GUIDE NO. AERB/NRF/SG/RW-2

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GOVERNMENT OF INDIA

AERB SAFETY GUIDE

PREDISPOSAL MANAGEMENT OF LOW AND INTERMEDIATE LEVEL RADIOACTIVE WASTE

ATOMIC ENERGY REGULATORY BOARD

AERB SAFETY GUIDE NO. AERB/NRF/SG/RW-2

PREDISPOSAL MANAGEMENT OF LOW AND INTERMEDIATE LEVEL RADIOACTIVE 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 (AERB) has been entrusted with the responsibility of laying down safety standards and framing rules and regulations for such activities. The Board has, therefore, undertaken a programme of developing safety standards, safety codes, and related safety guides and manuals for the purpose. While some of these documents cover aspects such as siting, design, construction, operation, quality assurance, and decommissioning of nuclear and radiation facilities, other documents cover 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, systems, structures and components of nuclear and radiation facilities. Safety codes establish the objectives and set requirements that shall be fulfilled to provide adequate assurance for safety. Safety guides elaborate various requirements and furnish approaches for their implementation. Safety manuals deal with specific topics and contain detailed scientific and technical information on the subject. These documents are prepared by experts in the relevant fields and are extensively reviewed by advisory committees of the Board before they are published. The documents are revised, when necessary, in the light of the experience and feedback from users as well as new developments in the field.

Safe management of radioactive waste is one of the prime requirements in the operation and maintenance of nuclear and radiation facilities including nuclear power plants. This safety guide provides guidance on meeting safety requirements pertaining to the predisposal management of low and intermediate level radioactive waste. In drafting this safety guide extensive use has been made of the information contained in the relevant documents of the International Atomic Energy Agency published under Radioactive Waste Safety Standards Programme and other safety series publications.

Consistent with the accepted practice, 'shall' and 'should' are used in the guide to distinguish between a firm requirement and a desirable option, respectively. Annexure and references/bibliography are included to provide information 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.

Non-radiological aspects such as industrial safety and environmental protection are not explicitly considered in this guide. Industrial safety shall be ensured through compliance with the applicable provisions of the Factories Act, 1948 and the Atomic Energy (Factories) Rules, 1996.

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

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

(S.K. Sharma)
Chairman, AERB

DEFINITIONS

Acceptable Limits

Limits acceptable to the regulatory body for accident condition or potential exposure.

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.

Alpha-bearing Waste

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

Approval

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

Assessment

Systematic evaluation of the arrangements, processes, activities and related results for their adequacy, 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 the site personnel, the public and the environment from 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 (See also 'Consent').

Authorised Limits

Limits established or accepted by the regulatory body.

Clearance Levels

A set of values established by the regulatory body and expressed in terms of activity concentrations and/or total activity, at or below which sources of radiation may be released from regulatory control.

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.

Confinement

Barrier, which surrounds the main parts of a nuclear facility, carrying radioactive materials and designed to prevent or to mitigate uncontrolled release of radioactivity into the environment during commissioning, operational states, design basis accidents or in decommissioning phase.

Consent

A written permission, issued to the 'consentee' by the regulatory body to perform specified activities related to nuclear and radiation facilities. The types of consents are 'licence', 'authorisation', 'registration' and 'approval', and will apply according to the category of the facility, the particular activity and radiation source involved.

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.

Design

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

Discharge (Radioactive)

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

Disposal (Radioactive Waste)

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

Documentation

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

Effluent

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

Emergency

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

Emergency Exercise

A test of an emergency plan with particular emphasis on coordination of the many inter-phasing components of the emergency response, procedures and emergency personnel/ agencies. An exercise starts with a simulated/postulated event or series of events in the plant in which an unplanned release of radioactive material is postulated.

Emergency Plan

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

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.

Incident

Events that are distinguished from accidents in terms of being less severe. The incident although not directly or immediately affecting plant safety, has the potential of leading to accident conditions with further failure of safety system(s).

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.

Licence

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

Long-lived Waste

Radioactive waste 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 waste 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 waste.

Near Surface Disposal

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

Nuclear Fuel Cycle

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

Pre-treatment (Radioactive Waste)

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

Radiation Facility

Any installation/equipment or a practice involving use of the radiation-generating units or use of radioisotopes in the field of research, industry, medicine and agriculture.

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.

Regulatory Body

See 'Atomic Energy Regulatory Board'.

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.

Spent Fuel

Irradiated fuel not intended for further use in reactors in its present form.

Storage (Radioactive Waste)

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

Surveillance

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

Waste Form

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

Waste Immobilisation

The conversion of radioactive waste into a 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 Treatment

Operations intended to benefit safety and/or economy by changing the characteristics of the waste 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

1.1.1 Radioactive waste is generated at all stages of nuclear fuel cycle operation and in the use of radionuclides in medicine, industry, agriculture and research. Safe management of radioactive waste is important for the protection of human health and the environment. Requirements governing the safety aspects of radioactive waste management are presented in AERB safety code [1].

1.1.2 Predisposal management of radioactive waste includes all steps or activities in the management of waste from its generation to its acceptance at a waste repository or its release from regulatory control. Predisposal management of low and intermediate level radioactive waste includes collection, segregation, transportation, treatment, conditioning and storage. It also includes characterisation of the waste, waste form or waste package at appropriate stages in the processing of the waste, until the delivery of the waste package to a waste repository. In case of gaseous waste, predisposal management involves 'in-situ' treatment, if required, and release to atmosphere.

1.1.3 Predisposal management of radioactive waste may take place in a separate dedicated waste management facility or at discrete locations within a larger facility operated for other purposes.

1.2 Objective

Objective of this safety guide is to provide guidance to the waste generator/ manager on predisposal management of low and intermediate level (LILW) radioactive waste to meet the regulatory requirements [1,2,3].

1.3 Scope

1.3.1 The safety guide deals with the safety aspects associated with the predisposal management of low and intermediate level waste (LILW) from nuclear and radiation facilities. This includes all steps and activities in the management of waste, from its generation to its disposal. Some stages of the nuclear fuel cycle generate both high-level waste (HLW) and LILW. Guidance on management of HLW is available in the AERB safety guide [4].

