GUIDE NO. AERB/NF/SG/RW-7

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GOVERNMENT OF INDIA

**AERB SAFETY GUIDE**

# DECOMMISSIONING OF NUCLEAR FUEL CYCLE FACILITIES OTHER THAN NUCLEAR REACTORS

**ATOMIC ENERGY REGULATORY BOARD**

**AERB SAFETY GUIDE NO. AERB/NF/SG/RW-7**

# DECOMMISSIONING OF NUCLEAR FUEL CYCLE FACILITIES OTHER THAN NUCLEAR REACTORS

**Atomic Energy Regulatory Board**
**Mumbai-400 094**
**India**

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# FOREWORD

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

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

Nuclear facilities, as they reach the end of their life, need decommissioning. This safety guide sets out recommendations relating to the decommissioning of nuclear fuel cycle facilities. It includes guidance on strategy and planning during design and operation of the facility to facilitate decommissioning. It discusses the salient responsibilities of the decommissioning organisation, the waste generator/manager and their interactions with the regulatory body. It also brings out decommissioning options, requirements of radiation protection for occupational workers and general public and radioactivity releases to the environment. In preparing this guide, extensive use has been made of the information contained in the relevant documents of International Atomic Energy Agency. Decommissioning of nuclear power plants and research reactors, uranium/thorium mining and milling facilities and medical, industrial, agriculture and research facilities using radiation sources have been dealt with in separate guides.

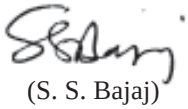
Consistent with the accepted practice, ‘shall’ and ‘should’ are used in the guide to distinguish between a firm requirement and a desirable option respectively. Annexure, references and bibliography are included to provide further information on the subject that might be helpful to the user. Approaches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

set out in the guide may be acceptable, if they provide comparable assurance against undue risk to the health and safety of the occupational workers and the general public, and protection of the environment.

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 the relevant AERB Advisory Committee on Codes and Guides and the Advisory Committee on Nuclear Safety.

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



(S. S. Bajaj)
Chairman, AERB

# DEFINITIONS

**Acceptable Limits**

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

**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.

**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**

(See 'Prescribed Limits')

**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.

**Collective Dose**

An expression for the total radiation dose incurred by a population and defined as the product of the number of individuals exposed to a source and their average radiation dose.

**Competent Authority**

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

**Conditioning of Waste**

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

**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.

**Contamination**

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

**Criteria**

Principles or standards on which a decision or judgement can be based. They may be quantitative or qualitative.

**Critical Group**

A group of members of the public which is reasonably homogeneous with respect to its exposure for a given radiation source and given exposure pathway and is typical of individuals receiving the highest effective dose or equivalent dose (as applicable) by the given exposure pathway from the given source. When exposure occurs by more than one pathway, the term may also be used to mean the group which receives the highest total dose by all the pathways of exposure from a given source or practice.

**Decommissioning**

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

**Decontamination**

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

**Design**

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

**Discharge (Radioactive)**

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

**Discharge Limits**

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

**Disposal (Radioactive Waste)**

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

**Documentation**

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

**Dose**

A measure of the radiation received or absorbed by a target. The quantities termed absorbed dose, organ dose, equivalent dose, effective dose, committed equivalent dose, or committed effective dose are used, depending on the context. The modifying terms are omitted when they are not necessary for defining the quantity of interest.

**Dose Limit**

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

**Effluent**

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

**Emergency**

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 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.

**Exposure**

The act or condition of being subject to irradiation. Exposure can be either external (irradiation by sources outside the body) or internal (irradiation by sources inside the body). Exposure can be classified as either normal exposure or potential exposure; either occupational, medical or public exposure; and in intervention situations, either emergency exposure or chronic exposure. The term 'exposure' is also used in radiation dosimetry to express the amount of ions produced in air by ionising radiation.

**Exposure Pathway**

A route by which radiation or radionuclides can reach humans and cause exposure.

**Hazard**

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

**High Level Waste (HLW)**

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

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

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

(c) Any other waste with similar radiological characteristics.

**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.

**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 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'.

**Intervention**

Any action intended to reduce or avert exposure or its likelihood to sources which are not a part of controlled practice or which are out of control as a consequence of an accident.

**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 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.

**Maintenance**

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

**Member of the Public**

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

**Monitoring**

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

**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.

**Occupational Exposure**

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

**Occupational Worker**

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

**Off-site**

Area in public domain beyond the site boundary.

**Operating Organisation**

The organisation so designated by responsible organisation and authorised by regulatory body to operate the facility.

**Operation**

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

**Prescribed Limits**

Limits established or accepted by the regulatory body.

**Pre-treatment (Radioactive Waste)**

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

**Quality Assurance**

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

**Radiation Facility**

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

**Radiation Surveillance**

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

**Radiation Worker**

Any person who is occupationally exposed to radiation and who in the opinion of the regulatory body should be subjected to radiation surveillance.

**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 wastes.

**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').

**Responsible Organisation**

An organisation having overall responsibility for siting, design, construction, commissioning, operation and decommissioning of a facility.

**Review**

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

**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.

**Safety Code**

A document stating the basic requirements, which must be fulfilled for particular practices or applications. This is issued under the authority of the regulatory body and mandatory to be followed by the respective utilities.

**Safety Guide**

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

**Segregation (Radioactive Waste)**

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

**Short-lived Waste**

Radioactive wastes 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.

**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.

**Unrestricted Use**

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

**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.

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# 1. INTRODUCTION

## 1.1 General

Decommissioning of a nuclear fuel cycle facility is generally carried out after the final shutdown of the facility. The decommissioned installation and the site may be released to a responsible organisation for restricted or unrestricted use as approved by the regulatory body. Regulatory requirements and socio-economic aspects are some of the important factors determining the necessity of decommissioning. The methodology of decommissioning may vary depending on the nature and type of facilities.

## 1.2 Objective

The objective of this safety guide is to provide guidelines for safe decommissioning of nuclear fuel cycle facilities other than nuclear reactors as per the regulatory requirements [1,2]. It also provides guidance with respect to the management of radioactive waste arising during decommissioning of nuclear fuel cycle facilities.

## 1.3 Scope

The scope of this safety guide includes guidance on the decommissioning of:

(a) fissile and fertile nuclear material conversion and processing facilities,

(b) fuel fabrication facilities,

(c) reprocessing facilities, and

(d) waste treatment, conditioning and storage facilities.

This safety guide addresses the roles and responsibilities of the various agencies involved, manpower and training requirements, as well as organisational and administrative aspects of decommissioning. The guide also covers design and operational features, strategies and planning, stages of decommissioning, various safety issues arising there from, safety assessment, radiation protection and management of radioactive waste during the decommissioning of nuclear fuel cycle facilities.

