THE ENVIRONMENTAL IMPACTS OF KOREAN ADVANCED NUCLEAR FUEL CYCLE KIEP-21 AND DISPOSAL CONCEPTS

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KIEP-21
: Waste streams and Repository Concept
Flowsheet for treatment of 1 MTHM of used PWR fuel with 4.5wt% U-235, 45000 MWD/MTU, and five provisional waste streams.
Repository concepts

Korean Reference Spent Fuel Disposal System (KRS)

Advanced Korean Reference Disposal System (A-KRS)

Waste Package/Disposal

(1) Metal waste-ILW

- Compact-Metal Disposal Package (c-MDP)
  - 0.92 ingot/1 MTU

(3) Vitrified waste-HLW

- Storage & Disposal Container (SNDC-2)
  - 0.1 block/1 MTU
Waste Package/Disposal

- **(4) Ceramic waste-ILW**
  - 80 cm Storage Rack (SR)
  - 0.6 block/1 MTU

- **(5) Vitrified waste-ILW**
  - Storage Rack (SR)
  - 2.4 blocks/1 MTU
## Volume/Heat Emission

### Volume

<table>
<thead>
<tr>
<th>Waste stream</th>
<th>Volume (unit: m³/1 MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste 1</td>
<td>0.14</td>
</tr>
<tr>
<td>Waste 3</td>
<td>0.14</td>
</tr>
<tr>
<td>Waste 4</td>
<td>0.08</td>
</tr>
<tr>
<td>Waste 5</td>
<td>0.01</td>
</tr>
<tr>
<td>Total</td>
<td>0.37</td>
</tr>
</tbody>
</table>

| Direct Disposal | 3.06 |

→ 1/8 volume reduction

### Heat emission

<table>
<thead>
<tr>
<th>Concept</th>
<th>Heat emission (unit: watts/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyroprocessing</td>
<td>2.00E+00</td>
</tr>
<tr>
<td>Direct Disposal</td>
<td>1.34E+02</td>
</tr>
</tbody>
</table>

(after 300 yrs)
Radionuclides Transport Model
<Assumptions>
(1) no radionuclides are lost due to transport effect
(2) all radionuclides reaching the biosphere would be ingested.
Geochemical modeling scheme

1. Granitic groundwater
2. Cement water
   : Granitic groundwater with Cement reaction
3. Bentonite porewater
   : Cement water with MX-80 bentonite
4. Monazite porewater
   : bentonite porewater with Monazite

* Neglect canister and overpack
* PHREEQC (V.2.17) code
Comparative and Parametric studies

- Effects of Back-end Fuel Cycle
  - Direct disposal (KRS) and Pyroprocessing (A-KRS)
- Waste Form Durability Effect
- Solubility Effect
A. Effects of Back-end Fuel Cycle

- Direct disposal (KRS) and Pyroprocessing (A-KRS)
B. Waste Form Durability Effect

- From $T_L = 4,000$ year to $T_L = 4$ million year at 10 m location
- Direct disposal case ($T_L = 4$ million year)
The graph shows the mass release rate (mol/year) over time (years) for different TL (time to live) values. The direct disposal case with a TL of 4 million years is shown as the highest curve. Other curves represent TLs of 40,000 years, 400,000 years, and 4,000 years. The graph includes a label indicating Pyroprocessing on the right side.
C. Solubility Effect
Boundary condition

<table>
<thead>
<tr>
<th></th>
<th>Solubility (mol/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Am(OH)₃(am)</td>
<td>1.63E-03</td>
</tr>
<tr>
<td></td>
<td>1.67E-03</td>
</tr>
<tr>
<td></td>
<td>5.29E-07</td>
</tr>
<tr>
<td></td>
<td>2.00E-09</td>
</tr>
</tbody>
</table>

| Waste 1       | Am²⁴³ Flux Flux Solb. Solb. |
| Waste 2       | Am²⁴³ Flux Flux Flux Flux |
| Waste 3       | Am²⁴³ Flux Flux Flux Flux |

<table>
<thead>
<tr>
<th></th>
<th>Inventory (mol/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste 1</td>
<td>Am²⁴³ 4.50E-03 Am²⁴¹ 1.05E-02</td>
</tr>
<tr>
<td>Waste 3</td>
<td>Am²⁴³ 8.88E-07 Am²⁴¹ 2.06E-06</td>
</tr>
</tbody>
</table>

1.63e-03_bentonite porewater
1.67e-03_monazite porewater
5.29e-07_cement water
2.0e-09_granitic groundwater
Because most TRU isotopes are recovered by pyroprocessing for future use in the fast reactors, the heat emission from the waste is reduced by a factor of 67 at 300 years, compared with emission from PWR spent fuels.

Major heat emitters in the first 300 years, Cs and Sr, are included in the intermediate level wastes, and is assumed to be managed by active ventilation.
In the near field, the peak radionuclide release rate is reduced by application of pyroprocessing.

- This is not because of separation of TRUs from the PWR used fuels, but because of better performance of waste forms than the spent fuel, which contains Iodine-129 in the gap between fuel pellets and cladding.
- Contributions of TRU elements are not significant.

In the far field,

- Those fission products that dominate the release rate in the near field also are main contributors.
- Furthermore, difference in TRU inventories and waste form performance do not make significant difference, due to assumed mechanism of radionuclide retention and dispersal in the far field.
- This needs further study to confirm.
Conclusion

- From the preliminary parametric study, it has been confirmed that waste-form durability and radionuclide solubility can have significant effects. For more meaningful comparison, we need to make a realistic assessment of repository performance, for which we need to achieve:
  - More detailed heat transfer analysis to determine repository configurations
  - More detailed geochemical analysis to determine waste-form dissolution, release of radionuclides from waste forms, and transport of radionuclides in the engineered barrier
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Thank you for your attention!