International Atomic Energy Agency

Decommissioning of Nuclear Facilities

Waste and Spent Fuel Management

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IAEA Regional Workshop
Manila, The Philippines
September 15-19, 2008

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

NOTE: This lesson has been modified to reflect both a summary of 'conceptual' material and practical considerations

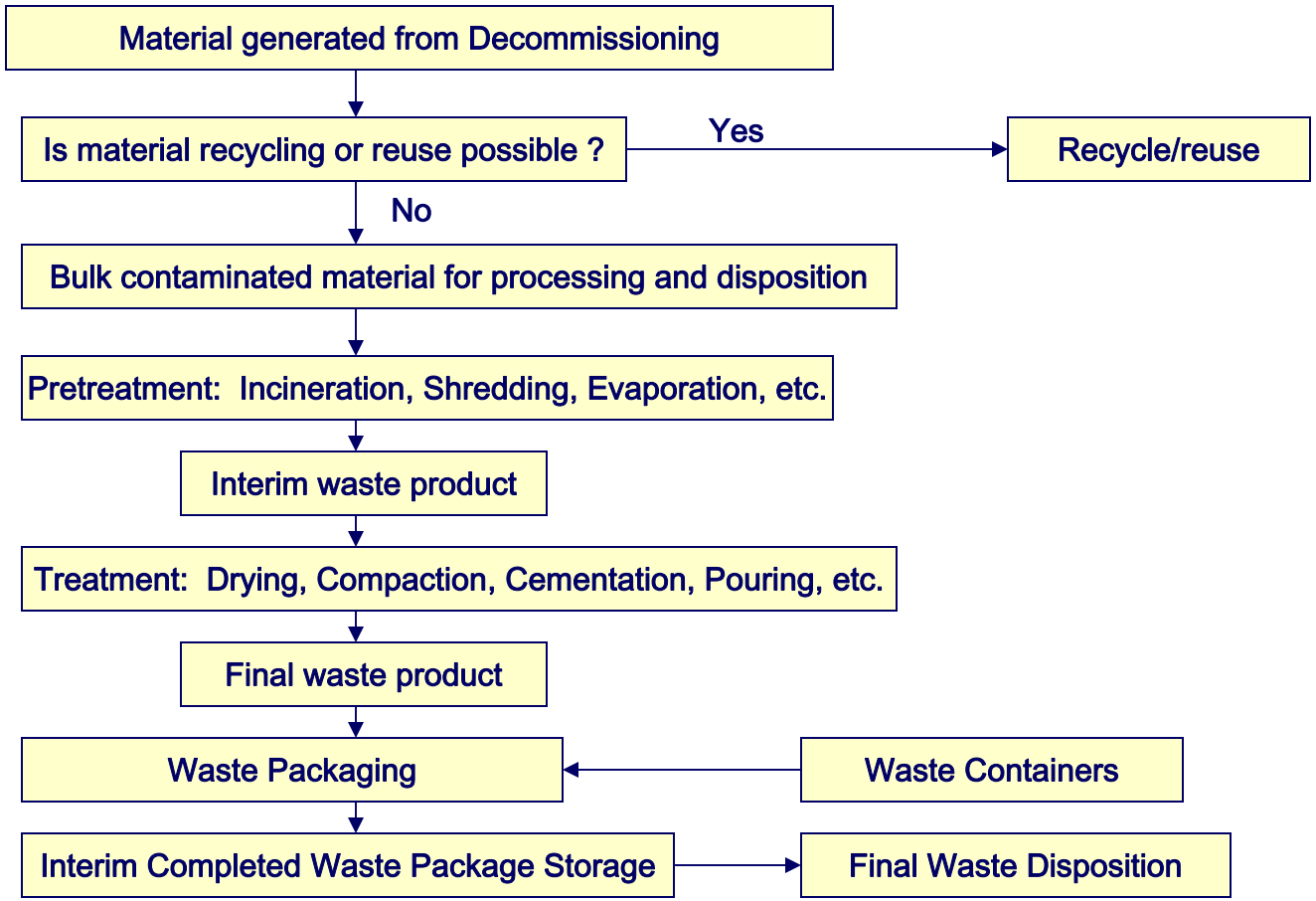
Radioactive Waste Programme Objectives

- Prevent unauthorized release of radioactive material
- Recognize the need for distinct radioactive waste vs. non-radioactive waste management streams
- Reduce waste volume
- Segregate wastes into categories for processing, disposition and transport
- Manage waste in accordance with optimization principles
- Assure that final waste products meet requirements for off-site treatment, transport and ultimate disposition

