GUIDE NO. AERB/RF/SG/RW-6

GUIDE NO. AERB/RF/SG/RW-6

GOVERNMENT OF INDIA

AERB SAFETY GUIDE

MANAGEMENT OF SPENT RADIOACTIVE SOURCES AND RADIOACTIVE WASTE ARISING FROM THE USE OF RADIONUCLIDES IN MEDICINE, INDUSTRY AND RESEARCH, INCLUDING DECOMMISSIONING OF SUCH FACILITIES

ATOMIC ENERGY REGULATORY BOARD

AERB SAFETY GUIDE NO. 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

Atomic Energy Regulatory Board
Mumbai-400 094
India

November 2007

Price

Orders for this Guide should be addressed to:

The Administrative Officer
Atomic Energy Regulatory Board
Niyamak Bhavan
Anushaktinagar
Mumbai-400 094
India

FOREWORD

Activities concerning establishment and utilisation of nuclear facilities and use of radioactive sources are to be carried out in India in accordance with the provisions of the Atomic Energy Act, 1962. In pursuance of the objective of ensuring safety of members of the public and occupational workers, as well as protection of environment, the Atomic Energy Regulatory Board has been entrusted with the responsibility of laying down safety standards and framing rules and regulations for such activities. The Atomic Energy Regulatory Board (AERB) 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 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.

Radionuclides, in the form of sealed and unsealed sources, are extensively used in medicine, industry, agriculture, research and various other applications. Such applications could result in generation of significant quantities of solid and liquid wastes and occasionally gaseous wastes. Much of the solid waste consists of contaminated items, such as paper, plastics, glassware, equipment, animal carcasses, excreta and other biological waste. Some of the solid wastes may have large activity and small volumes as in the case of spent sealed sources. Liquid radioactive wastes comprise of aqueous and organic streams, such as patients' urine (primarily in thyroid cancer therapy) and effluents from decontamination processes. In many applications of radionuclides, the radioactive waste generated may comprise of short-lived radionuclides, which may be managed by providing storage for decay. However, in applications, which involve long-lived radionuclides, an appropriate waste management programme should be in place prior to the start of the work with radionuclides. This safety guide provides guidance for ensuring adequate safety in handling and disposal of waste generated from application of radionuclides in medicine, industry, agriculture and research.

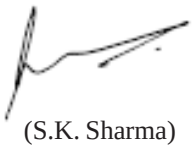
Consistent with the accepted practice, 'shall' and 'should' are used in this guide to distinguish between a firm requirement and a desirable option respectively. Annexures

and 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, 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.

An expert committee consisting of staff from the Atomic Energy Regulatory Board (AERB), Bhabha Atomic Research Centre (BARC) and Board of Radiation and Isotope Technology (BRIT) has prepared this safety guide. It has been reviewed by the relevant AERB Advisory Committee on Codes and Guides and Advisory Committee on Nuclear Safety.

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



(S.K. Sharma)
Chairman, AERB

DEFINITIONS

Classification (Radioactive Waste)

Determination of the physical, chemical and radiological properties of the waste to establish the need for further adjustment, treatment, conditioning, or its suitability for further handling, processing, storage or disposal.

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.

Contamination

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

Decommissioning

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

Decontamination

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

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.

Exemption Level

A value, established by regulatory body and expressed in terms of activity concentration and/or total activity, at or below which a source of radiation may be granted exemption from regulatory control without further consideration.

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.

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.

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.

Packaging

The assembly of components necessary to enclose the radioactive contents completely. It may, in particular, consist of one or more receptacles, absorbent materials, spacing structures, radiation shielding and service equipment for filling, emptying, venting and pressure relief, devices for cooling, absorbing mechanical shocks, providing handling and tie-down capability, thermal insulation; and service devices integral to the package. The packaging may be a box, drum, or similar receptacle, or a freight container, tank or intermediate bulk container.

Quality Assurance (QA)

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

Radiological Protection

The protection of people and environment from the effects of exposure to ionizing radiation or radioactive materials and the safety of radiation sources, including the means for achieving this, and the means for preventing accidents and for mitigating the consequences of accidents should they occur.

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.

Regulatory Body (same as 'Atomic Energy Regulatory Board')

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.

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

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.

Waste Form

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

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 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.

SPECIAL DEFINITIONS

(Specific for the present 'guide')

Characterisation

Determination of the physical, chemical, biological and radiological properties of the waste to establish the need for further adjustment, treatment, conditioning, or its suitability for further handling, processing, storage or disposal.

Processing

The processing of radioactive waste can involve the steps of pre-treatment, treatment and conditioning, which can involve a number of operations that change the characteristics of the waste. Processing may be necessary for safety, technical or financial reasons. Processing is necessary to eliminate or reduce the hazards (e.g. radiological, physical, chemical and biological hazards) associated with the waste.

Waste Acceptance Criteria

Quantitative or qualitative criteria specified by the AERB, or specified by an operator and approved by the AERB, for radioactive waste to be accepted by the operator of a repository for disposal, or by the operator of a storage facility for storage.

CONTENTS

1. INTRODUCTION

1.1 General

1.1.1 Radioactive waste arises from the use of radionuclides for diagnostic and therapeutic applications in medicine, process control and instrumentation in industry, and many applications in research, teaching, agriculture, geological exploration, construction and other fields of human endeavour. Radioactive waste generated in these applications is varied and may be in the form of solid, liquid or gaseous form and sealed sources. Solid waste may include contaminated equipment, glassware, gloves, paper, carcasses, excreta and other biological waste. Liquid waste may include aqueous and organic solutions resulting from medical and research applications, decontamination of laboratory equipment or facilities and from activity measuring systems, such as scintillation counting. Gaseous waste may be generated from the production and radio labelling of chemical compounds and organisms, also during the production of radionuclides and from the treatment of solid and liquid waste. A broader overview of waste arising from several of applications is presented in Annexures I, II, III and IV.

1.1.2 Good operating practices significantly reduce the amount of radioactive waste generated. The waste containing significant quantities of radionuclides, if not properly managed, may result in serious risks to human health and the environment. Therefore, particular attention needs to be given to the safety issues and regulatory control, taking into account the variable range of waste types encountered.

1.2 Objective

The objective of this safety guide is to provide guidance on the safe management of radioactive waste arising from the use of radionuclides in medicine, industry, agriculture and research. The guidance is intended for organisations and persons using radioisotopes resulting in generation of radioactive waste and those managing such wastes. The guidance given here is to meet the regulatory requirements stipulated in the safety code of Atomic Energy Regulatory Board (AERB) titled 'Management of Radioactive Waste' (AERB/NRF/SC/RW, 2007).

1.3 Scope

1.3.1 This safety guide is applicable to all activities involving management of radioactive waste associated with the use of radionuclides, including spent and disused sealed sources. The guide is focused on waste management at facilities using radionuclides for medicine, industry, agriculture and research. It also includes management of radioactive waste generated from

decommissioning of such facilities. The guide covers the managerial, administrative and technical procedures related with safe handling and management of radioactive waste, from its generation to its release from further regulatory control through a clearance mechanism, or its acceptance at storage facility pending the availability of a suitable disposal option or its acceptance at a disposal facility.

1.3.2 This safety guide covers the safe management of radioactive waste at facilities where it is generated. The guide provides general guidance on the transfer of radioactive waste from the premises of a generator to an authorised radioactive waste management facility.

1.3.3 This safety guide covers aspects related to management of spent radioactive sources arising in medicine, industry, and research; in handling and processing of radioactive materials; and in the subsequent management of radioactive waste and decommissioning of the facilities generating such wastes and is intended to be used in conjunction with other relevant AERB publications, as given in the provisional list.

1.3.4 There are often hazards of a non-radiological nature associated with radioactive waste due to the presence of other hazardous materials, such as pathogens, toxic chemicals and heavy metals. In some cases, these hazards dominate the choice of available waste management options. While, some guidance is given on the aspects to be considered in respect of these hazards, detailed recommendations regarding non-radiological hazards are beyond the scope of this safety guide. Utilities should prepare utility specific manuals and submit them to AERB.

2. PRE-DISPOSAL MANAGEMENT OF RADIOACTIVE WASTE

2.1 General

The management of waste arising from the use of radionuclides requires effective planning and provision of adequate facilities at institutional and/or national level. The emphasis is on the protection of people and environment from the undue exposure to ionising radiation emitted by the radioactive waste. There are many simple and practical procedures that may be used for the management of waste such as waste characterisation, classification and segregation. Decayed or disused sources should be returned to the original supplier or transferred to the authorised waste management agency.

2.2 Waste Minimisation and Control

2.2.1 In effective waste management programme, minimisation and control of generation of radioactive waste is very essential. The objective of this is to reduce the activity and the volume of wastes for storage, treatment and disposal. This consequently reduces the exposure to personnel involved in waste management, the impact on environment as well as the associated costs. The waste generating institutions should therefore prepare and practice a plan that would minimize the generation of waste i.e. the reduction in the primary waste generation as a result of the operational activities and the secondary waste generation during subsequent treatment and conditioning of the primary waste.