This safety guide does not address the decommissioning of fissile or fertile material ore mining facilities. The management of radioactive wastes arising from decommissioning of this facilities have been covered in the safety guide AERB/NF/SG/RW-5.

This safety guide does not deal with the decommissioning of nuclear power plants or research reactors, which is covered in safety guide AERB/NPP&RR/SG/RW-8.

Non radiological hazards arising during decommissioning activities are not addressed in this guide. However, they should be considered while carrying out the decommissioning activities in respect of a particular facility.

# 2. RESPOSNSIBILITIES OF ORGANISATION INVOLVED IN DECOMMISSIOING

## 2.1 General

Decommissioning of nuclear fuel cycle facilities is carried out as per the existing regulations. To achieve the objective of safe decommissioning of nuclear fuel cycle facilities, the role and responsibilities of each of the different agencies involved in the decommissioning activities should be clearly identified and defined. The different responsible agencies involved in the decommissioning of nuclear fuel cycle facilities are:

(a) the decommissioning organisation, and

(b) the waste generator/ manager.

## 2.2 Responsibilities of Decommissioning Organisation

The decommissioning organisation should :

(a) prepare detailed decommissioning plan and procedures,

(b) coordinate and implement recommendations of safety reviews,

(c) perform safety assessment of decommissioning,

(d) ensure availability of adequate resources such as funding, trained staff, equipment and facilities for decommissioning,

(e) establish and implement a quality assurance programme in decommissioning activities,

(f) ensure adequate protection to the occupational workers, the public and the environment,

(g) ensure the generation of the minimum volume feasible of radioactive waste,

(h) collect, monitor, categorise, segregate, characterise, transfer and transport radioactive waste as per approved procedure,

(i) ensure adequate provision for waste storage facilities,

(j) provide appropriate shielding and containment of the radioactive material and waste stored,

(k) ensure safety and security of the radioactive material and waste stored,

(l) maintain documents and records pertaining to decommissioning activities such as personnel radiation exposure, radioactive waste

generated, stored and transferred to waste management agency and compliance with regulatory requirements, and

(m) ensure the availability of an action plan for handling emergency situations of facilities to take care of exigencies.

### 2.3 Responsibilities of Waste Generator/Manager

Waste generator/manager should:

(a) coordinate with the decommissioning organisation and implement recommendations of the regulatory body with respect to waste management,

(b) meet acceptance criteria for the disposal of radioactive waste generated during decommissioning,

(c) characterise waste based on volume, specific activity, total activity, radionuclide content and physicochemical characteristics,

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

(e) establish and implement a quality assurance programme in respect of waste treatment, conditioning and packaging to meet regulatory requirements,

(f) ensure storage and disposal of waste as per the authorised procedure,

(g) develop procedure for disposal of nonconforming waste packages,

(h) ensure monitoring and surveillance of the environment to meet regulatory requirements,

(i) develop and demonstrate procedure for remedial action for anticipated safety significant events,

(j) ensure safety, security and retrievability of all interim stored waste and

(k) maintain documents and records pertaining to the radioactive waste stored or disposed of to the environment in compliance with regulatory requirements.

### 2.4 Interdependencies of Decommissioning Organisation and Waste Generator/Manager

Decommissioning of nuclear fuel cycle facilities may result in the generation of different varieties and quantities of waste. The basic steps of radioactive waste management from waste generation to disposal (such as pre-treatment, treatment, storage and conditioning) are interdependent on each other. Decisions on changing any agreed methodology may result in non conforming waste which may require special treatment and conditioning for storage and

disposal. Therefore, decisions relating to the various steps of decommissioning should be taken with due consideration of the impact on, or the needs of, radioactive waste management.

Effective and safe decommissioning of nuclear fuel cycle facilities with the participation of interdependent agencies should be achieved by:

(a) delineation of critical task to responsible agency,

(b) establishing coordination between the various agencies involved in decommissioning activities and

(c) exchange of information and documents amongst the various agencies involved in decommissioning.

## 2.5 Safety Issues Specific to Fuel Cycle Facilities

Specific safety issues to be considered for decommissioning of nuclear fuel cycle facilities are:

(a) presence and nature of all types of radioactive contamination including alpha emitting radionuclides,

(b) requirement of remote handling,

(c) potential of criticality hazard associated with the possible accumulation of fissile material during decommissioning activities (decontamination and dismantling),

(d) complexity of strategies for waste management owing to the diversity of waste streams and

(e) radiological and nonradiological hazard involving fire, explosion and chemical toxicity.

## 2.6 Requirements of Radiation Protection of the Occupational Workers

Radiation dose to the occupational workers from all exposures should be within the prescribed limits stipulated by the regulatory body. The radiation dose to the occupational workers should be kept low by:

(a) adopting the ALARA principle on radiation exposure,

(b) minimising incidental/accidental radiation exposure and

(c) mitigating the consequence of any radiation exposure due to any incident or accident.

To achieve the objective of radiation protection of the occupational workers, the decommissioning organisation should ensure the availability of;

(a) qualified radiation hazard control personnel,

(b) appropriate instruments for personnel monitoring,

(c) adequate personal protective equipment,

(d) adequate shielding and administrative procedure before personnel entry to high radiation field area,

(e) suitable contamination monitoring instruments for personnel and material and

(f) decontamination facilities.

## 2.7 Requirements of Radiation Protection of the Public

Due to any release of radioactive materials to the environment during decommissioning of nuclear fuel cycle facilities, the radiation dose to the public should not exceed the limit prescribed by the regulatory body. To restrict the radiation dose to the public, the decommissioning organisation should:

(a) keep all radioactive discharges as low as reasonably achievable and definitely below the authorised limits,

(b) monitor all discharges of radionuclides to demonstrate compliance with the regulatory requirements,

(c) establish and carry out an environmental monitoring programme adequate to ensure compliance with the regulatory requirements and

(d) maintain all monitoring records.

Radioactive waste generated from the decommissioning of nuclear fuel cycle facilities should be disposed of in such a way that the predicted impact on the health of future generations should not be greater than the relevant levels of impact that are acceptable today. The waste disposed of to the environment should not impose any undue burden or be a cause of concern to the future generations.

## 2.8 Protection of the Environment

Decommissioning of nuclear fuel cycle facilities should ensure adequate levels of protection to the environment from radiological and non-radiological effects. The radiological or non-radiological impact to the environment due to the decommissioning activities of nuclear fuel cycle facilities and the management of waste should be within the limits acceptable to the regulatory body or other statutory bodies.

