Decommissioning of Nuclear Facilities

Waste Management
Lesson Objectives

• Describe the requirements and methods for managing waste from decommissioning
• Review IAEA waste classification system
• Review waste streams that might be encountered during decommissioning
• Review waste characterization
• Review waste management practices
Primary Objectives with Managing Waste

• Costs - Disposal, transport, containers, characterization, handling, secondary waste
• Schedule - Sequencing, staging, ALARA, sharing resources, cash flow, material flow
• Regulatory - Satisfying final use criteria, avoiding non-compliance
• Safety - Ergonomics, safety, contamination
Typical Methods Used to Manage Decommissioning Waste

Material generated from Decommissioning

Is material recycling or reuse possible?

Yes

Recycle/reuse

No

Bulk contaminated material for processing and disposition

Pretreatment: Incineration, Shredding, Evaporation, etc.

Interim waste product

Treatment: Drying, Compaction, Cementation, Pouring, etc.

Final waste product

Waste Packaging

Waste Containers

Interim Completed Waste Package Storage

Final Waste Disposition
Waste Management Constraints

- Final waste acceptance criteria for disposal
- Container specifications, limits, capacities
- Transportation logistics
- Availability of containers, casks, and rail cars
- ALARA considerations
- Overall regulatory compliance
- Project and safety risk management
- Processing options and access to disposal site
## IAEA Solid Radioactive Waste Classification System

<table>
<thead>
<tr>
<th>Waste Classes</th>
<th>Typical Characteristics</th>
<th>Disposal Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exempted Waste (EW)</td>
<td>Activity levels at or below national clearance levels which are based on an annual dose to members of the public of &lt; 0.01 mSv</td>
<td>No radiological restrictions</td>
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<tr>
<td>Low and Intermediate Level Waste (LILW)</td>
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<tr>
<td>• Short Lived Waste (LILW-SL)</td>
<td>Activity levels above clearance levels and thermal power below about 2 kw/m³</td>
<td>Near surface or geological disposal facility</td>
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<tr>
<td>• Long Lived Waste (LILW-LL)</td>
<td>Restricted long lived nuclide concentrations. Limitation of long lived alpha emitting nuclides to 4000 Bq/g in individual waste packages and an overall average of 400 Bq/g per waste package. Long lived nuclide concentrations exceeding limitations for short lived waste</td>
<td>Near surface or geological disposal facility</td>
</tr>
<tr>
<td>High Level Waste (HLW)</td>
<td>Thermal power exceeding 2 kw/m³ and long lived nuclide concentrations exceeding limitations for short lived waste</td>
<td>Geological disposal facility</td>
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</tbody>
</table>
Example Dismantled Material from PWR Decommissioning

- Carbon Steel – 50%
- Concrete – 31%
- Stainless Steel – 9%
- Non-Ferrous Metals – 2%
- Insulation – 2%
- Motors/Wiring/Electrical Parts – 1%
- Other Materials – 5%
Waste Comprises a Large Portion of Decommissioning Costs

Note: An additional $6 Million is associated with labs, office complex and control room for a total decommissioning of $14 million.
Typical Waste Streams

- **Waste Categorization**
  - Low activity
  - Intermediate activity (short and long lived)
  - High Activity

- **Low Specific Activity (LSA) Waste Classifications**
  - LSA-I
  - LSA-II
  - LSA-III

- **Package Categories**
  - Type A
  - Type B (U)
  - Type B (M)
  - Type C
  - Industrial Type 1
  - Industrial Type 2
  - Industrial Type 3
Primary Decommissioning Waste Streams

- Burnable waste (protective clothing, wood)
- High level massive metallic waste (reactor internals, pressure vessel, primary coolant pumps)
- Low to mid level metallic waste (smaller pumps, tanks, piping, valves, structural supports)
- Concrete waste – Activated as well as surface and subsurface contaminated
- Light compactable material (insulation, asbestos)
- Special waste (contaminated lead, mixed waste)
Non-Radiological Waste Components

- Asbestos
- Poly-Chlorinated Bi-phenyls (PCBs) – transformers, paints, etc.
- Heavy metals (Pb, Zn, Ag, Hg, Cd, etc.)
- Solvents
- Chemical listed material
- Toxic substances
- Corrosives
Primary Waste Streams

Reactor internals and components
Primary Waste Streams

- Neutron activated radionuclide contaminated research experiments and targets
Primary Waste Streams

- Mechanical / Electrical Equipment
  - Glove boxes
  - Pumps, valves, fitting
  - Exhaust ventilation/hoods
  - Piping
  - Ducting
  - HVAC
  - Hot laboratories facilities
  - Transformers/motors
  - Waste systems
  - Duct chases, electrical cables
  - Hot machine shops and fabrication/maintenance
  - Fuel pool equipment and systems
Primary Waste Streams