2.2.2 In medical applications the use of activity should be decided on the basis of individual benefit/risk evaluation, whereas in research, the availability of an alternative technology and the cost of radioactive waste management should be important considerations. The generation of waste is controlled by using non-radioactive practices, such as the use of calorimetric or chemiluminescent assays instead of radioimmuno assays, or substitution of radionuclides with those having shorter half-lives. The shorter decay time may permit storage of waste for decay of activity and local disposal within the permissible levels. The need to use radionuclides should always be justified when designing an experiment or planning patient diagnosis. Essential aspect of waste minimization is to use minimum quantity of short-lived radionuclides required to achieve the objective of the application. Therefore, the optimization of procedure is an essential part in controlling the generation of waste.

2.2.3 Big equipment of source housings that are found to have fixed contamination with long-lived radionuclides are treated as radioactive waste. In such cases, contaminated portion alone from the equipment should be separated to reduce the volume of waste.

2.2.4 It is preferred to recycle and reuse radioactive material and equipment to reduce the amount of radioactive waste. For this purpose, a possible contractual agreement should be made with the supplier at the time of purchase of the equipment to accept the radioactive source at the end of useful life. This is particularly important when purchasing high activity sources used in irradiators, radiotherapy, radiography and gamma cell units.

2.3 Characterisation, Categorisation and Segregation

2.3.1 Characterisation

One of the important elements of waste management is characterisation and classification of the waste. It enables to select appropriate management option and also helps in identifying the potential hazards associated with it. The waste should be characterized according to its physical and chemical nature, physical half-life of radionuclide present in it, chemical toxicity, radio-toxicity and presence of flammable/non-flammable material.

2.3.2 Categorisation

Handling, treatment and interim storage of radioactive waste depends on the activity of the waste. Waste are categorised on the basis of activity levels in liquid waste and surface radiation dose rates of solid waste and the presence of other non-radiological hazardous materials. Waste should be categorised as per the AERB safety guide titled 'Classification of Radioactive Waste', AERB/NRF/SG/RW-1.

2.3.3 Segregation

2.3.3.1 Segregation of waste is an essential component of radioactive waste management. Waste should be segregated at the point of origin itself according to its characteristics and classification. While segregating wastes, characteristics such as half-life, physical and chemical form, metallic and non-metallic forms, dispersible and non-dispersible forms and combustible and non-combustible forms should be considered. It is emphasised that non-radioactive waste should not be mixed or collected along with radioactive waste. Further to reduce the volume, the radioactive waste of relatively short half-life should be collected separately. If the waste contains chemically toxic or carcinogenic substances, which are incompatible for release to the environment, these should be segregated and collected separately and should be managed with appropriate procedures.

2.3.3.2 In contrast to other nuclear applications, the use of radionuclides in medicine requires mostly one radionuclide per procedure. This makes segregation of waste by individual radionuclides possible and practicable. Segregation and collection of such waste according to half-lives, facilitates its management and helps in reducing waste quantity. Most of the short-lived radioactive

waste, after physical decay of activity to values below authorised limits should subsequently be disposed off as non-radioactive waste. For using delay, decay and disposal philosophy for managing short-lived waste generated in medical applications, the waste should be segregated according to their half-lives, e.g.

- waste with a half-lives less than 10 hours;
- waste with a half-lives 10 hours to 10 days;
- waste with a half-lives 10 days to 100 days; and
- waste with a half-lives greater than 100 days

2.3.3.3 Other considerations for segregation of waste should include the following:

(a) radionuclide present and activity content;

(b) physical and chemical form;

(c) spent sealed sources; and

(d) non-radiological hazards (toxic, biological, carcinogenic, infectious, flammable, etc.)

2.3.3.4 Liquid waste should be segregated taking the following criteria into account:

(a) radionuclide content and activity;

(b) half-lives of radionuclides and suitability for decay storage;

(c) organic/aqueous liquids;

(d) non-homogeneity of waste (sludges);

(e) infectious hazards; chemical hazards; and

(f) flammability.

2.4 Collection of Radioactive Waste

2.4.1 Waste should be segregated and collected considering the final method of disposal. Collection should be made in containers suitable for the solid waste, with due consideration to physical, chemical, biological and radioactive properties of the waste. Waste bags/containers should not be over-filled to an extent that their integrity is compromised. Other factors to be considered while packaging are the nature of waste such as paper, metal, glass and tools having sharp edges that may damage the package during storage or transportation. For biomedical radioactive waste, it is necessary to consider different types of packaging that control biomedical hazards or bacterial growth and future waste treatment method.

2.4.2 Containers used for collecting solid waste should be heavy duty cardboard, waxed cardboard or polyethylene/polypropylene containers and should be lined with primary packaging, such as a heavy duty plastic bag. The containers

should be brightly colored with the radiation symbol clearly displayed so as to distinguish them from bins for inactive waste. There should be a range of types and sizes of containers for segregation of the different types of solid radioactive waste at the time and place of generation. These radioactive waste containers should have lids, which should be preferably foot-operated.

2.4.3 Waste collection should be properly scheduled so that bio-hazardous materials are not allowed to deteriorate in the radioactive waste bins.

2.4.4 Liquid waste should be collected, segregated and characterized, as far as possible, at the point of origin according to its chemical, biological and radiological properties. Containers should be no more than three quarters filled before sealing. It should be more appropriate to collect in metallic/non metallic cans of approximately 5 - 10 L capacity for ease of handling. The cans should be firmly sealed and transferred to a centralized waste processing facility.

2.4.5 Radioactive liquid waste from active toilets in the nuclear medicine department should be connected directly through leak proof pipelines to delay tanks specially constructed for the purpose. The liquid waste from the tanks should be released to environment after storage for decay so as to comply with the limits specified by AERB.

2.4.6 Bio-hazardous waste requires hermetically sealed polyethylene drums instead of plastic bags not only for sharps but also for blood-contaminated waste. Biologically contaminated radioactive liquid waste should be collected separately and should be deactivated (e.g. by autoclaving, chemical disinfection) before further treatment.

2.5 Storage of Radioactive Waste

2.5.1 Storage of radioactive waste is required at the point of generation, transit and prior to disposal. Waste with short half-life and small quantity of radionuclides should be stored at the site for physical decay of activity. The waste with long half-life and high level of radioactivity should be packed and stored in interim facility after segregation, treatment and conditioning or final disposal. Radioactive liquids with different chemical properties should be stored separately if immediate disposal is not possible.

Special consideration should always be given to the management of contaminated sharp objects, such as needles and syringes, scalpel blades, blood lancets, glass ampoules, etc. These items are commonly referred as ‘sharps’. These should be stored separately with appropriate containment and marking.

2.5.2 Where there is a requirement for long-term storage, accumulation of damp waste should be avoided. Significant moisture can lead to undesirable and

possibly dangerous chemical and biological reactions whilst the waste is in storage. In such circumstances, damp or wet medical material should be drained, de-watered or dried to the extent possible, consistent with other safety concerns, before it is placed in waste receptacles. The addition of moisture absorbent, such as vermiculite, should be advantageous. Refrigerating or freezing of carcasses and similar remains is recommended for physical decay of activity to authorized disposal limit or before transporting for further treatment.

There may be situations at institutions where the waste generated is a mixture of radioactive substance and toxic chemical(s). The basis of disposal for such waste should not only be the authorised limit for disposal of radionuclide(s) present but also the permissible limit of the toxic material present in waste. If the content of toxic substance in waste is higher than the authorised disposal limit, the hazard due to chemical toxicity should be duly considered in addition to the radiological hazard.

2.6 Pre-treatment

Pre-treatment of waste is the initial step in waste management. This includes the method of collection, segregation, chemical adjustment and decontamination. Most of the methods followed in pre-treatment of waste are discussed above and appropriate procedure should be followed according to the quantity, nature and physical, biological and chemical properties of waste.

2.7 Treatment and Conditioning

Treatment of radioactive waste includes those operations intended to provide for safety or economy by changing the characteristics of the waste. The basic treatment concepts applicable are volume reduction, removal of radionuclides and change of composition.

Conditioning of radioactive waste involves those operations that convert the processed waste into a form, which is suitable for handling, transportation, storage and disposal. The operations may include immobilisation of the waste and placing it into a container and providing additional packing. In many instances, pre-treatment, treatment and conditioning take place in close conjunction with one another. The conditioning of waste should ensure maximum compatibility between the waste, the matrix and the container, maximum homogeneity of the waste form and low leachability, as well as control over the complexing agents and organic compounds. While conditioning the waste, consideration should be given to the nature of waste form and relevant acceptance criteria for storage and/or disposal of the waste. While some of these guidelines may not be applicable to most of the users, some specific applications of radioisotopes may need to fulfil these guidelines.

2.7.1 Solid Radioactive Waste

A variety of options are available for the treatment of solid waste such as compaction, incineration and decontamination. Care should be taken to ensure that the waste meant for compaction should not contain: (a) material that may damage the waste package, (b) hazardous material, (c) items that may release gas, and (d) loose radioactive powder that may lead to risk of spread of contamination. Combustible waste meant for incineration should not contain reactive chemical or volatile toxic material and it should be of low moisture content.