# 3. DESIGN FEATURES AND OPERATIONAL PRACTICES TO FACILITATE DECOMMISSIONING

## 3.1 General

All nuclear facilities need to be decommissioned at the end of their useful life or earlier based on safety considerations. The requirements for decommissioning including radiation protection and associated costs are well understood now. The nuclear industry, therefore, is becoming increasingly aware of the importance of considering decommissioning requirements during the design of nuclear facilities. Based on the experience acquired during the decommissioning of various nuclear fuel cycle facilities, recommendations have been formulated which need to be considered for existing facilities and while designing new facilities as well.

A provisional plan for the decommissioning of a nuclear fuel cycle facility at the design stage and its periodic review during the operational lifetime of the facility would help to minimise the decommissioning time, cost, generation of radioactive waste, eventual occupational doses and environmental impact arising from decommissioning activities.

## 3.2 Design Objectives

Appropriate features should be incorporated in the design of nuclear fuel cycle facilities specifically to facilitate decommissioning [3]. The overall objectives in this context are to:

(a) minimise radiation exposures to decommissioning workers as well as the public,

(b) minimise environmental impact,

(c) reduce decommissioning costs and

(d) minimise waste generation.

Modifications carried out during the operational phase of a facility should take into consideration simplification of dismantling of equipment and demolition of structure, and should include features which will:

(a) result in reducing the residual radioactive material inventory within the facility after shutdown,

(b) reduce the time necessary to perform a decommissioning task and minimise the presence of decommissioning personnel in areas of high radiation field or high contamination levels,

(c) minimise release of radioactive materials from the facility and the generation of secondary waste during decommissioning and

(d) facilitate incorporating and retrofitting possible modifications for decommissioning of existing facilities not specifically designed with decommissioning intent initially.

### 3.3 Design Considerations

During the site selection, design, construction, commissioning, operation and maintenance phases of the facilities, due consideration should be given towards minimising occupational exposures. Any design feature introduced to make decommissioning easier should not be in conflict with the basic safety requirements of normal plant operations. Plant layout should be optimally designed considering compactness and ease of dismantling. Design considerations should also take into account other benefits such as waste generation/reduction and ease of decommissioning. Co-location of nuclear fuel cycle facilities may result in additional benefits during decommissioning by way of sharing services, cost, utilities, manpower and experience of decommissioning.

In most of the facilities, large sized equipment are installed at the time of construction or erection when they are not radioactive and other surrounding structures are built subsequently. This results in major handling and radiation exposure problems while decommissioning. Therefore, design should take care of provisions for easy dismantling of large *sized* or highly active equipment and their subsequent storage or disposal during decommissioning.

### 3.4 Design Provisions

Some of the major design provisions to facilitate decommissioning should have the following features:

(a) material selection to minimise corrosion;

(b) detailed analysis of structural materials to predict radionuclide characteristics, estimate of radioactivity build-up, decay pattern and dose rate contribution likely at the time of decommissioning,

(c) preservation of samples of original construction materials and installation of retrievable in-vessel coupons for future analysis or studies,

(d) remote monitoring of radiation fields in inaccessible areas,

(e) protection and treatment of inner surfaces of the equipment or pipes by electropolishing, hot conditioning etc. to minimise deposition of activation and corrosion products,

(f) protection of concrete surfaces with suitable covering such as peelable coats or stainless steel cladding as appropriate to avoid contaminant penetration,

(g) use of an easily removable nonabsorbing thermal insulating medium (such as mirror insulation or insulating medium enclosed in metallic jackets),

(h) proper layout and location of the equipment and components for easier access and removal,

(i) facilities for remote removal of the radioactive components or equipment,

(j) appropriate material handling facilities,

(k) removable shielding with multilayer slabs/blocks,

(l) proper sloping of floor leading to sumps to facilitate collection of spillages and floor washings,

(m) means of evaluating the structural integrity during the design life and decommissioning phase,

(n) underground equipment and pipelines in waterproof concrete trenches with suitable inspection chambers/surveillance facilities to avoid subsoil contamination in the event of leakages,

(o) piping layout suitable for active process fluids to eliminate dead zones and low velocity areas or provision for periodic flushing,

(p) online decontamination facilities,

(q) facilities for quick isolation of various zones,

(r) feasibility of temporary local ventilation compatible with the main ventilation system,

(s) boreholes around the nuclear fuel cycle facilities for detection of any sub-soil contamination and its migration,

(t) use of steel plates or gratings in place of concrete slabs for reducing surface contamination and waste volume,

(u) drip trays and floor curbs, suitably sized and placed, to contain the spills,

(v) provision for decontamination of selected materials and components to low levels,

(w) contamination control measures such as tents and hoods,

(x) administrative controls and use of trained personnel,

(y) segregation of process equipment based on radioactivity levels and similarity in unit operation and

(z) modular construction.

### 3.5 Operational Practices

As-built drawings and details of the facility along with operational history should be documented and a system should be established to retrieve the information. If the responsibility of the facility is transferred to any other agency or the licensee is changed, the previous licensee should provide the succeeding agency or licensee with all the above pertinent information pertaining to the facility to continue and complete the decommissioning activities.

Some of the important operational practices to facilitate decommissioning of nuclear fuel cycle facilities include:

(a) use of approved procedures for major operation and maintenance (O & M) activities,

(b) periodic decontamination of process systems, equipment, piping, sumps etc.,

(c) periodic surveillance and monitoring of the facility and

(d) segregation of process function as per design intent.

# 4. STRATEGY AND PLANNING

## 4.1 General

Safe and effective decommissioning of a nuclear fuel cycle facility depends on the strategy and planning of the organization responsible for decommissioning. The details and the contents of the plan may vary, depending on the hazard potential and the complexity of the nuclear facility. Each facility should have a decommissioning plan consistent with the regulatory requirements.

The designer should prepare an initial plan for decommissioning at the design stage of all new facilities, which should be reviewed and updated periodically by the operating organisation. Detailed decommissioning plan should be prepared and submitted to the regulatory body for all existing facilities for approval well before decommissioning.

## 4.2 Initial and Ongoing Planning

The plan giving an outline of the decommissioning process should be submitted to the regulatory body in support of the application for license to commission and/or operate the facility [4]. The initial plan should take into account basic safety issues and the following aspects:

(a) use of available technologies or the ones being developed,

(b) generic study showing the feasibility of decommissioning,

(c) consideration of environmental aspects of decommissioning,

(d) cost of decommissioning and availability of finance,

(e) identification of existing facilities and equipment required to be used for decommissioning and their availability, and

(f) availability of waste disposal facility.

The facilities proposed to be decommissioned may have common service systems shared with other nearby facilities, which are not to be decommissioned simultaneously, but will continue to remain operational. In such cases the interfaces should be analysed carefully as suitable modifications may be needed to permit uninterrupted operation of those colocated facilities.

