A-FNS workshop

Radiological safety assessments for fusion neutron source in engineering design activities under IFMIF/EVEDA project

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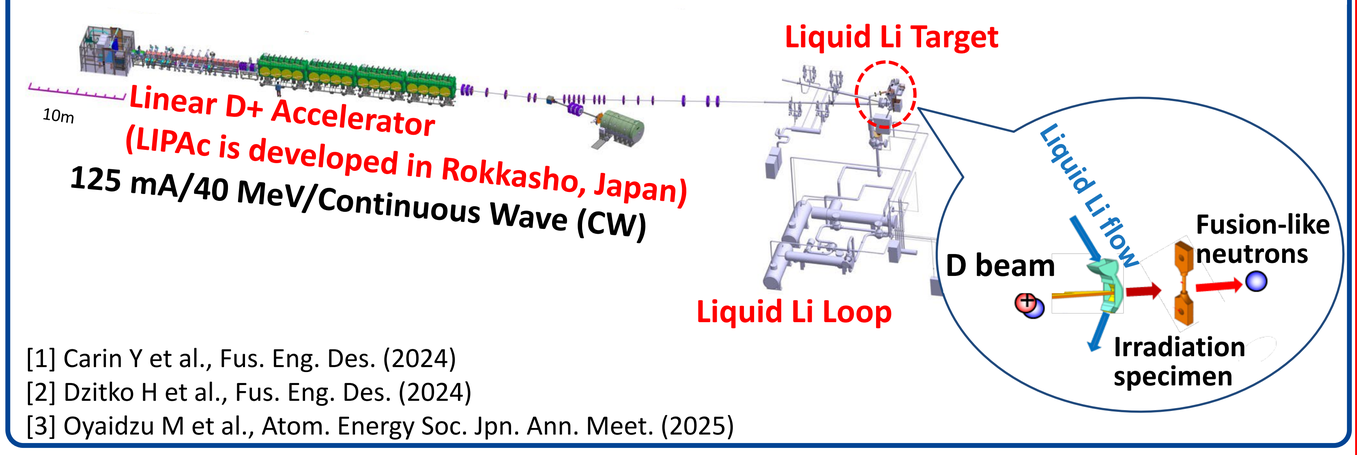
ABSTRACT

- **International Fusion Materials Irradiation Facility (IFMIF)-like fusion neutron source (FNS) produces fusion-like neutrons by injecting 125 mA/40 MeV deuteron beam into a liquid lithium target in order to elucidate fusion neutron irradiation effects on fusion reactor materials.**
- **Under the IFMIF/Engineering Validation and Engineering Design Activities (EVEDA) project, the present study (1) evaluated the production and migration amounts of radionuclides and (2) assessed worker and public doses under steady-state operation incidental/accidental cases.**

Introduction

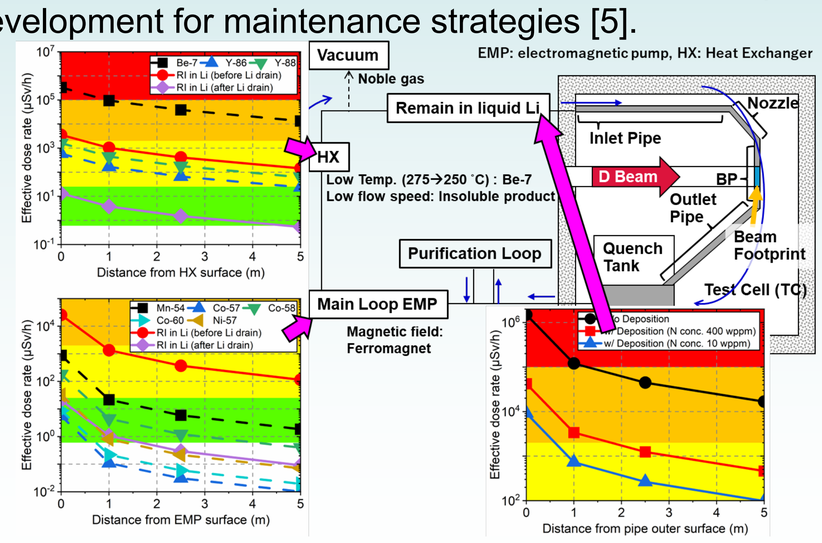
- IFMIF/DONES and A-FNS are IFMIF-like FNS in EU and Japan,
- IFMIF/EVEDA project is being performed as international collaboration between EU and Japan under the Broader Approach (BA) Agreement [1, 2] to develop common technologies for the IFMIF-like FNSs;
- IFMIF/EVEDA project includes;
  1. Development of the prototype accelerator LIPAc,
  2. Engineering design activities for FNS,
  3. R&D activities for Li Target Facility (including 1/10-scale pilot Li loop experiments [3]).
- The engineering design activity performed by Japan (2020-2025);
  1. Tritium migration estimation,
  2. Erosion/deposition modelling in the Li loops,
  3. Accident analysis in safety,
  4. Study on the optimization of the Li-Oil Heat Exchanger (HX),
  5. Use of LIPAc as testing facility.
- **Motivation**: Ensuring the radiological safety is necessary in the engineering designs.
- **Purpose**:
  Evaluation in the radiological risk for both worker and public in the FNS facility.