2.7.2 Liquid Radioactive Waste

The treatment of liquid waste depends on the particulate content, pH, presence of salts and acids. The presence of chemicals that may lead to uncontrolled reaction and generation of heat should be separated or avoided before the treatment. Precipitation, evaporation, ion exchange and filtration processes should be adopted for aqueous waste amenable to such processes and the residue so arising should be treated as solid waste. Exceptional cases are to be dealt with separately for fulfilling guidelines while issuing authorisation. In these processes, the secondary waste in the form of residue should be treated and/or conditioned accordingly. Dilution and disposal should be considered as an option to release of very low active waste into the environment maintaining proper clearance levels. The clearance level in terms of quantities or concentrations of activity per unit volume, prescribed by AERB should be achieved by adding non-radioactive waste in the radioactive waste. Such waste should be disposed in uncontrolled domain like municipal garbage and/or sewage system after obtaining necessary authorisation from AERB.

2.7.3 Organic Waste

For organic waste, incineration (with the exception of low flash point waste or volatile toxic waste), immobilisation and adsorption processes should be applied. While incinerating, consideration should be given to the minimum possible environmental implications of discharging both gaseous and particulate matter and both radioactive and non-radioactive components. Pre-filters and HEPA filters should be provided where necessary. Similarly, consideration should be given to minimize generation of airborne radioactivity inside the facility, in which the waste is being treated, particularly in handling ash, and subsequent management of contaminated ash.

2.7.4 Biological Radioactive Waste

Radioactive waste of a biological nature should be managed taking into consideration the associated radiological and non-radiological hazards such as biological and/or infectious, physical and chemical. For infectious biological waste from medical applications, pre-treatment should be undertaken to

eliminate all infectious agents before the waste is stored and/or disposed off. For this purpose, options such as steam sterilisation, dry heat treatment and sterilisation by irradiation should be adopted. The thermal processes such as incineration, steam autoclave and microwave processing are used primarily to destroy organisms and microorganisms present in the waste. Sometimes chemical processes are used to decontaminate biological waste by disinfection. Special consideration should always be given to the management of contaminated sharp objects, such as needles and syringes, scalpel blades, blood lancets, glass ampoules, etc. These methods are usually suitable for management as dry solid radioactive waste, although very small amounts of liquid might remain inside the needles/syringes.

3. TRANSPORT AND DISPOSAL OF RADIOACTIVE WASTE

3.1 General

Radioactive waste being hazardous to human and the environment, requires utmost care during its transportation, either for interim storage or for final disposal. Safety should be ensured not only for those directly involved in the transport operation but also for those who may be affected as a result of the transport or an accident during transport. While some of the guidelines below may not be applicable in most of the situations/circumstances, some specific applications would call for fulfilling these guidelines.

3.2 Criteria for Transport

In order to ensure safe transport, relevant regulations in 'Safety Code for the Transport of Radioactive Materials, AERB/SC/TR-1, 1986, should be followed for properly packing the radioactive waste to be transported. The consignor should meticulously follow all the rules and procedures stipulated by AERB in packing and labeling the consignment. The transport should take place only with the prior consent of the consignee and the consignor. The consignor should have all the details about the carrier. The radioactive consignment should be transported on a door-to-door basis to avoid storage in transit, multiple transhipment handling, misplacement and pilferage. The carrier should have the relevant documents and full knowledge of the contents of the consignment being transported. He should have the addresses and the telephone numbers of the consignor and consignee and the agencies to be contacted in case of any untoward incident. The carrier should be instructed/ educated adequately to take preliminary action during exigencies like breakdown of vehicle, mishap, falling of the consignment or detention of vehicle by law enforcing/tax collecting authority and other unforeseen circumstances to avoid delay. Formalities for exemption from various taxes should be made known to the carrier prior to the commencement of transport.

3.3 Transport Procedure

After receiving requisite approval for transport from AERB, the consignment should be packed and labelled as instructed by AERB. Proper packaging and labelling of the consignment should be checked by the designated radiological safety officer. The consignment should then be handed over to the carrier for transportation. The personnel accompanying the consignment should be briefed as mentioned above in section 3.2. All the relevant documents also need to be handed over to the carrier. The consignor should inform the receiving agency in advance; name of the transport agency, address, telephone number, vehicle number, name of the personnel accompanying and the probable date of arrival of the consignment at destination. After receiving the consignment,

consignee should confirm the safe and secured arrival of the consignment and inform the consignor about the receipt of the consignment. In the event of consignment not reaching on the scheduled day the consignee and consignor should initiate necessary action in tracing the consignment without any time delay. In the event of the consignment being received in a damaged/unsafe condition at the consignee's end, it should be reported immediately to AERB and also to the consignor.

3.4 Disposal of Solid Waste

The radioactive solid waste should be grouped in three types depending upon the contamination levels, associated radionuclides and the quantity. The first type of waste is with exempt level of contamination that should be disposed into municipal garbage system without any treatment. The second type of waste having contamination above exempt level but associated with radionuclides having very short half-lives may be generated in small quantities. Such waste should not be sent to authorised waste manager. These waste should be disposed in a local dedicated disposal facility with adequate safety and with the consent of the AERB after adequate decay of activity to below clearance levels by storing, wherever and whenever possible. The third type having contamination well above the clearance level and containing radionuclides having relatively long half-lives, large volume and needing processing/conditioning prior to disposal should be sent to authorised waste manager. Certain waste materials like animal tissues and carcasses due to their perishable nature cannot be transported to long distances. Such waste should be locally buried or incinerated with the consent of the AERB after providing for adequate decay of activity. In all the above cases, authorisation from regulatory body prior to disposal should be obtained as required under the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987, G.S.R. 125.

3.5 Disposal of Liquid Waste

3.5.1 Liquid waste should be classified as aqueous or non-aqueous (organic). Aqueous liquids should be treated and the activity concentration levels in the liquid effluent should be brought down to authorised limits prior to discharge into appropriate environment. However, the secondary waste generated during treatment needs further management. Normally the liquid waste generated in medicine, industry and research are in small quantities with short half-life radionuclides. As such their local disposal is possible by maintaining the releases within authorised limits. However liquid waste with appreciable level of activity and with long-lived radionuclides need special attention. Such waste should be diluted to achieve the authorised limits and suitably discharged or fixed in cement matrix prior to disposal at authorised facility.

3.5.2 The organic waste generated in medicine, industry and research normally consists of scintillation fluid associated with beta emitters like ^{3}H, ^{14}C, ^{32}P or

^{35}S. The liquid is generally toxic as toluene or xylene is the major component of the waste. These effluents are highly inflammable and the fumes are carcinogenic. Such liquid effluents even though having very low concentration of activity should not be released into environment, as it is a fire hazard. The reuse after distillation is also not recommended. Such effluents should be burnt in dedicated incinerator having off-gas cleaning facility. The risk of explosion in the incinerator while burning organic effluent should be taken into account. Chemical toxicity should also to be taken into consideration during processing/treatment. Another method is to convert the organic base into an aqueous form by treating with sodium hydroxide. The aqueous liquid so formed should be fixed in cement matrix. However, these processes mentioned above are normally not available with the waste generator and as such these types of effluents should to be sent to authorised waste manager for treatment and disposal.

3.6 Disposal of Gaseous Waste

The generation of gaseous waste in the use of radionuclides in medicine, industry and research is small. It may arise when handling volatile radioisotopes (such as ^{125}I, ^{131}I,etc.), applications wherein radioisotopes are handled in gaseous form, or operations releasing airborne activity. As such, these gaseous waste should be treated at the origin itself. The gas cleaning system normally consists of condenser, pre-filters and high efficiency particulate activity (HEPA) filters. The cleaned gas should be released to atmosphere through a chimney of appropriate height. Laboratories handling aspirator for transferring radioactive liquid or emptying the used vials generate airborne activity. The radiological hazard may not be significant, as the concentration level of activity is very low because of small quantities of activity handled and the radionuclides used are of short half-life. However, in poor ventilation conditions the possibility of inhaling such contaminated air cannot be completely ruled out. All such operations should be carried out in well-ventilated fume hood with air cleaning system and the gases should be released few meters above the highest elevation near the building. Secondary waste like condensate and filter should be suitably treated and disposed. Discharges of airborne releases should be within the authorised limits specified by AERB.

4. DECOMMISSIONING OF RADIATION FACILITIES

4.1 General

The term decommissioning refers to set of actions taken at the end of the useful life of a particular facility, or when a facility ceases to be utilised for its intended purpose. The facilities using radioactive materials and sources for medical, industrial and research purposes may require to be decommissioned for any of the above reasons. Decommissioning needs to be carried out in a systematic manner to ensure safety of the workers, environment and public. The decommissioning process involves removal of radioactive materials and sources, decontamination and dismantling, subsequent waste management, final radiation survey and release of the facility for unrestricted use and documentation. The duration of decommissioning depends on the type of facility, radionuclide inventory, the chosen decommissioning approach and the techniques employed. This could range from a few weeks in case of small laboratories to a few years for certain large facilities.