The decommissioning plan should be reviewed periodically and updated based on the following:

(a) subsequent technological developments,

(b) lessons learnt during operations and maintenance of the facility,

(c) safety significant events,

(d) significant modifications to the facility affecting the initial decommissioning plan,

(e) changes in regulatory requirements and

(f) changes in cost estimates and availability of financial resources.

### 4.3 Final Planning

Once it is decided to shut down a facility permanently, the operating organization should conduct detailed studies and finalise the proposal for decommissioning well before the final shutdown. The proposed final decommissioning plan should be submitted to the regulatory body for review and approval.

After the commencement of decommissioning, the approved plan may have to be modified due to unexpected events or other factors. Changes in approved decommissioning plan should be submitted to the Regulatory Body for further approval.

The final decommissioning plan should contain, where applicable, the following information:

(a) description of the nuclear fuel cycle facility including its final configuration and site details,

(b) operating history of the facility and significant modifications carried out during the operational phase,

(c) incidents that have occurred during the operational phase of the facility, particularly those involving spillage, damage to the plant and release of radioactive materials to the environment,

(d) reasons for taking the facility out of service, proposed decommissioning activities and programme including detailed decommissioning schedule,

(e) rationale for selecting the preferred decommissioning option, methodology and engineering techniques,

(f) assessment of the amount, type and location of residual radioactive and hazardous nonradioactive materials in the facility, employing appropriate computational methods and measurements to determine the inventories of radioactive materials (i.e., characterisation of the facility),

(g) criticality control,

(h) strategy for radioactive waste management , radiation protection and safety,

(i) detailed safety assessment and environmental impact assessment indicating the potential radiological and nonradiological hazards to the occupational workers, the public and the environment,

(j) environmental monitoring programme, equipment and methods to be used at various stages to verify that the facility complies with the requirements of site release for restricted/unrestricted use,

(k) organisation responsible for decommissioning, including details of qualification, training and experience of the personnel,

(l) technical and administrative considerations such as security, physical protection and emergency preparedness plan,

(m) finance mechanism for ensuring safe and satisfactory decommissioning and waste management,

(n) methods adopted to ensure that the decommissioning of the facility does not affect adversely the immediate environment and

(o) quality assurance programme.

### 4.4 Safety Assessment

Safety assessment should form an integral part of the decommissioning plan. The organisation responsible for decommissioning should carry out safety assessment of the facility for the various activities of decommissioning and submit this report to the regulatory body for review. The extent and detail of safety assessment should be commensurate with the complexity and the hazard potential of the facility. In the case of a long time interval between shutdown and decommissioning, the safety assessment of the facility should take into account the period from cessation of operation to final dismantling.

Non-radiological as well as radiological hazards associated with the decommissioning activities should be identified and evaluated in the safety assessment. Based on the assessment, the required protective measures should be defined so as to ensure that the regulatory requirements are met. These protective measures may necessitate changes in the safety systems that were used during operation. The acceptability of such changes should be clearly justified in the safety assessment. In addition, the requirements for maintenance or replacement of systems for mechanical handling, ventilation, power supply and waste handling should be considered in the safety assessment, and the implication of the reduced safety margin due to the deterioration of such systems should be evaluated.

Early in the planning stage for decommissioning, the degree and extent of contamination should be clearly determined, characterised, evaluated and classified. Surveys should be conducted to determine the residual inventories

and locations of radioactive, fissile and other hazardous materials. An accurate characterisation of the facility will provide the inputs for the safety assessment and the criticality analysis.

The safety assessment should identify potentially significant radiological and non-radiological hazards during the decommissioning phase, which might not have been normally encountered during the operational phase. These hazards should be dealt with according to relevant regulations.

The safety assessment should lead to the identification of actions that are necessary for ensuring safety during the various phases of decommissioning. Such actions may pertain to preventive and protective measures, which are engineered or administratively controlled to provide adequate safety.

### 4.5 Release from Regulatory Control

The radiological criteria for the release of materials from the facility and the clearance of the site for other uses including their release from regulatory control should be as specified by the regulatory body.

### 4.6 Costs and Financing

The cost of decommissioning should reflect all the activities described in the decommissioning plan, for example, planning and engineering during the post operational phases, development of specific decommissioning technologies, decontamination, dismantling, conducting the final survey and management of waste. The cost of maintenance, personnel qualification, surveillance, provision for safety and security of the facility etc. should also be taken into account, especially if any phase of decommissioning is deferred for an extended period of time. To meet the cost of decommissioning, provision for allocating resources should be established early in the planning stage of the facility.

# 5. DECOMMISSIONING PROCESS

## 5.1 General

Decommissioning involves various steps starting from characterisation after the final shutdown of the facility till release of the site for restricted or unrestricted use. Success of decommissioning depends entirely on carrying out the work safely, economically and keeping radiation exposures to occupational workers and public within the prescribed limits and, further, as low as reasonably achievable. The generation of waste and release of radionuclides to the environment should be minimum and in accordance with regulations and practices prevalent at that time.

The technology of decontamination and dismantling/demolition should be selected based on availability and proven nature. Such selection should also be based on reports of radiological and non radiological characterisation of the facility being decommissioned and considering in detail the impact of the selected technology on waste generation, its management and environment.

Final site clearance should be based on data arising from actual surveillance conducted at the site and acceptability of such data as per existing regulatory standards.

## 5.2 Selection of a Decommissioning Option

Decommissioning of any nuclear facility may have multiple options: immediate dismantling, deferred dismantling and entombment. The selection of a particular option should be based on considerations such as time elapsed after final shutdown, cost, safety, waste management, environmental impact, availability of proven technology and subsequent release of the site.

Nuclear fuel cycle facilities with their diversity in design and operational requirements may call for different approaches in the selection of an option. Radiological characterisation of the facility should precede the planning and commencement of decommissioning work.

Deferred decommissioning may not reduce the radioactive inventory present in the plant to be decommissioned in all cases. In some cases there is a potential for isotopic in-growth also. Deterioration of structures and difficulty in retrieval of operational data of the plant should be considered while selecting this option.

In the case of opting for deferred decommissioning, clear and unequivocal responsibilities should be allocated for safety during the entire period of idling of the facility. Safety should be ensured through a proper surveillance and maintenance programme. An entombed facility may need a reduced surveillance and maintenance programme.

Before a facility is put into a surveillance and maintenance mode, the risk of potential incidents should be minimised; for example, bulk of the radioactive process materials and operational waste should be removed. Consideration should be given to removing or containing and immobilising any remaining loose contamination, where practicable.