[1] Carin Y et al., Fus. Eng. Des. (2024)
[2] Dzitko H et al., Fus. Eng. Des. (2024)
[3] Oyaidzu M et al., Atom. Energy Soc. Jpn. Ann. Meet. (2025)

Effective dose assessment around the liquid Li loop

- Major radionuclides: Tritium (2.7×10^{15} Bq/year, 7.5 g/year) & Be-7 (5.02×10^{15} Bq/year), mainly produced by D-Li reaction,
  - Tritium is trapped in C.T. or H.T. (1.4×10^{11} Bq),
  - Be-7 deposits on C.T. (1.6×10^{13} Bq) & HX (2.0×10^{15} Bq).
- **Motivation**: although the major radionuclides are evaluated so far, other radionuclides have not been studied extensively.
- Calculations the production amounts of activated corrosion/erosion product (ACP/AEP) and activated Li impurity (ALI).
- Implementation of measured impurity concentrations in Li from EVEDA Li Test Loop (ELTL) for realistic activation calculations.
- Modeling of RI migration through the liquid Li loop [4].
- Effective doses assessments around the liquid Li loop contribute to development for maintenance strategies [5].

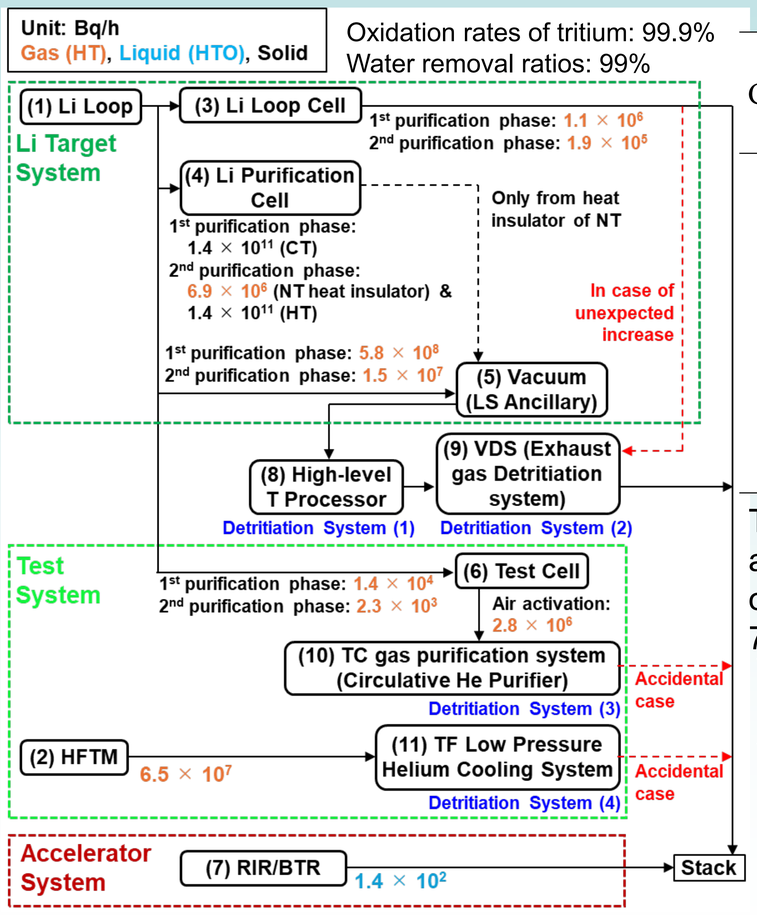


Effective doses around the Li-loop components due to the radionuclide in the liquid Li and deposits.

