The Radiation Level around the Research Reactor at the Daeduk Site

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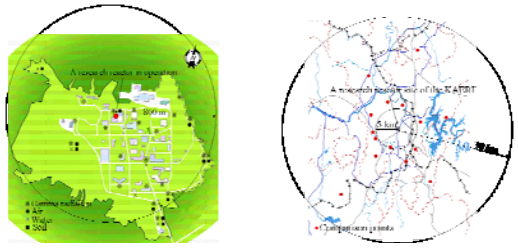
1. Introduction

Korea Atomic Energy Research Institute (KAERI) has been operating the research reactor (HANARO) with the thermal output of 30MWth at the Daeduk site since 1995, as Korea Research Reactor-1&2 (operated in 1962 and in 1972) of the Seoul site were stopped because of their aging. Environmental radiation monitoring is carried out for the confirmation of the environmental safety around the nuclear installation based on the Atomic Act as the nuclear facilities are operated. Generally, environmental radiation monitoring is implemented because of social, political and technical reasons, such as a compliance with statutory legislation, an assessment of the radiation exposure to the public, public reassurance and information. Especially due to the operation of a HANARO placed in the city, public concern has been raised with respect to the radiation level and environmental effects on-site and off-site. In the present study, the results of the environmental radiation monitoring around the installation before and after the HANARO operation are statistically analyzed and it is discussed whether any radiation level difference is brought about due to the operation of the HANARO.

2. Environmental Radiation Monitoring

The topographical map of the on-site area, which is within 800 m of the radius from the center of HANARO, is presented in Fig. 1 (a) and that of the comparison points 5 km ~ 30 km far away from it in Fig. 1 (b).



(a) (b)

Fig. 1. (a) The site of a HANARO in operation in the Daejeon province and (b) the comparison points for comparing their radiation levels with ones of the HANARO site.

As the environmental radiation monitoring program was represented in Table 1, the measurement of an environmental radiation, i.e. the gamma dose rate and the accumulated dose, was carried out in and around Daeduk nuclear utilization facilities, where the HANARO was placed, by using a real time environmental radiation monitor and TLD, respectively. The gamma dose rates were measured by the ion chamber (Reuter Stokes, RSS-1012) placed at the height of 1 m from the bottom in real-time. The accumulated dose was measured every quarter by the model Harshaw TLD 4500. The environmental radioactivity was analyzed on the soil, sediment, air particulate and water. Its samples were analyzed semiannually, quarterly or monthly.

Table 1. The environmental radiation monitoring program

Classification	Sample	Sampling points		Analysis period	Nuclide
		On-site	Off-site		
Radiation	Dose rate	6	1	Continuously	γ -radiation
	cumulative dose	34	19	Quarterly	γ -radiation
Radioactivity	Soil	7	5	Semiannually	^{90}Sr, γ -isotope
	Sediment	2	2	Quarterly	^{238}U, γ -isotope
	Surface water	4	2	Monthly	^{3}H
					γ -isotope
	Rain water	4	1	Monthly	^{3}H
					γ -isotope
	Ground water	1	2	Quarterly	^{3}H, γ -isotope
	Air particulate	6	1	Monthly	γ -isotope
	Air	5	1	Weekly	^{131}I
	Fall out	2	1	Quarterly	γ -isotope

3. Statistical test

First of all, the normality of the population, to which the sample belongs, was tested by using a Kolmogorov-Smirnov test method which was generally employed for the normality test. The hypothesis was given by,

hypothesis : $F_s(x) = F_T(x)$

where $F_s(x)$ is a sample accumulation distribution function ($=Pr(X_s<x)$) and $F_T(x)$ an accumulation distribution function ($=Pr(X_T<x)$). The test statistic D of the sample group composed of the average of the environmental radiation and radioactivity is given by,

test statistic : $D = \max | F_s(x) - F_T(x) |$

where the test was performed in the significance level, α of 5 %. The method of the test corresponding to the result of the normality test was adopted for the comparison of the averages between two sample groups,

the group before HANARO operation and the group after HANARO operation, or the on-site group and the group of comparison points.

