and post-closure safety aspects of the NSDF. Systematic examination of potential FEPs should lead to list of scenarios, which may be further screened for appropriateness. The scenarios with very low probability and negligible consequence should be screened out at the very beginning and reason for rejection should be well documented. Normal evolution scenarios are extrapolation of existing conditions and processes into the future. It should be adequately supported by a reasonable assurance that actual evolution should be within the range.

9.4.2 The scenario analysis involves identification and quantification of phenomena, which may initiate the release of radionuclides from a disposal facility and/or influence the rates at which releases and transport occur. The potential event and processes (EP) relevant to scenario analysis for near surface radioactive waste disposal facilities fall into following broad categories:

(a) human activities, and

(b) natural processes and events.

9.4.3 The results of scenario analysis consist of the release and transport parameters required for the consequence analysis and the estimates of the probabilities of occurrences of these scenarios as a function of time.

9.4.4 Expert judgment, fault and event tree analysis and other techniques as applicable should be used to focus on the important scenarios. The process, scenario factors considered and judgment made should be recorded.

9.5 Identification of Radiological Pathways

9.5.1 Screening of scenarios helps in identification of potential radiological pathways. The pathways may be for the disturbed and undisturbed conditions of the NSDF. The list of potential pathways should be further screened for dominant pathways, which contribute to significant radiological impact.

9.5.2 For normal evolution scenarios, natural processes and events like degradation of barriers, groundwater, soil, plants, animals, surface waters, aquatic animals (fresh and sea water) and air are important pathways. For disruptive event scenarios; intrusion, direct exposure and suspended radioactive material are important pathways.

9.6 Data Acquisition

9.6.1 Nature and type of data required for safety assessment depend on the purpose and objective of a particular analysis. Type of safety analysis may vary from preliminary to complex, depending upon the stage of investigation. In early stage of site selection, only a preliminary analysis with very limited data is required for the safety assessment. The data requirement grows with degree of refinement needed in the analysis. Important data required for safety assessment are:

(a) waste characteristics;

(b) container characteristics;

(c) NSDF characteristics;

(d) site characteristics;

(e) bioshperic characteristics;

(f) demographic and socio-economic characteristics; and

(g) monitoring data.

9.6.2 Data acquisition should begin with collection, collation and review of all available and published sources. Generation of field or laboratory data should be taken up in an iterative way commensurate with the objective of the analysis.

9.7 Development of Model

Development of model involves two stages such as development of conceptual model and mathematical model. Conceptual model provides an overall idea of the performance of total disposal system over a period of time. The model should include enough details to represent the system behaviour adequately and includes the following steps:

(a) identification and characterisation of the waste in terms of inventory, waste form and package and design information on NSDF sufficient to allow for adequate modeling of radionuclide releases, i.e. the source term;

(b) characterisation of the disposal site by using necessary information about tectonics and seismicity, geology, hydrology, geochemistry, surface process, meteorology, ecology and distribution of local population and their social and economic practices. This site information is important to define pathways and receptor to develop a conceptual physical, chemical and biological model of the site; and

(c) more than one conceptual model may be considered for the safety assessment and the reason for rejection of any model should be clearly documented.

9.8 Development of Mathematical Model and Software for Analysis

9.8.1 Mathematical model is the translation of conceptual model into a system of equations, which may take quantitative value of the parameters in such a way that it duplicates the response of the real system as closely as possible. The model should describe individual processes, subsystem or overall system performance. The model may be either deterministic or probabilistic.

9.8.2 Mathematical modeling needs to be developed into software. The software should be consistent with assumptions, data and processes describing the system. The software used should be benchmarked and validated.

9.9 Consequence Analysis

9.9.1 It involves estimating the consequences to humans due to the disposal practice during operational, closure and post closure period with models that involve the following:

(a) evaluation of radioactivity release rate (source term modeling);

(b) radionuclide concentration in different environmental segments using mathematical models (radionuclide transport modeling); and

(c) resultant radiation dose to critical group (biospheric modeling).

