Leachability of THOR Residues

IGD-TP Exchange Forum
04 November 2015
Outline

- THOR – Thermal Organic Reduction
- Technology overview
- Wastes treated
- Solid product characteristics
- Leach resistance
- Optional monolith waste form
- Summary
THOR - Thermal Organic Reduction

- Fluidized Bed Steam Reforming process
- Decomposition of Organic Compounds into carbon dioxide ($CO_2$) and Steam ($H_2O$)
- Reduction of Nitrates into Steam ($H_2O$), nitrogen gas ($N_2$), and ($CO_2$)
- Non-Incineration
- No dangerous Off-Gases
- No liquid effluents
- Captures 99.99% of radioactivity into the final, solid product
- Customizable final product characteristics
- Low maintenance
- Volume Reduction
- 14+ Years of Continuous, Full-Scale Operations in Erwin, TN
THOR Technology

- Thermal process
  - Fluidized bed of granular solids
  - Fluidized with steam
  - Operates at 650-850°C
- Waste preparation and inputs
  - Mineralizing additive
  - Waste feed injected into fluidized bed
  - Coal
- Inside the Fluidized Bed Steam Reformer
  - Water evaporates
  - Nitrates reduced to nitrogen gas
  - Inorganic waste constituents converted into insoluble minerals
THOR – Treated Wastes

- **Nitrate Wastes**
  - Main Chemical Component: Sodium Nitrate and other Nitrates and Nitrites
  - Other Chemical Components: Organics, Sulfates, Chlorides, Calcium

- **Ion Exchange Resins (IER)**
  - Main Chemical Components: Long-chain Organics
  - Other Chemical Components: Boron, Sulfur, Iron, Sodium, and Lithium
  - Commercial Treatment of IERs for over 14 years in Erwin, TN

- **Dry Active Waste (DAW)**
  - Main Waste: Filters
  - Other Waste: Clothing, Plastics, Rubber, etc.
  - Commercial Treatment of DAW for over 14 years in Erwin, TN

- **Various Wastes Liquids and Sludges**
  - Main Wastes: Oils, Sludges, etc.
  - Other Wastes: Heavy Metal (Uranium and Magnesium) bearing wastes
Solid Waste Products

- Small sized particles of ceramic mineral
- Alkali-Alumino-Silicate (feldspathoid) minerals (NAS)
  - Nepheline (Na₂O-Al₂O₃-2SiO₂)
  - Nosean (6 Nepheline + Na₂SO₄)
  - Sodalite (6 Nepheline + 2NaCl)
  - Leucite (K₂O-Al₂O₃-4SiO₂)

![Scanning Electron Microscope Image of Sodalite mineral](image1)

THOR Product Solids

![Typical Feldspathoid Structure](image2)
Solid Waste Products

- Process operating temperature is sufficiently low to not vaporize radionuclides

- Ceramic waste form contains cavities/sites that incorporate:
  - Radionuclides (Tc, Cs, most I)
  - Alkali Metals
  - Sulphur
  - Chlorides
  - Fluorides

- Spinel minerals form that contain various metals
  - Cr, Ni, Fe, Pb, etc.
Leach Resistance Performance of THOR Product

- Leach resistance performance is better than vitrified glass
- >99.99% retention of Cs, Tc and other radionuclides
- Can accommodate Cl, F, SO\(_4\), Mo, Re, Tc, etc.

Leach resistance of Tc-99 compared to other waste forms – analysis performed by Pacific Northwest National Lab
Optional Monolith Final Waste Form

• Granular mineral products are mixed with geopolymer binder to make monolithic final waste form
  • Geopolymers are amorphous to semi-crystalline, three-dimensional silico-aluminate minerals; mineral polymers resulting from mixing clay with sodium silicate and/or NaOH
  • Density of 1.78g/cc
  • Compressive strength of 159 bar at 33 days cure time
Summary – THOR Steam Reforming

Accommodates widely varying inputs
- Treats solids, liquids, or sludges with high or low pH
- High organic destruction
- Does not volatize Cs, Tc (and others)
- Mineralizes Cl, F, P, and SO$_4$, and radionuclides in leach resistant solid

Non-Incineration
- Operates below flammability limits
- Modular design can be provided

Leach resistant wasteform from processing
- Qualifications to date validate highly leach resistant
- Leach tests done on real waste and simulant
- Granular and monolith waste forms

THOR is Proven
- 14+ year history of commercial operations treating ion-exchange resins
Supplemental Slides/Data
THOR Product: 7-Day PCT Results for Granular Product made from simulant and actual Radioactive Waste

***PCT requirement for treated LAW waste: <2.0 g/m²

<table>
<thead>
<tr>
<th>Normalized Elemental Release</th>
<th>ESTD P-1B Granular</th>
<th>BSR Module B Simulant Granular</th>
<th>BSR Module B Radioactive Granular</th>
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<tr>
<td>(g/m²)</td>
<td>Std. Dev.</td>
<td>(g/m²)</td>
<td>Std. Dev.</td>
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<td>Al</td>
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<td>$^{133}$Cs</td>
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<td>$^{137}$Cs</td>
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<td>$^{127}$I</td>
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<td>pH</td>
<td>11.63 (Blend)</td>
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THOR Product: 7-Day PCT Results for Monoliths and Granules of Simulant FBSR Mineral Products

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<th>Normalized Elemental Release (g/m²)</th>
<th>Non-Radioactive</th>
<th>Radioactive</th>
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<tr>
<td></td>
<td>Fly Ash ESTD P-1B* GEO-7 Monolith (68% FBSR loading)</td>
<td>Fly Ash BSR Mod B GEO-7 Monolith (68% FBSR loading)</td>
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