Structural concrete (walls and floor), steel, paint coatings, rebar, studs, roofing and building material
Secondary Decommissioning Waste Streams

- Characterization waste
- Processing waste
- Decontamination waste
- Contaminated tools and equipment
- Protective clothing
- Shielding material
Secondary Waste Streams

- Characterization/survey sample waste - Core drillings (reactor walls, floors)
Secondary Waste Streams

- Characterization/survey sample waste (cont’d)
  - Soil Samples
  - Water Samples
  - Sample Media (smears, containers)
Secondary Waste Streams

- Preparation Waste Streams
  - Filter medias (air/particulate, liquids)
  - Lubricants, fluids, oils
- Decontamination Waste Streams
  - Solvents
  - Scabbling material/debris
  - Liquids/decontamination fluids
  - Absorbents
  - Abrasive media
  - Vacuum material
Secondary Waste Streams

• Contaminated equipment and tools (potential)
  • Fuel handling and reactor internal tools
  • Hand tools
  • Decontamination equipment
  • Lifting & rigging
  • Scaffolding / man lifts
  • Special equipment, robotic equipment
  • Temporary lighting
  • Personnel access tents and control area super-structure
Secondary Waste Streams

Worker protective clothing (PPE)

• Disposable (shoe covers, gloves, paper, tape)
• Re-useable (boots, respirators, coveralls)
Characterizing Waste Streams

Considerations

• Historical information, process knowledge
• Site walk downs, system takeoffs
• Representative samples, densities, quantities
• Identification and documentation of locations
• Determination of background contributions and interferences
• Ability to detect appropriate limits
Characterizing Waste Streams

- Waste stream characterization required to estimate the radionuclide concentrations to support proper waste packaging, transport and disposal
- Sampling
  - Non Intrusive
    - Contact dose
    - Fixed and smear sampling
  - Intrusive
    - Grab samples
    - Crud samples
    - Materials scrapings
- Methods of assay
  - Gamma spectroscopy
  - Liquid scintillation
  - Gross alpha or beta
Characterizing Waste Streams

• Direct sampling of every package is the most precise; however, often very time consuming and expensive.
• Estimation based on easily measured variables
  • Correlation to exposure rates or gamma energy flux
  • Assumes homogeneous waste streams
• Must sample/analyze representative media from waste stream, validate the homogeneity of the waste stream.
Direct Scanning - Bulk Assay
Retrieval and Packaging

• Sites not designed for decommissioning
• Disassembly can result in spread of contamination, odd shapes and weights
• Sequence of component extraction may require significant staging areas and plans
• Limitations on number of transport vehicles or casks may limit schedule flexibility
Container Options

- Drums
- Bags or Sacks
- Sea-lands
- Inter-modals
- Casks
- HICs
- B-25 type boxes
- Bulk rail cars

There are also country-specific packages
B-25 Boxes
Expensive per Unit Volume
Bags With Lifting Rigs
Inter-modals and Sea-lands
Open Top and Open End
High Integrity Container (HIC) for Placement inside of a Cask (Higher Activity)

- Dewatered ion exchange resins or highly contaminated items
Waste Minimization

- Processes/examples for waste pre-treatment, handling and treatment
  - Assay
  - Segregation
    - By activity and curie content/pedigree
    - Liquids: tank age, effluent releases, recycle materials
    - Solids: type, source
    - Airborne material
    - Personnel Protective Equipment (PPE)
    - Equipment for recycle
    - Decontamination area
Waste Minimization

- Pre-treatment
  - Liquids
  - Solvents
  - Mixed waste
- Treatment
  - Size reduction
  - Chemical treatment
  - Filtration / micro-filtration
  - Resin treatment / effluent polishing
  - Decontamination
Solid Waste Treatment Options

• Consist primarily of volume reduction (VR) and decontamination

• Volume Reduction
  • Compaction – VR of 2:1 to 5:1
  • Supercompaction – VR of up to 12:1
    • Compaction concerns: need for controlled ventilation, dealing with wet, explosive or pyrophoric wastes, and compaction resistant or irregularly shaped objects
Solid Waste Treatment Options

• Decontamination technologies
  • Chemical decontamination agents
    • Solvents, detergents, surfactants
    • Acids or alkalis
    • Complexing or chelating agents
    • Oxidizers
  • Physical decontamination
    • Dry abrasive blasting
    • Grinding and rotary hammers
    • Blasting with nonabrasive media
  • Metal melting – specialized usage
Solid Waste Treatment Options