9.9.2 The first step is to predict the radionuclide release rates from the NSDF. This is followed by the estimation of radionuclide concentrations in the various relevant compartments of the environment. The second step involves prediction of transport rates of radionuclides between various compartments and human. The third step involves a prediction of radionuclide interaction with human, resulting in calculation of doses to individuals and to the population for each scenario identified during the scenario analysis. The collective dose commitment is also estimated to indicate the total impact of the NSDF. The radionuclides in the various compartments can reach human through primary, secondary and tertiary exposure pathways. For example, primary exposure pathways include consumption of surface water and ground water, and secondary pathways include consumption of aquatic food, bathing, and swimming. The tertiary exposure pathways include transport by plants via irrigation and milk and meat of domestic animals via consumption of contaminated food. Consequence analysis requires mathematical models to perform its objectives. These models may be probabilistic or deterministic in nature. The results obtained in the consequence analysis are compared with the safety goals to assess the performance and acceptability of the disposal facility.

9.9.3 Consequence analyses of near surface repositories may be carried out by probabilistic or deterministic analysis.

9.10 Probabilistic Analysis

Probabilistic analysis involves a set of statistical techniques for studying effects. Parameters whose values are uncertain, events whose occurrence are random, and features, which may or may not be present, may be treated statistically. Fault tree/event tree analysis and Monte Carlo analysis techniques are the conventional methods employed to obtain information on the system reliability, consequence probability and the uncertainties in consequences in analysis results respectively. In fault tree approach, system failure logic is developed in tree like structures. The precise application of this technique requires precise knowledge of the system and explicit interrelationship among the various components of the system and the estimation of probabilities of occurrence of these components. The event tree represents the event/accident sequences following successive failure of mitigating measures/barriers. Monte Carlo analysis is a stochastic method, which is used for evaluating uncertainty in both the system reliability and consequence analysis. The technique is used by stepping through values of input parameter, assuming occurrence of the events according to their estimated probability distributions until a system failure or end result/consequence of interest occur. After a large number of simulations, a probability distribution of failures or consequence is obtained. Since the computational process is complex, analysis requires development of integrated model and software validation before use. The probabilistic analysis should include analysis of (risk) measures, sensitivity studies besides uncertainty analysis to develop confidence in analysis results.

9.11 Deterministic Analysis

Deterministic analysis techniques predict the steady or transient behaviour of a waste repository using mathematical models. Deterministic techniques are used in developing both the scenario and consequence analyses, postulating certain failure of waste packages, backfill materials, barriers including engineered safety features and finally assess impact to the public. Necessary sensitivity studies and uncertainty analysis need to be carried out to take care of modeling inaccuracy, inadequacy and/or variance in data and insufficiency in understanding of parameters. Mathematical models for transportation of radioactivity through ground water in the case of waste repositories describe the evolution of the environment in the vicinity of radioactivity releases and the transfer of radionuclides through the evolving environment. These models use three components such as the flow model, the source term model, and the solute transport model to evaluate the fate and transport of radionuclides in the subsurface environment. The results of deterministic analysis are assessed against the acceptable limits and criteria and to instill confidence in the NSDF functioning during operational, closure and post closure phases and for decision making.

9.12 Analysis and Presentation of Results

9.12.1 Outputs of model calculation of safety assessments are indicators of what might happen under certain conditions that may prevail in future. Therefore, the presentation of safety assessment results should be carefully prepared with the following:

(a) comparison of the results of the model calculation of the system against the limits prescribed by the Regulatory Body;

(b) performance of the individual engineered barrier and comparison of the behavior of the subsystem with established standards; and

(c) radiological impact based on intrusion, occupancy factor, peak concentration and time of peak.

9.12.2 Presentation of safety assessment results should include description of the site, selected design, waste inventory, description of FEPs, scenario generation and screening, conceptual models, basis of selection of a particular model, assumptions, summary of input parameters, code used, actual data and the confidence building.

9.13 Quality Assurance in Safety Assessment

9.13.1 Safety assessment is essentially an iterative process, which undergoes refinement in each cycle of iteration incrementally. Each cycle should be used to enhance the level of confidence. An essential element in developing confidence and assurance in safety assessment results is to have a quality assurance (QA) programme that includes management function, performance, documentation and compilation of all relevant information , data and procedures in an auditable manner and a system for continual improvement.