1.3.2 There may be non-radiological hazards associated with the predisposal management of LILW. Some guidance is given on measures to be taken in this regard also. Additional guidance in the areas of industrial health and safety and environmental protection may be obtained from the regulatory body. This safety guide does not include management of waste from mining and milling of uranium and thorium ores and decommissioning of these facilities. Guidance on these aspects is covered in the AERB safety guide [5].

2. ROLE AND RESPONSIBILITIES OF THE WASTE GENERATOR/MANAGER

2.1 General

2.1.1 Predisposal management of LILW requires to be carried out in accordance with the authorisation issued by the regulatory body. It may involve transfer of waste from one agency to another. In such cases, continuity of responsibilities for safety is to be ensured through appropriate authorization.

2.2 Responsibilities of the Waste Generator/Manager

2.2.1 Radioactive waste should be managed within the regulatory framework including clear allocation of responsibilities and provision for independent regulatory review.

2.2.2 Radioactive waste generator/manager should be responsible for all aspects of safe management of radioactive waste.

2.2.3 Radioactive waste management may span time scales involving a number of human generations. Waste generator/manager should clearly identify and ensure continuity of responsibilities and funding requirements whether these activities are carried out by one agency or several agencies in sequence and should also cover research and development activities to support operational and regulatory requirements.

2.2.4 Waste generator/manager or both should be responsible for identifying, on an appropriate time-scale, a destination for the waste in accordance with the regulatory requirements, and for seeking any necessary authorisation. The waste generator/manager should transfer the waste in an authorised manner to an agency for processing, storage or disposal.

2.2.5 Waste generator/manager should keep the generation of radioactive waste to the minimum practicable by suitable design, operation, post operation and decommissioning of the facility.

2.2.6 Waste generator/manager should:

(a) ensure provision for suitable and sufficient storage capacity on an appropriate time-scale, until relevant disposal routes are available;

(b) perform safety and environmental impact assessments of waste management facilities and activities;

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

(d) ensure suitable staff, equipment, facilities, training and operating procedures are available;

(e) establish and implement a quality assurance programme (QAP) at all stages;

(f) establish and keep records of the generation, processing, storage and transfer/disposal of radioactive waste;

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

(h) use operational experience to improve waste management safety;

(i) to carry out/support research and development activities in a time bound manner ensuring adequate funding;

(j) address issues related to decommissioning of nuclear and radiation facilities and management of resulting radioactive waste;

(k) assume complete responsibility even if the work is delegated to a different agency;

(l) establish emergency preparedness commensurate with the type of the facility and associated hazards;

(m) ensure effective organisational structure;

(n) meet requirements of the regulatory body with respect to normal/off normal discharges and corrective action, if any;

(o) obtain consent of the regulatory body for any modification in the design and operation procedures of existing facility;

(p) facilitate regulatory inspection and compliance with the recommendations of the regulatory body; and

(q) adhere to stipulations by the regulatory body and other statutory bodies.

2.3 Waste Management Interdependency

2.3.1 Interdependencies among basic steps in waste management (like minimisation of waste generation at source, segregation, pre-treatment, treatment, conditioning and storage) should be taken into account. Decisions on radioactive waste management made at one step should not foreclose other options for, or otherwise affect, a subsequent step.

2.3.2 Waste management safety, operational ease and economy depends on well-defined waste characteristics and quantities. Efforts should be made to obtain favourable waste characteristics without compromising the design and operational intent of the waste generating facility.

2.3.3 The waste generator/manager should examine different processing options, identifying the appropriate one and avoiding conflicting requirements that may compromise safety. An integrated approach should be followed to optimise various steps in the management of radioactive waste.

3. WASTE CHARACTERISATION AND MINIMISATION

3.1 General

Large volumes of low and intermediate level radioactive waste are generated in radiation facilities and nuclear fuel cycle operations ranging from uranium processing, fuel fabrication, nuclear power plants, research reactors, radio-chemical facilities and fuel reprocessing. Some streams may also contain low level of alpha contamination of long-lived radionuclides. Radioactive waste generation needs to be minimised by use of good design and operational practices.

3.2 Characterisation of Radioactive Waste

Characterisation of LILW is required for safe predisposal management. The waste should be characterised by proper sampling and determining chemical, physical, biological and radiological properties. Waste form/package should also be characterised by using appropriate methods to ascertain its quality. Methods based on process knowledge may be applied to improve sampling procedures so as to avoid undue occupational exposures. Such processes should be demonstrated before applying to ensure radiological safety.

3.2.1 Methodology

Waste should be characterised for radiological, physical, biological and chemical properties, to facilitate subsequent processing.

(a) Radiological Properties

- Radionuclide content
- Half-lives
- Activity and concentration of radionuclides
- Surface contamination (waste form/package).

(b) Physico-chemical Properties

Characterisation based on physico-chemical properties of different types of waste is as follows:

(i) Liquid waste characterisation:

- pH
- Organics
- Presence of decontaminating agents
- Total dissolved solids (TDS)

- Suspended solids
- Biological oxygen demand (BOD)
- Chemical oxygen demand (COD)
- Pathogens
- Other chemicals.

(ii) Solid waste characterisation:

- Combustibility
- Compactibility
- Metallic hardware
- Glass items
- Construction materials
- Pyrophoricity.

(iii) Gaseous waste characterisation:

- Radioactive gases and particulates
- Suspended solids
- Chemically reactive gases.

(c) Biological Properties

- Biological hazards
- Bio-accumulation.

3.3 Waste Minimisation

Operating practices of the facility should ensure minimum generation of radioactive waste. The waste shall be segregated, classified and categorised to facilitate selection of appropriate processes. Waste minimisation should be achieved by:

(a) appropriate planning and strategy;

(b) systematic review of operation;

(c) implementation of corrective action based on lessons learnt from past events;

(d) adoption of specified procedures for operation and maintenance;

(e) reducing system leakages;

(f) control of contamination of areas and equipment;

(g) optimised decontamination procedures;

(h) deployment of trained personnel;

(i) good housekeeping practices;

(j) improvement in practices and processes;

(k) control on movement of radioactive materials;

(l) good segregation practices at source;

(m) recycling and reuse of waste streams, as appropriate; and

(n) limiting secondary waste generation.