Radioactive Waste Programme Objectives

- **Must maintain on-site waste management and control systems – whether original plant or temporary systems**
  - **Gaseous effluent controls and monitoring**
  - **Liquid waste processing and monitoring**
  - **Solids management systems**
  - **Secondary waste management systems**

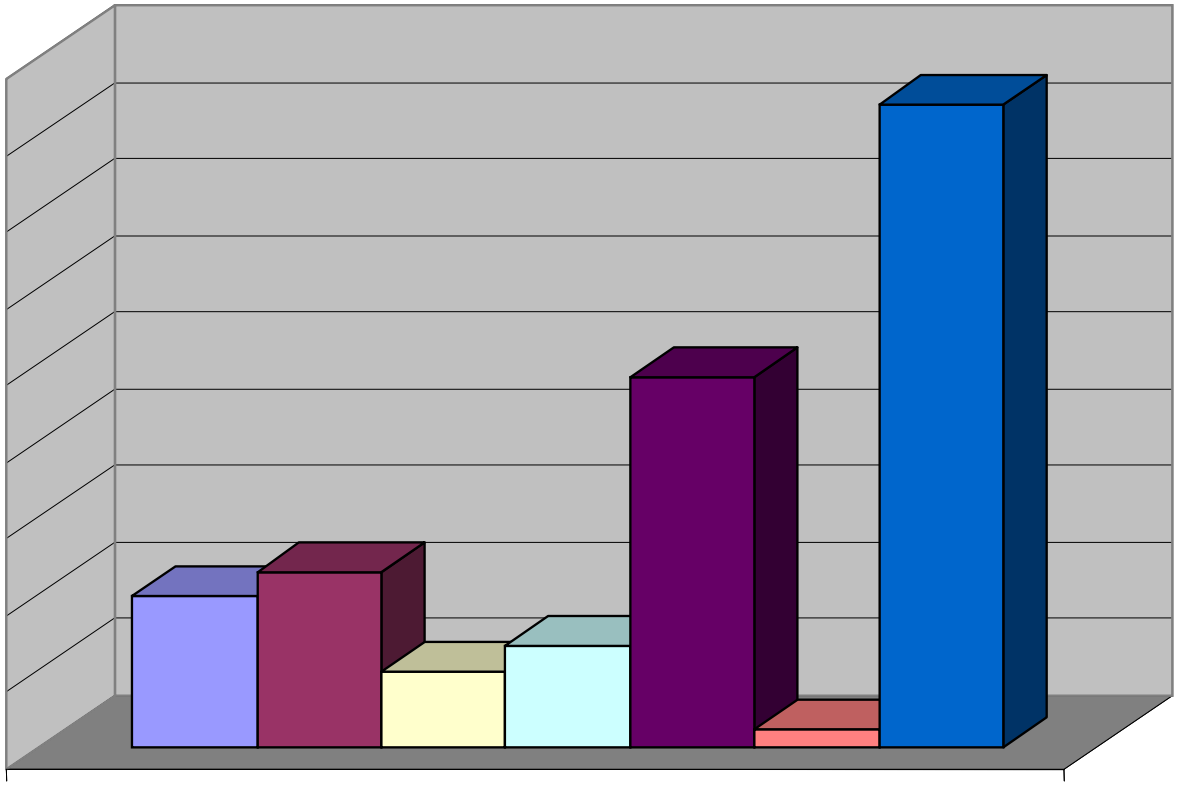
Typical Methods to Manage Decommissioning Waste