9.13.2 Details of developing confidence building are provided in Section 10 on Quality Assurance.

9.14 Safety Indicator

Safety indicators should provide early indication and evidence of radionuclide contamination in environmental matrices due to any release of radionuclide from the near surface repositories. Dose and risk to the individual and to the critical group form the primary indicators which play an important role in the safety assessment. Concentration of radionuclide in air, surface water, groundwater, soil and vegetation form important indicator to the near surface disposal facilities by recording and establishing their concentration trend.

10. QUALITY ASSURANCE

10.1 General

10.1.1 Quality assurance (QA) programme applies to all components of the disposal system, structure and other safety related activities from planning, design, construction, operation, closure, long term record keeping and institutional control activities. This helps to provide assurance that the relevant safety requirements and the criteria are met.

10.1.2 The waste generator/manager is responsible for establishing and implementing the quality assurance programme and also obtaining necessary approvals from the regulatory body.

10.2 QA on Siting

10.2.1 Quality assurance programme for all activities associated with siting should be established. During site selection, the information such as imageries showing surface features, characteristics of soil, groundwater, rock etc. should be collected from standard sources and verified by carrying out test/experiment following the standard procedures.

10.2.2 Records of various studies carried out and results obtained should be maintained properly. Records of experiments, investigation and data should be maintained to illustrate that quality assurance has been followed.

10.3 QA Components of Safety Assessment

10.3.1 Application of QA in safety assessment should ensure:

(a) all input data is properly checked, validated and documented to a traceable source; and

(b) computer models are verified, calibrated, validated and audited to confirm reproducibility.

10.3.2 Sensitivity and Uncertainty Analysis

10.3.2.1 Sensitivity and uncertainty analysis in the safety assessment should be performed. The uncertainty in the result of assessment may be due to:

(a) simplification of a complex physical system into a simpler conceptual model amenable to mathematical modeling;

(b) exposure scenarios which take into account the future climates or individual habits; and

(c) parameter estimation and temporal or physical variability in the parameters.

10.3.2.2 In the deterministic model, a representative set of input parameters are chosen and analysis is performed to get a single value of the result. To understand the degree to which the uncertainties in these parameters affect the result, one parameter is altered at a time and the outcome is determined. This is done with a set of parameters. The result is often used to measure those parameters more precisely which have large impact on the outcome.

10.3.2.3 In probabilistic approach, the parameters are described by a probability distribution function which assigns a probability for the parameter to assume certain value. The result is the probability distribution of model output and assessment end points.

10.3.3 Verification

Verification of the method of calculation should be achieved by solving test problems designed to show that the equations used in the mathematical models are solved satisfactorily. Comparison of the result with different methods are effective approach for verification.

10.3.4 Calibration

Calibration should aim to reduce the uncertainty in conceptual and numerical models by comparing model or sub-model predictions with field observations and experimental measurements. Calibration is a site-specific procedure and a set of site-specific input data is required to compare the results of prediction and observation at that site.

10.3.5 Validation

Modeling results should be validated at variety of different sites or under a wide range of conditions. Validation of models for the long term evolution of a specific site is not possible over an extended time scale. Limited validation should be possible through the use of data from natural analogue studies or climate analogues. Some relevant process such as weathering of waste package materials, wind re-suspension, radionuclide transport by groundwater or transfer elements from soil to biota should be investigated in appropriate natural analogues with adequate level of details and sufficient understanding of boundary conditions.

10.4 QA on Design, Construction and Operation

10.4.1 During design, construction and operation of the NSDF; site specific requirements should be kept in mind with respect to barrier design, waste characteristics and operating procedures to ensure that they do not have unacceptable consequences to safety. During the construction of various systems of the NSDF such as engineered barriers (RCC trenches, tile holes/ HIC, earth trenches), back fill materials, various material handling facilities;

appropriate quality assurance programme should be planned to obtain overall safety of the system, minimise the migration of the radioactivity to the environment and occupational exposures to the working personnel.

