Tritium concentration in precipitation around Wolseong Nuclaer Power Plant

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1. Introduction

Wolseong Nuclear Power Plant (NPP) located in Gyeongju consists of four Pressurized Heavy Water Reactors(PHWRs) and two Pressurized Water Reactors (PWRs). A lot of tritium is generated, especially in PHWRs that use D_2O as coolant and moderator. Tritium is a low energy beta-emitting nuclide and is released as a gas from the NPP. The gaseous tritium from the NPP disperses following the wind direction.

PHWRs release tritium continuously, while PWRs release tritium intermittently into the atmosphere. Wolseong NPP discharged 5.73 TBq/yr, 22.2 TBq/yr, 36.3 TBq/yr, and 25.2 TBq/yr of tritium from unit 1, unit 2, unit 3, and unit4, respectively, in 2021[1]. Radioactive material (Tritium) in gaseous form is the main transport routes that can affect the environment [1].

In this study, the range of tritium dispersion in the atmosphere was confirmed by analyzing the correlation between the tritium concentration in precipitation and the wind direction around Wolseong NPP.

2. Methods

2.1 Sampling sites and Sample collection

The sampling sites were selected considering the distance and the cardinal direction centered on the Wolseong unit 4. The main wind direction at the Wolseong NPP is from northwest to south east (NW direction). NE (or NNE) and SW (or SSW) direction also have high frequency of wind direction as shown Fig 1.

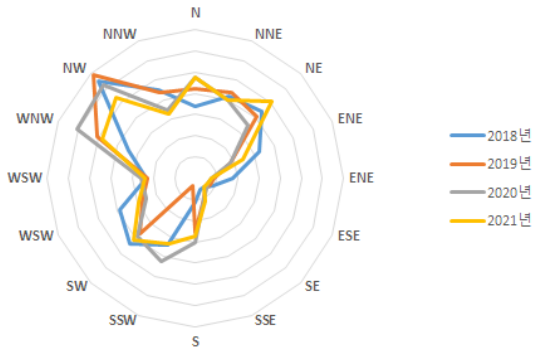

Fig. 1. Wind direction frequency Wolseong NPP during the January 2018 –2021 period.

Considering the of tritium following the wind direction, sampling locations were selected mainly in the southern (SW and SSW) and northern (NE and NNE) regions of the NPP. For comparison, we selected 3 points far away from NPP. A total of 13 sampling sites were selected:5 sites (S1~S7) in south, 1 site (W1) in west, and 5 sites (N1~N5) in north. The sites are presented in Table 1 and Fig 2. Samples were collected from November 2021 to June 2022. In case of S2 site, samples were collected from March to June 2022.

Table 1: Sample Location considering cardinal direction and distance centered on Wolseong unit 4.

Station	Distance (km)	Direction
S1	1.05	S
S2	1.86	S
S3	2.10	SSE
S4	3.10	SW
S5	3.75	SSW
S6	13.2	SW
S7	18.9	S
W1	1.24	W
N1	3.75	NNE
N2	4.30	NNW
N3	5.25	NNE
N4	10.9	NNW
N5	28.6	NW

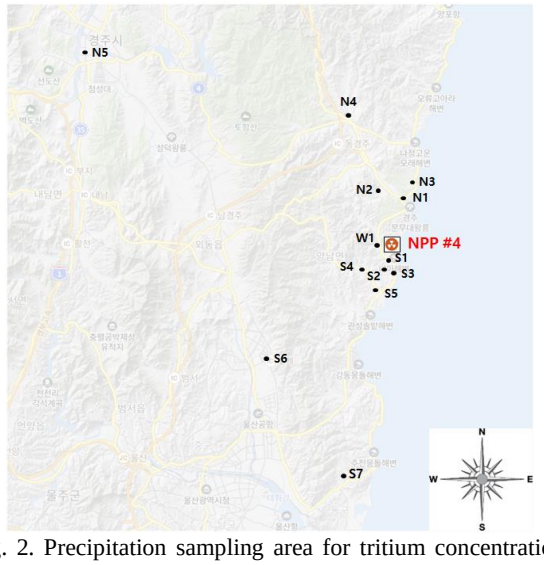

Fig. 2. Precipitation sampling area for tritium concentration. analysis.

