Radioactive waste, definitions

IAEA Glossary

Radioactive waste: Waste that contains, or is contaminated with, radionuclides at concentrations or activities greater than clearance levels as established by the regulatory body.

Joint Convention

"Radioactive material in gaseous, liquid or solid form for which no further use is foreseen by the CP or by a natural or legal person whose decision is accepted by the CP, and which is controlled as RW by a RB under the legislative and regulatory framework of the CP".

Introduction

Radioactive waste arises from many different activities:
- Operation and decommissioning of nuclear facilities (e.g., nuclear power plants)
- Application of radionuclides in industry, medicine, and research
- Cleanup of contaminated sites
- Processing of raw materials containing naturally occurring radionuclides

Sources of Radioactive Waste (1)

Nuclear fuel cycle - Power generation
- Spent nuclear fuel
- Depleted uranium
- Enhanced levels naturally occurring radionuclides
- Radioactive waste, liquid effluents
- Radioactive waste, solid wastes
- Chemical sludges
- Reprocessing of spent fuel

Sources of Radioactive Waste (2)

Nuclear fuel cycle - Other
- Making and milling and U ore extraction
- Uranium tailings
- Tailing from irradiation facilities
- Fuel fabrication
- Refractory materials
- Chemical sludges
- Reprocessing of spent fuel

Sources of Radioactive Waste (3)

Industrial applications
- Production of radioactive sources
- Use of radioactive sources
- Sealed sources
- Unsealed sources
- Enhanced levels naturally occurring radionuclides
- Radioactive waste, liquid effluents
- Radioactive waste, solid wastes
- Chemical sludges
- Reprocessing of spent fuel

Sources of Radioactive Waste (4)

Medical applications
- Diagnosis and treatment
- High activity, sealed sources
- Sources, I-131, P-32, Y-90, Sr-90
- Co-60, I-125, I-131, Am-241,

Outline of Lecture

This lecture provides:
- An overview of radioactive waste arising from various practices, and the rationale for waste classification systems
- A description of the IAEA system of radioactive waste classification
- A summary of management approaches used for different types of waste
- Overview of the IAEA Safety Standards for Predictive, Disposal and Decommissioning
Sources of Radioactive Waste (5)

- Research and development
  - Wide variety of uses
  - Wide variety of techniques

- Other
  - Historical sources - radium processing
  - Defense programs - "legacy" wastes

Waste Management Approaches (1)

- Decay Storage – hold the waste in storage until sufficient decay has occurred for desired management approach

Sources of Radioactive Waste (6)

- Naturally-Occurring Radioactive Materials (NORM) Wastes
  - Phosphate industry
  - Production of metals
  - Refractory materials
  - Energy Production (Oil and Gas, Coal, Biomass, Geothermal)

  - Usually large volumes, Rn-222, Ra-226

Waste Management Approaches (2)

- Concentrate and Contain – reduce waste volume and condition and/or containerize waste to limit dispersion in the environment

Spent Fuel Management Options

- Interim storage for later use or reprocessing, or for cooling prior to direct disposal
- Reprocessing gives new fuel and HLW, which can be vitrified for geological disposal
- Direct geological disposal

Waste Management Approaches (3)

- Dilute and Disperse – discharge the waste in a manner that reduces environmental concentrations to acceptable levels

Waste Management

- Radiation waste management
- Processing
- Storage
- Disposal
- Treatment
- Characterization

Waste Properties

- Physical properties
  - Physical state (solid, liquid, gas)
  - Weight and volume
  - Solubility
  - Dispersability (e.g. powder)
  - Compressibility

- Radioactive properties
  - Radionuclide contents
  - Radiation intensity
  - Heat generation
  - Criticality risk

- Biological properties
  - Potential biological hazards

- Chemical properties
  - Reactivity (e.g. oxidizing)
  - Corrosive
  - Organic content
  - Gas generation
  - Stability, miscibility
  - Complexation/sorption of radionuclides

Waste Processing

- Characterization
- Treatment
- Disposal

Clearance

Pre-Treatment

Post-Treatment

Waste
Devising radioactive waste management strategies, planning, designing and operating waste management facilities. Communication between interested parties by providing well understood and operating waste management facilities terminology (e.g., Joint Convention).

Why have a waste classification?

- Allows appropriate decisions to be made at each step of waste management lifecycle
- Enables efficient management by operators (otherwise decisions are ad hoc or made on case by case basis)
- Provides a systematic foundation for waste segregation and strategy development
- Facilitates record keeping and giving a broad indication of the potential hazards involved in the various types of waste at the operational level
- Communication between interested parties by providing well understood terminology (e.g., Joint Convention)
- Not change accepted terminology
- Be flexible
- Be simple, easy to understand
- Be universally applicable
- No such system exists!