4. PREDISPOSAL MANAGEMENT OF LIQUID WASTE

4.1 General

The general philosophy for radioactive waste management being followed is given below:

(a) Delay and decay of short-lived radionuclides

(b) Concentrate and contain activity as practicable (concentration of ILW may transform it into high level waste which should be managed as per the AERB safety guide [4]

(c) Dilute and disperse low-level radioactive waste within the authorised limits.

Well-designed storage system needs to be established at the waste generating and treatment facility. Inter-facility waste transfer/transport system employing pipeline and tankers is also important system in the management of radioactive waste.

4.2 Waste Collection, Segregation and Storage

4.2.1 The waste collection/storage system for liquid radioactive waste involves the use of storage tanks specifically designed and installed for this purpose. Such a system should take into account the following:

(a) adequate in-house waste collection system to ensure segregation of waste at source;

(b) retrievability and inter-facility transfer of waste;

(c) sufficient capacity of the storage system for normal, shut down/ maintenance and anticipated operational occurrences;

(d) system materials compatibility, shielding, decontamination/cleaning, inspection and maintenance;

(e) quality assurance measures during design, installation and operation;

(f) safety features such as high and low level alarms;

(g) provision for containment dyke/vault in case of tank failures and leak detection;

(h) provision for representative sampling for analysis of tank contents; and

(i) adequate instrumentation system for measurement of parameters such as levels, volume, activity and density.

4.2.2 In order to ensure radiological safety while collecting and storing liquid waste, the following aspects should be considered:

(a) tanks/containers are provided with dyke within vault;

(b) appropriate shielding is provided in case of intended use for ILW;

(c) appropriate radiation symbols are affixed indicating the nature of radiation, nuclides present and the activity;

(d) tanks/containers are decontaminated periodically so that dose rates do not increase due to sedimentation. Storage system should be subjected to constant surveillance. This involves periodic monitoring of the system/storage areas for radiation field, keeping an inventory of activity of waste and regulating entry of personnel into storage areas; and

(e) radiological hazards of the waste.

In addition to the above, storage should be in well-protected and ventilated areas, away from occupied zones of the plant.

4.3 Waste Categorisation

Waste should be segregated at source based on the activity content and physico-chemical characteristics to plan treatment before discharge. Liquid waste should be characterised and categorised as per the AERB safety guide [6].

4.4 Waste Transfer/Transportation

4.4.1 Liquid waste needs to be transferred from the place of their generation to the treatment plant/discharge point through pipelines and/or by tankering. Over-ground/underground piping system should be provided when large volume of low and intermediate level waste is to be transferred. Provision of tanker should be considered for transfer of small volume of waste. The detailed design including safety features of tankers and piping system should be submitted to the regulatory body as a part of licensing.

4.4.2 On-site transport of radioactive waste should be carried out as per the approved procedure. The off-site transport of radioactive waste should be governed by AERB safety code [7]. Any deviation from the above should have prior approval of the regulatory body.

4.4.3 Adequate security should be provided during off-site transportation/transfer of radioactive waste to ensure safety incase of any untoward incident.

4.4.4 Adequate packaging, shielding and supervision should be provided to keep the radiation exposure to personnel minimum and also to minimise the potential for the release of radioactive material in the event of a transport accident.

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

4.4.6 The consignor (sender) should have the responsibility for safe transport of radioactive waste through the public domain. It should include among others safety of the package, control during transportation and necessary instructions in the event of emergency situation.

4.4.7 On-site/off-site transport of large quantities of radioactive material generated from site remediation or any incident/accident should be carried out after obtaining necessary clearances from the regulatory body.

4.4.8 Approved procedure for transport of radioactive waste should include, among others, tie down arrangement, health physics coverage and qualified crew.

4.5 Waste Transfer through Pipelines

Pipelines should be laid as per the approved design. The following requirements should be met for safe transfer of liquid waste:

(a) above ground pipelines passing beyond access controlled area of the facility to have fencing along the route;

(b) adequate shielding;

(c) multiple containment/ barrier where necessary;

(d) pipeline material compatibility with waste and the environment;

(e) minimum number of bends and junctions to avoid hot spots;

(f) leakage monitoring and management provisions;

(g) provision for accounting of waste transferred;

(h) provision for testing of system integrity; and

(i) provision for repair/maintenance/replacement.

4.6 Waste Transportation by Tanker

Transportation by tankers should ensure the following:

(a) Adherence to approved procedure including display of radiation symbols and dose rate on its sides;

(b) adequate provisions for shielding, cooling, secondary containment, pressure relieving systems, as applicable;

(c) adhering to prescribed activity limits and safe waste levels;

(d) providing the consignor with action plan for accidental and vehicle breakdown scenarios;

(e) material selection based on compatibility with waste characteristics and provision for leakage control/collection/monitoring;

(f) carrying out integrity test of waste tanker;

(g) filling the tanker to a safe level taking into account the gradient in the route including pressure relief, venting and breathing; and

(h) training for the tanker crew for routine operation and emergency situations.

4.7 Waste Treatment

4.7.1 Treatment of aqueous and organic waste is to be carried out by a single or multiple processes in combination based on the considerations for safety, secondary waste generation and techno-economic aspects.

4.7.2 Treatment of Aqueous Waste

Among others, for treatment of low and intermediate level radioactive aqueous waste, the following methods should be considered:

(a) filtration;

(b) chemical treatment;

(c) ion exchange;

(d) evaporation;

(e) solar evaporation; and

(f) membrane process.

Brief description of the above processes are given in the Annexure A.

4.7.3 Treatment of Organic Waste

For treatment of organic waste, following processes, among others, should be considered.

(a) thermal incineration;

(b) chemical combustion/wet oxidation using $H_2SO_4 + HNO_3$ or $H_2SO_4 + H_2O_2$ mixture at elevated temperatures; and

(c) chemical decontamination using chemicals like NaOH and Na_2CO_3 for removal of activity. The decontaminated waste may be recycled or incinerated.

