Task 3 – NORM Waste Management Cost Assessment

ENVIRONET NORM PROJECT
Working Session During NORM IX Symposium

Horst Monken Fernandes
Decommissioning and Environmental Remediation Section
Division of Nuclear Fuel Cycle, Waste Technology and Research Reactors

23 September 2019
TYPES OF RESIDUES

• Types of NORM Residues
  – Waste rock from mining operations
  – Tailings from the dry separation of heavy minerals
  – Bauxite tailings
  – Tailings and Phosphogypsum from phosphate fertilizers production
  – Scale deposits
  – Sediments and sludge
  – Furnace slag
  – Furnace dust
  – Liquid NORM residues
  – Gaseous NORM residues
WHAT ARE DIFFERENT COUNTRIES DOING?

• That will depend on a variety of issues:
  – Number of NORM generating industries and amount of residues/wastes being generated;
  – Availability of disposal site(s).
    • Commercial x state owned waste disposal facilities
    • Associate costs: long-term stewardship and institutional controls
    • Geographical characteristics is a point to consider - transportation
  – Public attitude and perception
  – Industry engagement: education
  – Possibility to dilute the waste and use the residue → public acceptance and regulatory requirement
  – Regulatory framework and enforcement
COMMON APPROACHES
APPLICATION OF Waste Hierarchy

- Prevention
- Minimisation
- Reuse
- Recycling
- Energy recovery
- Disposal

Most favoured option
Least favoured option
Waste Classification Scheme

Classification scheme for radioactive waste – application to NORM waste

1 Bq/g
IF NORM RESIDUE IS CONSIDERED WASTE

Keeping in Mind the Waste Management Hierarchy
Steps in the Predisposal Management of Radioactive Waste

• Characterization and classification of radioactive waste
  – Physical, mechanical, chemical, radiological and biological properties
  – Waste or waste package will meet the acceptance criteria for processing, storage, transport and disposal of the waste

• Processing of radioactive waste
  – Pre-treatment: waste collection, segregation, chemical adjustment and decontamination
  – Treatment: reduction of volume, removal of radionuclide, change the form of composition of the waste, change of the form or physical properties of the waste

• Storage of radioactive waste
• Waste acceptance criteria
Flow diagram for the management of solid radioactive waste

1. Waste generation
   - Pretreatment collection, segregation, chemical adjustment, decontamination
     - Clearance
       - Storage for decay
         - No
           - Are clearance levels met?
             - Yes
               - Immobilization of residues and filters
               - Compaction
                 - In-drum compaction
                 - Drum compaction
               - Storage of conditioned waste
                 - Disposal facility
             - No
               - Clearance
     - Treatment of combustible waste
       - Thermal treatment
         - In-drum compaction
         - Drum compaction
         - Storage of conditioned waste
         - Disposal facility
     - Treatment of compactible waste
       - Conditioning in an overpack
       - Conditioning and packaging
       - Storage of conditioned waste
       - Disposal facility
     - Treatment of non-combustible, non-compactible waste
       - Placement in container
Life cycle of a disposal facility
Low-Level Radioactive Waste Repositories: An Analysis of Costs

• Technical factors affecting costs
  – Planning and licensing
  – Construction
  – Operation
  – Decommissioning and closure
  – Post closure activities

• Non-technical factors affecting costs
  – Socio-political factors
  – Regulatory requirements
  – Taxes and insurance
  – Finance
  – Timing
  – Land acquisition and cost of services
Summation of cost elements (undiscounted)
Operating costs versus repository type

- Near-Surface Repositories
  - Operational
  - Planned

- C/B and Geological Repositories
  - Old Mines
  - Operational
  - Planned

- Cavern-based Repositories
  - Operational
  - Planned
Total construction costs versus capacity

![Graph showing total construction costs versus capacity]
## NORM Disposal Costs (55-gal drum)

<table>
<thead>
<tr>
<th>Disposal Method</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Additional Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill</td>
<td>722</td>
<td>941</td>
<td>1334</td>
<td>None</td>
</tr>
<tr>
<td>Landfill</td>
<td>548</td>
<td>914</td>
<td>1280</td>
<td>Radiological and chemical analysis, physical properties check, transportation, waste profile, packing</td>
</tr>
<tr>
<td>Surface Treatment</td>
<td>182</td>
<td>384</td>
<td>594</td>
<td>Radiological and chemical analysis, physical properties check, transportation, waste profile, packing</td>
</tr>
<tr>
<td>Injection</td>
<td>89.60</td>
<td>376</td>
<td>1828</td>
<td>Radiological and chemical analysis, physical properties check, transportation, waste profile, packing</td>
</tr>
<tr>
<td>Recycling steel</td>
<td></td>
<td>Steel purchase price pays for transportation costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encapsulation in Pipes and Disposal in Abandoned Wells</td>
<td>1448</td>
<td>1976</td>
<td>6094</td>
<td>None</td>
</tr>
<tr>
<td>Injection into private wells</td>
<td>276</td>
<td>1675</td>
<td>4205</td>
<td>None</td>
</tr>
</tbody>
</table>
## Commercial Disposal Costs for NORM

<table>
<thead>
<tr>
<th>Disposal Method</th>
<th>On-Site/Off-site</th>
<th>Costs ($/bbl) – ($/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection</td>
<td>Off-site</td>
<td>236 – 1,484</td>
</tr>
<tr>
<td>Injection</td>
<td>Off-site</td>
<td>157 – 1,046</td>
</tr>
<tr>
<td>Landfill</td>
<td>Off-site</td>
<td>598 – 661</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,900 – 4,400</td>
</tr>
<tr>
<td>Treatment/Injection</td>
<td>On-site</td>
<td>220 – 1,466</td>
</tr>
<tr>
<td>Injection</td>
<td>On-site</td>
<td>157 – 300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1046 – 2,000</td>
</tr>
<tr>
<td>Injection</td>
<td>On-site</td>
<td>23.6 – 236</td>
</tr>
<tr>
<td></td>
<td></td>
<td>157 – 1,573</td>
</tr>
</tbody>
</table>

a) 1 bbl = 42 gal  
b) Source: American Petroleum Institute  
c) Prices adjusted to 2019
Atoms for peace and development

at your service for more than 60 years
Thank you!