4.2 Planning

4.2.1 Decommissioning plan should be commensurate with the type and complexity of the facility. This plan may comprise of three phases: initial, ongoing and final. The authorised user institution is responsible for the safety of the facility during the decommissioning operations.

4.2.2 Initial decommissioning plan should be prepared and submitted to AERB by the authorised user institution in support of the license application for the construction of the facility. The plan should describe the preferred decommissioning option, technology to be adopted and management of resultant waste. The plan should address provision of financial resources and their availability.

4.2.3 Ongoing planning should comprise review of the initial plan with respect to technological developments, operating history of the facility and amendments in regulatory requirements.

4.2.4 The final plan should take into account a thorough safety analysis of the decommissioning operation; identify emergency preparedness actions and relevant protective measures to mitigate the consequences.

4.2.5 Before any decommissioning strategy is undertaken or a technique is selected, an evaluation of its effectiveness should be performed. This evaluation should include:

(a) estimated doses to the workers;

(b) effectiveness of the technique;

(c) consideration of possible generation of aerosols;

(d) estimation of volume reduction;

(e) any possible on-site and off-site consequences as a result of decontamination/decommissioning activity;

(f) generation of solid and liquid waste, their characterisation, treatment and conditioning and disposal;

(g) non- radiological hazards;

(h) additional radiation protection measures needed; and

(i) resources required.

4.3 Regulatory Requirements

The user institution should get the decommissioning plan approved by AERB. The decommissioning plan should specify the provisions for handling emergency situations such as any accidents during the decommissioning process, power failure, fire, failure of equipment, and spillage of radioactive materials. The authorised user institution should communicate with AERB through reports submitted at various stages of decommissioning and also in case of any abnormal situation during the entire operation, which may have radiological safety implications. A detailed report should be submitted to AERB on completion of the decommissioning operation including the details of radionuclide inventory, effluent discharges and radiation survey of areas where sources and materials were handled during decommissioning.

4.4 Source Removal

4.4.1 The removal of the radioactive sources will normally result in a significant reduction of the radiation hazards. Decommissioning of the facility containing sealed radioactive sources for use in medicine, industry and research starts with the proposed shutdown of the unit. The first step after obtaining necessary permission from AERB should be to remove all possible radioactive sources from the facility and to store them in approved temporary locations till they are finally disposed by the appropriate method given in section 3.

4.4.2 In case of the facilities using unsealed sources, source removal should be accomplished by identifying and collecting all unused radio-chemicals and declaring them as radioactive wastes, to be managed as per methods described in section 2.

4.5 Decontamination and Dismantling

4.5.1 Decontamination refers to the removal or reduction of radioactive contamination on materials, items, buildings, and areas of the facility. Decontamination may lead to minimisation of the volume of material that should be disposed off as

radioactive waste. Work surfaces, handling tools, laboratory equipment and certain areas of the facility wherein radioactive sources were handled, should be decontaminated with suitable techniques and agents.

4.5.2 The applicability of decontamination techniques depends on availability of suitable decontamination agents, disposability of the agents, availability of infrastructure to treat the secondary waste generated, and safety of the overall operation.

4.5.3 Dismantling may facilitate decontamination. During dismantling, provision should be made for:

(a) reduction in size of the objects/components using suitable remote and direct handling tools to facilitate handling and decontamination;

(b) facilitating the access to radioactive sources or contaminated areas;

(c) segregation of contaminated and uncontaminated equipment structures and materials which will reduce the waste volume; and

(d) minimising the spread of contamination.

4.5.4 The requirements for appropriate monitoring in and around the vicinity of the facility should be specified in the decommissioning plan. All potential release points should be monitored. Off-site monitoring should be performed to demonstrate the adequacy of the control over the release of radioactive materials to the environment during decontamination or dismantling. Radiation survey should be performed before and after decontamination and the benefits/ risks of the decontamination should be presented in the final report of decommissioning.

4.6 Waste Management

4.6.1 A waste management plan, which is part of the decommissioning plan, should be developed giving consideration to the different categories of waste generated during decommissioning and to their safe management. The efficacy of the existing plan for management of radioactive waste should be assessed to suit its compatibility for managing the radioactive waste that may arise from decommissioning operations. Any additional provisions in terms of procedures, resources and equipment should be included.

4.6.2 Safe storage should be provided in the facility for the decommissioned waste to allow for decay or its transfer to the authorised waste manager after obtaining approval from the AERB.

4.6.3 A large part of the waste and the other materials arising during the decommissioning process may be sufficiently low in activity concentration for regulatory control to be wholly or partly removed. Some waste may be suitable for disposal in normal landfill sites while some materials, such as steel

and concrete should be suitable for recycling or reuse outside the nuclear industry. Such waste or items should be recycled or disposed off in compliance with criteria established by the AERB.

4.7 Training

The management and staff involved in the decommissioning should have adequate knowledge of the procedures to be followed for the decommissioning operations and also to deal with any emergencies arising during the operation. Necessary training should be arranged for the concerned staff before actual decommissioning operations are undertaken.

4.8 Report

On completion of decommissioning, a final report should be submitted to the AERB. The report should contain all the relevant details of the facility before and after decommissioning. These should include reason for decommissioning, procedures and tools used, radiation survey report, inventory of radioactive isotopes, the types of waste generated and their storage/disposal reports, abnormal events during decommissioning, lessons learnt and suggestions, if any.

5. RADIOLOGICAL SURVEILLANCE

5.1 General

The objective of radiation protection is to protect the workers, members of the public and the environment from the adverse effects of radiation while allowing the justified practices. Radiation protection consideration during the management of waste arising from the use of radionuclides in medicine, industry and research are governed by the principles of justification, optimisation and dose limitations. As part of radiation protection programme, it is essential to carry out the radiological surveillance of the workplace as well as the environment around the site. Physical security of the radioactive material and waste containers (packages) is also an important aspect of the radiation protection programme. Procedures for ensuring physical security of radioactive material should be included in the radiation protection manual prepared by each facility.

5.2 Radiation Protection

5.2.1 Radiation exposure of workers and public should be kept as low as reasonably achievable (ALARA). Tasks involving radiation exposures should be planned and likely individual and collective doses should be estimated. Consideration should be given to ways and means of reducing doses by selecting different possible approaches.

5.2.2 An appropriate radiation protection programme commensurate with the complexity of the facility and the radiological hazards should be in place. Monitoring of personnel, area, effluent and the environment should be carried out. The procedures and measurement techniques for monitoring should be got approved by the AERB. Records of the results of such monitoring should be maintained.

5.2.3 Radiation protection programme should be periodically reviewed and revised as necessary at various stages in the light of experience gained. Personnel assigned with the responsibility to effect an adequate radiation protection programme should have the qualifications, resources and adequate authority.

5.2.4 During the operations involving management and decommissioning of radioactive waste, the availability of the following should be ensured:

(a) adequate radiation shielding;

(b) prevention of personnel contamination and minimisation of intake of radioactive material (e.g. local/cell ventilation with appropriate filtration system);

(c) personnel monitoring (including bioassay);

(d) work place monitoring including contamination survey; and

(e) monitoring for airborne radioactive substances in the work place.

5.2.5 For optimisation of radiation protection associated with different sources, the individual doses should remain below dose constraints. It should also be ensured that the dose to the individuals from all sources does not exceed individual dose limits prescribed by the AERB.

5.3 Physical Protection

5.3.1 Physical security arrangement of the facilities where radioactive waste including spent/disused sources are generated or managed should be in place to ensure that radioactive waste or material is not accidentally or deliberately removed from its proper location without authorisation. Spent sealed sources or disused sources after their useful life, should be sent with physical and radiation protection measures to an authorised waste manager.

5.3.2 Among wide range of unsealed radionuclides used for research purposes, ^{3}H and ^{14}C are long-lived isotopes handled in significant quantity (GBq). These result in low volume and high specific activity waste. Head of the user institution should be specifically responsible for control and safe management of such waste.

5.4 Surveillance and Monitoring

5.4.1 Safe radioactive waste management practices should include keeping radioactive releases from the various stages of operations to the minimum. As part of this activity, in-house monitoring of effluents should be carried out so that the respective releases are within authorised limits.

5.4.2 Radiological survey of waste package (i.e. plastic bag, drum or other container) should be conducted for:

(a) identification of an appropriate storage area;

(b) selection of treatment process;

(c) exposure control during handling of waste; and

(d) ensuring containment of the package.

5.4.3 Survey of a radioactive waste package should comprise measurement of:

(a) activity content (Bq/g) or dose rate (mSv/h) at a specified distance from packages/containers storing waste and waste storage area; and

(b) transferable surface contamination at all stages of its transfer from laboratory to the facility for treatment.

5.4.4 All waste packets should bear a neatly written label, inscribed with radiation symbol (trefoil), isotope content and its concentration (Bq/g, Bq/l) and total

activity (MBq), type of emitted radiation, radiation field measured (mSv/h). Periodic environmental monitoring of all the facilities such as medical cyclotrons, commercial radiopharmacy, etc., where the radioactive effluent discharge takes place should be carried out to ensure that radiation doses received by the public are within the authorised limits. Pre-operational monitoring should be carried out to establish the local background level of radiation.