4.8 Process Control and Monitoring

Waste analysis and monitoring facility should be established to generate physical, chemical and radiological data of radioactive waste. This assists the waste generator/manager in:

(a) assessing segregation efficacy;

(b) ensuring process performance in compliance with the design intent;

(c) taking prompt corrective action if malfunction is observed;

(d) enabling control in release/disposal of waste; and

(e) demonstrating compliance with authorisation and plant technical specification; and

(f) adherence to operating procedures.

4.9 Waste Conditioning/Immobilisation

Waste conditioning/immobilisation involves addition of an agent to the active waste, which transforms the waste into a form suitable for transport/storage or disposal. The methods of waste immobilisation include cementation, polymerisation and bituminisation. The conditioning process should aim at providing:

(a) formation of monolithic and homogeneous mix;

(b) compatibility of matrix with waste and material of construction of the container;

(c) techno-economic viability of processing and storage/disposal;

(d) stability against chemical/biological/radiological and other possible degradation for the intended design life;

(e) low solubility or leachability in water;

(f) non-combustibility and non phyrophoricity;

(g) minimum product volume;

(h) low specific surface area;

(i) mechanical strength;

(j) ease of handling/transportation;

(k) absence of transferable surface contamination; and

(l) durability of packaging.

5. PREDISPOSAL MANAGEMENT OF SOLID WASTE

5.1 General

Predisposal management of solid waste involves segregation, collection, categorisation, treatment, conditioning and transportation before disposal. The conditioned solid waste needs to meet the waste acceptance criteria for storage/disposal. Waste storage may be necessary before/after treatment and conditioning.

5.2 Waste Collection and Storage

5.2.1 Waste collection and storage system should envisage adequate provision for:

(a) in-house collection, segregation and storage of waste at source;

(b) packaging to avoid leakages, dispersion and spread of contamination;

(c) covered interim-storage in a designated and approved area before further transport to treatment facility during normal and off-normal condition;

(d) containers designated with colour code for collection of active and inactive solid waste separately; and

(e) on-site and off-site waste transportation.

5.3 Waste Segregation and Categorisation

5.3.1 Waste should be segregated based on physico-chemical properties and surface dose rate at the source itself to avoid unnecessary exposure. Solid waste should be segregated to facilitate further treatment and processing as follows:

(a) combustible waste such as paper, mops, wood, cotton and other cellulose material to facilitate incineration;

(b) compressible waste such as rubber, PVC, leather, spent air filters to facilitate compaction;

(c) metallic waste such as metallic scrap, structures, containers, discarded equipment to facilitate volume reduction by fragmentation, cutting and melting;

(d) miscellaneous building material wastes such as concrete, soil and masonry items to facilitate packaging;

(e) spent resins to facilitate immobilisation;

(f) wet waste such as charcoal, filter, sludge from chemical treatment of active liquid waste along with settled bottom concentrate of pre-treatment tank and sumps, incinerator ashes and evaporator concentrates to facilitate solidification or embedment;

(g) sealed radiation sources from medical application and industries to facilitate encapsulation in suitable matrix before disposal; and

(h) special category of waste such as alpha waste including de-clad waste to facilitate appropriate conditioning.

5.3.2 Solid wastes should be characterized and categorised as per AERB safety guide [6] to facilitate handling, treatment and processing.

5.4 Waste Transportation and Monitoring

5.4.1 Waste Transportation

Solid radioactive waste produced at nuclear and radiation facilities are transported in appropriate carriers to another location within or outside the facility for conditioning/treatment/disposal. The solid radioactive material shall be transported in a packaged form taking into account the following aspects:

(a) containment;

(b) shielding;

(c) classification of package; and

(d) heat dissipation (if applicable).

5.4.2 Monitoring

All waste packages should be monitored before storing. The radiation monitoring of the waste should preferably be carried out in low background radiation field. This should be aimed at:

(a) measurement of radiation field;

(b) segregation of active and inactive waste; and

(c) measurement/estimation of activity content and composition of radionuclides present in the waste package.

5.5 Waste Processing and Treatment

5.5.1 Process Selection

Treatment of solid waste should aim at volume reduction before or during conditioning. The treatment process depends upon the activity content and the physico-chemical characteristics of the waste. While handling the waste in the treatment facility, the following aspects should be considered.

(a) use of suitable containers/system to minimize dispersion or spread of contamination of areas and environment;

(b) use of adequate shielding/remote handling gadgets, where necessary, to minimise personnel exposure; and

(c) use of suitable system for solid wastes with significant alpha contamination.

5.5.2 Treatment of Solid Waste

Depending on the radioactive and physico-chemical nature of solid waste, the following treatment should be adopted:

(a) mechanical methods for size reduction such as fragmentation and compaction;

(b) incineration; and

(c) other methods such as melting and acid digestion.

Brief description the above processes are given in Annexure-A

5.5.3 Handling and Storage of Tritium Contaminated Solid Waste

Tritium contaminated solid waste materials like cotton, mops and rubber should be dried. The dried solids should be disposed off as per approved procedures.

5.6 Waste Conditioning/Immobilisation

5.6.1 Solid and solidified wastes should be conditioned to make it suitable for handling, transportation, storage and disposal.
The techniques used are:

(a) immobilisation of waste in media such as bitumen, concrete or thermosetting polymers,

(b) limited to process like vacuum dewatering in case of special waste like spent resin with low levels of short-lived radionuclides if specially authorised; and

(c) packaging in metallic or non-metallic containers.

5.7 Waste Packaging

All radioactive solid waste (primary and secondary) after treatment and/or conditioning/immobilisation should be packed in a manner conforming to the waste acceptance criteria approved by the regulatory body for on-site or off-site transportation and disposal. Some of the important parameters of the waste package to be specified are:

(a) average and maximum surface dose rate of package/container;

(b) total activity per package and contributing radionuclides ;

(c) type of immobilisation/waste form;

(d) leach rate values of waste form;

(e) bulk density of waste form;

(f) anti-corrosive measures for containers;

(g) gross weight and volume of packages;

(h) shape/dimension for optimum utilisation of engineered volume; and

(i) waste emplacement location.

