Evaluation of Environmental Radiation Trends through Long-Term Monitoring in the Emergency Planning Zone of Hanbit Nuclear Power Plant (2017–2024)

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Introduction

In 2015, the Emergency Planning Zone (EPZ) for domestic nuclear power plants in Korea was expanded from 8–10 km to 30 km, newly including the Yeonggwang, Muan, Hampyeong, and Jangseong regions near the Hanbit NPP. This expansion emphasized the need for continuous environmental radiation monitoring. This study presents the first comprehensive, long-term multi-media analysis in Korea, covering rainwater, soil, seawater, and food from 2017 to 2024 within the Hanbit EPZ. The results provide a scientific characterization of long-term variations and trends in environmental radiation and the associated public dose.

Methods

▶Sample Collection

Environmental samples were collected from within the Hanbit NPP EPZ between 2017 and 2024, following NSSC and ICRP guidelines. Sampling covered **rainwater, surface soil, seawater, and foodstuffs**. Rainwater (9 sites, monthly) represented airborne radionuclides; surface soil (semi-annually) was collected from non-cultivated land; seawater (5 sites, quarterly) was obtained from coastal areas; and food samples (quarterly) included local agricultural and marine products.

Environmental Medium	No. of Sampling Sites	Sampling Frequency	Major Radionuclides Analyzed	Sample Pretreatment Method
Rainwater	9	Monthly	^{137}Cs, ^{3}H	Filtration, Concentration
Surface Soil	9	Semi-annually	^{137}Cs ^{6}Co	Drying, Homogenization
Seawater	5	Quarterly	^{137}Cs, ^{3}H	Coprecipitation, Concentration
Foodstuffs	5	Quarterly	^{131}I, ^{134}Cs ^{137}Cs	Washing, Grinding

Figure 1. Sampling Locations and Environmental Media

▶Analytical Methods

Gamma-emitting radionuclides (^{60}Co, ^{131}I, ^{134}Cs, ^{137}Cs), tritium (^{3}H), and gross beta activity were analyzed using **HPGe gamma spectrometry**, **liquid scintillation counting**, and **low-level alpha–beta counting**. Pretreatments such as concentration, drying, and co-precipitation were applied. Detection limits were within 0.001–0.006 Bq/L for liquids and 0.2–0.5 Bq/kg-dry for soil.

▶Quality Assurance

All instruments were calibrated with KRISS-certified sources, and the laboratory achieved "A" ratings in annual proficiency tests by KINS, ensuring analytical accuracy and international reliability.

Results and Discussion

From 2017 to 2024, environmental radiation monitoring within and around the Emergency Planning Zone (EPZ) of the Hanbit Nuclear Power Plant confirmed that overall radiation levels remained stable, with all variations falling within the natural range.

▶Rainwater and Atmospheric Pathway

No artificial radionuclides (^{60}Co, ^{131}I, ^{134}Cs, ^{137}Cs) were detected in any rainwater sample. The natural nuclide ^{7}Be was occasionally observed during rainfall events. Gross beta activity ranged from **22.5–261 mBq/L**, consistent with the national background level (**60.2–654 mBq/L**), while tritium (^{3}H) remained ≤**1.86 Bq/L**, corresponding to natural background levels.

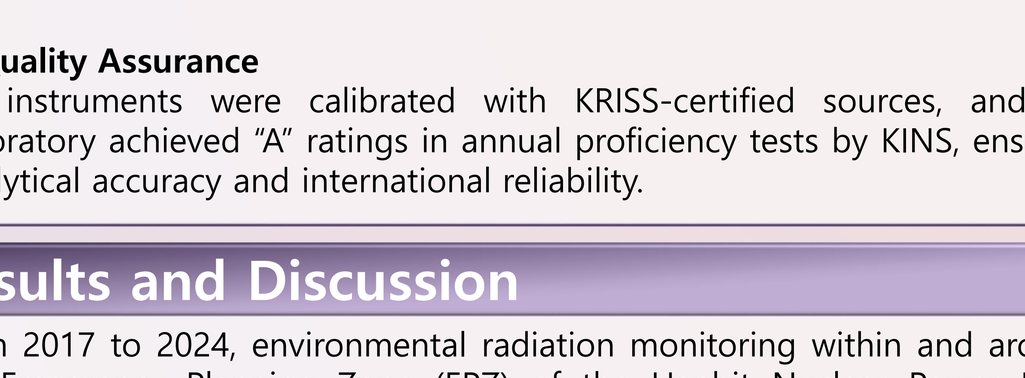

Figure 1 shows the annual gross beta concentration in rainwater, indicating stable trends across all monitoring years.

▶Surface Soil

Cesium-137 (^{137}Cs) was the only artificial gamma-emitting radionuclide detected, with concentrations ranging from **0.134–4.89 Bq/kg-dry** in 2017 to **0.405 Bq/kg-dry** in 2024, showing a gradual decline over time. This decrease is attributed to natural radioactive decay and soil migration.