5.4.5 Environmental monitoring programme should involve collection of environmental samples (for example water, air, soil) and measurement of their radiation and contamination levels. All potential radioactive release points should be monitored. Off-site monitoring should be necessary to demonstrate adequacy of the control over the release of radioactive materials to the environment. The off-site monitoring programme, which exists for the operational period of facility, may require modifications appropriate to the type and nature of operation. The requirements for on-site and off-site monitoring should be specified in operating manual of the facility.

6. QUALITY ASSURANCE PROGRAMME

6.1 General

A quality assurance (QA) programme defines the organisation, responsibilities, relevant performance standards and organisational interfaces. The objective of the programme is to provide a systematic, well-managed approach to ensure that all activities are conducted in a consistent manner, which meet regulatory requirements and ensure safety of workers, members of public and the protection of the environment. The basic responsibility for achieving quality in performing a task rests with those assigned the task. The aim of a QA programme for radioactive waste management is to ensure that all operations are optimally managed, waste disposal and discharges are within authorized limits and that packages of waste are produced in conformity with the specifications required for regulatory compliance. It also includes a system of document control and records to demonstrate that the required quality has been achieved, and initiate corrective action where required.

6.2 Quality Assurance Requirements

6.2.1 A QA programme for management of radioactive waste should be applicable to all activities including handling, segregation, characterization, treatment, conditioning, packaging, storage, transportation and disposal of radioactive waste. The programme should be developed by the user of radioactive material and reviewed by the AERB prior to the actual waste generation. The details of the QA programme should be commensurate with the extent and complexity of the activities giving rise to the waste and to its magnitude and potential hazards. The QA programme should ensure compliance with the conditions of authorisation for radioactive waste management.

6.2.2 At every stage of waste management, it is essential that all concerned persons should be aware of the overall waste management system; understand relevant operating procedures, associated hazards and relevant safety precautions. It is also important that waste management staff have an adequate understanding of the local and national radioactive waste management strategies. The responsibilities and authority of the personnel and organisation involved should be clearly defined.

6.2.3 A system of documents control and records should ensure evidence that the required quality has been achieved and should include operational and reporting procedures.

6.2.4 Training of personnel should be an integral part of the QA programme. The scope of the training programme should be commensurate with the size and complexity of the proposed operation. Training should include: fundamental and practical aspects of occupational health; safety and radiation protection; regulatory requirements; waste characterisation, including radiological, physical

and chemical properties; pre-treatment; treatment and conditioning; storage; and monitoring and transport. Site-specific requirements, license requirements, as well as the operating procedures for implementing the regulations should also be included. All personnel involved in the radioactive waste management operations whose performance may affect the safety should be trained to an appropriate level. Refresher training courses should be provided at appropriate intervals to reinforce quality control procedures.

6.2.5 The requirements and acceptance criteria for waste containers, and waste packages should also be included in the programme. Acceptance criteria for waste packages are set to ensure that the waste packages should be in an acceptable physical condition for their safe handling during storage or transport. Waste packages resulting from conditioning process, and intended for transfer to the interim storage facility should be permanently labelled with an identity code and a radiation trefoil. Packaging for interim storage should have acceptable physical stability and should be designed for safe handling. Drums and containers to be used as primary packages for transport should comply with the transport regulations.

6.2.6 A proper record of the waste package should be kept as part of the quality assurance programme. The minimum information for each individual package should include:

(a) origin of waste;

(b) identification number of the package;

(c) type and design details of the package and unloading documentation;

(d) weight of packages;

(e) external size and/or volume of the package;

(f) maximum dose rate at contact and 1 m from the surface of the package and date of measurement;

(g) result of surface contamination measurement;

(h) radionuclide and activity content;

(i) physical nature; and

(j) other associated hazards (such as potential pathogenic, chemical etc.).

6.2.7 Containers used for storage should be selected according to the chemical and radiological characteristics and the volume of the radioactive waste to be contained in them and should facilitate handling and storage requirements. The waste packages and containers should be inspected regularly for their integrity and accountability.

6.2.8 Instrument/equipment used for handling and radiological surveillance in the waste management operations, should comply with established QA procedures including regular calibration checks and preventive maintenance.

7. RESPONSIBILITIES AND DOCUMENTATION

7.1 General

Various agencies involved in the management of spent/disused radioactive sources and the radioactive waste arising from the use of radionuclides in medicine, industry and research are the supplier of the source, the waste generator (user), the authorized radioactive waste manager and the AERB. There is need for close coordination among all these agencies with the primary objective that radioactive waste does not cause undue hazard to the public and the environment. The preparation and maintenance of a comprehensive system for documentation and record keeping is an essential component of waste management system. In many instances, the local regulations govern the records that need to be preserved. Records need to be clear, legible, permanent and maintained up-to-date and readily available for future reference.

7.2 Supplier

The supplier of the radioactive material should have primary responsibility to take back the spent/disused radioactive sources supplied by him. For long-lived unsealed sources, the disused sources should also be accepted by their supplier. It is the responsibility of the supplier to devise an appropriate system and procedures to accept the sources and subsequent safe management so that such sources do not unnecessarily remain in public domain. The supplier should have an arrangement with the authorised waste manager for disposal of radioactive waste that cannot be disposed of by the supplier himself. This applies to local as well as foreign suppliers.

7.3 Waste Generator (User)

Waste generator in this context is the user who uses radioactive material and generates radioactive waste. As explained in 7.2, the user of sealed radioactive sources should have an agreement with the suppliers of such sources for the transfer of these sources on completion of their useful life or in case of any damage. It is the prime responsibility of the waste generator to obtain authorisation for the management of radioactive waste and to dispose off the waste as per the stipulated procedures approved by the AERB. The waste generator should have a well-defined waste management plan approved by the AERB. Disposal of long-lived sources poses a challenge as they continue to pose potential hazard even after outliving their useful lives. It is obligatory on the part of the waste generator that the facilities incorporating these sources are decommissioned in line with the guidelines from the AERB. Further, the waste generator should ensure that the spent/disused sources are properly decommissioned, packed and transported to the supplier without undue delay as per the transport regulations. For unsealed sources which are short lived,

the waste generator is responsible to dispose the waste at the local approved disposal sites and should make sure that the activity released to the environment does not exceed the authorized limits prescribed by AERB. In case of non-availability of approved disposal sites at the waste generator end, the radioactive waste should be transferred to the supplier or the authorised waste manager. If imported sources need to be transferred to an authorised waste manager, the waste generator should provide details of source removal technique from the source housing so that the agency is able to manage the waste effectively. The waste generator should in all cases ensure that the generation of radioactive waste is kept to the minimum practicable. It is the responsibility of the waste generator to submit a periodic report to AERB, in accordance with a schedule and format established by AERB, regarding waste management operations performed and of any safety related unusual occurrence during the reporting period.

7.4 Authorised Waste Manager

The authorised waste manager plays an important role in the management of radioactive waste. This agency should be authorized by AERB for management of radioactive waste and for receipt of decayed/disused sources. In case when the decayed sources could not be returned to the supplier for various reasons, the authorised waste manager should provide all help to accept the radioactive waste from the waste generator in the interest of public safety, when approached by the waste generator. The role of the authorised waste manager should include the following:

(a) to establish and implement a suitable waste management programme with appropriate quality assurance to ensure compliance with conditions of authorisation;

(b) to ensure that equipment and facilities are available to carry out the radioactive waste management activities in a safe manner;

(c) to ensure that the staff is adequately trained and have operational procedures available to perform their duties in a safe manner;

(d) to conduct safety and environmental impact assessment of the facility;

(e) to ensure monitoring of all concerned personnel;

(f) to report any discharges or releases exceeding the authorised limits promptly to AERB; and

(g) to notify AERB of incidents, events or accidents, if any.

7.5 Interactions of Waste Generator/Authorised Waste Manager with AERB

The waste generator and authorised waste manager should closely interact with AERB and obtain necessary authorisation/guidelines/clarifications as given below for safe management of radioactive waste:

(a) specific authorisation for the management of waste with terms and conditions of authorisation. These include on-site disposal of radioactive waste from short-lived sources;

(b) standards with respect to discharge of activity in the environment;

(c) guidelines with respect to decommissioning and transfer of waste to the supplier or authorised waste manager;

(d) compliance assurance programme including inspections of the waste management operations;

(e) remedial actions in the event of contravention of safety requirements; and

(f) updated waste management regulations, safety principles and requirements.

Waste management is governed in the country by Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987. Under these Rules, AERB approves on-site waste disposal facilities for disposal of unsealed sources, generally used in nuclear medicine and research applications. The Rules also provide for issuance of authorisation to the operators for the management of the waste.

7.6 Documentation Pertaining to Supply of Radioactive Sources

Supplier should maintain appropriate records relating to supply of radioactive sources to different users. The records should depict the name of the radionuclide, its physical and chemical form, and activity as on date, date of supply, mode of transport and date of receipt of the source(s) by the users. Records should also be maintained for the spent/ disused/ damaged sources received from various users. Any untoward incidents during transport and receipt of the sources should also be recorded. The records should also include the sources recycled or transported to the authorized waste manager.