IAEA Solid Radioactive Waste Classification System

Waste Classes	Typical Characteristics	Disposal Options
Exempted Waste (EW)	Activity levels at or below national clearance levels which are based on an annual dose to members of the public of < 0.01 mSv	No radiological restrictions
Low and Intermediate Level Waste (LILW)	Activity levels above clearance levels and thermal power below about 2 kw/m^3	Near surface or geological disposal facility
•Short Lived Waste (LILW-SL)	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	Near surface or geological disposal facility
•Long Lived Waste (LILW-LL)	Long lived nuclide concentrations exceeding limitations for short lived waste	Geological disposal facility
High Level Waste (HLW)	Thermal power exceeding 2 kw/m^3 and long lived nuclide concentrations exceeding limitations for short lived waste	Geological disposal facility

Radioactive Waste Example Costs for Research Reactor Decommissioning



Total Reactor & Systems D&D of $ 8 Million

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

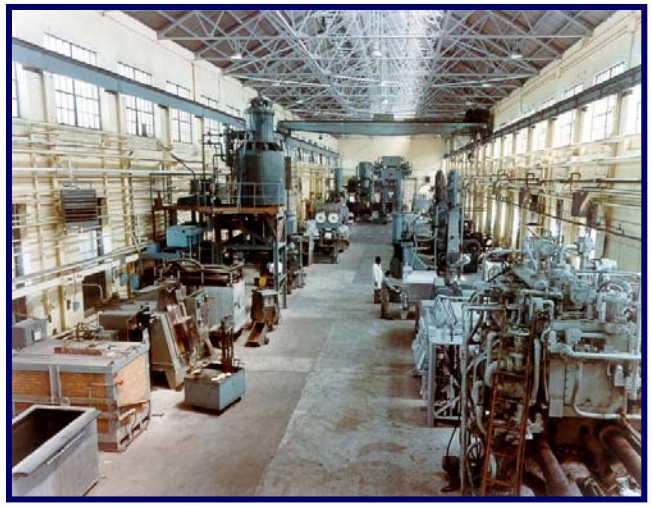
- Higher levels of contamination/activation
  - Larger metallic waste (reactor internals, pressure vessel, primary coolant pumps)
- Low to mid levels of contamination
  - Metallic waste (smaller pumps, tanks, piping, valves, structural supports)
- Concrete waste
  - Activated as well as surface and subsurface contaminated
- Lightly contaminated compactable material (insulation, asbestos)
- Burnable waste (protective clothing, wood)
- Special waste (contaminated lead, mixed waste)

Typical Waste Streams

- **Hazardous Non-Radioactive Waste**
  - **Asbestos**
  - **Poly-Chlorinated Bi-phenols (PCBs) – transformers, paints, etc.**
  - **Heavy metals (Pb, Zn, Ag, Hg, Cd, etc.)**
  - **Solvents**
  - **Chemical listed material**
  - **Toxic substances**
  - **Corrosives**

Primary Waste Streams

- **Mechanical / Electrical Equipment**
  - Glove boxes
  - Pumps, valves, fitting
  - Exhaust ventilation/hoods
  - Piping (exposed and embedded)
  - Ducting
  - HVAC
  - Transformers/motors
  - MCC's, duct chases, electrical cables
  - Waste management systems
  - Hot laboratories facilities
  - Cranes, handling equipment
  - Hot machine shops and fabrication/maintenance
  - Fuel pool equipment and systems



Primary Waste Streams

Interior facility floor drains, sumps

Primary Waste Streams

Exterior drainage and storm sewers

Primary Waste Streams

Contaminated soil (under concrete slabs)

Secondary Waste Streams

- Characterization waste
- Preparation waste
- Decontamination waste
- Contaminated tools and equipment
- Protective clothing
- Shielding material

Characterizing Waste Streams

- The goal of waste stream characterization is to estimate the radionuclide concentrations in order 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 the most precise, however is often very time consuming and expensive
- Must sample/analyze representative media from waste stream, validate the homogeneity of the waste stream
- Determine waste geometries (drums, boxes, sea vans)
- Model using shielding codes/calculations to correlate measured variable to package nuclide concentrations

Characterizing Waste Streams

- Inventory of waste packages
  - Segregate low and high level wastes
  - Maintain accurate records of inventory
  - Maintain accurate records of disposal
  - Try to handle only once – place waste into ultimate disposal container
- Lessons learned
  - Watch for cross contamination
  - Source check instruments at the beginning and end of shift
  - Use correct instruments for expected radiation types
  - Training for personnel – use consistent survey techniques
  - Activation analysis assumes material used is known