6. PREDISPOSAL MANAGEMENT OF GASEOUS WASTE

6.1 General

6.1.1 Processes involving radioactive materials may give rise to radioactive gases, vapours or aerosols. Hence, air/gas cleaning system is an essential part of the management before disposal of radioactive gaseous wastes from nuclear and radiation facilities so as to protect the operating personnel and public from inhalation of air borne radioactive particles and gases.

6.1.2 Gaseous waste from nuclear industry are discharged to the environment through sufficiently tall stacks to provide necessary dilution and to minimise the ground level concentration. The total activity being discharged is maintained as low as reasonably achievable within the prescribed limits.

6.1.3 In the nuclear fuel cycle, airborne activity is generally associated with process off-gases, particulates containing radioisotopes and gaseous fission/activation products.

6.2 Categorisation of Radioactive Gaseous Waste

The gaseous waste should be categorised as per the guidelines provided by the regulatory body to facilitate predisposal management.

6.3 Treatment of Gaseous Waste

In order to provide safety in working areas, the following management methodologies for gaseous waste should be considered.

6.3.1 Off-gas Cleaning

In the management of radioactive gaseous waste, dispersion and dilution available by atmospheric mixing is an important factor. However, necessary pre-cleaning operations should be carried out for treatment of process off-gas streams of nuclear and radiation facilities before dilution and dispersion. The gas cleaning techniques employed should be commensurate with the physical and chemical properties of the contaminants and the degree of decontamination required.

6.3.2 Ventilation System

6.3.2.1 The ventilation system in a nuclear facility is very important to maintain the airborne activity in working areas within limits and to maintain designed direction of flow. The ventilation should be a once-through system. The operating areas of nuclear facility, in general, should be categorized into different zones depending on the nature of operation carried out at different areas, maintaining air flow direction from low to high activity areas and operated under negative pressure to restrict the release of activity to the environment. The ventilation exhaust system should be provided with suitable devices to contain the airborne radionuclides.

6.3.2.2 Ventilation systems in nuclear and radiation facilities should be designed to:

(a) provide control of airborne activity released from the facility by maintaining the required negative pressure and properly directed flows in various systems;

(b) provide an acceptable working environment and comfort conditions; and

(c) demonstrate that the required discharge standards are being achieved.

6.3.2.3 To achieve satisfactory operation of ventilation system, a nuclear facility should have the following provisions:

(a) Airtightness of the building to achieve minimum leakage;

(b) air inlet systems with adequate filtration;

(c) keeping the high active areas as small as practicable;

(d) a good physical containment of the active materials by means of adequate barriers such as fume hoods and glove boxes with low air leakage;

(e) separate ventilation systems for such containments, each with its own extract and filtration system, where materials with differing activity levels are handled;

(f) mobile local re-circulatory clean-up filtration systems within specific areas to limit the airborne contamination;

(g) proper access into the controlled areas through airlocks;

(h) adequate fire protection to potential fire sources and by use of fire resistant materials in the construction of ventilation systems; and

(i) an exhaust ventilation system with HEPA and/or sorption filters as the ultimate barrier to take care of both normal and anticipated operational occurrences of the nuclear facility.

6.3.3 Clean-up Systems used in Gaseous Waste Management

Clean-up systems should be provided to restrict the release of suspended particulates. Some of the components that may be used in suitable combination are as follows:

(a) inertial/cyclone separators;

(b) bag filters;

(c) electrostatic precipitators;

(d) wet scrubbers;

(e) fume hoods;

(f) glove boxes and their filters;

(g) local/mobile re-circulatory filtration units;

(h) pre-filters;

(i) HEPA filters; and

(j) combined particulates and iodine filters.

6.4 Monitoring of Airborne Gaseous Activity

Air in the working areas as well as the exhaust air should be regularly monitored for the following:

(a) particulate activity;

(b) iodine activity;

(c) fission product noble gases; and

(d) tritium activity.

6.5 Effluent Release

Gaseous effluents should be exhausted through high stacks to minimise the exposure hazard to the public. The height of the stack is decided such that during normal operation of the plant, the dose to the members of the public at the site boundary should be within the regulatory limits. This condition is satisfied with and without the availability of the diluents system. Also the height of the stack is determined such that the dose rate at the freely accessible areas outside the facility should not be more than the limit prescribed by the regulatory body.

6.6 Inspection and Maintenance

6.6.1 Periodic inspection and maintenance should be carried out for all components needed for operation of gaseous waste management systems. Periodic tests should be carried out in accordance with a written test manual, and the results should be recorded. Some of the items to be tested are given below:

(a) main air quantities;

(b) air distribution;

(c) flow tendencies;

(d) negative pressure levels;

(e) locking devices;

(f) functioning of all components like dampers;

(g) events of faults;

(h) events of break down;

(i) emergency power system; and

(j) in-situ testing of filter installations.

6.6.2 Necessary measures, such as repairs and replacement of components should be carried out based on analysis of these test results.

7. RADIOLOGICAL SAFETY

7.1 General

Radiological safety of occupational workers and members of public needs to be ensured by implementation of the dose limits prescribed by the regulatory body [8]. Selection of the treatment method takes into account the associated radiation exposure of the operating personnel and also the collective exposure of the public. The principle of optimisation is employed while considering different options.

7.2 Radiological Safety Aspects of Liquid Waste

Treatment of liquid waste should be carried out in specially designed facilities to provide adequate safety for operating personnel. Appropriate shielding should be provided to process equipment and areas of high radiation field to minimize the occupational exposure. Ventilation should be such that the facility is kept at a negative pressure with respect to the atmosphere. It should also be ensured during the design that air concentrations of the activity in occupancy areas do not exceed permissible levels.

7.3 Radiological Safety Aspects of Solid Waste

7.3.1 The following aspects should be considered in addition to the provisions mentioned in section 5 for collection/storage and transport of solid waste:

(a) exposure to the persons is kept minimum by providing safe mechanical handling arrangement;

(b) containers are properly packed and tagged;

(c) containers are safely fastened or anchored to the body of the vehicle; and

(d) appropriate colour coding for containers.