The following activities should continue to be performed during the deferred decommissioning phase:

(a) maintenance of appropriate systems for physical protection commensurate with the risk entailed,

(b) monitoring, surveillance and inspection, commensurate with the level of hazard,

(c) maintenance of essential equipment, such as equipment for ventilation, mechanical handling and monitoring,

(d) maintenance of the facility, barriers and containment structure,

(e) preservation of documents about the surveillance and maintenance activities performed and

(f) provision of a financial mechanism to guarantee that funds are available for decommissioning when necessary.

### 5.3 Characterisation of the Facility

Characterisation of a facility being decommissioned should be conducted to gather information on the type and quantities of various materials having radiological and nonradiological hazard potential [5]. Characterisation involves calculations, measurements, sampling, analysis, comparative study of the estimated and actual distribution of hazardous materials in the facility being decommissioned. Characterisation of waste arising from dismantled equipment and that of the final site should also be covered in the scope of the work.

Prior to the start of the decommissioning work, a survey of radiological and industrial hazards relevant to the entire facility should be made. A detailed report should be prepared for identifying the location and inventory of radioactive and hazardous materials in order to select decommissioning techniques, sequencing of various activities, reducing radiation exposure, shipping requirements of waste, waste conditioning methodology and assessment of environmental impact.

Adequate radiation and contamination surveys should be conducted to determine the radionuclides, maximum and average dose rates, contamination levels and penetration depths for inner and outer surfaces throughout the facility. Characterisation of facilities dealing with alpha activity should call

for special techniques as the contamination could be shielded from the surveys and thus go undetected. Hence, for the sake of completeness, contamination in shielded or self-shielded components, such as inside pipes and equipment, should also be characterised. Reports prepared during the survey should be compared with those prepared during the operation of the facility, if available.

Compatibility of chemicals to be employed for decontamination or dismantling with those existing in the plant prior to decommissioning should be checked after the survey.

For facilities that have been shut down for a long time prior to decommissioning the survey should also assess the potential of hazards associated with the deterioration of structures, buildings and equipment.

Uncertainty about the amounts of fissile material present may have severe consequences with respect to assessment of criticality related incidents during decommissioning. Hence efforts should be made during the characterisation of the facility to identify and quantify fissile material left in the plant.

### 5.4 Removal of Process Materials

At the time of shut down of a facility for decommissioning, significant amounts of process materials may be present in the plant at various locations. Such radioactive and hazardous materials should be removed to a safe and protected location and accounted for. The report of accounting should be made available for verification.

### 5.5 Decontamination

Decontamination of systems, structures and components is an essential part of decommissioning work.

Objectives of decontamination in a decommissioning programme are to:

(a) reduce radiation exposure to the work force performing decommissioning,

(b) control spread of contamination during decommissioning and avoid associated hazards,

(c) salvage equipment/materials,

(d) convert the radioactive waste to a lower category,

(e) reduce the volume of waste,

(f) restore the site and facility or parts there of for restricted or unrestricted use,

(g) remove loose contamination and

(h) reduce overall cost of decommissioning.

In some cases contamination may be fixed inside a protective casing. It should be evaluated very carefully whether in such cases it is advantageous to leave the contamination as it is by closing the open ends as in the case of a length of pipe. Attempts for decontamination may dislodge the radioactivity, causing disturbance in the decommissioning activity.

Selection of a suitable decontamination option should be based on an evaluation of its compatibility, effectiveness and the potential for reducing exposure to the work force performing the decommissioning activity. The evaluation should include:

(a) assessment of the achievable decontamination factor (DF),

(b) cost benefit analysis considering radiological and waste conditioning, management and disposal aspects,

(c) availability of the decontamination equipment/chemicals,

(d) utility of technology available readily to achieve the desired results,

(e) demonstration of the process selected to verify its capability,

(f) assessment of exposures, collective dose and impact on environment,

(g) assessment of the primary and secondary wastes arising from the decontamination, including the availability of technology for their treatment and conditioning,

(h) availability of facilities and space for treatment, storage and disposal of the waste generated,

(i) availability of trained staff required for the work,

(j) extent to which modifications are required to undertake the decontamination work and

(k) feasibility of automation/remotisation.

## 5.6 Dismantling

Dismantling comprises disassembly and removal of any system, structure and components during decommissioning by various means such as mechanical tools/saws, shears, plasma/arc cutting, thermic lancing water jet cutting.

Objectives of dismantling in decommissioning are to facilitate:

(a) physical removal of materials,

(b) easy decontamination of dismantled components,

(c) minimisation of waste volume,

(d) segregation of waste and

(e) easy handling.

Dismantling in fuel cycle facilities should be planned meticulously in order to minimise exposure, reduce spread of contamination and optimise cost. Planning of dismantling should consider the following:

(a) history of operations and type of processing agents that have been employed in the facility,

(b) type of contamination,

(c) sequencing of dismantling operations based on proper zoning of the facility in the light of the results of characterisation,

(d) paths for movement of equipment for dismantling, handling tools, waste containers and personnel,

(e) possibility of utilisation of existing clean up or filtration system and handling facility,

(f) piping and equipment layout and

(g) modeling and mock-up trials of critical operations.

The options available for dismantling and their selection depend on the types and characteristics (size, shape and accessibility) of the equipment and structures to be dismantled. Each dismantling task should be analysed to determine the most effective and safe method to perform it. The major requirements are as follows:

(a) dismantling technology should be readily available, proven and cost effective,

(b) dismantling equipment to be used should be reliable and simple to operate, decontaminate and maintain,

(c) equipment should be easy to maintain and should have less parts likely to get contaminated in operation,

(d) equipment should be adequately resistant to the levels of radiation encountered,

(e) employing the technology/equipment selected should result in low radiation exposure,

(f) trained staff should be readily available to operate the equipment,

(g) careful evaluation of the feasibility of utilisation of robotics and remote handling should be carried out to avoid direct hands-on operation in highly contaminated areas,

(h) cost benefit analysis should be carried out keeping in mind performance and budgeting of collective dose,

(i) effective methods should be available for controlling airborne radionuclides,

(j) technique used should be compatible with the working space available in the field,

(k) effects of each dismantling task on adjacent systems and structures and on other work in progress should be evaluated and

(l) effective methods should be available for handling and controlling hazardous materials.

The material removed during the dismantling activities should be placed in a appropriate container.

Dismantling operations in radiochemical plants call for a careful study of the piping and equipment layout in the hot cells. Utilisation of remote handling gadgets employed for operation of the plants should be evaluated for assisting dismantling operations. Additional provisions for viewing the parts being dismantled may be required.

