FiR 1 Triga Research Reactor Decommissioning plans, EIA process, Nuclear waste issues

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FiR 1 – a part of the national nuclear energy program

TRIGA order was signed by Frederic de Hoffman (General Atomics) and Minister Pauli Lehtosalo on 30.5.1960.

August 31, 1962
FiR 1 was inaugurated by President of the Republic Urho Kekkonen and Director of General Atomics Dr. Frederic de Hoffman in the presence of high level state and industry representatives.
FiR 1
Finnish TRIGA Research Reactor
– International Role in Boron Neutron Capture Therapy (BNCT)

Regional Role in Isotope Production, Education and Training
FiR 1 Research Reactor (TRIGA Mark II, 250 kW)

- Epithermal neutron irradiation facility for Neutron Capture Therapy constructed in 1998
  - epithermal neutron flux $1.1 \times 10^9 / \text{cm}^2\text{s}$ was created by the FLUENTAL™ neutron moderator
  - BNCT treatments until January 2012

- In core irradiations for isotope production, activation analysis and irradiation testing (thermal $10^{13} \text{n/cm}^2\text{s}$, fast $10^{13} \text{n/cm}^2\text{s}$)
  - Main isotopes for tracer studies produced in the reactor $^{82}\text{Br}$, $^{24}\text{Na}$ and $^{140}\text{La}$

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- Operation license till end of 2023.
  - Has to be modified for shut down and decommissioning phase
Internal structures of FiR 1 reactor
The decision about shutdown and decommissioning

- VTT Technical Research Centre of Finland has decided to shut down the FiR 1 TRIGA research reactor as soon as it is technically and legally justified.
  - VTT considers the reactor as a profit unit without strategic role for VTT.
  - The income from the reactor services has not covered all the costs of the reactor.

- The Ministry of Employment and the Economy (TEM) released a press release on VTT’s decision on July 12th 2012.

- VTT, TEM and STUK hold series of meetings 2012 - 2013

- A start of decommissioning EIA preparation, early 2013
Environmental Impact Assessment (EIA)

  - assessment procedure shall be applied to nuclear power plants and other nuclear reactors, including the decommissioning of these plants and reactors
- The EIA coordinating authority is the Ministry of Employment and the Economy (TEM).

- The assessment is a prerequisite for the project to apply for the modification of the conditions in the operating license issued by the Government and to receive required permits from STUK.
EIA process

1. Environmental impact assessment programme presents evaluation methods and the project and its options, and
2. Environmental impact assessment report as a summary description of the results of the assessment work, and
3. Consultation of those parties whose circumstances or interests may be affected by the project and public hearings.
4. Nuclear waste handling, storage and disposal plans included

In the EIA the direct and indirect effects are assessed for
a) human health, living conditions and amenity;
b) soil, water, air, climate, organisms and biological diversity;
c) the community structure, buildings, landscape, townscape and cultural heritage;
d) the utilization of natural resources; and
e) interaction between these factors
Alternatives to be assessed

- the different options leading to final handling and/or disposal of the spent nuclear fuel as well as the decommissioning waste are evaluated.

- The EIA procedure will assess the following basic options:
  - Alternative A1: Immediate dismantling
  - Alternative A2: Delayed dismantling
  - Alternative A0: The reactor will continue operation (to be decommissioned at a later date)

- In all alternatives processing, transportation, storage and disposal of spent nuclear fuel and decommissioning waste are taken into account.

- All the alternative methods of implementation will be assessed.
Alternatives to be assessed in the EIA

- **A0**: continued operation
- **A1**: Immediate
  - Decommissioning waste
  - Immediate export to USA/DoE
  - Intermediate storage in reactor building
    - Transport from reactor
      - DoE
      - Posiva
      - Final disposal in Finland
    - Intermediate storage at a NPP SNF facility
      - Loviisa
      - Olkiluoto
- **A2**: Delayed
  - Decommissioning waste
  - Export with final disposal abroad
    - Fortum (Loviisa)
    - TVO (Olkiluoto)
  - Final disposal in Finland
    - Fortum (Loviisa)
    - TVO (Olkiluoto)
## Amounts and activity of FiR 1 decommissioning waste

