Radioactive Waste Management in the Operation of a Research Reactor

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Contents

- Introduction
- Management of radioactive waste
- Programme for the management of radioactive waste
- The nature and the amount of generated waste
- Gaseous radioactive waste
- Liquid radioactive waste
- Solid radioactive waste
- Classification of radioactive waste
- Handling of radioactive waste
- Radioactive waste storage management

Introduction

- The management of radioactive waste is subjected to the requirements of the IAEA Safety Standard SSR-3;
- Requirement 85 of SSR-3:
  - "*The operating organization for a research reactor facility shall establish and implement a programme for the management of radioactive waste*"

Management of radioactive waste

The operating organization needs to include provisions such as:

- To ensure that any radioactive waste generated in kept to the minimum practicable in terms of both activity and volume;
- Maintain an inventory of all radioactive waste that is generated, stored, transferred or disposed;
- Ensure that radioactive waste is managed in accordance with the requirements of national regulatory authority and the requirements of applicable IAEA standards, and in accordance with the relevant authorization;
- Establish a programme for the management of radioactive waste.

Programme for the management of radioactive waste

Elements of a radioactive waste management programme at a research reactor:

- Keeping the generation of radioactive waste to the minimum practicable;
- Possible reuse and recycling of materials;
- Appropriate classification and segregation of waste;
- Collection, characterization and safe storage of radioactive waste;
- Adequate storage capacity for the radioactive waste expected to be generated;
- Ensuring that radioactive waste can be retrieved at the end of the storage period;
- Pre-treatment, treatment and conditioning of radioactive waste to ensure safe storage and disposal;
- Safe handling and transport of radioactive waste;
- Adequate control of discharges;
- Monitoring of sources and environment;
- Maintaining facilities and equipment for the collection, processing and storage of waste;

Programme for the management of radioactive waste (cont'd)

Elements of a radioactive waste management programme at a research reactor:

- Initiating , as necessary, research and development activities to improve existing methods for processing radioactive waste or to implement new techniques;
- Adopting and implementing corrective actions on the basis of the results of monitoring.

The nature and the amount of generated waste

Gaseous, liquid and solid radioactive waste is generated in various types and amounts from the operation of research reactors. The nature and the amount of such waste depend on factors such as:

- Type of research reactor;
- Specific design features;
- Operating procedures and practices;
- Irradiation of various targets, including those for radioisotopes production and neutron activation analysis;
- Maintenance programme;
- Modifications to the facility, lifetime extension activities;
- Refuelling and operational occurrence;
- Operational history of the facility;
- Integrity of the fuel.

Gaseous radioactive waste

Typical sources of gaseous radioactive waste generated during the operation of research reactors include the following:

- Gaseous radioactive elements or compounds from the pools, coolant systems, irradiation facilities and experimental facilities;
- Airborne radioactive material produced in ancillary facilities, including fume cupboards and decontamination areas.

Measures to keep the generation of gaseous radioactive waste to the minimum

- Levels of coolant impurities should be kept as low as practicable;
- Pools with exposed water surfaces should be designed to inhibit the migration of gases to the surface;
- Maintenance activities should be carefully planned to reduce the possibility of leakage of gaseous waste;
- Irradiation facilities and targets that use a gaseous coolant and transfer medium should use a pure gas with low activation properties such as nitrogen or helium;
- The areas with potential for the generation of gaseous waste should have provisions for the renewal of air and its purification through filters.

Liquid radioactive waste

Typical sources of liquid radioactive waste generated during the operation of research reactors include the following:

- Cooling water blow down;
- Primary system drains;
- Liquid waste from the demineralized water plant;
- The drain of the ventilation system;
- Demineralized waste water recovered from the drainage of large equipment in maintenance operations;
- Washbasin and shower liquids;
- Floor drain liquids;
- Liquids from laboratories (these can be radioactive or non-radioactive);
- Liquids from decontamination cells and biological shield cooling.

Measures to keep the generation of liquid radioactive waste to the minimum

- The proper selection of reactor materials;
- Reducing leakage from various systems;
- Chemical adjustment of the coolant to avoid activation, corrosion and deposits;
- Planning and performing maintenance work with due care to avoid the spread of contamination;
- Taking precautions to avoid contamination of equipment and building surfaces to reduce the need for decontamination;
- Optimizing decontamination procedures;
- Reducing the production of secondary waste by the appropriate selection of waste processing methods.