### 5.7 Demolition

Demolition involves bulk removal of civil concrete structures from the facility being decommissioned and should be carried out only after the removal of contaminated concrete surfaces and satisfying radiological safety requirements. Care should be exercised during demolition to avoid cross contamination.

Selection of a demolition technique should be based on industrial experience with the techniques available from non nuclear facilities and also experience reported in respect of nuclear facilities. The selected process should be suitable for the thickness of the concrete to be demolished and should also be acceptable from the point of view of noise and vibration limits applicable to the area.

Prior to the initiation of demolition jobs the volume of the waste to be handled and disposed should be considered.

### 5.8 Execution of Decommissioning Task

Execution of the decommissioning task should be undertaken after ensuring the availability of the following:

(a) approved scheme/procedure,

(b) trained man power,

(c) tested radiation protection and surveillance system/equipment,

(d) approved waste management scheme and

(e) waste management facilities.

The decommissioning task should be considered to be completed only after the complete removal of all radioactive material/waste from the site and its final cleanup.

### 5.9 Final Radiological Survey

On completion of decommissioning activities, it should be decided whether the facility could be released for restricted/unrestricted use as deemed fit by the regulatory body. In order to achieve this aim a radiological survey of the facility should be performed within the criteria set by the regulatory body and to demonstrate that the decommissioning objectives have been fulfilled.

The radiological survey should be conducted for the entire area of the facility as per criteria stipulated by the regulatory body. The radiation levels should be below prescribed limits and such surveys should be repeated at prescribed intervals as stipulated by the regulatory body so as to find out the presence of any radionuclide in the area before it is being declared as green field for unrestricted use.

The survey data should be documented in a final survey report and submitted to the regulatory body. The result of the survey should also form a part of the final decommissioning report. The radiological surveillance report should include:

(a) decommissioning criteria employed,

(b) methods and procedures used to ensure compliance with the criteria and

(c) measurement data together with appropriate statistical analysis.

# 6. ORGANISATION AND MANAGEMENT

## 6.1 General

Effective implementation of a decommissioning programme requires well defined policy and organisational set up. The organisation responsible for decommissioning should ensure the availability of adequate trained manpower to meet the decommissioning requirements. Appropriate training programmes should be inducted on topics covering nuclear and radiological safety, fire safety and industrial safety, in addition to various aspects of decommissioning, to maintain the required level of competence. The operating organisation may itself take up the responsibility decommissioning of the facility.

## 6.2 Organisation and Administrative Control

The responsible organisation should set up a decommissioning cell at the headquarters for overall supervision of the decommissioning programme. The responsible organisation should decide on matters pertaining to decommissioning policies, strategies, award of contracts for decommissioning, health and safety, quality assurance, waste management, documentation/ records and supporting administrative services. A separate decommissioning cell at the site should also be formed well in advance to execute the planned decommissioning work of the facility. A typical functional organisation chart for decommissioning of nuclear fuel cycle facilities is presented in Annexure-1.

The site decommissioning cell should continue to function till the release of the facility/site for unrestricted public use or for use by an organisation as authorised by the regulatory body.

Facility management measures from the operational phase of the facility may be relevant to decommissioning. These measures should be reviewed and modified to ensure that they are appropriate and if necessary, additional administrative measures should be taken. Some of the steps which may need to be taken are:

(a) collection and updating of all information related to plant design (drawings, specifications, various modifications and implementation) and also information related to the operational phase of the facility,

(b) establishment of an organisational structure, which ensures that the responsibilities for all aspects of contaminated material management are defined,

(c) establishment of an accounting system to quantify the sources, types, activities and disposition of contaminated materials and

(d) training of manpower through introductory and refresher courses with a view to fostering operator awareness on the process of decommissioning, waste minimisation and reduction in radiation exposure.

### 6.3 Responsibilities of the Headquarters Cell

The headquarters cell should be responsible for the following:

(a) preparation of the decommissioning plan and its submission to the regulatory body for approval,

(b) liaison with regulatory body, waste management agency, site decommissioning cell, environmental monitoring agencies, if any, and statutory bodies at national/state level regarding the release of radiological/chemical effluents to the environment,

(c) implementation of the decommissioning plan and submission of the final decommissioning report,

(d) management and coordination for removal of recoverable/reusable materials,

(e) ensure compliance by the site cell with regard to:

  (i) exposure control of decommissioning personnel including overexposure investigations,

  (ii) safe disposal of radioactive wastes,

  (iii) release of radioactive materials below the prescribed levels for reuse in-house and

  (iv) release of materials below the clearance level for unrestricted use,

(f) maintenance and updating of documents on surveillance,

(g) provision of resources such as financing, trained manpower, etc. and

(h) Research and development (R & D) activities related to the development and testing of various facilities/mechanisms for decontamination and dismantling.

### 6.4 Responsibilities of the Site Cell

The site cell should shoulder with the following responsibilities:

(a) implementation of the decommissioning activities at site as per the approved decommissioning plan,

(b) preparation/submission of periodic progress reports on the execution of decommissioning activities including major deviations and constraints encountered,

(c) obtaining permission from appropriate authorities for any major deviation from the approved plan,

(d) periodic and final radiation survey and

(e) assistance to headquarters cell in preparing the final decommissioning report including the manner in which the decommissioning plan objectives were achieved, together with supporting data.

The site decommissioning cell should identify, install and maintain equipment that are important in relation to safety. Some of the equipment required may be available from the operational phase of the facility but such equipment should be assessed both for suitability in the changing circumstances and also for extended period of use. A management system should be established to ensure that all equipment necessary for safety are checked periodically, maintained and any functional degradation is rectified promptly.

A system should be established for carrying out routine preventive maintenance of safety related equipment/structures. Such maintenance should be carried out both during the decommissioning phase and also during any intervening period of surveillance and maintenance.

### 6.5 Manpower and Training

The decommissioning organisation should form a team comprising appropriate site personnel and decontamination experts in order to manage the decommissioning project. Retention of key personnel who had been familiar with the facility during its operational phase would be beneficial for the execution of the project.

The decommissioning organisation should have adequate competent staff to cover areas such as:

(a) safety assessment,
(b) radiation protection,
(c) decontamination,
(d) remote handling,
(e) dismantling,
(f) quality assurance and quality control,
(g) industrial safety,
(h) criticality safety and
(i) waste management.

The decommissioning organisation should ensure that adequate control, supervision and training specific to the facility being decommissioned are provided. Personnel should be made familiar with the facility, safety requirements, radiation protection requirements and safety procedures.

Basic requirements for a training programme including refresher training should be a part of the decommissioning plan.

Organisational structure during decommissioning activities should be described in the decommissioning plan and responsibilities at different levels should be delineated.