7.7 Record Keeping by Waste Generator

Waste generator should keep records related to the radioactive waste management facility during commissioning, operation, upgrading or decommissioning. The documentation system should provide an integrated record of the waste from the time of generation through handling and treatment to storage and final disposal or transfer to authorised waste manager. separate records should be maintained for solid and liquid wastes. Discharge of radioactive waste into the environment should be recorded as per regulatory requirements. A systematic record of all the spent/disused sources transferred to the supplier or authorised waste manager should be maintained by the waste generator.

7.8 Record Keeping by Authorised Waste Manager

A suitable and comprehensive record keeping system should be developed for radioactive waste management activities. Information on waste inventories including waste received from waste generator should be properly recorded, updated (such as changes in waste characteristics during processing) and retained in such a way that relevant information is available in future. Details of history of disused sealed sources should be included in the inventory. The record system should allow for traceability of waste from the point of its collection through long-term storage and/or disposal. Periodic reports should be sent to the AERB with the following details:

(a) details of materials removed from the regulatory control, released or discharged to the environment including sealed sources;

(b) the current inventory of radioactive waste including waste received from waste generator, identification, origin, location, physical and chemical characteristics and a record of radioactive waste removed from the facility, if any;

(c) safety and environment assessment methods used;

(d) results of safety and environmental assessments;

(e) effluent and environmental impact monitoring results; and

(f) results of internal audits.

ANNEXURE-I

LIST OF UNSEALED RADIONUCLIDES USED IN MEDICAL APPLICATIONS*

Isotope	Half-life	Principal application	Waste characteristics	Mode of disposal
^{3}H	12.3 y	Clinical measurements, research, labeling	Solid, liquid (organic solvents HTO, HT)	Burial, dispersal, incineration
^{14}C	5.73×10^{3} y	Research, labeling, clinical measurements	Solid, liquid solvent, exhaled CO_2	Burial, dispersal, incineration
^{18}F	1.83 h	PET imaging	Solid, liquid	Delay and decay
^{24}Na	15.0 h	Clinical measurement	Liquid	Dispersal, delay and decay
^{32}P	14.3 d	Clinical therapy	Solid, liquid	Burial, dispersal, delay and decay
^{51}Cr	27.7 d	Clinical measurements	Mainly liquid	Dispersal
^{59}Fe	44.5 d	Clinical measurements,	Mainly liquid	Dispersal, delay and decay
^{57}Co	271 d	Clinical measurements	Solid, liquid	Burial, dispersal, delay and decay
^{58}Co	70.8 d	Clinical measurements	Solid, liquid	Burial, dispersal, delay and decay
^{67}Ga	3.26 h	Clinical measurement	Liquid	Dispersal, delay and decay
^{89}Sr	50.5 d	Clinical therapy	Mainly liquid	Burial, dispersal, delay and decay
^{90}Y	2.67 d	Clinical therapy	Mainly liquid	Burial, dispersal
^{99}Mo	2.75 d	Extraction of ^{99m}Tc	Mainly liquid	Delay and decay
^{99m}Tc	6.02 h	Clinical measurement	Solid, liquid	Delay and decay
^{111}In	2.83 d	Clinical measurement	Solid, liquid	Burial, dispersal
^{125}I	60.1 d	Clinical measurement, labeling	Solid, liquid, occasionally vapour	Burial, dispersal, delay and decay, absorption on charcoal
^{131}I	8.04 d	Clinical measurement, therapy	Solid, liquid, occasionally vapour	Burial, dispersal, delay and decay, absorption on charcoal

ANNEXURE-I (CONTD.)

LIST OF UNSEALED RADIONUCLIDES USED IN MEDICAL APPLICATIONS*

Isotope	Half-life	Principal application	Waste characteristics	Mode of disposal
^{153}Sm	46.7 h	Clinical therapy	Liquid	Delay and decay
^{166}Ho	26.8 h	Clinical therapy	Liquid	Delay and decay
^{169}Er	9.4 d	Clinical therapy	Liquid	Delay and decay
^{186}Re	90.6 h	Clinical therapy	Liquid	Delay and decay
^{201}Tl	3.04 d	Clinical measurements	Mainly liquid	Burial, dispersal, delay and decay

* Activity used for application as per the guidance levels given in the IAEA Basic Safety Standard, 115

ANNEXURE-II

LIST OF SEALED RADIONUCLIDES USED IN MEDICAL APPLICATIONS

Application	Radionuclide	Half-life	Source activity	Comments
Bone densitometry	^{241}Am	432 a	1-10 GBq	Mobile units
	^{153}Gd	242 d	1-40 GBq	
	^{125} I	60.1 d	1-10 GBq	
Manual brachytherapy	^{198}Au	2.7 d	50-500 MBq	Small portable sources
	^{137}Cs	30.0 a	30-300MBq	
	^{226}Ra	1600 a	50-500 MBq	
	^{60}Co	5.3 a	50-1500 MBq	
	^{90}Sr	29.1 a	50-1500 MBq	
	^{103}Pd	17.0 d	50-1500 MBq	
	^{125}I	60.1 d	200-500 MBq	
	^{192}Ir	74.0 d	5-100 MBq	
	^{106}Ru	1.01 a	10-20 MBq	
	^{90}Y	2.7 d	50-500 MBq	
Vascular brachytherapy	^{32}P	14.3 d	200 MBq	Catheterisaion
	^{89}Sr	50.5 d	150 MBq	
	^{192}Ir	74 d	0.1-1 TBq	
Remote after-loading brachy therapy	^{137}Cs	30.0 a	0.03-10 MBq	Mobile units
	^{192}Ir	74.0 d	0.1-200 TBq	
Teletherapy	^{60}Co	5.3 a	50-1000 TBq	Fixed installations
	^{137}Cs	30.0 a	500 TBq	
Whole blood irradiation	^{137}Cs	30.0 a	2-100 TBq	Fixed installations
	^{60}Co	5.3 a	50-1000 TBq	
Research	^{60}Co	5.3 a	Up to 750 TBq	Fixed installations
	^{137}Cs	30.0 a	Up to 13 TBq	
Calibration Sources Anatomical Markers	^{63}Ni	96 a	<4 MBq	Fixed installations in instruments or mobile
	^{137}Cs	30.0 a	<4 MBq	
	^{57}Co	271 d	Up to 400 MBq	
	^{226}Ra	1.6 ´ 10^3 d	<10 MBq	
Sources as standards in instruments	^{147}Pm	2.62 a	<4 MBq	Sources
	^{36}Cl	3.01 ´ 10^5 a	<4 MBq	
	^{129}I	1.57 ´ 10^7 a	<4 MBq	
Gamma radiosurgery knives	^{60}Co	5.3 a	Up to 220 TBq	Skull cap

ANNEXURE-III

LIST OF SEALED AND UNSEALED RADIONUCLIDES USED IN INDUSTRIAL APPLICATIONS

Radionuclide	Sealed source application	Tracer application	Other applications
^{3}H	Foil thickness measurements	Water movement	Luminous articles and electronic valves
^{32}P	Foil thickness measurements	Agriculture	
^{35}S, ^{45}Ca		Agriculture	
^{41}Ar			Leak testing and gas movement
^{46}Sc			Silt movement
^{57}Co	Check sources		Occasionally in electronic valves
^{60}Co	Industrial radiography, gauging, well logging, radiation processing		
^{63}Ni	Foil thickness measurements		
^{82}Br		Water movement and leak testing	
^{85}Kr	Gauging		Occasionally in electronic valves
^{90}Sr	Thickness gauging		
^{137}Cs	Industrial radiography		
^{147}Pm			Luminous paint
^{140}Ba-^{140}La	Neutron sources	Steel slag	
^{144}Ce-^{144}Pr	Neutron sources		
^{192}Ir, ^{170}Tm	Industrial radiography		
^{226}Ra with Be	Neutron sources		Activation and other studies
^{227}Ac with Be	Neutron sources		Activation and other studies
^{210}Po, ^{239}Pu	Neutron sources		Activation and other studies
^{241}Am	Foil thickness measurements		Smoke detectors
^{203}Hg		Hg recovery	

ANNEXURE-IV

RADIOACTIVE WASTE ARISING FROM THE USE OF RADIONUCLIDES

IV.1 General

Radionuclides in sealed and unsealed form have various applications in medicine, industry and research, with activity ranging from few kBq to several PBq and half-lives varying from few seconds to several years. During the process of application, radioactive waste is generated in solid, liquid and gaseous forms. Other forms of waste could be articles contaminated with radioactive material and defective equipment containing radioactive material. In some applications, the waste may arise due to the decay of activity when useful life of the source has ceased or due to the decontamination process carried out at the workplaces. The radioactive content present in the waste may be low or high. Therefore, the handling and management of waste generated during these applications needs to be carried out in an appropriate manner. In applications, involving sealed sources, the spent or unused sources need to be properly accounted for and disposed of in a safe manner by either transporting them to the original supplier or to an approved waste management agency.

