Provisional scenario of radioactive waste management for DEMO

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2. Basic idea for waste management scenario
3. Estimation of ….
   *induced radioactivity, decay heat and dose rate*
4. Provisional scenario of management for radioactive waste
5. Summary
Introduction

• Waste management scenario has been considered for DEMO

➡ The scenario has a large impact on planning the facilities required for DEMO.

✓ Hot cell
✓ Waste storage …

A provisional management scenario of the radioactive waste has been proposed for DEMO
Waste management strategy of fusion reactors has been considered as an issue after decommissioning.

Radioactive waste is also generated in every periodic replacement of in-vessel components.
Basic idea for waste management scenario

Replacement (* every a few years)

Sector assembly
- Decay heat
- Tritium
- Tungsten dust

Interim storage

Reactor

Decommissioning

Dismantlement

Maintenance

Back plate

Blanket

Divertor

Breeder & Multiplier

Reuse

Disposal

Disposal

Recycle

Shallow land burial
### Specifications of a Fusion DEMO

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main radius</td>
<td>~ 8.2 m</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>3.0</td>
</tr>
<tr>
<td>Elongation</td>
<td>1.65</td>
</tr>
<tr>
<td>Triangularity</td>
<td>0.33</td>
</tr>
<tr>
<td>Fusion power</td>
<td>1.35 GW</td>
</tr>
</tbody>
</table>

![Diagram showing various components of a fusion DEMO](Image for 8 m DEMO)

- **Maintenance port**
- **Permanent shield**
- **Vacuum vessel**
- **Blanket**
- **Divertor**
- **TFC**
- **CS**
- **Back plate**
- **Conducting shell**

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<table>
<thead>
<tr>
<th>Component</th>
<th>Life time</th>
<th>Volume</th>
<th>Material</th>
<th>Weight</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blanket</td>
<td>3 year</td>
<td>737 m³</td>
<td>W coating</td>
<td>4 ton</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>F82H</td>
<td>455 ton</td>
<td>29 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mixed breeder (Li₂TiO₃ / Be₁₂Ti)</td>
<td>1470 ton</td>
<td></td>
</tr>
<tr>
<td>Back plate</td>
<td></td>
<td>465 m³</td>
<td>F82H</td>
<td>3669 ton</td>
<td>56 %</td>
</tr>
<tr>
<td>Divertor</td>
<td>1 year</td>
<td>111 m³</td>
<td>W mono-block</td>
<td>201 ton</td>
<td>15 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>F82H</td>
<td>790 ton</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1312 m³</td>
<td>—</td>
<td>6589 ton</td>
<td>100 %</td>
</tr>
</tbody>
</table>

![Diagram](image1.png)  
![Diagram](image2.png)
How to estimation for radioactive

3D neutron and gamma-ray fluxes  
**MCNP-5**

*Neutron spectrum*

Radioactivity, Decay heat and contact dose rate  
**THIDA-3**

*Gamma-ray source (as radioactivity)*

Future work

Dose map in reactor  
**MCNP-5**

The neutron energy spectrum calculated by MCNP-5 with 3D model based on the Boltzmann equation is used for calculating Radioactivity, decay heat and contact dose rate by THIDA-3.

The induced radioactivity of the components in the reactor calculated by THIDA-3 is used as an input to calculate the gamma-ray source for evaluating the dose map by using MCNP-5.
Neutron energy spectrum

14.06 MeV (DT neutron)

Backscattering effect of blanket and neutron shielding

Current neutron flux, n/cm²/sec/lethargy

Energy, eV

- Blanket (OB Blanket: equatorial plane)
- Blanket (IB Blanket: equatorial plane)
- Divertor (area of dome)

*12 dpa/FPY
*16 dpa/FPY
*5 dpa/FPY

( * F82H)
Neutron wall load

$1.1 \text{ MW/m}^2$

Blanket

$0.8 \text{ MW/m}^2$

Divertor

$\text{cf } 1 \text{ MW/m}^2 = 4.4 \times 10^{17} \ (\text{n/m}^2/\text{s})$

$= 4.4 \times 10^{13} \ (\text{n/cm}^2/\text{s})$
Decay heat for a fusion reactor

The total decay heat is as high as 36.22 MW and decreases to 2.00 MW one month later.