The staff required for surveillance and maintenance to assure compliance with radiation protection, if necessary after decommissioning, should be a part of the decommissioning organisation.

### 6.6 Emergency Planning

An emergency plan should be worked out and described in the decommissioning plan. This plan should be subjected to the approval of the regulatory body. It should be ensured that procedures to deal with unlikely events are prepared and that the personnel are trained in emergency procedures. Provision should be made for regular review and updating of these procedures by conducting periodic emergency exercises.

An effective emergency preparedness plan for a facility should comprise the following:

(a) line of authority,

(b) areas of individual responsibility,

(c) specific guidelines,

(d) training and refresher courses for emergency response and

(e) testing of systems, hardware, communications and procedures.

### 6.7 Access Control

Arrangements should be made to ensure that only designated persons have access to the site and the facility. Necessary precautions should be taken to prevent persons carrying out unauthorised actions that may jeopardise the safety of the facility and plant personnel.

Suitable procedures should be established for controlled movement of material in and out of the facility.

## 6.8 Quality Assurance Programme

The decommissioning organisation should establish a quality assurance programme for decommissioning of the facility covering all activities that may have an influence on decommissioning in a safe manner. Quality assurance (QA) should start with the initial planning and be maintained at each significant step upto the point where final the decision is taken regarding completion of decommissioning. The programme should provide systematic approach to all activities affecting safety and quality. The objective of the QA programme is to ensure that all the mandatory requirements with regard to the safety of the public and occupational workers as well as the protection of environment are met.

Activities pertaining to decontamination, dismantling and waste management should be performed by trained personnel with approved operating procedures. Working procedures should be prepared for each decommissioning activity.

Records of each task carried out during decommissioning should be maintained. Information regarding the location, configuration, quantity and type of radioactive material remaining in the facility before and after decommissioning should be maintained. The documentation should include an account of materials and structures removed from the facility and their destination.

# 7. RADIATION PROTECTION AND WASTE MANAGEMENT

## 7.1 General

The radiation dose to the occupational workers at any stage of decommissioning should be governed by the concepts of justification, optimisation and dose limitation[6]. Radiation exposure to occupational workers during decommissioning activities should be within the prescribed limits and as low as reasonably achievable. In case of intervention, the radiological exposure to the occupational personnel should be justified and optimised, resulting in minimum radiation dose.

Decommissioning of nuclear fuel cycle facilities may generate low, intermediate and high level radioactive waste. The decommissioning organization should establish an effective radioactive waste management programme to ensure safe handling and disposal of radioactive waste arising during decommissioning. An effective waste management programme should:

(a) provide adequate protection to the occupational workers and

(b) ensure adequate protection to the public and the environment.

## 7.2 Radiation Protection in Respect of Occupational Workers

Radiation dose to the occupational workers should not exceed the limit prescribed by the regulatory body during any decommissioning activity of nuclear fuel cycle facilities. Radiation dose to the occupational workers should be minimised by;

(a) reducing radioactive sources and

(b) reducing radiation dose rates.

Reduction of radioactive source should be achieved by:

(a) segregating active and non active materials, equipment, components and systems at the source,

(b) isolating areas, equipment and systems which have the potential for radiation hazards,

(c) isolating areas during decontamination, dismantling and demolition to prevent the spread of contamination and

(d) use of appropriate dismantling and decontamination techniques to avoid or reduce the generation of secondary waste.

Reduction of radiation dose rate should be achieved by:

(a) adequate shielding,

(b) remote handling,

(c) decontamination of selected components and equipment,

(d) removing the most contaminated or active components and systems first and providing shielding,

(e) providing local shielding at strategic points and

(f) providing suitable fixtures at adequate distance to perform operations.

Occupational exposure and the cumulative dose of decommissioning personnel should also be minimised by:

(a) training of personnel through full scale mock-up before the start of actual work,

(b) performing the required activities in the shortest possible time,

(c) using improved plans and techniques to facilitate faster operation and

(d) reducing airborne activity by providing appropriate ventilation and by the use of appropriate personnel protective equipment.

### 7.3 On-site Radiological Surveillance

A pre-decommissioning on-site survey should be conducted to collect data for preparing a detailed decommissioning plan. On-site pre-decommissioning survey should include:

(a) maximum, minimum and average radiation and contamination levels on systems, components and areas,

(b) identification of important radionuclides and measurement of their concentrations and

(c) characterisation of contamination inside equipment, components and piping.

The on-site radiological survey should also ensure the availability of sufficient information for mitigating any radiological hazard to occupational personnel. After selecting the detailed decommissioning plan, adequate radiation and contamination survey should be carried out as per the plan and the activities during decommissioning. The extent and the frequency of the periodic surveys should be clearly spelt out in the decommissioning plan to ensure adequate

safety with regard to the occupational workers. For facilities having alpha contamination or alpha bearing waste, special care should be taken during detailed radiation monitoring.

### 7.4 Off-site Radiological Surveillance

Off-site radiological surveillance and monitoring should be carried out to provide data regarding the presence of radionuclides and their concentration in the environment to assess the radiological impact of the decommissioning activities. Off-site surveillance includes the monitoring of:

(a) radiation fields and

(b) radionuclide concentrations in air, water, soil and vegetation.

Off-site environmental survey should be carried out prior to the decommissioning of nuclear fuel cycle facilities to provide the reference level of radionuclides and their concentration for assessing the environmental effects of decommissioning.

### 7.5 Waste Management

The type of radioactive waste generated in the decommissioning of nuclear fuel cycle facilities will depend on the following:

(a) nature of the facility to be decommissioned and

(b) processes and techniques employed for decommissioning.

Radionuclides generally present in the decommissioning waste of nuclear fuel cycle facilities are:

(a) uranium, plutonium, thorium etc. and their decay products and

(b) fission products.

### 7.6 Categorisation of Radioactive Waste

To achieve the objective of safe handling and disposal, radioactive waste should be categorised and segregated at the source [7]. Radioactive solid, liquid and gaseous waste generated during decommissioning of nuclear fuel cycle facilities should be categorised based on the prevailing guidelines prescribed by the regulatory body.

### 7.7 Minimisation of Waste Generation

Generation of radioactive waste from the decommissioning of nuclear fuel cycle facilities should be minimised by:

(a) categorisation and segregation of waste at the source,

(b) isolation of radioactive and non radioactive materials to prevent spread of contamination,

(c) recycling and reuse of decommissioned materials, equipment, components and structure to the extent possible and

(d) decontamination of material, equipment, components and structures using suitable methods to minimise the generation of secondary waste.