Waste Treatment and Conditioning

- Conditioned waste characteristics
  - Monolithic
  - Homogeneous
  - Low contaminant leaching
  - Good stability
  - Good mechanical strength

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

Liquid Waste Treatment Options

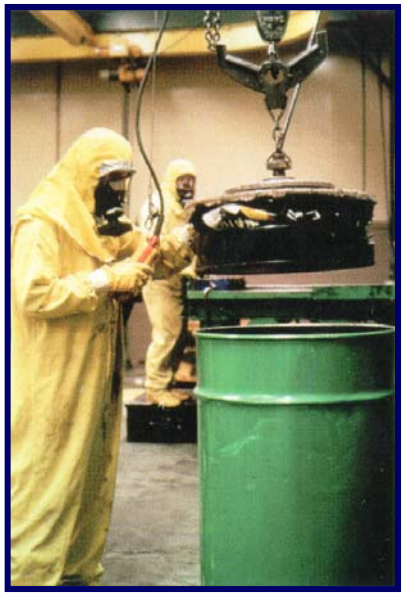
- Filtration – primary means to remove suspended solids
- Ion exchange resin (bead or resin) a key means to remove solids and ionic species – can be adversely affected by surfactants, organics or chelating agents potentially used in plant decontamination
- Evaporators – useful in some applications – diminished effectiveness if suspended solids are present
- Solidification – direct encapsulation in concrete or absorption

Gaseous Waste Treatment Options

- Filtration is the primary treatment as radioactive decay will typically limit effectiveness or need for gaseous system delay holding tanks and carbon banks for iodine removal.
- May still need moisture separators for gaseous tritium removal

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**

Waste Storage

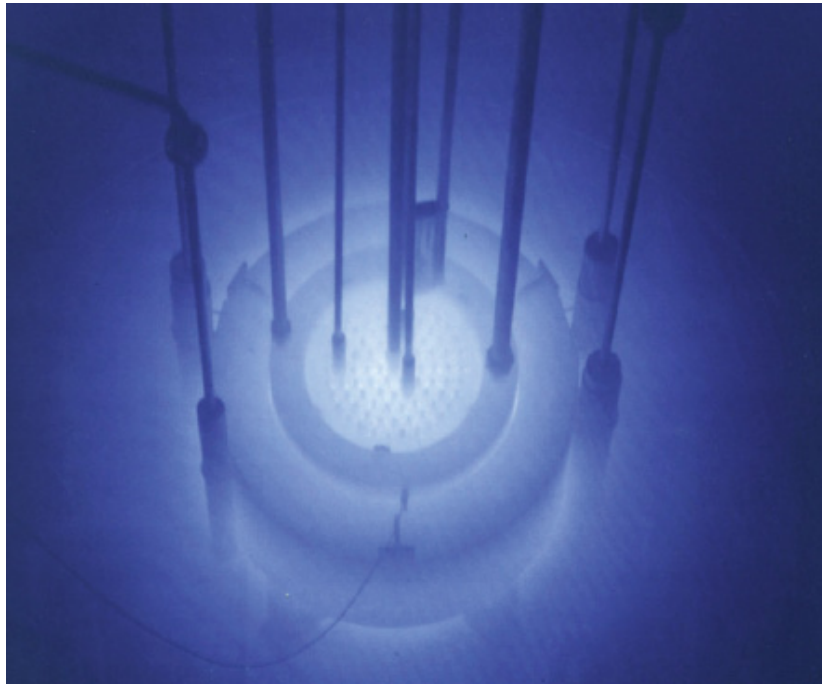
- Interim (low and intermediate activity waste stored on site)
  - Criteria for radiation protection
  - Facility protected from the elements
  - Packaged waste stored outdoors
    - Weather deterioration
    - Animal intrusion

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
  - Facility/waste packages protected from the elements

Spent Fuel Storage

- **Management Options**
  - **Typical spent nuclear fuel re-processor**
  - **Consolidation or off-site transfer to country of origin**
  - **Dry storage - cask**
  - **Wet storage – pool**
  - **On-site storage**