7.3.2 Segregation of solid waste should be ensured at the source. Further segregation if required for selection of treatment process should be carried out in enclosure designed for the purpose. Such enclosures should be operated under negative pressure.

7.4 Radiological Safety Aspects of Gaseous Waste

Releases of radioactive materials to the environment from predisposal management facilities for LILW should be controlled in accordance with the stipulations and regulations based on the limits and conditions set by the regulatory body.

7.5 Emergency Preparedness and Event Reporting

7.5.1 Emergency situations in a waste storage/treatment facility may arise due to:

(a) failure of waste storage system;

(b) breach in the liquid waste carrying pipeline;

(c) failure of the filter system of the waste treatment facility; and

(d) fire in a waste storage area especially where organic liquid waste or combustible solid waste are stored.

7.5.2 Emergency procedure should be drawn in advance so that effect of such an eventuality is mitigated. This should include:

(a) assessment of severity of the event vis-a-vis its impact on the environment;

(b) identification of responsibilities for facility operators at different levels and their proper coordination;

(c) training and mock-up drill to handle emergency situations; and

(d) adequate post-exposure follow up in respect of the group who are over exposed.

7.5.3 Post-event analysis should include an evaluation of the environmental impact of the event, and the corrective steps taken to avoid recurrence of such events. Such abnormal events should be promptly reported to the competent authority.

7.6 Surveillance

7.6.1 Radiation protection surveillance for occupational workers of the facility and for members of public should be carried out by designated authority. This is achieved by a well-planned monitoring programme both within and outside the facility. The facility monitoring should include:

(a) measurement of ambient levels of radiation field in working areas, air activity levels and contamination levels keeping in view the design basis with set alarm level;

(b) identification of event that may lead to violation of technical specifications; and

(c) individual monitoring for exposure to radiation and upkeep of the exposure records.

7.6.2 Monitoring of the environment during operation of the facility should be planned so as to provide information on:

(a) radiation exposure of the public due to operation of the facility;

(b) correlation of the environmental monitoring data with the data obtained during facility operation;

(c) validity of the modelling technique adopted in order to arrive at discharge limits; and

(d) specific radionuclide, if any, that may get accumulated preferentially in the environment.

7.6.3 Environmental surveillance programme should include analysis of:

(a) soil from surface and from appropriate depths;

(b) ground water from bore wells located at sites;

(c) water body into which the liquid waste is discharged after treatment; and

(d) the food harvested from such water bodies.

8. QUALITY ASSURANCE(QA)

8.1 General

The quality assurance programme provides a systematic and structured process to deliver the product and achieve work performance to meet process requirements. The quality assurance has wide scope related to performance monitoring, assessment, corrective action and innovation. It covers all aspects of managing the facilities and activities including safety, health, task performance and environmental requirements.

8.2 Salient QA Features

QA programme should be established, documented, implemented and its effectiveness uniformly improved. The aspects which need specific emphasis with respect to this guide are described hereunder.

(a) Facilities and equipment for the predisposal management of LILW waste are designed, constructed, commissioned, operated and decommissioned in accordance with the appropriate specifications and requirements for safe operation.

(b) Steps in the predisposal management of waste, from its generation to its conditioning, are such as to facilitate compliance with known or anticipated acceptance requirements for the storage and disposal of waste.

(c) The regulation and conditions of authorisation are complied with.

8.3 QA Programme for Documents

8.3.1 The waste generator/manager should prepare separate quality assurance manuals for design, construction, commissioning and operation of the waste management facility. These should be submitted to the regulatory body for review and for incorporation of any check points/hold points of regulatory interventions, if so desired by the regulatory body.

8.3.2 The scope and details of the QA programme should be commensurate with the extent and complexity of the activities in relation to the waste and the quantities and potential hazards associated with the waste. The QA programme should specify implementing procedures for the following activities:

(a) characterisation of the waste;

(b) development of the specifications for packages for LILW;

(c) approval of the conditioning process for the waste;

(d) confirmation of the characteristics for waste packages; and

(e) review of quality control (QC) records.

8.4 Implementation and Control of Performance

This includes the following:

(a) waste treatment, packaging and conditioning should be carried out as per instructions/procedures mentioned in the document;

(b) control of performance should include monitoring, inspection, testing, verification and assessment of activities including their acceptance criteria as appropriate. These should be performed by individual or groups other than those who originally performed the work; and

(c) assessment should include self-assessment and also independent measurements.

8.5 Conformance/Compliance

Any non-conformance/non-compliance action of regulatory stipulations should be reported to the concerned authority in the organisation and the regulatory body as applicable. The non-compliance should be analysed, reported and corrective action initiated to avoid recurrence. QA system should provide for analysis and measures for continual improvement of task performance.

9. DOCUMENTATION AND RECORD KEEPING

9.1 General

The waste generator/manager needs to maintain documents and records of radioactive waste generation and management consistent with the regulatory requirements. A comprehensive record system is required for regulating radioactive waste management practices**.**

9.2 Record Keeping

As per the requirements, a list of documents should be maintained with the waste generator/manager. The documents and records should be stored in the facility premises. In view of the long-lived radionuclides present in the LILW, proper records on the genesis and treatment of radioactive waste should be maintained.

9.3 Record Keeping Procedures

9.3.1 The facility should establish a procedure for maintaining adequate documentation and records in accordance with the QA programme. These records should include:

(a) operational records for treatment, conditioning and packaging;

(b) specifications for waste packages and audit records for individual containers and packages;

(c) monitoring records;

(d) operation procedures;

(e) preservation aspects of records as to permanent/non-permanent for future reference; and

(f) waste characterisation records. These should contain the following information:

(i) source or origin and date of generation;

(ii) physical and chemical form;

(iii) amount (volume and/or mass, radionuclides present, and specific activities/contact dose rates); and

(iv) potential hazards associated with the waste.

9.4 Reporting

The waste generator/manager should periodically submit reports on compliance with the conditions of authorisation to the regulatory body, as per the schedule. Routine reports should provide information on the waste management operations conducted during the reporting period. The report should also be promptly submitted to the regulatory body for any incident/ accident with safety significance for review.