Possible Approaches to Classification

- Classification by origin
- Classification by half-life
- Short-lived waste, long-lived waste
- Classification by physical state
- Solid, liquid, gaseous
- Nuclear fuel cycle, isotope production,..
- Very Low Level waste (VLLW), Low Level Waste (LLW), Intermediate level Waste (ILW), High Level Waste (HLW)
- Classification by activity concentration

The following waste types are defined:
- Exempt waste
- Very short-lived waste (VSLW)
- Very low level waste (VLLW)
- Low level waste (LLW)
- Intermediate level waste (ILW)
- High level waste (HLW)
- Radioactive waste
- Radioactive material
- Minor actinide waste
- Mined fuel material
- Neutronic fuel material
- Waste management systems

An ideal waste classification system would:

- Be simple, easy to understand
- Not change accepted terminology
- Be flexible
- Address all stages of waste management lifecycle
- Cover all types of radioactive waste

IAEA Waste Classification

 supersedes

From waste spent nuclear fuel to radioactive materials having such low levels of radioactivity that they do not need to be managed or regulated as radioactive waste
Also covers disused sealed radiation sources (DSRS), where they are considered waste, and waste containing radionuclides of natural origin.
Application of the Concept of Exemption and Clearance

Exempt Waste (EW)
- Waste that has been cleared, exempted or excluded from regulation

Low Level Waste (LLW)
- Waste that contains material with radionuclide content above clearance levels, but with limited amounts of long lived activity
- LLW includes very high activity waste with short half life that requires shielding and some long lived material at relatively low activity levels
- LLW requires robust isolation and containing for periods of up to a few hundred (e.g. 300) years, but would not be hazardous beyond that period of time.

Intermediate Level Waste (ILW)
- Waste which, because of its high radionuclide content and the potential mobility of the materials involved, requires a higher level of containment and isolation than is provided by near-surface disposal
- However, needs little or no provision for heat dissipation during its handling, transportation and disposal
- ILW may include long lived waste that will not decay to an acceptable activity level during the time which institutional controls can be relied upon

High Level Waste (HLW)
- Waste with radioactivity levels intense enough to generate significant quantities of heat by the radioactive decay process or with large amounts of long lived activity which need to be considered in the design of a disposal facility for the waste
- HLW includes spent reactor fuel which has been declared as waste, vitrified waste from the processing of reactor fuel and any other waste requiring the degree of containment and isolation provided by geological disposal
- Geological disposal in deep, stable formations is the preferred disposal option

Very Low Level Waste (VLLW)
- Waste containing material that can be slightly above the exempt region
- Typical waste would include soil and rubble with activity low enough not to require shielding
- Disposal facilities for such waste do not need a high level of containment and isolation and near surface landfill is generally suitable

Very Short Lived Waste (VSLW)
- Waste that can be stored for decay over a limited period of up to a few years and subsequently cleared for uncontrolled disposal or discharge after a suitable period of storage
- This would include radioactive waste containing short half life radionuclides typically used for research and medical purposes

Summary of IAEA System GSG - 1

Geological Disposal
- The depth of disposal is only one of the factors that will influence the viability of a particular disposal facility, all the safety requirements for disposal as established in SSR Part 5 will apply

Technological Aspects
- Economical Aspects
- Regulatory Aspects
- Waste types
- Interim Storage

Very Short Lived Waste (VSLW)

Summary of IAEA System GSG - 1

Very Short Lived Waste (VSLW)

Low Level Waste (LLW)

Intermediate Level Waste (ILW)

High Level Waste (HLW)
Classification as Practiced

- Many member states have defined their own classification systems, customized to fit national needs
- As part of Joint Convention, each country reports on national system of waste classification and reports a national inventory of radioactive waste

Selection of Waste Management Options

- A multi-factor problem
  - Waste types, sites, policy, costs, populations, stakeholder views...
- Selected options must be consistent with national policy and strategy for waste management
- Need to consider interdependencies with other predisposal and final disposal options
- Adequate characterization of the wastes is essential

Statutory Obligations (1957)

Article III, Paragraph A.6.

"To establish or adopt, in consultation and where appropriate in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for purposes of health and minimize of danger to life and property (including such standards for labour conditions), and to provide for the application of these standards to its own operations as well as to the operations making use of materials, services, equipment, facilities, and information made available by the Agency ...