2.2 Measurement

A distillation apparatus was used to extract 8 mL of distilled water from samples taken at each site. The distilled water was mixed with Ultima Gold LLT scintillation fluid. The prepared samples were stored in a cool and dark place for 24 hours and then measured using a scintillation counter (Quantulus 1220 and GCT 6220, PerkinElmer).

3. Results

3.1 Tritium in the precipitation

During the sampling period, it rained 14 times. The concentration distribution at each site is shown in Fig 3. The concentration distribution was higher mainly in southern regions. Table 2 and Figure 4 show the sample information and wind direction when the maximum concentration was detected at each point.

In case of the southern region, tritium was detected during the sampling period, except for one point (S6). The S3 site was the highest of all sites. For S1 and S3, the maximum concentration was observed on April 13, 14, and the wind direction was N and NNE. At this time, tritium was also detected at S1 and S7, and was detected at no other sites (See fig 4a).

At S2 and S7 sites, the maximum concentrations were detected on June 13, 14 and the wind directions were NE and NNE. The tritium concentration was detected 3 times at S7 site. At this time, tritium was also detected at S1, S2, S3, and S5 (See fig 4b).

The maximum concentration in precipitation at S4 was observed from March 17 to 19. The wind directions were NNW, NW, and N. Tritium was also detected at S1, S2, and S4 during the period (See fig 4c).

The maximum concentration at S5 was observed on June 5, 6, and the wind directions were NNE and NE. Tritium was detected in all southern points except for S6 on that day (See fig 4d). Tritium was detected in none of the samples from S6.

In case of W1, tritium concentration was low or not detected at all. The maximum concentration was observed on April 26 and the wind direction was mainly NNE and there were also WNW, SW, W, and NW. Tritium was detected at S1, S2, S4, N1, N2, N3, and N4 on that day (See fig e).

In case of northern region, the concentration of tritium was low or not detected at all. Maximum concentrations at N1 and N3 were detected on June 27, 2022. Also, the wind direction was SSW. Tritium was not detected at the south sites (See fig 4f).

The maximum concentrations at N2 and N4 were detected on March 25 and 26. Wind directions were mainly SW, SSW, and S and there were also NNE, NNW on March 25 (See fig 4g). On that day, tritium was detected at S1. During entire period, tritium was not detected at N5 selected for comparison.

Table 2: Sampling result and information (13 points).

Location	Sample Number	Maximum Concentration [Bq/L]	Date [2022]
S1	14	246 ± 3	April 13,14
S2	9	56.1 ± 1.7	June 13,14
S3	9	440 ± 3	April 13,14
S4	13	25.2 ± 1.2	March 17,18,19
S5	14	20.7 ± 1.3	June 5,6
S6	11	Not dected	
S7	12	8.04 ± 1.13	June 13,14
W1	14	34.8 ± 1.3	April 26
N1	12	42.4 ± 1.4	June 27
N2	13	45.7 ± 1.5	March 25,26
N3	14	38.2 ± 1.4	June 27
N4	14	15.5 ± 1.2	March 25,26
N5	11	Not dected	

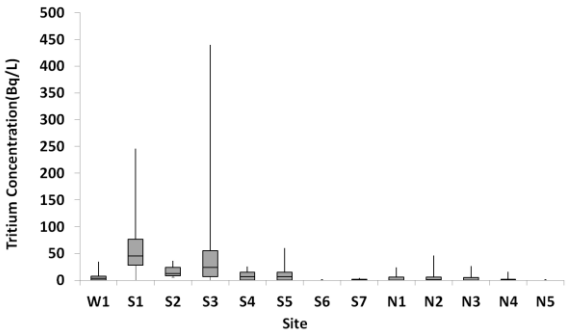

Fig. 3. Tritium concentration distribution of sampling points.