Solid radioactive waste

Typical sources of solid radioactive waste generated during the operation of research reactors include the following:

- Irradiated target cans;
- Used irradiation rigs and reactor components;
- Neutron beam guide tubes;
- Non-fuel components discarded from the spent fuel assemblies and control rods;
- Defective/damaged core components like control rods;
- Waste arising from the pool service area;
- Ventilation system waste (e.g. charcoal filters, HEPA filters);
- Spent ion exchange resins;
- Cleaning materials and used personal protective items;
- Laboratory waste (e.g. gloves, shoe covers, tissue paper, disposable glassware, discarded neutron activation foils);
- Contaminated items arising from maintenance and other works.

Measures to keep the generation of solid radioactive waste to the minimum

- Careful planning and performance of maintenance work;
- Careful control of the packaging and handling of radioactive material;
- Efficient operation of processing systems for gaseous and liquid radioactive waste;
- Effective procedures for the control of contamination;
- Effective methods of decontamination;
- Adopting good segregation practices;
- Selection of materials, and reuse and recycle of materials wherever possible;
- Use of low active and short lived radioactive sources for testing purposes;
- Timely return of disused radioactive sources to the supplier.

Classification of radioactive waste

- The classification of radioactive waste assists in the development of operational management strategies and in the implementation of the radioactive waste management programme at research reactors;
- Segregation of waste with different properties is helpful in conditioning, storage, transport and disposal of waste;
- To appropriately segregate waste and determine the arrangements for waste management, it is necessary to know:
    a) Its origin, criticality and radiological properties;
    b) Its physical, chemical and biological properties;
    c) The intended methods of processing, storage and disposal.

Classification of radioactive waste (cont'd)

- According to physical properties:
  a) Gaseous radioactive waste;
  b) Liquid radioactive waste;
  c) Solid radioactive waste.

Classification of radioactive waste (cont'd)

- According to activity:
  a) Low level;
  b) Intermediate level;
  c) High level waste.

- According to half life of radioactive decay:
  a) Temporary;
  b) Short lived;
  c) Long lived.

Handling of radioactive waste

- Radioactive waste should be treated by:
  - Changing its physical or chemical properties;
  - Enclosure in a container.

- Packaging and confinement of radioactive waste should be carried out in such a way as to ensure:
  - Safe transport;
  - Safe storage;
  - Stable disposal thereof.

Handling of radioactive waste (cont'd)

- Radioactive waste may need special handling to take account of other hazardous properties such as:
  - Toxicity;
  - Flammability;
  - Explosiveness;
  - Spontaneous fission and formation of critical mass;
  - Residual heat removal.
- Transport of radioactive waste :
  - Appropriate procedures and arrangements should be followed for the on-site movement of radioactive waste;
  - For transport off site, regulatory requirements need to be satisfied.

Handling of radioactive waste (cont'd)

The potential for migration or dispersion of radionuclides in radioactive waste should be minimized and external dose rate should be limited by:

- Providing appropriate processing areas;
- Following and applying documented procedures relevant to the type of waste, its handling and treatment requirements and its packaging and disposal requirements;
- Complying with national and international guidelines.

Requirements for facilities for radioactive waste management

- The facilities used in radioactive waste management should enable:
  - Collection and storage of radioactive waste;
  - Good accessibility for maintenance, repairs and easy decontamination;
  - Prevention of radioactive waste release, and collection and return of any release.

- The facilities should allow for the verification of correct functioning of the process by measurement of parameters;
- The facilities should be capable of withstanding the effects of a potential explosion or fire.

Radioactive waste storage management

- Management of radioactive waste involves storage for various reasons such as:
  - Operational demands (e.g. initial decay, batch processing);
  - Unavailability of suitable disposal facilities.
- During storage consideration should be given to:
  - Maintaining the waste package specification over time (ageing and sealing of packages);
  - Identification, inspection, handling, retrieval;
  - Criticality safety;
  - Provision of cooling (if necessary)
  - Provision of ventilation.

Requirements for radioactive waste storage facilities

- Radioactive waste storage facilities should be adequately located, designed, constructed, operated, secured and maintained to allow for safe custody of the waste packages;
- Waste storage facilities should provide for the protection of persons, property and the environment against the radiological hazards associated with radioactive waste;
- The location, design, construction, operation and maintenance of storage facilities should show conservative characteristics;
- Ventilation systems should be in place to ensure a clean work area.

