Grading of Requirements for Radioactive Waste Activities in Nuclear Research Reactors: Radioisotope Production Facilities

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ABSTRACT

A graded approach is applicable in all stages of the lifetime of a research reactor. During the lifetime of a research reactor, any grading performed should not, in any manner, affect safety functions and operational limits and conditions are preserved, so that there are no undue radiological hazards to workers, public or environment. The grading of activities should be based on safety analyses, and regulatory requirements. Other elements to be considered in grading are the complexity and the maturity of the technology, operating experience associated with the activities and the stage in the lifetime of the facility. In order to ensure that proper and adequate provision is made for the safety implications associated with the management and disposal of radioactive waste, the waste is characterized and classified. The general scheme for classifying radioactive waste as presented in the current study is based on considerations of long term safety, and thus, by implication, disposal of the waste. This classification provides a starting point for the grading of activities associated with the packaging and disposal of radioactive waste.

Keywords: Grading approach / Management system / Research reactors / Radioactive waste

INTRODUCTION

The graded approach is defined as follows according to IAEA Safety Glossary (1):

1. For a system of control, such as a regulatory system or a safety system, a process or method in which the stringency of the control measures and conditions to be applied is commensurate, to the extent practicable, with the likelihood and possible consequences of, and the level of risk associated with, a loss of control. An example of a graded approach in general would be a structured method by means of which the stringency of application of requirements is varied in accordance with the circumstances, the regulatory systems used, the management systems used, etc. For example, a method in which:
   (1) The significance and complexity of a product or service, activity or controls are determined;
   (2) The potential impacts of the product or service on health, safety, security, the environment, economical aspects and the achieving of quality and the organization’s objectives are determined;
   (3) The consequences if a product fails or if a service is carried out incorrectly are taken into account.

2. An application of safety requirements that is commensurate with the characteristics of the practice or source and with the magnitude and likelihood of the exposures. In practical terms, a graded approach applies to management system requirements of a product, item, system, structure or component, service, activity or controls of a process commensurate with its relative importance, complexity, variability, maturity, potential impact on safety, health, environmental, security, quality and economical aspects. By the application of a graded approach, the controls, measures, training, qualification, inspections, detail of procedures, etc. might be adapted to the level of risk or importance for safety, health, environmental, security, quality and economical aspects. In evaluating these aspects the system is to be considered holistically. The graded approach will result in an effective application of appropriate resources (time, money, staff, etc.) with regard to defined
requirements. For each specific product, item, system, structure or component, service, activity or controls the graded approach will affect the type and level (extent and depth) of controls applied, for example:

- the type and level of planning and analysis;
- the type and level of verification, inspection and testing;
- the review and approval requirements of activities, documents and records;
- the detail of documentation and records;
- the type and level of qualification and training for individuals; and

The type and level of controls can change from organization to organization, with time and with the state or the life cycle stage of the facility or activity.  

GRADING METHODOLOGY

Grading Method

Establishing a systematic method for grading is essential. This will assure consistency in grading, minimize subjectivity and reduce the likelihood and consequence of improper grading. To establish the method for grading the organization should:

a. Determine the criteria for grading appropriate to an organization’s objectives and activities through:

- Identifying the areas where significant impacts might be anticipated, e.g. safety, health, environmental, security, quality and economical aspects and stakeholders’ confidence;
- Developing criteria in each area to determine relative significance in case the activity is inadequately conceived or performed or the item, system, structure or component fails in service. An already established classification scheme and/or external requirements should be taken into account. The safety classification of the structures, systems and components dictates the classification scheme for the grading process related to the systems, structures and components;
- Evaluating the level of complexity of activity or item, system, structure or component.

b. Determine the optimum number of grading levels that encompass the identified criteria (typically, organizations find that 3–4 grading levels are sufficient). It is a general practice that grade 1 is the highest and grade 4 is the lowest.

c. Determine the applicable controls appropriate to each grading level.