ANNEXURE-A

LOW AND INTERMEDIATE LEVEL RADIOACTIVE WASTE(LILW) MANAGEMENT

A.1 Major Streams of LILW

Major streams of LILW generated from nuclear reactors, reprocessing plants and radiochemical laboratories are given below: These waste are categorised based on the activity content and physico-chemical consideration before being taken for segregation/storage or treatment prior to discharge.

A.2 Liquid Waste

A.2.1 Classification

Liquid waste are classified as given below based on specific activity and physico-chemical nature such as presence of chemicals, dissolved/suspended solids and organic impurities to facilitate further processing.

A.2.1.1 Potentially Active Waste

These are generated from showers and sinks in change room of the facilities and drainage from potentially active areas and protective wear decontamination. These waste may be contaminated with detergents**.** These waste are transported to treatment/disposal facility by suitable pipelines.

A.2.1.2 Low Active Non-chemical Waste

These are generated from system leakages and evaporator condensates once through cooling system, fuel pool storage bay and secondary washings of floor and spent resin handling system. These waste are transported to the treatment facility through pipelines/tankers for treatment and/or discharged to environment within the stipulated discharge limits.

A.2.1.3 Low Active Chemical Waste

These are generated from reprocessing plants, radiochemical laboratories and decontamination centers at chemical laboratories of different facilities, as process rejects such as dedeutration and fluidisation of resins, lubricating and transformer oils, spent tributyl phosphate (TBP)/dodecane, organic solvent purification system, ammonium-di-uranate filtrate, ion exchange regenerants and decontamination solutions. Since waste from different sources have varied chemical composition, a proper segregation, storage and treatment system is imperative. These segregated waste are separately transported to a treatment facility.

A.2.1.4 Intermediate Level Waste Stream

These are generated from decontamination of highly active system, organic solvent purification system, ion exchange regenerants, sample analysis from reprocessing plants (such as raffinates from reprocessing and other process and decontamination solution concentrates). These waste have generally high chemical loading. Organic and inorganic waste are collected for segregation and treatment taking into consideration the type of facility generating these waste.

A.2.1.5 Organic Waste

Organic waste such as lubricating oils from primary heat transport pumps, hydraulic fluids from fuelling machines and turbine oils are generated in power stations. Tributyl phosphate in diluent (dodecane) is the most commonly used solvent in reprocessing plant. The decontamination liquids include toluene, carbon tetrachloride and aqueous solution of organic compounds like citric acid, picolinic acid and EDTA.

A.2.2 Pre-treatment and Treatment of Aqueous Radioactive Waste

A.2.2.1 Filtration

Many of the radioactive liquid waste streams contain suspended matter of varying nature. Principal among these are laundry and decontamination waste. Their pre-filteration prior to regular treatment becomes necessary for ensuring effectiveness of the process to follow. Various filtration processes employed are coarse filtration, micro filtration and ultra-filtration and are employed before the process like ion exchange and reverse osmosis. The technique is comparatively simple and the concentrates come in the form of slurry or filter media. Decontamination factor (DF) varies from 2 to 5 depending upon the particulate load, associated activity and filtration efficiency.

A.2.2.2 Chemical Treatment

For radioactive liquid waste containing total dissolved solids above 500 ppm chemical treatment employing co-precipitation is selected. Overall DF of 10 or more, DF of 100 for specific nuclides and DF up to 1000 for alpha may be achieved in this process. Volume reduction factor in this process is low to moderate.

A.2.2.3 Ion exchange

Ion exchange is widely used for the treatment of liquid waste having total solids less than 1000 mg/l and free from surfactants, organic and chelating agents. Equipment are relatively simpler and high volume reduction factors and DF of 100 to1000 may be achieved.

A.2.2.4 Evaporation

This process is suitable for waste containing large salt concentrations, low level of suspended matter and requiring high DF. The waste should be free of explosives or thermally unstable ingredients, and detergents. Volume reduction depends on salt concentration in the solution. The process is sensitive to scaling, foaming, salt precipitation and corrosion. DF achievable range from 10,000 to 1,00,000. Normally such process is carried out in steam heated thermosyphon evaporator.

A.2.2.5 Solar Evaporation

At site with favorable meteorological conditions like high temperature, low humidity and high wind velocity, it is possible to employ low temperature non-boiling evaporation in open solar pans. Large areas available for evaporation coupled with incident solar energy are known to provide evaporation of moderate to large volumes of low-level waste. The process leads to accumulation of concentrated radioactive wet sludges/salts at the bottom for disposal or reuse. It also helps in dispersion of radionuclides like tritium from specific waste into the atmosphere.

A.2.2.6 Membrane Process

This process is suitable for removal of dissolved species due to their characteristic size and charge by the application of pressure in excess of the inherent osmotic pressure of the solution. It is applicable primarily to inorganic species and is capable of removing ionised and non-ionised dissolved solids, colloids and suspended solids. Though this application covers the entire range of liquid waste, the process may be differentially used for some of the streams such as laundry waste. This may also be used to concentrate very low level radioactive liquid streams to levels where other process such as chemical treatment and evaporation are not economical. Membrane decontamination factors (MDF) vary widely for each nuclide. For gross-beta, MDF of up to 100 and for gross-alpha up to 10,000 respectively have been reported. The overall system DF depends upon the desired percentage water recovery.

A.3 Solid Waste

A.3.1 Classification

The classification is based on surface dose rate/specific activity presence of long- lived alpha and other radionuclides, conditioning process and disposal options.

A.3.1.1 Low Active Waste

Any solid waste generated from potentially active areas are included in this category. They contain materials such as tissue papers, cotton, wood, construction materials, plastic, rubber having very low activity content.

A.3.1.2 Intermediate Level Waste (ILW)

These waste having relatively higher activity are generated from active operational areas and laboratories and constitute contaminated glass wares, components, equipment, structural and other miscellaneous items. Solid waste of higher contamination levels such as spent ion exchange resins, filters from liquid and gaseous streams, process concentrates such as process sludges and resins are included in this category. In some instances hulls from fuel reprocessing facilities also may be ILW.