Administrative requirements for radioactive waste storage

- Documented procedures should be followed to:
  - Ensure that short lived radioactive waste is stored;
  - Ensure proper use of storage containers;
  - Periodically inspect and monitor the waste;
  - Ensure the integrity of the waste package.

- Other requirements of the radioactive waste storage:
  - Provision of means to avoid overfilling;
  - Provision of pumps to empty the storage tanks;
  - Leak proof walls and floor;
  - Protection against adverse weather conditions, etc.

Processing of radioactive waste at Research Reactors

- The purpose of processing is to produce a waste product that meets the acceptable criteria for disposal;
- Radioactive waste should be processed:
  - In accordance with established procedures;
  - As early as practicable to reduce the likelihood of its dispersal.

Processing of radioactive waste at Research Reactors (cont'd)

- General consideration relating to processing radioactive waste include:
  - Limitation of the external and internal exposure of the workers;
  - Avoidance of fires and explosions;
  - Minimization of the leakage of liquid waste;
  - Minimization of releases of volatile or airborne radionuclides;
  - Presentation of criticality.

Monitor and treatment of airborne releases

- The air within the reactor building can become contaminated due to:
  - The leakage of gases or vapours;
  - The re-suspension of fine particulate material of surface contamination;
  - The fine particulate material being handled in the facilities;
  - Generation of particulates due to grinding or abrasive operations.
- Treatment methods, continuous or according to monitoring result, include the following:
  - Filtration for particulate and aerosol material;
  - Adsorption for volatile species;
  - Storage and decay.
- Provision of redundant systems where safety/ reliability are important.

Monitor and treatment of airborne releases (cont'd)

- The off-gas systems may contain significant amounts of radioactive contamination;
- Off-gas treatment may include:
  - Storage for radioactive decay;
  - Adsorption and filtration;
  - Other chemical and physical cleaning methods.
- Design of gaseous waste treatment systems should be informed by safety assessment;
- Influence of modifications and new experiments on the types and amounts of gaseous radioactive waste should be considered;
- Used filters and sorption beds should be handled carefully to prevent dispersion of trapped radioactive substances;
- Continuous monitoring of exhaust systems to ensure no release to environment takes place beyond the stipulated levels.

Processing of liquid radioactive waste at Research Reactors

- In the processing of liquid waste, consideration should be given to:
  - The amount of waste to be treated;
  - Radionuclides present;
  - Activity concentrations;
  - Concentrations of particulates;
  - Chemical compositions;
  - Possible presence of corrosive substances.
- In selecting a processing option, consideration should be given to:
  - Exposure, generation of secondary waste, mixing of streams, cross contamination, chemical compatibility, recycling etc ….

Processing of liquid radioactive waste at Research Reactors (cont'd)

- Methods for the treatment of liquid radioactive waste include:
  - Evaporation;
  - Chemical precipitation;
  - Ion exchange;
  - Centrifugation;
  - Filtration, ultrafiltration;
  - Incineration;
  - Reverse osmosis.
- If the waste contains fissile material, the potential for criticality should be evaluated and eliminated;
- Spent ion exchange resins are usually managed as liquid waste;
- Discharged liquids should be readily dispersible in water.

Application of volume reduction techniques

- The treatment of radioactive waste may include:
  - Reduction in volume of the waste (e.g. compaction);
  - Removal of radionuclides;
  - Change of form or composition;
  - Change of the properties of the waste.
- Incineration of combustible solid radioactive waste normally achieves the highest volume reduction.

Application of volume reduction techniques (cont'd)

- Compaction is a suitable method for reducing the volume of certain types of waste;
- Segmentation or disassembly and other size reduction techniques may be used before conditioning waste;
- For non-combustible and non-compressible solid waste, direct conditioning should be considered.

Packaging of radioactive waste

- Radioactive waste arising from the operation of research reactors should be packaged to:
  - Provide an appropriate degree of confinement;
  - Minimize the potential for migration or dispersion of radionuclides;
  - To limit the external dose rate associated with the package.
- The waste package should be suitable for:
  - Safe handling and transport;
  - Storage and disposal;
  - Satisfying the respective acceptance criteria.

Packaging of radioactive waste (cont'd)

- Liquid waste is often solidified after concentration in a suitable matrix such as cement, bitumen or polymer;
- Waste and its container should be compatible for extended storage;
- A package container may need to be enclosed in an additional over-pack to meet transport, storage or disposal acceptance criteria;
- If there is likely to be a significant delay between packaging and disposal, the package integrity should allow:
  - Retrieval after storage;
  - Enclosure in an over-pack if necessary;
  - Transport and handling;
  - Performance meeting the requirements of the disposal facility.