Grading Process

It is important to establish a process to apply the grading method and it should include determination of the competencies required to use the process. The grading process contains the following steps:

1. Assessing the significance of the process, including the significance of the product, service, activity and controls of the process, using the criteria for grading;
2. Identifying the classification, if applicable;
3. Identifying a grade based on the assessment (preliminary grade);
4. Considering other factors that may change the preliminary grade level, such as:

- external requirements: contracts, codes, regulations, standards
- significant adverse impacts on safety, health, environmental, security, quality and economical aspects
- complexity
- process and organizational interfaces
- variability
- uniqueness
- performance history
- accessibility (e.g., for test, inspection, maintenance, during normal operation)
- ability to prove functionality or reliability after installation
5. Assign a grade (final grade) and as appropriate, verify that the most appropriate grade has been assigned;
6. Allocate/specify controls appropriate to the grade;
7. Apply controls.\(^{(5, 6)}\)

**Waste Management in Radioisotope Production Facilities**

Waste represents an inevitable consequence of human activity. Waste management requires planning and administration to guarantee the protection of human health and of the environment, and to prevent damage to future generations. The main objective is that the waste produced by the Plant complies with regulatory acceptance criteria and is further optimized to achieve ALARA values. Waste generation in the facility is considered as from the initial design stage, which guarantees an adequate selection of materials and the supply of the necessary systems. The application of general waste reduction principles will be controlled, including the restriction of areas where operations with radioactive materials are carried out, the limitation of contamination in the areas, and the recovery of everything that may be reused. Those areas in which radioactive material is handled will be supplied with environmental monitors. High-activity alarms will allow the minimization of any potential emission. If feasible, the disassembly and cutting stages will contribute to waste minimization and reduction. The Radioisotopes Production facility (RPF) located in ETRR-2 Complex – Egyptian Atomic Energy Authority – Inshas - EGYPT, is developed as an example of a radioisotope production facility which has a waste management system. The facility produces radioactive waste in the three physical states: solid, liquid, and gaseous.\(^{(7)}\)

**Classification of Radioactive Waste**

In order to ensure that proper and adequate provision is made for the safety implications associated with the management and disposal of radioactive waste, the waste is characterized and classified. The general scheme for classifying radioactive waste as presented here is based primarily on considerations of long term safety, and thus, by implication, disposal of the waste. This classification provides a starting point for the grading of activities associated with the packaging and disposal of radioactive waste so that appropriate controls can be applied to protect workers, the public and the environment. The classification of radioactive waste can be used to guide activities associated with planning a disposal facility and at any stage between the generation of raw waste and its disposal. Such grading can apply:

- **At the conceptual level:**
  - in devising waste management strategies;
  - in planning and designing waste management facilities;
  - in assigning radioactive waste to a particular conditioning technique or disposal facility.

- **At the legal and regulatory level:**
  - in the development of legislation;
  - in the establishment of regulatory requirements and criteria.

- **At the operational level:**
  - by defining operational activities and in organizing the work to be undertaken with the waste;
  - by providing a broad indication of the potential hazards associated with the various types of radioactive waste;
  - by facilitating record keeping.

- **For communication:**
  - by providing terms or acronyms that are widely understood in order to improve communication among all parties with an interest in radioactive waste management, including generators and managers of radioactive waste, regulators and the public.\(^{(8)}\)

The classes of radioactive waste identified in IAEA Safety Standards Series \(^{(9)}\) are summarized in the following table.
Table (1): Classes of radioactive waste.

<table>
<thead>
<tr>
<th>Waste type</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Exempt waste</td>
<td>Activity levels are equal to or below acceptance levels based on an annual dose rate to members of the public below 0.01 mili-sieverts</td>
</tr>
<tr>
<td>2. Low and intermediate level waste</td>
<td>Activity levels are above acceptance levels for exempted waste and thermal power is below approximately two kilowatts per cubic meter</td>
</tr>
<tr>
<td>2.1. Short life waste</td>
<td>Limited long-life radionuclide concentrations (restriction of long-life alpha-emitter radionuclides to 4000 Becquerels per gram in individual waste packages, and to a general average of 400 Becquerels per gram per waste package)</td>
</tr>
<tr>
<td>2.2. Long life waste</td>
<td>Radionuclide concentrations are above the restrictions to short-life waste</td>
</tr>
<tr>
<td>3. High level waste</td>
<td>Thermal power is above two kilowatts per cubic meter, and radionuclide concentrations above the restrictions to short-life waste.</td>
</tr>
</tbody>
</table>

**RPF Radioactive Waste Management**

The RPF facility produces waste in the three physical states:

- Solid
- Liquid
- Gaseous

A flow chart showing the three types of RPF waste activities is presented in APPENDIX 1.