3.2 Relation of precipitation and tritium concentration

In this study, in order to confirm the correlation between precipitation and tritium concentration, the amount of precipitation was measured whenever it rained or snowed.

A correlation between precipitation amount and tritium concentration was observed. The maximum concentration of tritium was higher when the precipitation was small than when the precipitation was high. It is presumed that the tritium concentration is high when precipitation is low, since tritium released into the atmosphere is less washed away by the precipitation. The results of the correlation between tritium concentration and rainfall correlation during November 2021 to June 2022 is shown in Fig 5.

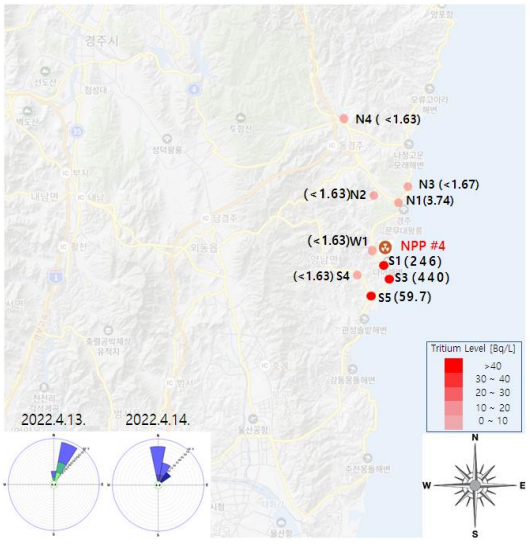

Fig 4a. Tritium concentration distribution and wind direction in precipitation (April 13, 14).

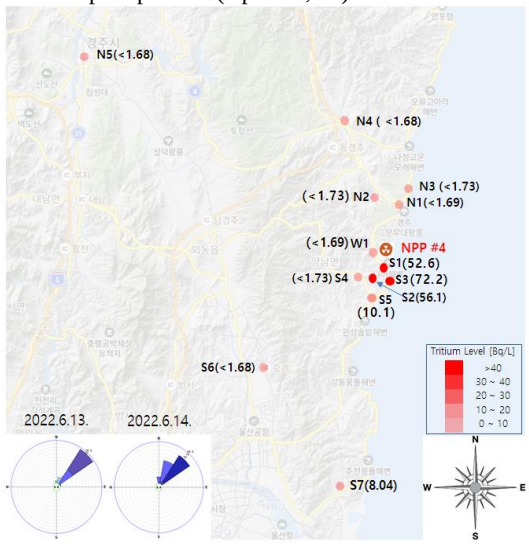

Fig 4b. Tritium concentration distribution and wind direction in precipitation (June 13, 14).

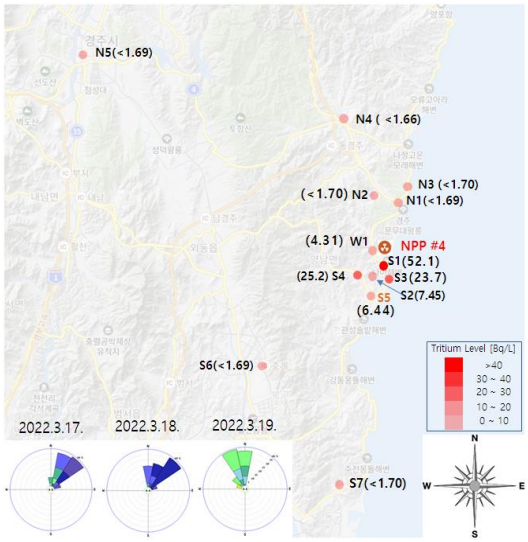

Fig 4c. Tritium concentration distribution and wind direction in precipitation (March 17, 18, 19).