Traditionally spent fuel management is not considered a part of decommissioning

Waste Packaging and Handling

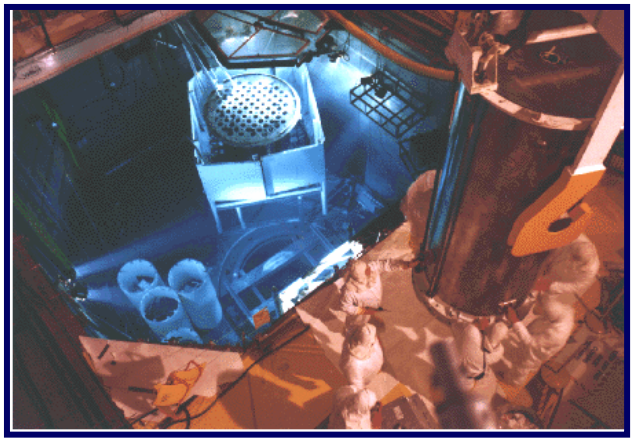
- Packaging considerations
  - Facility handling and storage requirements
    - Exposure control
  - Compatibility and corrosion resistance
  - Packaging ventilation
  - Adequate fire resistance
  - Ease of decontamination
  - Integration with facility material handling equipment
  - Off-site transportation

Waste Packaging and Handling

- Classification of Waste for Transport
  - Amount of radioactivity present
  - Types of radionuclides present
  - Distribution of radioactivity in waste
  - Chemical hazards

Waste Packaging and Handling

- Handling, lifting methods
  - High gamma source material
  - Ingestion risk material
  - Reactor internals, size reduction & cutting tools
  - Rigging (bells, shields, underwater lifting)



Waste Packaging and Handling

- Interim storage
- Final assay, documentation/manifesting
- Transportation – rail, truck, barge

Waste Packaging and Handling

- **Final disposal**

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

Waste Transport Issues

- Packaging type –
  - Industrial Package
  - Shielded cask
  - Surface contaminated object
  - Strong tight container
- Radiation limits
  - Package surface
  - Transport (driver and public exposure)

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 Considerations

- Disposal facility availability
- Site handling capability
- Cost
- Waste acceptance criteria
- Political considerations
- Regulatory
- Transportation Issues