IV.2 Medical Applications

Radionuclides are used for diagnostic and therapeutic purposes in health care industry. This includes in-vivo nuclear imaging with radiopharmaceuticals, radiotherapy, and use of radionuclides for new diagnostic investigations and treatment planning. The radionuclides used range from very low activity short-lived unsealed sources to highly radioactive long-lived sealed sources in heavily shielded assemblies. Most commonly used radionuclides are elisted in Annexure-I.

IV.2.1 Unsealed Sources

IV.2.1.1 Diagnostic Applications

Aqueous-based radionuclides in kBq quantities are used in in vitro applications to measure levels of drugs or hormones in biomedical samples mixed with the required radiopharmaceuticals. Although the half-lives of some of the radionuclides used are long, the radiations emitted are weak in energy. The quantity of radionuclides incorporated in this practice ranges from 400 kBq to 800 MBq and the entire activity becomes radioactive waste at the end of the experiment.

Some of the diagnostic *in vivo* investigations are imaging and non-imaging types. In-vivo imaging investigation of body/organ functions is carried out by tracing the administered radiopharmaceutical with the help of gamma ray spectrometer or with the help of gamma camera, SPECT, PET. The *in vivo* non-imaging investigations are carried out to study functional status of organs either by measuring organ uptake and clearance rate of radiopharmaceutical from the organ or measuring dilution factor of radioactivity. The half-life of radionuclides administered in patients for both these applications is relatively short and varies from a few hours to a few days. Majority of the radiopharmaceuticals used for in-vivo application are prepared by labelling them with short-lived ^{99m}Tc, which is eluted from in-house ^{99}Mo-^{99m}Tc generators. The activity in such applications is retained largely in the patient's body for a few days after which it gets cleared out of the body. The radioactive waste arising from the applications comprises of injection syringes, needles, cotton swabs, laboratory glassware which may be contaminated with the administered radiopharmaceutical. The spent ^{99}Mo-^{99m}Tc generators end up as solid radioactive waste.

Cyclotron produced positron emitting radionuclides are being widely used to get important oncological information. The most commonly used radionuclide among them is ^{18}F, which has comparatively longer half-life than the others. The other radionuclides are ^{11}C, ^{13}N and ^{15}O and the quantity that may be administered for an investigation is up to 2 GBq. The radiation associated with these radionuclides is 0.511 MeV photons emitted in annihilation process. Since these radionuclides have very short half lives ($T_{½}$ = 2 to 110 minutes) as compared to other radionuclides, handling and disposal of waste generated is relatively simple.

IV.2.1.2 Therapeutic Applications

Various types of unsealed radionuclides are used in therapeutic applications and the activity administered to the patient is much higher than that used in diagnosis. ^{131}I is a widely used radionuclide in the treatment of thyrotoxicosis, hyperthyroidism, cancer thyroid and neuroblastoma. Administered activity to individual patient is typically in the range of 200 MBq to 11 GBq. ^{131}I is available in two physical forms - liquid and powder. The liquid sodium iodide is supplied for both oral administration and injection whereas the powder filled in gelatine capsules are provided as individual oral dose. Thyrotoxicosis patients are treated as outpatient, whereas the patients treated for cancer thyroid and neuroblastoma are hospitalised in isolation until external radiation level at 1 m from the patient is less than 5 μSv/h. In iodine therapy major waste arises from the excretion of radioactivity in urine. This waste is generally managed by providing a special facility (delay tanks) in the hospital for collection and storage for decay. The activity in waste is allowed to decay to authorised limits before discharging with dilution from inactive effluents from the hospital before release into the municipal sewage system.

In certain therapeutic applications, such as administration of ^{131}I-MIBG (meta-iodo benzyl-guanidine), radiopharmaceutical is diluted with sterile isotonic saline prior to administration. Such practices increase the volume of the waste and result in generation of additional solid radioactive waste e.g. saline bottles etc. in addition to other waste discussed above.

Other uses of unsealed radiopharmaceuticals in therapy involve injection of a sterile and undiluted solution of the radionuclides. Radioactive waste in these practices arises only from the decayed or unused sources.

High-energy beta emitting radionuclides such as ^{166}Ho, ^{186}Re and ^{188}Re in liquid form (in 5 – 10 ml volume) are used in angio-balloon therapy, where activity in the range of few MBq is loaded in the balloon. The whole radioactivity loaded in balloon comes out as radioactive waste.

IV.2.2 Sealed Sources

IV.2.2.1 Diagnostic applications

The common diagnostic practices, using sealed sources, include measurement of bone density, anatomical marking, etc. In addition, there are reference and calibration sources used for testing the performance/quality of instruments meant for diagnostic investigations. ^{241}Am, ^{153}Gd or ^{125}I are used in bone density scanner and the activity levels are up to several GBq. The activity used in anatomical markers, calibration and reference sources is very small. All these sealed sources become solid radioactive waste for disposal at the end of their useful life.

IV.2.2.2 Therapeutic Applications

Several beta and beta-gamma emitting radionuclides in sealed form are used in clinical treatment such as for brachytherapy, teletherapy, gamma knife, blood irradiation, etc. These sources are of high activity and are properly shielded. These sources demand foolproof safety and security after their useful life till they are safely disposed. The decayed sources are returned to the supplier for safe disposal. However, if the sources are not in use for a long time, these should be returned to the supplier for security/safety purposes. Also, a proper accounting of all sources received and decayed sources returned to the supplier is very essential in order to ensure the safe disposal and to ensure safety and security of such high activity sources.

IV.3 Industrial Applications

A wide variety of radionuclides are used for various types of industrial applications viz. preservation by radiation processing, improving the quality of products, etc. Depending upon the type of application, radionuclides are used either in sealed form or in unsealed form as radiotracers. The activity of

the radionuclide with short half-lives used as tracers is of the order of a few MBq to a few TBq whereas the activity of sealed sources with longer half-lives used in other industrial applications may vary from a few MBq to several PBq.

IV.3.1 Unsealed Source Applications

IV.3.1.1 Radiotracer Applications

There are a number of industrial applications in which small activities of the radionuclides are in unsealed forms. The most important tracer applications include leak detection in buried pipelines, study of process parameters in chemical process, sediment transport studies in ports and harbours, management of oil well reservoir and oil recovery efficiency, hydrological investigations such as ground water studies, seepage in dams and canals, measurement of flow rate etc. The activity of radionuclides used as tracer depends upon the type of application and the maximum permissible concentration from the radiological safety standpoint.

During the use of these radiotracers, adequate care is to be taken to avoid spillage and to minimize generation of waste. The radioactive waste generated may be in form of contaminated articles used in the studies; most of the activity used in the studies gets diluted and dispersed in the environment.

IV.3.1.2 Consumer Products

Self luminous paints and bulbs containing minute quantity of radioactive materials such as ^{147}Pm, ^{3}H in gaseous form, are used in consumer products such as watches, alarm clocks, indicator sign boards, tube light starters, etc. In addition, ^{232}Th of low specific activity is coated on gas mantles for increasing the brightness.

The quantity of radioactive material used in consumer products is so small that they do not pose any radiation hazard to the user. Further, quality assurance programme followed by manufacturer of such products is under strict regulatory control, which ensures total radiological safety. Hence, the disposal of these consumer products is not of very serious concern. However, if a very large number of such devices need to be disposed off, proper guidance from the AERB is required.

IV.3.2 Sealed Source Applications

The major areas in which radionuclides are used in sealed form are as follows:

- Non-destructive testing of castings and weldings and other industrial products by gamma radiography technique.

- Nucleonic gauges for level control of liquids and other materials in closed columns, thickness, density and composition measurement, soil moisture and density gauges, well logging tools for oil well exploration studies and mining industries.
- Smoke alarms, static charge eliminators, pollution monitoring instruments and other such devices.
- Gamma irradiation for radiation processing of food products and sterilisation of medical products.

Among the above four major applications, industrial radiography sources assume prime importance because a large number of these sources are used in the open (construction sites/ workshops) and the radiography sources are frequently moved from one site to the other.

IV.3.2.1 Gamma Radiography

^{192}Ir and ^{60}Co are the two of the most widely used gamma radiography sources in industries. Other gamma radiography sources such as ^{170}Tm, ^{75}Se and ^{137}Cs are also used to a limited extent. The activity of ^{192}Ir and ^{60}Co radiography sources is generally in the range of 37 GBq to 370 GBq and in some cases higher activity sources are used. The decayed radiography sources are returned to the supplier for safe disposal. However, if the gamma exposure devices are not in use for a long time, these should be returned to the supplier for security/ safety of the radiation source. Also, a proper accounting of all sources received and decayed sources returned to the supplier is very much essential in order to ensure not only the safe disposal of radiography source but also safety and security of all industrial radiography sources.

IV.3.2.2 Nucleonic Gauges and Consumer Products

Devices incorporating radionuclides such as ^{60}Co, ^{137}Cs, ^{204}Tl, ^{90}Sr, ^{147}Pm, ^{85}Kr, ^{241}Am are used in large numbers in industries as level gauges, thickness, density and composition gauges, gamma scanning, radiometry and also for the measurement and monitoring of various important parameters related to various types of industrial products. In addition, devices incorporating isotopic neutron sources (^{241}Am-Be) and gamma sources (^{137}Cs) are used for the measurement of moisture content and density of soil and also for oil well exploration studies. A vast majority of the radionuclides used in these applications are of installed type while a few of them such as soil moisture/ density gauges, gamma scanning and radiometry sources are of portable type. The activity of the sources used in nucleonic gauges vary from few MBq to TBq and the half lives of the radionuclides used in these applications are fairly long and hence do not need frequent replacements.