**1. Solid Waste**

**Solid Waste Types**

Most of the waste produced in the facility has a low radioactivity level. Such waste is classified as class 1 and 2.1. The molybdenum process may yield a small amount of class 2.2 waste. All solid wastes are collected in plastic bags and then transferred to plastic containers in shielded containers, afterwards, transported - in some cases after their temporary storage in the solid waste area - to the waste treatment plant, or disposed of as a municipal waste. The solid waste management process begins with the classification, segregation and collection of the wastes in different bags in accordance with the characteristics of the work involved. Exempt solid waste is sent to the municipal waste after monitoring. Low activity or medium activity waste that may be decontaminated is transferred to the decontamination areas, where they are treated for their reutilization, or disposed as minor radioactive level waste to waste treatment plant after decay or directly as inactive or exempted waste. Medium activity solid waste that cannot be decontaminated is sent to the waste treatment plant for final disposal.

**Radioactive Solid Waste from Hot Cells**

Solid waste is collected and temporarily stored in plastic bags inside each hot cell. It is segregated in accordance with its type and activity content.
Solid Waste Management in Supervised Areas

Supervised areas produce exempted waste such as target preparation, reagent preparation, storage, and packaging. Once the bag is full, it is closed, labeled, and transferred to the monitoring room for measuring and sending to the municipal waste. Dead animals are collected in labeled bags, temporarily stored in a freezer in the solid waste area, and finally transported to waste treatment plant.

Solid Waste from Ventilation Systems

After an adequate decay period, used filters are put in plastic bags and temporarily stored in solid waste area until they are transferred to the waste treatment plant. The charcoal for radiiodine retention from the molybdenum process ventilation columns is transferred to drums after an adequate decay period, and later sent to the waste treatment plant. [7]

2. Liquid Waste

Liquid Waste Types

Most of the waste produced in the facility has low radioactivity level. Intermediate level waste (class 2.2 and 2.1) is produced from the molybdenum process. The RPF is supplied with three different systems for the management of the liquid waste named as follow:

- The radioactive liquid waste system, for collection and transfer of low and intermediate level waste from the liquid waste tanks of glove boxes and hot cells,
- The suspicious liquid waste system also referred to as potentially radioactive, for collection and transfer of inactive liquid in normal operation conditions, but potentially radioactive at incidental operation conditions,
- The Sewer system or network, for transfer exempt drains.

Radioactive Liquid Waste Management in Production Hot Cells and Glove Boxes

Production hot cells and glove boxes have dedicated tanks for the collection of liquid waste. The storage capacity of these tanks is capable of receiving the waste generated in one year and collection of the process effluents for temporary storage till decay. The liquid waste is transferred through vacuum from the dedicated collector tanks in the hot cell or glove box to shielded containers. Afterwards, it is transported to the liquid waste treatment plant. The maximum quantities of waste generated in the process are:

- Chromium production: 35 liters/year
- Iodine-131 production: 10 liters/year
- Iodine-131 fractionation: 5 liters/year
- Iodine-125 production: 10 liters/year
- Technetium load: 20 liters/year
- Molybdenum-99 production (class 2.1 and 2.2): 900-600 liters/year
- Glove boxes: 20 liters/year
Suspicious Liquid Waste Management System

Potentially-radioactive liquid waste is managed through the suspicious liquid waste management system. The glove boxes and radiochemical hoods have sinks that discharge directly in this system. The liquid from these drains is collected by a plastic pipe network and transferred by gravity to the control tanks. Each of these tanks have 0.20 m³ effective capacity.

