Statistical Analysis of Environmental Tritium around Wolsong Site

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Introduction

To find the relationship among airborne tritium, tritium in rainwater, TFWT (Tissue Free Water Tritium) and TBT (Tissue Bound Tritium), statistical analysis is conducted based on tritium data measured at KHNP employees' house around Wolsong nuclear power plants during 10 years from 1999 to 2008. The results show that tritium in such media exhibits a strong seasonal and annual periodicity. Tritium concentration in rainwater is observed to be highly correlated with TFWT and directly transmitted to TFWT without delay.

Methods and Results

Auto-correlation analysis technique can investigate linearity and memory effect of time-series data. As time-series data have strong linearity and memory effect, auto-correlation function has a positive value during a longer delay time. On the other side, cross-correlation analysis is used to find a linkage between input and output time-series data and provides information of causal relationship between them. Auto-correlation and cross-correlation function are calculated as follows.

$$r(k) = \frac{C(k)}{C(0)} \tag{1}$$

$$C(k) = \frac{1}{n}\sum_{i=1}^{n-k}\left(x_t - \bar{X}\right)\left(x_{t+k} - \bar{X}\right) \tag{2}$$

$$r_{xy}(k) = \frac{C_{xy}(k)}{\sigma_x \sigma_y} \tag{3}$$

$$C_{xy}(k) = \frac{1}{n}\sum_{i=1}^{n-k}\left(x_t - \bar{X}\right)\left(y_{t+k} - \bar{Y}\right) \tag{4}$$

where, k is time lag, n length of time-series, $\bar{X}$ and $\bar{Y}$ average of x_t and y_t, σ_x and σ_y standard deviation of x_t and y_t, respectively. Using the cross-correlation, we can get the delay time defined by time lag between zero lag and any lag of maximum cross-correlation value. As the delay time is shorter, the response of output time-series to input time-series and the propagation of environmental stress are faster.

The seasonal Kendall test is used to test for trends in monthly measured concentration of tritium in the atmosphere, rainwater, and indicator organism (pine needle). This non-parametric method is suitable for the analyses of data that exhibit non-normal distributions, seasonality, values below the limit of detection, and serial correlation. The statistics S used to test for significant trends is defined as:

$$S = \sum_{i=1}^{n-1}\sum_{j=i+1} sgn(x_j - x_i) \tag{5}$$

where,

$$sgn(x_j - x_i) = \begin{Bmatrix} 1 & \text{if } x_j - x_i > 0 \\ 0 & \text{if } x_j - x_i = 0 \\ -1 & \text{if } x_j - x_i < 0 \end{Bmatrix} \tag{6}$$

A positive value of S indicates that the tritium concentration increase with time, and a negative value of S indicates that the concentration decline with time. For n>10 the test statistic S has an approximate normal distribution, and the standard normal variate Z to test for trends is

$$Z=\begin{cases} \frac{S-1}{[Var(S)]^{1/2}} & \text{if } S>0 \\ 0 & \text{if } S=0 \\ \frac{S+1}{[Var(S)]^{1/2}} & \text{if } S<0 \end{cases} \qquad (7)$$

Environmental tritium show a strong seasonal and annual periodicity which is reflected in the periodicity of the auto-correlation function in Figure 1. Cross-correlation function between tritium in rainwater and TFWT in pine needle do not show any delay time, and the response time is very short as shown in Figure 2. Cross-correlation function is shown to be positive immediately after rainfall phenomenon. One interesting finding is that TFWT concentration in pine needle continuously increases with time from 1999 to 2008, so continuous attention should be paid to determine whether accumulation of tritium within indicator organism is going on or not.

Conclusion

The response of environmental radioactivity of tritium around Wolsong site is analyzed using time-series technique and non-parametric trend analysis. Tritium in the atmosphere and rainwater is strongly auto-correlated by seasonal and annual periodicity. TFWT concentration in pine needle is proven to be more sensitive to rainfall phenomenon than other weather variables. Non-parametric trend analysis of TFWT concentration within pine needle shows a increasing slope in terms of confidence level of 95%. This study demonstrates a usefulness of time-series and trend analysis for the interpretation of environmental radioactivity relationship with various environmental media.

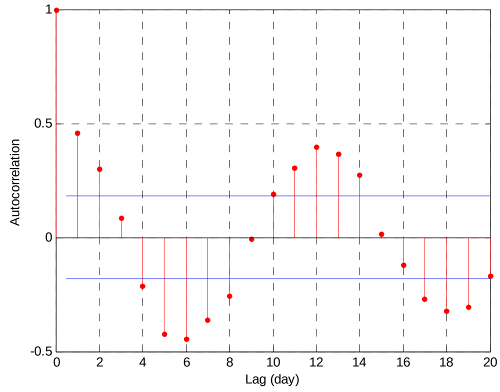

Fig. 1 Auto-correlation function of airborne ^{3}H

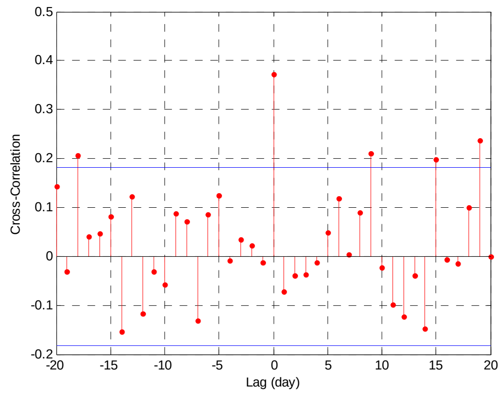

Fig. 2 Cross-correlation function between ^{3}H in rainwater and TFWT in pine needle

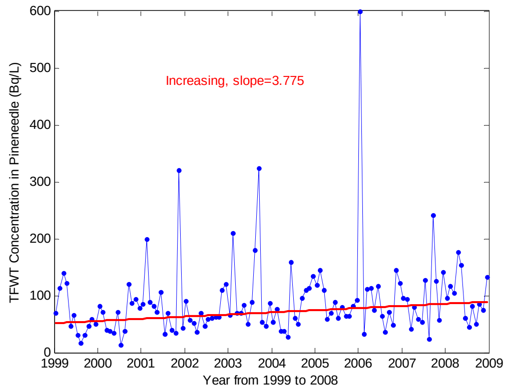

Fig. 3 Trend of TFWT concentration in pine needle

Reference

1. Korea Institute of Nuclear Safety, The Annual Report on the Environmental Radiological Surveillance and Assessment around the Nuclear Facilities.