### 7.8 Waste Treatment and Disposal

The radioactive waste generated during decommissioning of nuclear fuel cycle facilities should be treated on the basis of:

(a) physicochemical properties of the waste,

(b) radiological properties,

(c) location of the requisite processing equipment,

(d) transportation and storage requirements,

(e) disposal options and

(f) economic considerations.

Low and intermediate level radioactive waste generated during decommissioning of nuclear fuel cycle facilities should be treated and conditioned to facilitate further handling, storage and disposal. The waste packages should meet the requirements of storage, transportation and disposal.

Decommissioning of some of the nuclear fuel cycle facilities may result in the generation of high level solid and liquid waste. The conditioned waste should be stored in suitable retrievable storage facilities till permanent disposal options are available.

### 7.9 Transportation of Waste

On-site and off-site transport of radioactive waste should be carried out in approved containers conforming to the requirements stipulated by the regulatory body (AERB/SC/TR-1) [8].

# 8. COMPLETION OF DECOMMISSIONING

## 8.1 General

Completion of decommissioning is declared on the basis of the final status and future use of facility/site. On completion of decommissioning a final decommissioning report should be submitted to the regulatory body for approval and for confirming that the decommissioning is completed. Based on the final radiation/contamination level achieved after decommissioning, the regulatory body may release the facility/site for:

(a) restricted use, or
(b) unrestricted use.

Restricted or unrestricted use of the decommissioned facility/ site should be decided on case to case basis, taking into consideration the residual radiation present after decommissioning, the population of the surrounding area and environmental and socio-economic factors.

## 8.2 Restricted Use

In this category, the use of decommissioned facility/site should be confirmed to activities under regulatory control with restriction so as to limit the radiation exposure.

## 8.3 Unrestricted Use

In this category, the facility/site may be restored to a prefacility state and unconditionally released by the regulatory body. No physical restriction is imposed for use of the site or its resources.

## 8.4 Documentation and Records

On completion of decommissioning, appropriate records should be retained as prescribed by the regulatory body. These records should be maintained for confirmation of the completion of decommissioning in accordance with the approved programme.

The final decommissioning report should be prepared on the basis of records and should contain the following information:

(a) description of the facility, objectives of decommissioning and activities relevant to decommissioning, remaining building/ equipment not decommissioned or partially decommissioned, report of final radiation survey, occupational dose received during decommissioning, abnormal events, incidents occurring and lessons learnt during decommissioning;

(b) criteria used as basis for release of equipment, building or site from regulatory controls or for any other control regime approved by the regulatory body;

(c) inventory of radioactive materials including amounts and types of waste generated during decommissioning and the location of their storage or the mode of their disposal;

(d) inventory of materials, equipment and premises released from regulatory controls;

(e) status of removal of controls and any remaining restrictions on the site;

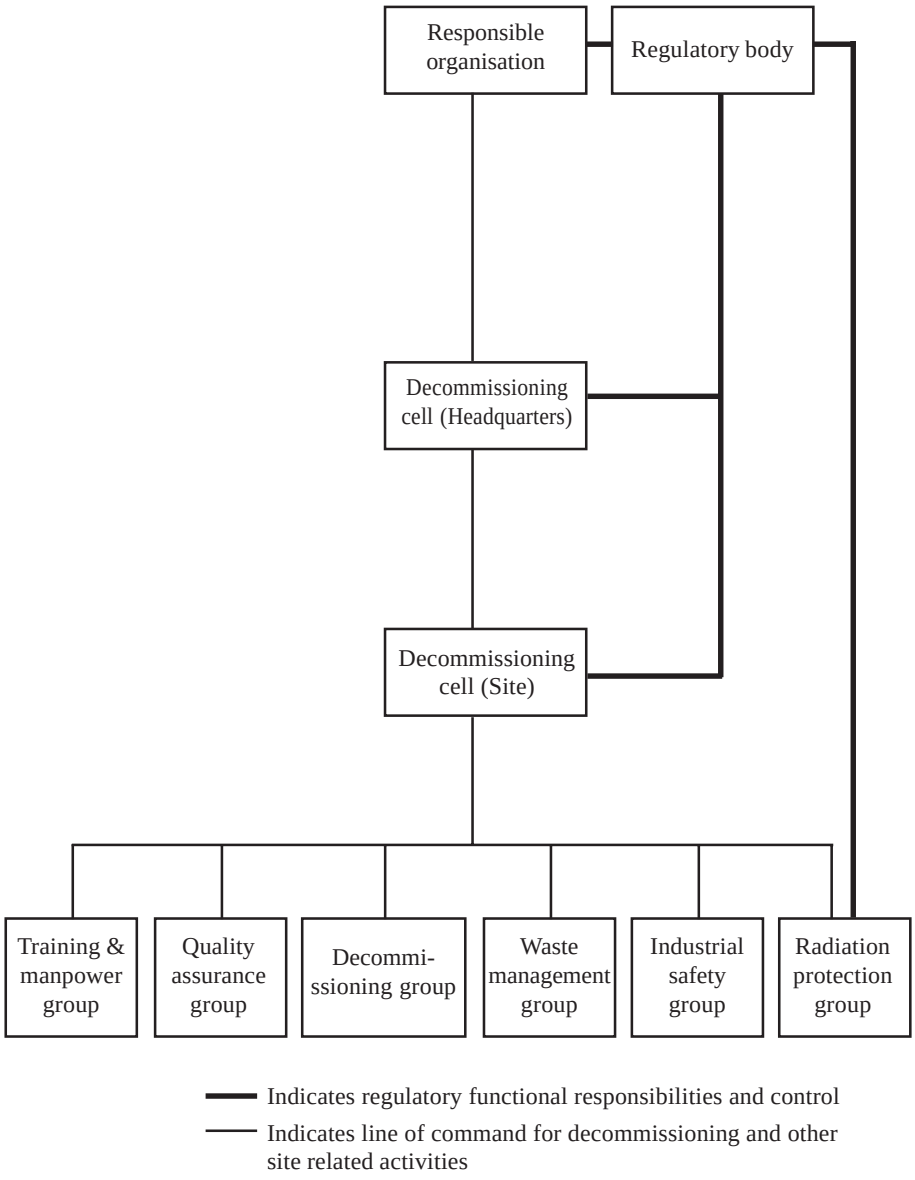
(f) staff required for surveillance and maintenance programme to assure compliance with restrictions and observance of barriers and

(g) A statement regarding the status of the removal of controls and any remaining restrictions on the site

The report should be submitted to the regulatory body for approval and confirmation of the completion of decommissioning.

# ANNEXURE-1

## TYPICAL FUNCTIONAL ORGANISATION CHART FOR DECOMMISSIONING OF NUCLEAR FUEL CYCLE FACILITIES



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