<table>
<thead>
<tr>
<th></th>
<th>m (kg)</th>
<th>V (m3)</th>
<th>A (Bq)</th>
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<tbody>
<tr>
<td><strong>Activated parts</strong></td>
<td></td>
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<tr>
<td>- Steel</td>
<td>3556,4</td>
<td>0,44</td>
<td>2,36·10^{13}</td>
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<tr>
<td>- Al</td>
<td>3932,9</td>
<td>1,46</td>
<td>6,39·10^{11}</td>
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<td>- concrete</td>
<td>10900</td>
<td>4,5</td>
<td>8,27·10^{10}</td>
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<tr>
<td>- graphite</td>
<td>5125,4</td>
<td>2,7</td>
<td>4,60·10^{10}</td>
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<td><strong>Contaminated parts</strong></td>
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<td></td>
<td></td>
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<tr>
<td>- steel</td>
<td>2072,7</td>
<td>0,26</td>
<td>2,76·10^{8}</td>
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<tr>
<td>- Al</td>
<td>365,5</td>
<td>0,14</td>
<td>9,4·10^{7}</td>
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<tr>
<td>**Mixed decommissioni</td>
<td>ing waste and ion exchange resin**</td>
<td>2000</td>
<td>7,4</td>
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<tr>
<td><strong>Sum</strong></td>
<td>27960</td>
<td>16,0</td>
<td>2,44·10^{13}</td>
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1 The given volumes are not bulk volumes, but are calculated from the relation between volume (v), mass (m) and density of the solid (ρ), i.e. ρ=m/V.
Aluminium

Potential problems under repository conditions

Corrosion due to high pH (11-13)
- Heat generation: \( \text{Al} + 3\text{H}_2\text{O} + \text{OH}^- = \frac{3}{2} \text{H}_2 + \text{Al(OH)}_4^- \)
  Highly heat generating reaction! Moreno: no problem in SFR
- Gas production: \( 2\text{Al(s)} + 2\text{OH}^- + 4\text{H}_2\text{O} \rightarrow 2\text{AlO(OH)}_2^- + 3\text{H}_2(g) \)
  Build up of high gas pressures and destruction of containers.
- Reaction with other metals, e.g. steel: \( \text{Al} + \text{Fe}^{3+} = \text{Fe} + \text{Al}^{3+} \)
  Not a problem.

Carbide formation: \( 4\text{Al} + 3\text{C} = \text{Al}_4\text{C}_3 \)
  Carbide formation doesn’t occur under repository conditions
Graphite

- Worldwide: about 250,000 tonnes
- Finland: 0.5 tonnes

- Switzerland has about the same graphite content as Finland

- The patented Swiss graphite storage model (2005):
  i) Pack steel etc. into concrete containers (about 50 vol%)
  ii) Crush activated graphite (5 mm pieces)
  iii) Mix graphite with grout to get artificial sand
  iv) Make graphite concrete
  v) Fill remaining voids in concrete container with the “graphite concrete”.
Graphite

- Published experimental results (e.g. from UK) indicate that the released carbon C 14 under repository is both **organic** (CH₄, ...) and **inorganic** (CO₂, ...)

- Experimental setup

- Experimental results

![Diagram showing experimental setup and results]
VTT’s research report – literature survey

OUTLINE

- The FiR1 TRIGA waste with regard to C-14 and Al
- Aluminium chemistry
- Graphite chemistry
- Results from international studies
- Discussion of the results
- Suggestions for experiments for VTT’s graphite

- Report published 2014 (draft available 2013)
## Preliminary Schedule 2012 for the EIA and decommissioning

<table>
<thead>
<tr>
<th>Task Name</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
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<td>An Authoritative Statement (TEM)</td>
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<td>Preparation of the assessment report</td>
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<td>Final disposal of the decommissioning waste</td>
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Challenging Road Map

- FiR 1 research reactor would be the first nuclear facility in Finland to be decommissioned.
- Further actions e.g. for detailed planning and survey of:
  1. Inventories
  2. Decommissioning safety, procedures, project plan, procurements
  3. Intermediate NW storage plans, packaging and transportation
  4. Special NW issues of Aluminium, Graphite and Fluental materials
  5. Spent fuel return programme of DoE, agreement for FiR 1

- MoUs with different Finnish stakeholders in the nuclear waste management need to be transferred into current situation as agreements and into legally binding documents

- Networking Studsvik Swafo (SWE) , Risoe DD (DK), Triga Users, TüV Rheinland (DE), xx ..
- Regulatory process – graded approach
THANK YOU

Winter of FiR 1 surroundings in Otaniemi