A month after the shutdown, the total decay heat decreases to 5.5% of the initial one.
Radioactivity for a DEMO

**Long-lived radionuclide**

- **W coating of blanket**
  - $^{186m}Re$ (halftime: $2.0 \times 10^5$ year)
  - $^{192m}Ir$ (halftime: 241 year)
- **First wall of blanket**
  - $^{14}C$ (halftime: 5700 year)
  - $^{63}Ni$ (halftime: 100 year)

<table>
<thead>
<tr>
<th>Time</th>
<th>$^{14}C$</th>
<th>$^{63}Ni$</th>
<th>$^{186}Re$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 year</td>
<td>$4.1\times10^{10}$</td>
<td>$9.5\times10^{11}$</td>
<td>$5.1\times10^{10}$</td>
</tr>
<tr>
<td>1000 year</td>
<td>$6.3\times10^{8}$</td>
<td>$1.2\times10^{10}$</td>
<td>-</td>
</tr>
<tr>
<td>Calc. (Bq/ton)</td>
<td>$3.6\times10^{10}$</td>
<td>$1.0\times10^{9}$</td>
<td>$5.1\times10^{10}$</td>
</tr>
<tr>
<td>L1 (Bq/ton)</td>
<td>$1\times10^{16}$</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>L2 (Bq/ton)</td>
<td>$1\times10^{11}$</td>
<td>$1\times10^{13}$</td>
<td>-</td>
</tr>
<tr>
<td>L3 (Bq/ton)</td>
<td>$1\times10^{10}$</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CR (Bq/g)</td>
<td>1</td>
<td>100</td>
<td>1000</td>
</tr>
</tbody>
</table>
**Radioactivity for a DEMO cont.**

○ Blanket

(* Material – roots in $\gamma$ or $\beta$)

- Dominant nuclides have root in $\beta$ ray
  - W coating: $^{186}$Re and T
  - F82H first wall: T and $^{63}$Ni

- Dominant nuclides have root in $\gamma$ ray
  - W coating: $^{185}$W and $^{187}$W
  - F82H first wall: $^{55}$Fe, $^{54}$Mn and $^{56}$Mn

○ Divertor

(* Material – roots in $\gamma$ or $\beta$)

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Diagram showing induced radioactivity over time after shut down (in days). The graphs compare different materials and their decay rates.
The disassembly of blanket and divertor is performed in the hot cell by advanced remote handling after temporary storage of about 1 years.
Hot cell and waste storage for a DEMO

- To separate the each area
- To maintain negative pressure in the each area
- To manage the tritium and W dust
- To control the temperature of environment
- To perform everything of the maintenance in the remote handling (RH)

Considering Hot cell and waste storage specific requirements ...

![Diagram of Hot cell and waste storage layout](image)
Provisional scenario of radioactive waste management for DEMO

<table>
<thead>
<tr>
<th>Reactor</th>
<th>Shut down</th>
<th>Detritiation</th>
<th>Atmosphere release</th>
<th>Cooling time for decay heat</th>
<th>Prepare for replacement</th>
<th>Cleanup of W dust</th>
<th>2 - 4 months</th>
<th>Replacement and maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 days</td>
<td>24</td>
<td>30 days</td>
<td></td>
<td>16</td>
<td>3d</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hot cell / Temporary storage</th>
<th>Remove the blanket and divertor from back plate</th>
<th>Detritiation of the blanket and divertor</th>
<th>Temporary storage of the blanket and divertor</th>
<th>Disassembly of the blanket and divertor</th>
<th>Recycling process for multipliers and breeder pebbles</th>
<th>Separate waste by level for burial disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 month</td>
<td>24</td>
<td>2 - 10 years</td>
<td>2 months</td>
<td>3 months</td>
<td>3 months</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Packaging / Interim storage</th>
<th>Packaging of radioactive waste</th>
<th>Interim storage of radioactive waste</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 months</td>
<td>20 - 50 years</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Waste disposal</th>
<th>Shallow land burial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

• As preparatory work for planning the plant facilities and functions required for radioactive waste that is generated in every periodic replacement of in-vessel components, a waste management scenario is under consideration.
• The assessment for an 8 m DEMO indicates the radioactive waste generated in every replacement is estimated to amount to about 6,000 tons.
• This result suggests the necessity of reducing the waste by recycling and reducing materials.