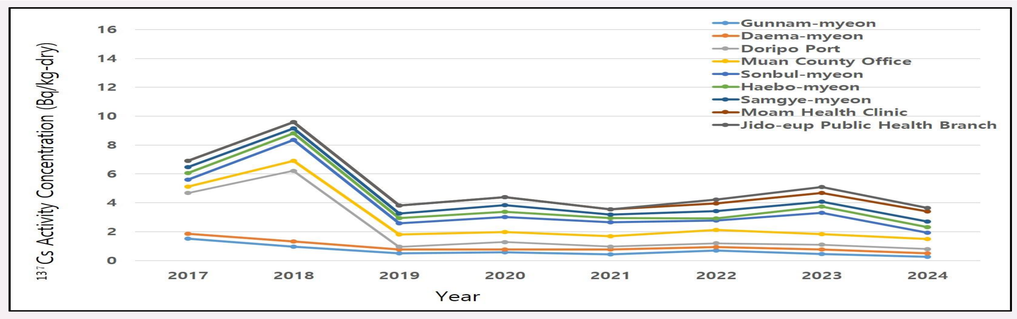

Figure 2 illustrates the temporal decline of ^{137}Cs in surface soil.

▶Seawater

Natural ^{40}K was consistently detected, and artificial ^{137}Cs appeared only at trace levels (**0.00076–0.00242 Bq/L**). Gross beta activity ranged between **6.85–14.3 Bq/L**, and tritium (^{3}H) between **1.02–5.35 Bq/L**, all within normal variation.

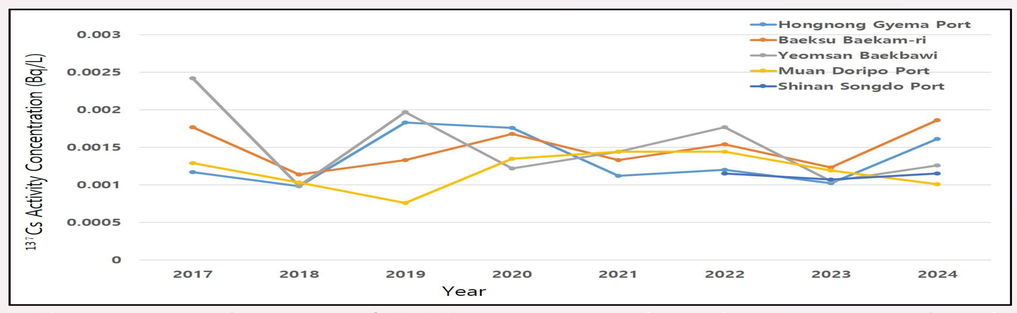

Figure 3 presents the annual ^{137}Cs concentrations in seawater, showing no abnormal changes.

▶Food Samples

Analyses of agricultural and marine food samples (rice, apples, onions, octopus, mullet, etc.) indicated **no detection** of artificial radionuclides throughout the study period. All results were below the detection limits of the analytical instruments and met the radioactivity standards of the Korean Food Code.

▶Public Dose Assessment

Effective doses were estimated using internationally recognized dose coefficients (ICRP Pub.119, IAEA standards). Pathways included ingestion (rainwater, seafood) and external exposure (soil).

Table 1. Annual Effective Dose by Exposure Pathway

Environmental Medium	Radionuclide	Exposure Pathway	Annual Dose (μSv/year)
Rainwater	^{3}H	Ingestion	16.6
Surface Soil	^{137}Cs	External	0.27
Seawater	^{137}Cs	Ingestion (Seafood)	0.026
Total			16.9 μSv/year (<1.7% of 1 mSv limit)

The total annual effective dose was estimated at **16.9 μSv/year**, representing less than **1.7% of the public dose limit (1 mSv/year)**. These findings confirm that the Hanbit EPZ maintains a safe and stable radiological environment, with no measurable impacts from plant operation.

Conclusion

▶This study presents the results of an eight-year (2017–2024) comprehensive monitoring program of environmental radiation within and around the **Emergency Planning Zone (EPZ)** of the **Hanbit Nuclear Power Plant.** Throughout the study period, **artificial radionuclides were rarely detected**, and **concentrations in all media remained well below domestic and international safety standards.**

▶Tritium (^{3}H) levels in rainwater and seawater were very low—comparable to **natural background levels**—and **no abnormal trends** were observed in **gross beta activity. Cesium-137 (^{137}Cs)** in surface soil showed concentrations ranging from **0.136 to 4.89 Bq/kg-dry,** indicating a **gradual decrease over time,** while **seawater samples contained only trace levels (0.00076–0.00242 Bq/L).**

▶No artificial radionuclides were detected in local agricultural or marine food samples, confirming that **public exposure through ingestion is negligible.** Overall, the long-term monitoring demonstrates that **the radiological environment of the Hanbit EPZ has remained stable and safe,** with **no measurable impact from plant operation**. This study provides **a valuable framework for future radiation environmental management and predictive monitoring systems.**