IAEA Safety Standards on Predisposal Waste Management

Safety Standards Categories

- SF: Safety Fundamentals
- GSRs: General Safety Requirements
- SSRs: Specific Safety Requirements
- GSGs: General Safety Guides
- SSGs: Specific Safety Guides

Summary

Waste classification:
- Defines several classes of waste based on their main characteristics: activity, half-life, volume
- Provides essential input for the development of national waste management policy
- Influences the choice of waste management option (e.g., storage followed by near-surface or geological disposal)

Status of Safety Standards

- IAEA Safety standards are
  - Binding for IAEA's own activities
  - Not binding on the Member States (but may be adopted by them) EXCEPT in relation to operations assisted by the IAEA e.g.:
    - Integrated Regulatory Review Service
    - Technical Cooperation Fund work
- States wishing to enter into project agreements with the IAEA
  - http://www.iaea.org/standards/default.asp
The basic objectives, concepts and principles involved in ensuring protection and safety in the event of radiation accidents are stated. The policy document of the IAEA Safety Standards on Disposal of Radioactive Waste is a comprehensive guide for disposal facilities. It states the following:

1. Objective
   - Limitation of risks to individuals
   - Protective actions to reduce existing and future risks
   - Optimization of protection
   - Justification of facilities and activities
   - Responsibility for safety

It does not address the entire scope of radioactive waste, including transportation of waste to the site and waste disposal at the site. The IAEA Safety Standards on Disposal Waste Management provide a framework for the planning, development, operation, and closure of disposal facilities. The safety approach is consistent with the IAEA's response to the Fukushima Daiichi nuclear accident and its lessons learned.
The Requirements

1. Government responsibility
2. Regulatory responsibility
3. Operator’s responsibility
4. Safety in development and operation
5. Safety in research, test and experimental reactors
6. Understanding and confidence in safety
7. Preliminary safety analyses
8. Containment
9. Safeguards
10. Surveillance and control
11. Stepwise development
12. Using the regulatory approach
13. Scope of the safety case
14. Documenting the safety case
15. Site characterization
16. Design
17. Construction
18. Commissioning
19. Operation
20. Waste acceptance
21. Monitoring
22. Post-closure and institutional control
23. Administrative and control
24. Nuclear security measures
25. Safety assessment
26. Existing disposal facilities

IAEA Safety Standards on Decommissioning

The requirements of IAEA Safety Standards on Decommissioning will be addressed in IAEA Functions and Procedures of the Regulatory Body for Safety, which will replace the current IAEA Safety Standards on Decommissioning. The revised version of IAEA Safety Standards on Decommissioning will be published in 2018.

IAEA Safety Standards on Decommissioning

- Understanding and confidence in safety
- Scope of the safety case
- Preliminary safety analyses
- Containment
- Safeguards
- Surveillance and control
- Stepwise development
- Using the regulatory approach
- Site characterization
- Documenting the safety case
- Site characterization
- Safety assessment
- Existing disposal facilities

Activity Levels in Reactor LILW

<table>
<thead>
<tr>
<th>Sample</th>
<th>Activity (Bq/kg)</th>
<th>U</th>
<th>Pu</th>
<th>Am</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS 402</td>
<td>1234</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>DS 401</td>
<td>1234</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>DS 402</td>
<td>1234</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Tailings Properties

<table>
<thead>
<tr>
<th>Mine</th>
<th>Oak Grade (%)</th>
<th>Uranium Production (%)</th>
<th>Volume of Tailings (t)</th>
<th>Uranium Tailings Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Lake</td>
<td>12.3</td>
<td>14.3</td>
<td>1.6</td>
<td>3.4</td>
</tr>
<tr>
<td>Separation</td>
<td>12.7</td>
<td>11.9</td>
<td>1.8</td>
<td>2.9</td>
</tr>
</tbody>
</table>

Thank you!
### Radioactivity in NORM

<table>
<thead>
<tr>
<th>Material</th>
<th>Radionuclide Concentration (Bq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale in pipes and equipment in oil/gas production</td>
<td>40 - 15,000,000 (average one thousand to hundreds of thousands)</td>
</tr>
<tr>
<td>Sludges from ponds of produced water</td>
<td>10,000 to greater than 40,000</td>
</tr>
<tr>
<td>Sludges from production of produced water</td>
<td>10,000 - 40,000</td>
</tr>
<tr>
<td>Sludges in natural gas supply equipment</td>
<td>40,000 - 150,000</td>
</tr>
<tr>
<td>Coal fired power plants</td>
<td>100 - 25,000</td>
</tr>
<tr>
<td>Drinking water treated waste</td>
<td>~600 (only Ra reported)</td>
</tr>
<tr>
<td>Resins</td>
<td>~1,300,000 (only Ra reported)</td>
</tr>
<tr>
<td>Phosphate fertilizer</td>
<td>1,000 - 25,000</td>
</tr>
<tr>
<td>Phosphate processing waste</td>
<td>1,000 - 4,000</td>
</tr>
<tr>
<td>Slag</td>
<td>2,000 - 7,000</td>
</tr>
<tr>
<td>Scale</td>
<td>~40,000 (only Ra reported)</td>
</tr>
<tr>
<td>Other mineral processing waste</td>
<td>up to 40,000 (generally 100 - 1,500)</td>
</tr>
</tbody>
</table>

These data should only be used as rough indicators of the levels of radioactivity.