3. Results and Discussion

Test statistic D of the sample groups was between 0.1664 ~ 0.1711. These values are less than D of the standard probability distribution table at the significance level of 5 %. Therefore, there was no significant difference between two groups and the population distribution of the samples was estimated to be conformable to a normal distribution. Based on the result, the T-test and F-test, which were generally used to compare the averages and variance between two groups, were performed for the average and variance comparison of two groups at the significance level of 5 %. The T-test and F-test statistic were given by,

$$T = \frac{x_1 - x_2}{s\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad or \quad T = \frac{x_1 - x_2}{\sqrt{\frac{{s_1}^2}{n_1} + \frac{{s_2}^2}{n_2}}}$$

$$F = \frac{{s_1}^2}{{s_2}^2}$$

where

T : *T test statistic*
x_1 : *The average of sample* 1
x_2 : *The average of sample* 2
s^2 : *The* cov *ariance of sample* 1 *and* 2
n_1 : *Size of sanple* 1
n_2 : *Size of sanple* 2
s^2_1 : *Variance of sanple* 1
s^2_2 : *Variance of sample* 2
F : *F test statistic*

Table 2 represented the results of the T-test for the gamma dose rates and accumulated dose before HANARO operation (1985 ~ 1994) and after HANARO operation (1995 ~ 2008). The P value and F value on the gamma dose rates were 3 times and 19 times higher than 0.05 and it was not thought that there were some differences in the average and variance between the case before HANARO operation and after HANARO operation. Similarly, in case of the accumulated dose, the P value and F value were 11 times and 20 times higher than 0.05. Thus, the two groups were not thought to bear a significant difference. The results of the T-test for the on-site and off-site of the Daeduk nuclear utilization facilities are seen in Table 3. The gamma dose rates gave a P value and F value 13 times and 1.1 times higher than 0.05, respectively. Also, the accumulated dose showed the P value and F value 17 times and 3 times higher than 0.05. Therefore, there was not considered to be any difference between the two.

Table 2. The environmental radiation before and after HANARO operation

	Gamma dose rate (uR/h)	Accumulate dose (mR/quater)
Before operation	11.5 ± 0.53	26.5 ± 1.75
After operation	11.9 ± 0.57	26.0 ± 1.67
P value	0.14	0.55
F value	0.97	0.99

Table 3. The environmental radiation between on-site and off-site

	Gamma dose rate (uR/h)	Accumulate dose (mR/quater)
On-site	11.9 ± 0.57	25.0 ± 0.54
Off-site	12.1 ± 0.16	25.1 ± 1.25
P value	0.67	0.83
F value	0.055	0.13

On the other hand, the radioactivity of artificial gamma radioisotopes on samples of soil, sediment, water and air was less than MDA, except for ^{137}Cs or ^{131}I. In Table 4, The T-test results are represented for the comparison of the environmental radioactivity in the on-site and off-site areas. Here, the P value and F-value were higher than 0.05. Thus, it was seen that there could not be said to have been differences between the two.

Table 3. The environmental radioactivity between on-site and off-site

	On-site	Off-site	P value	F value
^{238}U(sediment, Bq/kg-dry)	29 ± 4.0	29 ± 4.1	0.18	0.97
^{3}H(ground water, Bq/L)	4.3 ± 1.44	3.0 ± 0.96	0.13	0.45
^{3}H(rain water, Bq/L)	2.8 ± 0.42	2.3 ± 0.87	0.38	0.27
^{90}Sr(soil, Bq/kg-dry)	0.86 ± 0.216	0.91 ± 0.179	0.70	0.72
^{131}I(air, mBq/m^3)	0.062 ± 0.0062	0.058 ± 0.0093	0.67	0.75
^{137}Cs(soil, Bq/kg-dry)	0.97 ± 0.129	1.7 ± 2.03	0.42	0.00
^{137}Cs(sediment, Bq/kg-dry)	1.0 ± 0.26	1.4 ± 1.09	0.26	0.02
^{137}Cs(fallout, Bq/m^2-90days)	0.054 ± 0.0190	0.065 ± 0.0349	0.58	0.27

4. Conclusion

The statistical test on the environmental radiation and radioactivity for in and around Daeduk nuclear utilization facilities was carried out to confirm the constancy of the radiation level. It was thought that the environment around the research reactor could not be seen to have particular effects by its operation according to the analysis.

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