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Reassessing radioactive waste inventories at North Korean nuclear facilities: updated estimates and sensitivity bounds

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Introduction

- Whang and Baldwin [1] assumed two reprocessing campaigns totaling 100 tU and estimated 500,000 L of high-level waste (HLW), 300,000 L of chemical decladding waste and 600 t of irradiated graphite.
- Their estimates and the later dismantlement assessment [2] predate the reprocessing episodes reported after 2009 and the accumulation of milling waste at Pyongsan.
- This study updates the 2005 baseline through mid-2025 and tests whether the increased waste-management burden remains robust under uncertainty.

Waste inventory re-estimation

Reprocessing waste

- Reports identify multiple operating episodes at the Radiochemical Laboratory (RCL) during 1989–2025 [3,4]. The study does not equate each episode with a complete core discharge.
- The calculation uses a cumulative throughput of 300–350 tU, equivalent to approximately six to seven 50-tU full cores.
- Applying the Whang–Baldwin unit factors of 5,000 L/tU for HLW and 3,000 L/tU for decladding waste gives the estimates in Table I [1,5,6].
- The calculation assumes no liquid volume reduction because the 1992 IAEA inspection found the RCL denitration unit incomplete [4].

Pyongsan milling tailings

- Hecker and Braun [7] estimate ore throughput at about 360,000 t/yr. At an ore grade of approximately 1,000 ppm, this contains about 360 t of uranium, while most of the ore mass becomes tailings.
- At 360,000 t/yr over 20 years, cumulative tailings reach approximately 7 Mt as a scenario estimate rather than a measured inventory.
- The total falls to 3.5 Mt at half the assumed throughput and reaches approximately 9 Mt for an operating period of 25 years.
- The tailings contain Ra-226 (half-life of 1,600 years), Rn-222, Pb-210 and Po-210. Satellite imagery shows discharge through pipes into an open settling pond [8].
- A July 2025 ROK government survey found no above-limit radioactivity in adjacent waters [9].

Decommissioning solid waste

- Whang and Baldwin [1] estimated about 300 t of activated steel, 600 t of graphite containing C-14 and Cl-36, and several thousand tons of concrete from the 5 MWe reactor.
- Their RCL estimate comprises 500–1,000 t of steel and 16,000–24,000 t of concrete [1].
- Facilities added after 2005 would further increase these totals [8].

Analytical gaps

- Neither this study nor prior work estimates the radioactivity inventory (Ci), decay heat (W per container) or liquid-waste chemical composition.
- These parameters determine vitrification plant throughput, the number of canisters and the required storage duration.
- The Pyongsan tailings estimate also relies on a limited source base.

Updated estimates

Table I: Updated cumulative waste estimates at Yongbyon, 2025

Category	W&B [1]	This study	±50% range
Full-core equiv.	2	6–7	—
Throughput (tU)	100	300–350	—
HLW (m³)	500	1,500–1,750	750–2,625
Decladding (m³)	300	900–1,050	450–1,575
Graphite (t)	600	600	—
Pyongsan (Mt)	—	~7	3.5–9

±50% range: parametric sensitivity test, not a statistical confidence interval.
Pyongsan range: scenario envelope based on throughput and operating-period variations.

Sensitivity of unit factors

- The unit factors derive from Eurochemic PUREX experience in the 1960s–70s, while North Korea's actual process remains unknown.
- The ±50% parametric sensitivity test examines how the increase over the 2005 baseline depends on these factors. The range does not represent a statistical confidence interval.
- Using 2,500 L/tU gives an HLW volume of 750–875 m³, whereas 7,500 L/tU gives 2,250–2,625 m³.

Waste management

- The revised HLW volume would make direct overseas shipment substantially more demanding than assumed in 2005.
- Vitrification remains plausible, but the number of canisters depends on waste-composition data that are not yet available.
- For Pyongsan tailings, a phased approach involving hydraulic containment, dewatering, capping and groundwater monitoring is consistent with IAEA-TECDOC-1403.
- Isotopic analysis of HLW samples could potentially reconstruct reactor operating histories and cross-check future fissile-material declarations [10]. This dual use of waste characterization warrants further investigation.

Conclusions

- The central estimates reach 1,500–1,750 m³ of HLW and 900–1,050 m³ of decladding waste, approximately three times the 2005 figures.
- Pyongsan tailings reach approximately 7 Mt under the central assumptions, within a scenario envelope of 3.5–9 Mt.
- These estimates provide a planning envelope for the waste-management workload of future, rather than a measured or statistically bounded inventory.

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