A.3.1.3 Alpha-bearing Solid Waste

Waste having significant alpha contamination belongs to this category. These waste are generated from fuel fabrication and reprocessing facilities and research laboratories.

A.3.2 Processing and Treatment/Conditioning

A.3.2.1 Fragmentation

This method is applied to large objects or equipment parts, disposal of which may otherwise require large space or may not be suitable to accommodate in a conventional or usual disposal facility. The process indirectly reduces the volume by changing the shape of the waste. It facilitates storage of waste in containers and further processing by compaction or incineration. Some of the tools engaged are electric torches, plasma torches, mechanical saws, cutter grinders, shredders and shears. The operation is carried out in specially designed enclosures with personnel protection system, as required.

A.3.2.2 Compaction

Waste containing mostly compressible material such as paper, plastic, cotton, rubber and glass may be subjected to this process in order to achieve volume reduction, before disposal. The extent of segregation determines the efficiency and safety of this process. Segregation is necessary to ensure that explosive and pyrophoric materials are excluded.

Compactor machine is kept under negative pressure and connected with the exhaust ventilation system through HEPA filter to prevent release of airborne particulates during the compaction operation.

Squeezed liquid from the waste during compression is collected in a container. An anti-spring back device is used after compression to hold the compacted waste in place. Volume reduction factor varies from 1.5 to 5 depending on the applied pressure, composition of the waste and degree of sorting/segregation.

A.3.2.3 Incineration

Incineration technique may be considered based upon techno-economic and safety evaluation. Segregation is necessary to ensure that no explosive material is present in the waste. Polymeric waste with only limited quantities of chloride and phosphorous should be treated through this method.

This process gives a volume reduction factor up to 100 and weight reduction factor up to 25. Operation of incineration system is to be carried out under negative pressure with adequate gas cleaning system to avoid any leakage and spread of ground level activity. Monitoring facility is provided for accounting activity release through the flue gas.

A.4 Gaseous Waste

A.4.1 Sources

Gaseous waste include process gas and air stream from active ventilation system. Major sources of gaseous waste from nuclear power plants are as below:

- Reactor core - Fission products noble gases and radioiodine
- Area leakages - Argon
- System leakages - Tritium.

A.4.2 Management of Gaseous Waste

A.4.2.1 Particulate Activity

The atmosphere in the nuclear facility may be contaminated with particulate activity due to the various processes being carried out or solid decay products of certain radioactive gases resulting in deposition of activity on inactive particles. Separate air clean-up systems are provided for normal operation and accident conditions of nuclear power plant and research reactors. In these facilities, only HEPA filters are installed for removal of particulate activity during normal operation. During accident conditions HEPA filtration system is automatically taken out of service. The emergency clean-up systems such as primary containment filtration and pump back (PCFPB) system, primary containment controlled discharge (PCCD) system and secondary containment recirculation and purge (SCR&P) having combined particulate and iodine filters installed in them for removal of both particulate and iodine activity are brought into service, at predetermined stages, either manually or automatically depending on their assigned role in the event management.. A standard HEPA filter handles a volumetric air flow of 1700 m^3/h. HEPA filter provides a collection efficiency of the order of 99.97% for sub-micron particles. The service life of the filter depends on the nature/concentration of particulate matter and on the operating conditions of the system. The filter is replaced when the pressure drop across the filter system increases above the limits or removal efficiency drops below the acceptable level.

A.4.2.2 Airborne Radio-Iodine

Fission product iodine is of main radiological concern with respect to environmental release, in the event of a reactor accident. The ventilation and containment clean-up systems employ combined particulates and iodine filters for the removal and retention of particulates, iodine deposited on the particulates and different chemical forms of radioiodine. HEPA filter, which forms an integral part of this filter, effectively removes the iodine deposited on the particulates. Activated charcoal, impregnated with suitable chemicals (KI + KOH), is used as the adsorbent for the removal of elemental and organic forms of iodine. In-situ testing of these filters are carried out periodically to ensure that the system provides the desired performance.

The adsorbent deteriorates in its performance due to ageing and poisoning. The service life of iodine filter is about two years. These filters are periodically replaced irrespective of their use in actual operation.

A.4.2.3 Noble Gases and Tritium

Management of radioactive noble gas like Argon–41, which arises due to activation of Argon-40 (present in air) with a half life of 1.9 h is by delay and also by dilution process to the extent possible. The generation rate of argon has been considerably controlled by replacing the air in some systems with carbon dioxide or water. Long-lived isotopes viz. Kr-85 and Xe-133 generated as fission products are normally managed in nuclear power plants by controlling the leakage of fission products from the fuel cladding itself. The concentration of Kr and Xe are relatively low and are managed by dilution and dispersion through tall stacks.

The tritium activity in various areas of reactor building is controlled by heavy water vapour recovery system. The system draws air from tritium contaminated areas like boiler house and recovers the precious heavy water as well as minimizes the tritium activity in the air. The system employs molecular sieves as the adsorbent and operates in a closed loop.

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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/NRF/SG/RW-1	Classification of Radioactive Waste.
AERB/NRF/SG/RW-2	Predisposal Management of Low and Intermediate Level Radioactive Waste.
AERB/NRF/SG/RW-3	Predisposal Management of High Level Radioactive Waste.
AERB/NRF/SG/RW-4	Near Surface Disposal of Radioactive Solid Waste.
AERB/NF/SG/RW-5	Management of Radioactive Waste from Mining and Milling of Uranium and Thorium
AERB/RF/SG/RW-6	Management of Spent Radioactive Sources and Radioactive Waste arising from the use of Radionuclides in Medicine, Industry and Research including Decommissioning of such Facilities
AERB/NF/SG/RW-7	Decommissioning of Nuclear Fuel Cycle Facilities other than Nuclear Reactors
AERB/NPP&RR/SG/RW-8	Decommissioning of Nuclear Power Plants and Research Reactors
AERB/NPP/SG/O-11	Management of Radioactive Waste Arising from Operation of Pressurised Heavy Water Reactor Based Nuclear Power Plants
AERB/SG/D-13	Liquid and Solid Radwaste Management in Pressurised Heavy Water Reactor Based Nuclear Power Plants

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