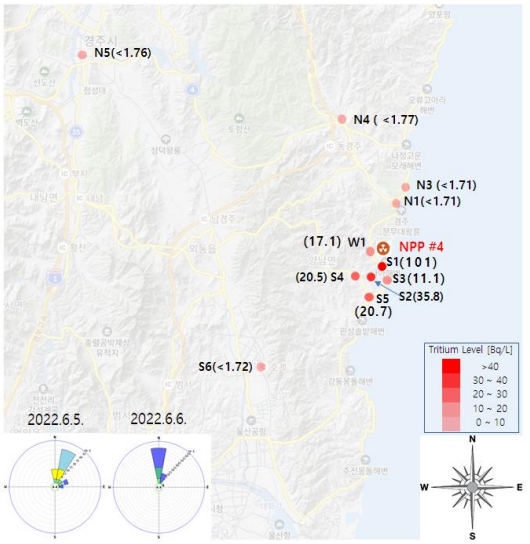

Fig 4d. Tritium concentration distribution and wind direction in precipitation (June 5, 6).

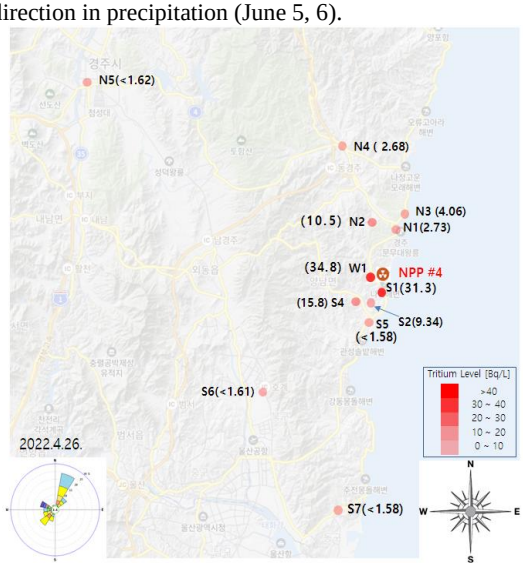

Fig 4e. Tritium concentration distribution and wind direction in precipitation (April 26).

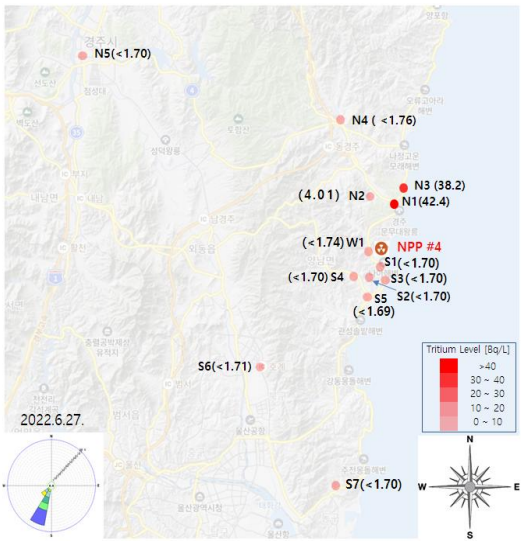

Fig 4f. Tritium concentration distribution and wind direction in precipitation (June 27).

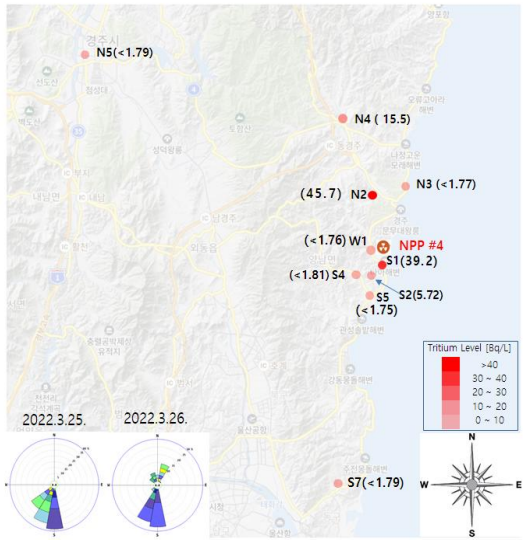

Fig 4g. Tritium concentration distribution and wind direction in precipitation (March 25, 26).