10.4.2 Construction of engineered concrete structure should be in accordance with the approved codes and standards.

10.4.3 Quality assurance programme should cover:

(a) quality of the input materials like steel, cement, sand, stone, aggregates, water and admixtures;

(b) adherence to quality control test procedures;

(c) identification of all types of possible defects and defining their acceptability and unacceptability;

(d) adherence to approved written procedures for sampling and sample preparation;

(e) use of specified material for maintenance; and

(f) record of deviations from the set procedures and specified standards along with their resolution and maintenance of proper record of post-concrete inspection and repair carried out.

10.5 QA on Waste Acceptance

The quality assurance programme should cover the specific requirements of waste acceptance for the management of radioactive waste. Waste generator should provide necessary information to comply with the waste manager's requirements.

10.6 QA on Closure and Post-Closure

Quality assurance programme should be developed and applied to structures, systems, components and activities related to closure and post-closure phases of the NSDF. In particular this programme should provide for the collection and preservation of all information recorded during the previous phases that could be important for safety in the future.

10.7 Approval of QA Programme

Waste generator/manager should submit quality assurance programme and its implementation for review and approval of the regulatory body.

11. DOCUMANTATION AND RECORDS

11.1 General

To comply with the regulatory requirements and also for planning of future action, waste generator/manager establishes a system for generation, storage and retrieval of documents and records with up-to-date information on the following:

(a) site selection and qualification data;

(b) site layout and design;

(c) operating manual and technical specifications;

(d) diagrams of individual modules indicating emplacement of waste and inventory with date;

(e) data and parameters used in safety assessment and its results;

(f) approved waste acceptance criteria for near surface disposal;

(g) authorisation for disposal/storage of solid waste;

(h) closure and long term care procedures:

(i) environmental surveillance and monitoring programme; and

(j) emergency preparedness and site remediation plans.

11.2 Waste Disposal/Storage Records

Solid waste disposal/storage records should contain information on:

(a) physical form;

(b) chemical and radiological characteristics;

(c) type of conditioning and packaging;

(d) volume (m^3) and activity (MBq) of waste disposed off;

(e) presence of alpha or long lived beta radionuclides;

(f) type of disposal facilities (earthen trenches/RCC vault, tile hole/ HIC);

(g) location of the disposed package;

(h) date of disposal; and

(i) deviation, if any.

11.3 Environmental Monitoring and Surveillance Records

11.3.1 Environmental surveillance records should include external radiation monitoring around the NSDF and the monitoring of air, water (surface and sub-surface), soil and vegetation at a specified location of the disposal/storage system. Records of analysis of air, water (ground water and surface water), soil and vegetation samples monitoring should contain the following information separately for each matrix:

(a) date of sampling;

(b) frequency of sampling;

(c) location of sampling and identification mark;

(d) specific activity for gross and important individual nuclides (Bq/ml or Bq/g);

(e) methods of analysis; and

(f) deviation, if any.

11.3.2 Records of external radiation monitoring in and around the disposal facility should contain the information on:

(a) date of monitoring;

(b) frequency of monitoring (weekly, monthly etc);

(c) location of survey carried out with identification mark;

(d) distance/height of field measurement;

(e) maximum radiation field (mGy/h);

(f) minimum radiation field (mGy/h);

(g) average radiation field (mGy/h); and

(h) deviation, if any.

11.3.3 Environmental surveillance record should encompass pre-operational, operational, closure and post-closure monitoring and surveillance data. The data on each phase should be documented and recorded separately.

11.4 Safety Significant Events, Maintenance and Site Remediation Records

Safety significant events such as flooding, failure of the disposal facilities, fire, maintenance and remedial actions should be recorded and maintained.

11.5 Retention of Records

Records of radioactive solid waste disposed off or stored, environmental surveillance and monitoring should be preserved by the installation for time period, say 300 years. Other documents and records pertaining to the management of radioactive solid waste should be retained by the installation for an extended period in compliance with regulatory requirements.