Consumer products such as smoke alarms, static charge eliminators, pollution

monitors and other such devices use very low activity sources generally in the range of a few kBq. The decayed/ damaged/unused sources, resulting from these applications should be returned to the supplier for safe disposal.

For applications involving use of Am-Be neutron sources, due to their long half-life, proper care should be taken for their safe disposal at the authorised waste manager.

IV.3.2.3 Gamma Irradiators

The use of gamma radiation for radiation processing of food products and sterilisation of surgical items and other such medical products is also one of the most important industrial applications. Since the radiation dose to be delivered to the products is very high (10-25 kGy), very large activity (upto 40 PBq) of gamma emitting radionuclides such as ^{60}Co or ^{137}Cs are used in such irradiation plants. The decayed sources are returned to the supplier for safe disposal. The sources used in such applications are generally stored under a water pool and hence the muck and the pool water need to be monitored periodically prior to disposal.

IV.4 Research Applications

Wide ranges of unsealed and sealed radionuclides are used in research in health care, biological studies, agriculture centres and pharmaceutical development facilities. The range of radionuclides used in biomedical research is much wider than those used in diagnostic and therapeutic practices but the content of radioactivity in labelled compound is low.

In research application, the total quantity of radionuclide used comes out as a waste. The half-life of radionuclides may vary from few days to several years. The radioactive content in the waste may range from a few kBq to a few MBq and the radiation involved may be low energy beta to moderate energy neutrons. The physical form of waste generated is solid, liquid, gas, carcasses, excrement etc.

IV.5 Associated Practices

IV.5.1 Decontamination Process

The tools, equipment, glassware, medical equipment and facilities used in handling radioactive materials in hospitals, research and industries may sometimes get contaminated and require immediate decontamination giving rise to radioactive waste in liquid or solid form. While working with radioactive liquids, it may happen that the solution spills accidentally. In order to contain the spillage and to avoid spread of contamination, the area needs to be decontaminated immediately. The articles with permanent or fixed contamination with long-lived radionuclide e.g. work tables, tools, laboratory wares, fixtures

and swabs used for testing leakage of sealed sources, etc. should also be discarded as radioactive waste.

IV.5.2 Decommissioning of Facilities

Decommissioning of facilities handling large quantity of radioactive materials, generate contaminated building materials. The metal machine parts, infrastructures of beam lining and collimators get induced radioactivity during production of radionuclides. In case of medical cyclotron facility, concrete shielding around the cyclotron gets activated with Europium activity while producing ^{201}Tl with external targets. This activation in concrete has been reported up to 70 cm depth. The iron reinforcement bars in concrete get activated with ^{60}Co to more than 10 kBq/kg. ^{3}H, the less important radionuclide is also formed due to activation in the operation of cyclotron and the concentration may be more than 10 Bq/g. Thus, the cyclotron facility could present a decommissioning problem and generate a considerable volume of metal and concrete waste containing some activation products. Wherever practicable, decommissioning should be deferred for decay until clearance levels are met, in order to reduce or prevent waste management costs.

IV.6 Mixed Waste

The radioactive waste generated may, sometimes also bear non-radiological hazards such as of pathogenic, infectious or toxic nature. The radioactive waste containing such a mixed hazard should be categorised and treated in an appropriate manner.

BIBLIOGRAPHY

1. International Atomic Energy Agency, Management of Waste from the Use of Radioactive Material in Medicine, Industry Agriculture, Research and Education, IAEA Safety Guide No. WS-G-2.7, Vienna (2005).
2. International Atomic Energy Agency, Management of Waste from the Use of Radioactive Material in Medicine, Industry, Agriculture, Research and Education, Safety Guide, Safety Standard Series No. WS-G-2.7, Vienna (2005).
3. International Atomic Energy Agency, Handling ands Processing of Radioactive Waste from Nuclear Applications, IAEA Technical Report Series No. 402, Vienna (2001).
4. International Atomic Energy Agency, Management of Radioactive Waste from Use of Radionuclides in Medicine, IAEA-TECDOC-1183, Vienna (2000).
5. International Atomic Energy Agency, Decommissioning of Medical, Industrial and Research Facilities, IAEA Safety Standard Series, Safety Guide WS-G-2.2, Vienna (1999).
6. International Atomic Energy Agency, Clearance of Materials Resulting from Use of Radionuclides in Medicine, Industry and Research, IAEA-TECDOC-1000, Vienna (1998).
7. International Atomic Energy Agency, International Labour Organisation, OECD Nuclear Energy Agency, an American Health Organisation, World Health Organisation, International Basic Safety Standards for Protection against Ionising Radiation and for the Safety of Radiation Sources, Safety Series No. 115, Vienna (1996).
8. Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987.
9. Atomic Energy (Radiation Protection) Rules, 2004.
10. Atomic Energy Regulatory Board, Safety Code for the Transport of Radioactive Materials, AERB/SC/TR-1, 1986.
11. Atomic Energy Regulatory Board, Safety Code on Management of Radioactive Waste, AERB/NRF/SC/RW, 2007.
12. Atomic Energy Regulatory Board, Safety Code on Nuclear Medicine Facilities, AERB/SC/MED-4/Rev.1, 2001.

LIST OF PARTICIPANTS

EXPERT COMMITTEE FOR THE PREPARATION OF SAFETY GUIDE (ECSGRW-6)

Dates of meeting	:	September 26, 2002	February 01, 2003
		October 16, 2002	March 28, 2003
		October 25, 2002	April 10, 2003
		November 15, 2002	May 28, 2003
		December 09, 2002	May 29, 2003
		January 03, 2003	July 12, 2003
		January 13, 2003	August 25, 2003
		January 21, 2003	October 09, 2003
		January 25, 2003	January 2004

Members of ECSGRW-6

Dr. Gursharan Singh (Chairman)	:	BARC
Shri Mahesh Chander	:	BARC (Former)
Shri S.P. Agarwal	:	AERB
Shri V.G.R. Subramanian	:	BRIT (Former)
Shri N. Swaminathan	:	BARC
Shri K.V.S. Sastry (Co-opted)	:	BRIT
Shri P.K. Gaur (Co-opted)	:	BARC (Former)
Shri M.V. Surendernath (Co-opted)	:	BARC (Former)
Smt. M.V. Inamdar (Member Secretary)	:	AERB

ADVISORY COMMITTEE FOR PREPARATION OF SAFETY DOCUMENTS ON RADIOACTIVE WASTE MANAGEMENT (ACSDRW)

Dates of meeting	:	January 8 & 9, 2004 October 21, 2002 April 15, 2003 April 28, 2003 August 13, 2003 June 4, 2004 July 27, 2004

Members and Invitees of ACSDRW:

Shri K. Balu (Chairman)	:	BARC (Former)
Shri P.D. Sharma	:	NPC (Former)
Shri A.R. Sundararajan	:	AERB (Former)
Shri S. Sankar	:	BARC (Former)
Shri N.K. Bansal	:	BARC (Former)
Shri S.S. Ali	:	BARC (Former)
Shri P.M. Gandhi	:	BARC
Shri M.L. Joshi	:	BARC
Shri R.C. Rastogi	:	BARC (Former)
Shri K.K. Chandraker	:	AERB (Former)
Dr. S.K. Gupta	:	AERB
Shri S. Vedamurthy	:	NPC (Invitee)
Dr. P. Vijayan (Member Secretary)	:	AERB

ADVISORY COMMITTEE ON NUCLEAR SAFETY (ACNS)

Date of meeting : November 20, 2006

Members and Invitees of ACNS:

Shri G.R. Srinivasan (Chairman)	:	AERB (Former)
Shri S.C. Hiremath	:	HWB (Former)
Shri D.S.C. Purushottam	:	BARC (Former)
Shri A.K. Anand	:	BARC (Former)
Shri H.S. Kushwaha	:	BARC
Shri R.K. Sinha	:	BARC
Shri S.S. Bajaj	:	NPCIL (Former)
Prof. J.B. Doshi	:	IIT, Bombay
Shri S. Krishnamony	:	BARC (Former)
Dr. S.K. Gupta	:	AERB
Shri K. Srivasista (Member-Secretary)	:	AERB

PROVISIONAL LIST OF SAFETY CODE AND GUIDES ON RADIOACTIVE WASTE MANAGEMENT

Safety Series No.	Title
AERB/NRF/SC/RW	Management of Radioactive Waste
AERB/SG/RW-1	Classification of Radioactive Waste
AERB/NRF/SG/ RW-2	Pre-disposal Management of Low and Intermediate Level Radioactive Waste
AERB/SG/RW-3	Pre-disposal Management of High Level Radioactive Waste
AERB/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 Pressurized Heavy Water Reactor Based Nuclear Power Plants

AERB SAFETY GUIDE NO. AERB/RF/SG/RW-6

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

BCS