Sewer System Liquid Waste Management

Effluents from the condensation of fan coils, eyewash station and inactive sinks are collected through a plastic pipeline. The discharge from sinks and toilets runs directly to the building’s sewer network. (7)

3. Gaseous Waste

This waste results from the following radiochemical processes:

- Molybdenum-99 production
- Iodine-131 production
- Iodine-125 production

Moreover, the air renewal currents in the areas and airtight boxes will drag radioactive particles, surface contaminants in airtight boxes and areas in which radioactive materials are handled, generating aerosols that will be retained by the absolute filters present in the ventilation systems.

Molybdenum-99 Process Gases

The gas treatment system corresponding to this process is fitted with a hydrogen converter to produce water, a water condenser for generated water, and storage tanks for gases. Mo-99 hot cells have 14 (fourteen) tanks for the storage and decay of process gases. These tanks contain a mixture of hydrogen, nitrogen, radioactive iodine, and noble gases. Once these products decayed for approximately 6 weeks, the gases are released into the airtight box, from where they are dragged by the cell ventilation system.

Iodine-131 and Iodine-125 Process Gases

The process system has charcoal traps to retain radioactive iodine as first containment. Gases exiting through these charcoal traps and leaks are vented into the airtight box, from where they are dragged by the cell ventilation system. (7)

Application of Grading of Requirements for Radioactive Waste Activities in RPF

The selection of the best disposal option for each class of RPF waste types can be considered as a graded application of controls to ensure long term safety. For lower classifications, the extent of control required is minimal, with adequate safety being provided through administrative control measures. For higher classifications, a greater degree of control will need to be applied to an increasing number of factors such as inventory control, monitoring, containment, biological protection during transfer operations and secure storage. A reasonable degree of assurance can be given that institutional control measures to contribute to the safety of near surface disposal facilities for waste containing mainly short lived radionuclides can be kept in place over such time frames. Limitations placed on the activity (total activity, specific activity or activity concentration) of waste that can be disposed of in a given disposal facility will depend on the radiological, chemical, physical and biological
properties of the waste and on the particular radionuclides it contains. The grading of the requirements for the different RPF waste types is shown in the following table.

**Table (2): Grading of requirements for radioactive waste activities**

<table>
<thead>
<tr>
<th>Waste type</th>
<th>Requirements</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radioactive solid waste from hot cells</td>
<td>Collecting, temporary storage for decay, administrative controls, monitoring and transporting to the liquid waste treatment plant.</td>
<td>X</td>
</tr>
<tr>
<td>Solid waste management in supervised areas</td>
<td>Collecting, monitoring and transferring to municipal waste</td>
<td>X</td>
</tr>
<tr>
<td>Solid waste from ventilation systems</td>
<td>Collecting, temporary storage for decay, and transporting to the solid waste treatment plant.</td>
<td>X</td>
</tr>
<tr>
<td>Radioactive liquid waste management in production hot cells and glove boxes</td>
<td>Collecting, temporary storage for decay, administrative controls, monitoring and transporting to the liquid waste treatment plant.</td>
<td>X</td>
</tr>
<tr>
<td>Suspicious liquid waste management system</td>
<td>Collecting, monitoring and transferring to the sewerage network.</td>
<td>X</td>
</tr>
<tr>
<td>Sewer system liquid waste management</td>
<td>Collecting, and transferring to the sewerage network.</td>
<td>X</td>
</tr>
<tr>
<td>Molybdenum-99 process gases waste</td>
<td>Storage, decay of process gases, and dragging by the cell ventilation system.</td>
<td>X</td>
</tr>
<tr>
<td>Iodine-131 and Iodine-125 process gases waste</td>
<td>Charcoal traps to retain radioactive iodine, released gases are vented, and dragged by the cell ventilation system</td>
<td>X</td>
</tr>
</tbody>
</table>

**ABBREVIATIONS**

CVS : Cell ventilation system  
LW : Liquid waste  
ILW : Intermediate level waste  
LLW : low level waste  
HLW : High level waste  
T : Temporary  
SE : Sewer system  
SULW : Suspicious liquid waste  
SW : Solid waste
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REFERENCES

APPENDIX 1: Flow chart of the three types of RPF waste