Off-site dose control by minimization of releases

Limitation of discharges

- Discharges should be within the authorized limits set by the regulatory body;
- The reactor shall be operated in a way that ensures that releases of radioactive material to the environment are kept as low as reasonably achievable;
- The main options to control releases to the environment are:
  - To provide for temporary storage of gaseous and liquid effluents to allow for initial decay before discharge;
  - Treatment to remove radionuclides from the effluent stream for disposal by other means.
- All activities concerning radioactive effluents should be in accordance with the quality assurance programme.

Off-site dose control by minimization of releases (cont'd)

Dose constraint

- Ensure that the dose to representative person (critical group) is unlikely to exceed any relevant dose limit;
- Cumulative releases from all sources and practices under control should be taken into account;
- When setting a dose constraint, account should be taken of:
  - Dose contributions from all sources and practices;
  - Foreseeable changes in any condition that could affect public exposure;
  - Uncertainties associated with the assessment of exposure.

Authorized limits on discharges

- Set for the facility by the regulatory body;
- Ensures that doses to the representative person due to discharges do not exceed the appropriate dose constraint;
- Provide an adequate margin for operational flexibility and variability;
- Appropriate release and dispersion models should be used;
- Should be set per unit time (weekly, monthly; yearly);
- Discharge limits are defined for liquid and gaseous routes.

Reference levels

- To assist reactor management in fulfilling the optimization principle and ensuring that the dose constraints are not exceeded;
- Reference levels:
  - Set by the management of the reactor;
  - Should be within the authorized limits;
  - Should be included in the OLCs and comply with the radiation protection objectives.

Determine the discharge levels

- The operating organization should:
  - Determine the characteristics and activity of the material to be discharged;
  - Determine the possible points and methods of discharge;
  - Determine all significant exposure pathways;
  - Assess the doses to the representative person due to the planned discharges;
  - Consider the radiological environmental impacts;
  - Arrange for environmental monitoring to assess the impact of the facility operation on the environment.
- The regulatory body sets the authorized discharge limits accordingly;
- All discharges should remain within these limits.

Source monitoring

- Releases of radioactive effluents should be monitored;
- The following types of measurements should be considered:
  - Online monitoring;
  - Continuous sampling;
  - Intermittent sampling.
- The choice of sampling method should depend on:
  - The characteristics and amounts of discharged radionuclides;
  - Sensitivity of the measuring equipment;
  - Expected variation with time;
  - The need for prompt detection of unplanned discharges.
- The results of monitoring should be recorded and reported periodically to the regulatory body or another competent authority.

Monitoring of airborne and liquid releases

- Monitoring of airborne releases:
  - Best monitored by continuous sampling;
  - Noble gas monitoring;
  - Particulate monitoring;
  - Monitoring for special radionuclides:
    a) Tritium;
    b) Iodine.
- Monitoring of liquid releases:
  - Usually checked by spot sampling of the tank contents rather than by continuous monitoring;
  - Includes gross beta-gamma, low energy beta, tritium and alpha activity;
  - Identification of radionuclides by gamma spectrometry.

Environmental monitoring

- Pre-operational programme for environmental monitoring should be conducted before the facility is commissioned;
- Operational programme of environmental monitoring should be similar to the pre-operational programme;
- The operational programme should be reviewed in the light of experience and should be modified if necessary;
- The programme should provide information for:
  - Confirming the adequacy of control over effluent discharges;
  - Correlating results with data obtained from source monitoring;
  - Checking validity of environmental models;
  - Assessing trends.

Review and modification of the discharge control measure

- Review the discharge control measures periodically;
- Modifications as necessary;
- In agreement with the regulatory body;
- Taking into account:
  - Operating experience;
  - Changes in exposure pathways;
  - Changes in the characteristics of the representative person.

Abnormal releases

- If reference levels are exceeded, the operating organization should:
  - Investigate the matter;
  - Take corrective action.
- If authorized limits (or dose limits) are exceeded, the operating organization should:
  - Suspend the discharge operation and take corrective action;
  - Notify the regulatory body;
  - Estimate the amount of radioactive material released;
  - Record relevant details of the discharge;
  - Investigate and identify the cause of non-compliance;
  - Correct the cause of non-compliance to prevent its recurrence;
  - Submit a report to regulatory body with corrective action taken

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Thank you

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