[4] Kenjo S et al., Fus. Eng. Des. (2024)
[5] Kenjo S et al., Fus. Eng. Des. (2025)

Tritium migration estimation

- Quantitative evaluation of tritium migrations in the FNS facility,
- **Motivation**: Upgrade tritium migration model around the liquid Li loop [6] to estimate the release amounts from the facility through the stack.
- Tritium Process Laboratory (TPL) in JAEA released 2×10^5 Bq/h (HT) & 2×10^6 Bq/h (HTO) with the stack flow rate of 3.88×10^4 m^3/h [7].



Effective doses around the Li-loop components due to the radionuclide in the liquid Li and deposits.

Four calculation cases of normal operation and DS off-normal events.

Case	Category	Tritium form in LLC	Condition
1	Normal	HT	
2	Normal	HTO	
3	Normal	HTO	Unexpected increase of tritium concentration in LLC
4	Off-normal	HTO	DSs not working

Tritium release amounts from the stack and stack flow rates calculated based on the limitations in Japanese law (HT: 7×10^1 Bq/cm^3, HTO: 5×10^{-3} Bq/cm^3).

Case	HT (Bq/h)	HTO (Bq/h)	Stack flow rate (m^3/h)
1	1.1×10^6	$6.4. \times 10^4$	3.84×10^2
2	5.8×10^2	1.2×10^6	6.98×10^3
3	5.8×10^2	6.9×10^4	4.15×10^2
4	5.8×10^8	1.1×10^6	6.85×10^3

[6] Oyaidzu M et al., Fus. Sci. Tech. (2022)
[7] Yamada M et al., Fus. Sci. Tech. (2002)

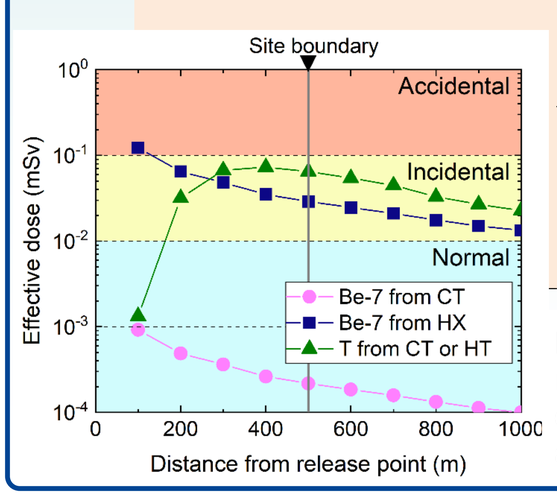
Assessment for the public doses

- Evaluate public impact when tritium and Be-7 release,
- Atmospheric dispersion calculation code ROPUCO [8],
- Public dose limit in normal condition: 1 mSv/year (ICRP60),
- **Potential radiological risks in the FNS facility can be reasonably reduced with the commonly used measures by preventing multiple failures.**

[8] Kenjo S et al., Fus. Eng. Des. (2024)

Public doses due to tritium and Be-7 released outside the FNS facility during normal operation and a hypothetical accident under the most severe meteorological conditions (wind speed of 1 m/s, unstable atmosphere (class F), and no precipitation for tritium and precipitation rate of 5 mm/h for Be-7)

	Normal Operation	Hypothetical accident
Tritium	3×10^{-3} μSv	DS failure 5×10^{-2} μSv
		Li fire at CT/HT 65 μSv
		Li fire at CT/HT & DS failure **6.5 mSv**
Be-7	0 Sv	Li fire at CT/HX CT: 0.2 μSv, HX: 29 μSv
		Li fire at CT/HX & aerosol filtering failure CT: **2.2 mSv**, HX: **2.9×10^2 mSv**



Effective doses in the public due to released tritium (T) and Be-7 in case of accidents at HX, CT, or HT with DS and AFS at release height of 10 m.

Conclusion

- **This study assessed the impacts of the radioactive products in the engineering design activities under the IFMIF/EVEDA project by Japan.**
- **Radiological public risk in the FNS facility can be reasonably reduced by preventing multiple failures.**
- **The achievements of the activities will advance the FNS design especially for the liquid Li target system, DS, and safety system, as well as contribute to the radiological safety assessments in FNS.**

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