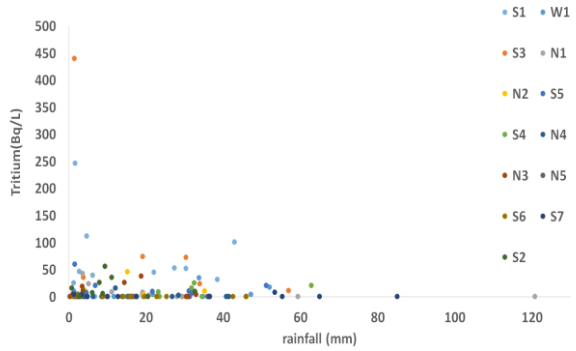

Fig. 5. Relation of rainfall and tritium concentration of sampling points during November 2021 – June 2022 period.

3.3 Relation between tritium concentration and distance

The tritium concentration was related to the distance from the NPP as shown fig 6. In both the southern and the northern regions, tritium was mainly detected at points close to the NPP. The concentration of tritium was higher the closer to the NPP. On the other hand, it was low or not detected at points far from the NPP.

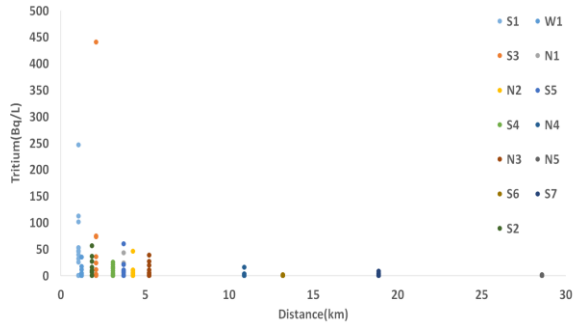

Fig.6. Relation of distance and tritium concentration Wolseong NPP during November 2021 – June 2022 period.

3.4 Tritium Transfer to precipitation sample

In this study, rainwater was collected and analyzed for each precipitation. It rained just only one day (Feb. 13) in February 2022. Samples for this study were collected on February 14, 2022, immediately after precipitation. Another rainwater from the same site was collected on February 28, 2022, fifteen days after the precipitation.

As shown in Table 3, tritium was not detected in the samples collected on February 14, 2022 at sites W1 and N2. Meanwhile, tritium was detected in the samples taken on February 28, 2022 at the same sites. Higher concentrations were observed in the samples taken on February 28 although samples taken on February 14 and February 28 were originated from the same rainwater that fell on February 13. It is strongly suspected that tritium in the air was transferred to the rainwater sample during the period from February 15 to February 28. So, special care must be taken in collecting samples to accurately measure the tritium concentration in precipitation.

Table 3: Comparison of tritium concentrations in precipitation collected on different days at the same site (February 13, 2022)

Precipitation date		February 13	
Collection date		February 14	February 28
Concentration [Bq/L] at	W1	<1.33	5.01 ± 1.05
	N3	<1.33	7.51 ± 1.08

4. Conclusions

The tritium concentration in precipitation is related to the distance from the NPP, the wind direction and the amount of precipitation. Although W1 and S1 are approximately the same distance from the NPP, the tritium concentration in W1, located to the west, is lower than that in S1, due to the influence of wind direction. In addition, the effect of tritium on precipitation is greater in the southern region than in the northern region. Tritium concentration is correlated with amount of the precipitation. A suspicious phenomenon was observed for the transfer of tritium from the air to the precipitation sample. Special care must be taken in collecting samples to accurately measure the tritium concentration in precipitation.

REFERENCES

[1] Korea Hydro & Nuclear Power, “Environmental Radiation Investigation and Evaluation Report around nuclear power plant”, 2021.