Other Volume Reduction Options

- Shredding units – VR of 3:1
- Baling units – used to improve ease of waste handling
- Incineration – VR up to 100:1
  - Incineration concerns – primarily waste segregation issues
    - Corrosive material
    - Non-combustibles
    - Explosives and pyrophorics
    - Medium and high level waste
    - Ash handling
Waste Volume Reduction Considerations

- Compaction
- Broker secondary segregation
Waste Volume Reduction Considerations

- Resin technology
- Decontamination methods for low waste generation
Waste Volume Reduction Considerations

Material recycling-metal melting
Waste Storage

• Interim (low and intermediate activity waste stored on site)
  • Criteria for radiation protection
  • Facility protected from the elements
  • Transport and handling logistics
  • Packaged waste stored outdoors
    • Weather deterioration
    • Animal intrusion
Waste Storage

- Long term storage (low and intermediate activity waste on-site or other non-disposal site)
  - Waste Acceptance Criteria (WAC)
  - Waste forms, assay and inventories
  - Waste packaging and compliance to IAEA transportation regulations
  - Criteria for radiation protection
  - Waste protected from the elements
Waste Profiles

• Describe physical, chemical, and radiological characteristics of waste
• Brief history of waste
• RCRA analysis plus moisture
• Sample results from approved laboratory
• Sample costs plus fee $10 to $40 K/ profile
• Pre shipment sample to site
Waste Data

- Be clear on type and quantities
- Specify units, be consistent and appropriate
- Segregate low- and high-activity wastes
- Maintain accurate inventory
- Maintain records of disposition / disposal
- Avoid re-handling of data and materials
- Format data for final report
Waste Packaging and Handling

Sizing, weight
Waste Packaging and Handling

- Interim storage
- Final assay, documentation/manifesting
- Transportation
Waste Packaging and Handling—Overall Issues

- Package shielding requirements
- Size and shape of package
- Special transport requirements (e.g., heavy loads or barges)
- Exclusive or non-exclusive use shipment
- Weight of package often limiting factor
Intermodal Containers on Rail
Barge Transport for Large Items
Transportation Cask on Flatbed
Scheduling Challenges-Rail

- Rail can be one third the cost but less flexible, and you lose control to rail company
- Limited rail heads
- Fewer cars than trucks in national inventory
- Scheduling delivery and pickup is a challenge, it feels like a “monopoly”
- Delays by rail company can be recovered
Waste Disposal

- Waste Acceptance Criteria (WS-R-1)
- Waste documentation – radiological assay and inventories, shipping papers
- Waste packaging and compliance with IAEA Transportation Regulations
- Engineered waste disposal facilities – radiological and non-radiological
- Typical waste disposal cells
Waste Disposal

Final disposal
Waste Disposal Considerations

- Disposal facility availability
- Cost
- Waste acceptance criteria
- Political considerations
- Regulatory
- Transportation Issues
Waste Disposal Considerations

- Primary concern is preparation of waste in order to meet disposal facility WAC
- Disposal concerns
  - Compatibility of waste with surrounding media
  - Chemical, mechanical, biological, thermal and radiation stability
  - Low leach rate of contaminants
  - Solid form with low dispersability
  - Radionuclide activity and concentration
Waste Disposal Considerations

• Disposal Concerns (cont’d)
  • Gas generation (radiolytic, biological, chemical)
  • Presence of explosive or pyrophoric material
  • Presence of free standing liquids
  • Chelating agents or organic complexing agents
  • Presence of hazardous material
  • Chemical durability
  • Nuclear criticality
Lessons Learned

• Importance of communication with offsite laboratory
• Correct sources for specific contaminants
• Plan must account for hard-to-detect nuclides.
• Training for personnel-consistent techniques
• Activation analysis assumes materials are known and present as predicted.
• “As-built” does not guarantee “as-found.”
Lessons Learned

• Get the projected volumes right – waste costs a project money.
• Carefully evaluate material flow so as to have sufficient staging and lay-down areas.
• Plan for needed use of cranes, package shielding or casks and material handling strategies.
Lessons Learned

• Engineer the waste sizing based on worker efficiencies as well as packaging and transport constraints
• Account for water turbidity (when performing underwater decontamination, cutting, grinding)
• Plan for releases where not expected
Lessons Learned

• Develop a comprehensive plan to address the technical and regulatory issues for the unrestricted release of material
• Address hazardous waste, mixed waste, and secondary waste in the low-level waste management plan
• Develop strategies for the long term storage of radioactive waste which cannot currently be disposed (e.g., spent nuclear fuel)
Summary

• Successful Radioactive Waste management requires
  • Minimizing costs
  • Minimizing exposure to on-site workers
  • Minimizing volume of waste requiring disposal
  • Volume reduction, super-compaction, incineration, consolidation
  • Survey and release (clearance)
References