ANNEXURE

TYPICAL SITE CHARACTERISTICS OF NEAR SURFACE DISPOSAL FACILITIES

	Site (Location)/ Year of commissioning	Regional Geology	Morphology	Soil Type	Groundwater Velocity	Disposal Modules (ET, RCT, TH)	Annual Rainfall (mm)
Coastal	RSMS, Trombay, Maharastra, 1956	Basaltic rock terrain with amygdales of zeolites	Undulating topography with gentle slope	Black cotton soil with good sorption for Cs (600– 1000 ml/g), Sr (140 – 300 ml/g).	0.5 – 1.0 m/d towards bay	Modules are partially below water table for part of the year (during monsoon period)	High (approx. 2300)
Coastal	SWMF, Tarapur, Maharastra, 1969	Basaltic rock terrain	Nearly flat terrain	Black cotton soil with good sorption for Cs (600 – 1200 ml/g), Sr (140 - 400 ml/g).	0.5 m/d towards bay	Modules are partially below water table for part of the year (during monsoon period)	High (approx. 2000)
Coastal	SWMF, Kalpakkam, Tamilnadu, 1984	Charnockite crystalline rock covered with alluvial soil	Flat with sporadic charnockite spherical blocks	Sandy soil with silt. Sorption for Cs (20-460 ml/g) very low and almost nil for Sr (1-190 ml/g).	4-5 cm/d	Modules are partially below water table for part of the year (during monsoon period)	Medium (approx. 1200)
Inland	SWAMP, Kota Rajasthan , 1972	Quarzitic sandstone with thin course of sandy soil	Mild undulating surface with horizontal to sub-horizontal dip	Sandy soil often mixed with gravels. Poor sorption for Cs and Sr.	Groundwater confined in joints, bedding planes and fractured during monsoon period only.	No contact with groundwater.	Medium (approx. 750)

ANNEXURE (CONTD.)

TYPICAL SITE CHARACTERISTICS OF NEAR SURFACE DISPOSAL FACILITIES

Site (Location)/ Year of commissioning		Regional Geology	Morphology	Soil Type	Groundwater Velocity	Disposal Modules (ET, RCT, TH)	Annual Rainfall (mm)
Inland	SWMF, Narora Uttar-Pradesh, 1989	Unconsolidated sedimentary formation	Flat	Alluvium silt with low percentage of clay. Very low sorption for Sr (10-15 ml/g) (25-35 ml/g) and moderate sorption for Cs (300-375 ml/g).	1.1 – 3.7 cm/d	High Integrity Container (HIC). Disposal modules are always above water table.	Medium (550-1100)
	SWMF, Kakrapar Gujarat, 1993	Basaltic rock terrain	Flat	Black cotton clayey soil. Very good sorption for Cs (541 - 2775 ml/g) and Sr (271 - 891 ml/g)).	0.6 – 1.0 m/d. Water table rises upto 1.5 m during monsoon while it lowers down to the depth of 3.5m in remaining period	Disposal modules are partly below water table for part of the year.	Good (approx. 1500)
	SWMF, Kaiga , Karnataka , 2000	Laterite	Plateau	Lateritic soil up to 7m. Low sorption for Cs (30-35 ml/g) and Sr (30-35 ml/g).	1.0 m/d. Water table fluctuation 0.5 – 7.5m.	Disposal modules are partially below water table for part of the year.	High (approx. 3000)

RSMS = Radioactive Storage and Management Site
SWMF = Solid Waste Management Facility
SWAMP = Solid Waste Management Plant

ET = Earth Trench
RCT = Reinforced Concrete Trench
TH = Tile Hole

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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	Predisposal 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/SG/RW-5	Management of Radioactive Waste from Mining and Milling of Uranium and Thorium.
AERB/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.
AERB/SG/RW-7	Decommissioning of Nuclear Fuel Cycle Facilities other than Reactors.
AERB/SG/RW-8	Decommissioning of Nuclear Power Plants and Research Reactors.
AERB/SG/O-11	Management of Radioactive Waste Arising during Operation of Nuclear Power Plants.
AERB/SG/D-13	Liquid and Solid Radwaste Management in Pressurised Heavy Water Reactors.

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