Nuclear Reactor on Transporter

Waste Disposal Considerations

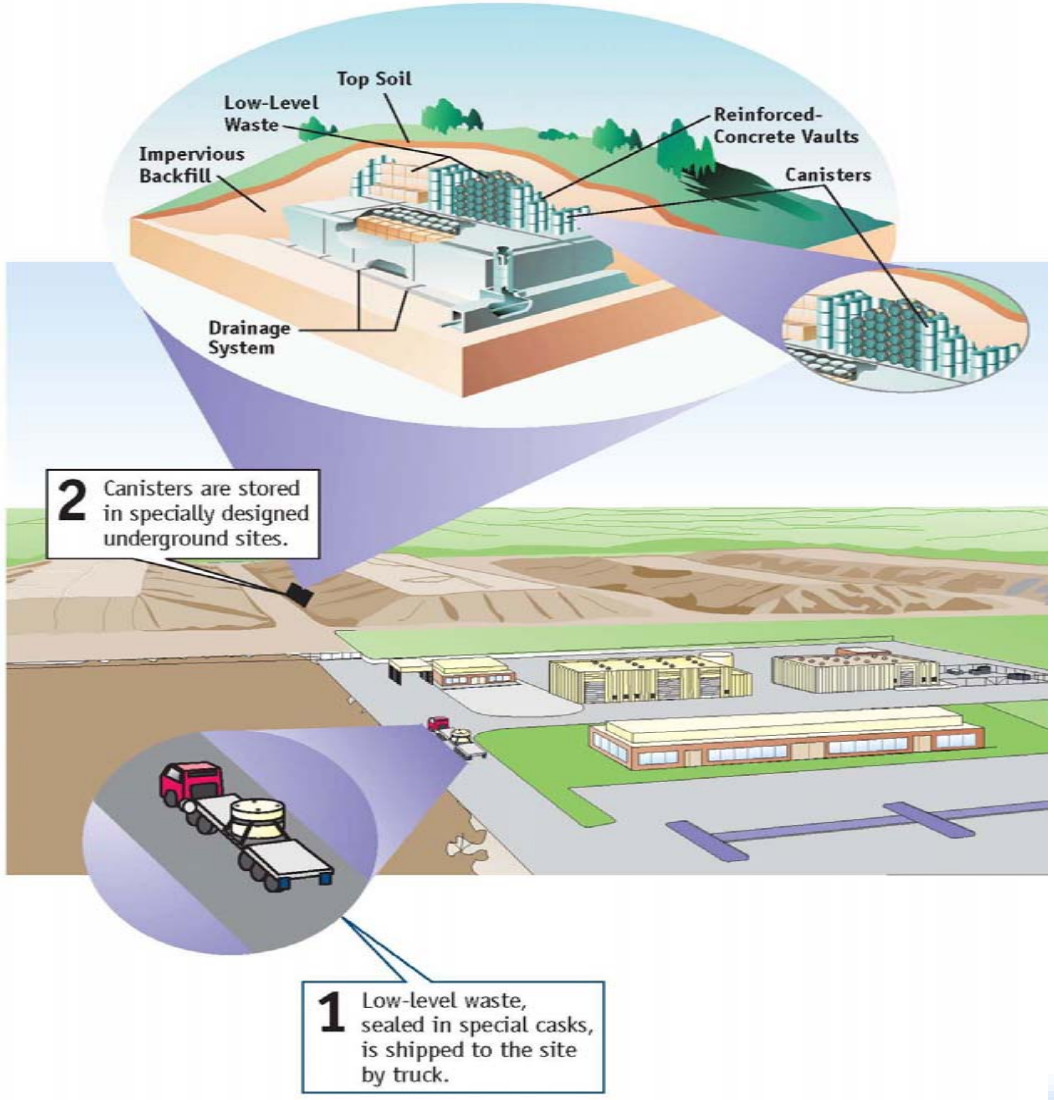
- Primary concern is preparation of waste in order to meet disposal facility WAC
- Disposal concerns
  - Compatibility of waste with surrounding media
  - Chemical, mechanical, biological, thermal and radiation stability
  - Low leach rate of contaminants
  - Solid form with low dispersability
  - Radionuclide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

Waste Disposal

- **Typical low and intermediate waste disposal cell**



Practical Considerations

- Get the projected volumes right – waste costs a project money
- Understand the Waste Acceptance Criteria and required certifications
- Perform the decommissioning with the end waste package in mind
- Expect “hidden” contamination
- Work for packaging efficiency (weight or activity based)
- Expect questions from stakeholders

Practical Considerations

- Where possible, use treatment options that are simple, efficient, environmentally friendly and readily available
- Plan for needed use of cranes, package shielding or casks and material handling strategies
- Engineer the waste sizing based on worker efficiencies as well as packaging and transport constraints
- Water turbidity (when performing underwater decontamination, cutting, grinding)
- Plan for releases where not expected

Practical Considerations

- Develop a low-level waste management plan which is based on a comprehensive site characterization effort
- Initiate advance planning projects for major end items (large component removal) if possible as a disposal option
- Include waste packaging,transport and disposition as part of the up-front planning process for all system and equipment removal activities
- Carefully evaluate material flow so as to have sufficient staging and lay-down areas
- Develop working rapport with waste storage or disposal site staff

Practical Considerations

- Develop a comprehensive plan to address the complex 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
- Remain cognizant of regulatory requirements, available waste disposal options, and waste acceptance criteria for waste disposal sites
- Develop strategies for the long term storage of radioactive waste which cannot currently be disposed (e.g., spent nuclear fuel)

Summary

- Radioactive Waste management is all about optimization via
  - Minimizing costs
  - Minimizing exposure to on-site workers
  - Minimizing volume of waste requiring disposal through volume reduction, super-compaction, incineration, consolidation
  - Survey and release (clearance)
  - Use of alternative materials
- Waste management system design must meet facility requirements and treatment goals

Summary

- Waste management planning must address all phases of operations and proceed from defined objectives
- Treatment systems must be tailored for specific waste streams
- Selection of waste packaging must address onsite use and storage and offsite transport
- Must consider final waste disposal requirements

- Success is in the planning and use of an optimized process !!!

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