# Long-term trend assessment in environmental radioactivity around nuclear facilities in Daedeok site

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## 1. Introduction

Since KAERI (Korea Atomic Energy Research Institute) started operation of the research reactor HANARO in 1995, the environmental radiation monitoring on the site has been carried out. In order to confirm that the surrounding environment is not changed by the operation, a radioactivity analysis is performed periodically on the representative monitoring items such as air, soil, surface water, underground water and foods and the levels have been examined and compared with a range of last data. With these radiological environmental data, a long-term trend analysis was performed by a statistical technique of Mann-Kendall analysis and the results showed the accumulation trends around site are decreasing or no trend. It was concluded that the radioactivity accumulation due to research reactor operation was insignificant.

## 2. Methodology and data

In this section a method of the long-term trend assessment and the environmental data to be discussed are described.

### *2.1 Methodology*

The Mann-Kendall test is a non-parametric test for identifying trends in time series data. The test compares the relative magnitudes of sample data rather than the data values themselves [1]. One benefit of this test is that it does not require the data to be a particularly distributed. Moreover, the test is low sensitive to abrupt breaks due to inhomogeneous time series [2]. Any data reported as non-detects can be included by assigning them a common value that is smaller than the smallest measured value in the data set [3]. According to this test, the null hypothesis $H_0$ assumes that there is no trend (the data is independent and randomly ordered) and this is tested against the alternative hypothesis $H_1$, which assumes that there is a trend.

The data values are evaluated as an ordered time series. Each data value is compared to all subsequent data values. The initial value of the Mann-Kendall statistic, S, is assumed to be 0(e.g., no trend). If a data value from a later time period is higher than a data value from an earlier time period, S is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, S is decremented by 1. The net result of all such increments and decrements yields the final value of S. Let $x_1$, $x_2$, …, $x_n$ represent n data points where $x_j$ represents the data point at time j. Then the Mann-Kendall statistic (S) is given by

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k)$$

$$sign(x_j - x_k) = 1 \quad if\, x_j - x_k > 0$$
$$= 0 \quad if\, x_j - x_k = 0$$
$$= -1 \quad if\, x_j - x_k < 0$$

A very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend. However, it is necessary to compute the probability associated with S and the sample size, n, to statistically quantify the significance of the trend.

$$Var(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{g} t_p(t_p - 1)(2t_p + 5)\right]$$

where n is the number of data points, g is the number of tied groups (a tied group is a set of sample data having the same value), and $t_p$ is the number of data points in the pth group.

When n is greater than 10, define a normalized test statistic Z as follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if\; S > 0 \\ 0 & if\; S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & if\; S < 0 \end{cases}$$

Provided that there are not many tied values within the data set. Then the Z has a normal distribution of a mean 0 and derivation 1. The maximum value of the first-class error, which selects the alternative hypothesis incorrectly when the null hypothesis is true, is significance level α. At significance level α, if $|Z| > Z_{\alpha}$, then null hypothesis is rejected. This means that a positive Z value means an increasing trend and a negative Z value means a decreasing trend. Here $Z_{\alpha}$is the value that probability that positive Z is greater than $Z_\alpha$ is 0.05.

*2.2 Data*

The environmental radiation and radioactivity around Daedeok site is monitored to investigate the accumulation tendencies. The environmental samples are as follows:

-Radiation: continuous environmental radiation by ERM and accumulated radiation dose by TLD

-Radioactivity: air, soil, sediment, pine needle, rainwater, surface water, underground water, fallout, farm products, livestock products.

The monitoring nuclides include gross alpha, gross beta, $^{238}$U, $^{235}$U, $^{234}$U, $^{3}$H, $^{54}$Mn, $^{59}$Fe, $^{60}$Co, $^{90}$Sr, $^{131}$I, $^{134}$Cs, $^{137}$Cs, etc.

A long-term trend analysis was performed on the nuclides in which the concentration exceeds MDA (minimum detectable activity)

## 3. Results and discussion

The environmental and accumulation radiation dose were monitored to evaluate the external exposure dose by external radiation by a continuous radiation monitor (ERM) and thermos-luminescent dosimeter (TLD), respectively. Since the environmental radiation dose was monitored to check the short change, the trend analysis of the accumulation radiation dose was performed at 56 monitoring points. The results showed no trends in every monitoring points.

The environmental radioactivity on gross alpha and gross beta, Uranium, Tritium, Strontium, and gamma-radionuclides were analyzed routinely in the various samples such as air particulate, iodine, air moisture, soil, sediment, pine needle, rainwater, surface water, underground water, fallout, farm products, and livestock products. A trend analysis was performed on nuclides in which a concentration exceeds the MDA. The samples such pine needle, farm products and livestock products were excluded in the trend analysis. Most of long-term trends on the environmental radioactivity showed no trend, while several cases showed decreasing as follows.

The nuclides including gross alpha, gross beta, gamma isotopes were monitored on air samples at six sampling points. Air samples are collected using fiberglass filters every week and gross alpha and gross beta were measured using low-level alpha/beta counter. Gamma isotopes were measured using HPGE gamma-ray spectroscopy. The trend analysis results showed no constant trends on the basis of data from 1996 to 2017.

The gross beta and tritium and gamma isotopes were analyzed in the surface water monitored at six sampling points around site. The gross beta among the surface water at main gate post showed decreasing trend on the data from 1998 to 2017. Tritium in surface water showed no increasing or decreasing trend and gamma isotopes were less than MDA.

The strontium, uranium and gamma isotopes were analyzed in the soil around site. The strontium showed decreasing trend on the basis of data from 1998 to 2017. The gamma isotopes of soil at main building sampling point showed decreasing trend and uranium showed no trend.

## 4. Conclusions

The long-term trend of environmental radioactivity around Daedeok site was assessed using Mann-Kendall analysis method that is a non-parametric statistical method. The long-term trend analysis was performed on the samples such as air, soil and sediment and the nuclides such as gross alpha, gross beta, $^{90}$Sr, $^{137}$Cs, ERM, TLD, $^{238}$U. Most results showed no trend and several sample and monitoring nuclides showed decreasing trend. So it is concluded that there has been no tendencies of accumulation in environmental radioactivity.

## REFERENCES

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