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Radiological Operational Safety Verification for LILW Disposal Facility

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1. Introduction

The successful implementation of radioactive waste repository program depends on scientific and technical aspects of excellent safety strategy as well as on societal aspects such as stakeholder acceptance and confidence. Monitoring is considered as key element in serving both ends. It covers all stages of the disposal process from site selection to institutional monitoring after the repository is closed. Basically, the purpose of the monitoring of radioactive waste disposal facility is not to reveal any increase of radioactivity due to the repository, but to provide reassurance and confirmation that the repository is fulfilling its passive safety purpose as an initial disposal concept and that long-term safety driven by regulatory requirements is ensured throughout the entire lifetime of disposal facility including post-closure phase.

Five principal objectives of monitoring of geological disposal are summarized by IAEA-TECDOC-1208 as follows [1] 1) Supporting management decisions in a staged programme of repository development; 2) Strengthening understanding of system behavior; 3) Societal decision making; 4) Accumulating an environmental database; 5) Nuclear safeguards (if repository contains fissile material, i.e., spent fuel or plutonium-rich waste)

Based on the results of detailed studies of the above objectives and related phenomena, 6 categories of potential monitoring parameters are determined as follows: (1) degradation of repository structures, (2) behavior of the waste package and its associated buffer material, (3) near field chemical interactions between introduced materials, groundwater and host rock, (4) chemical and physical changes to the surrounding geosphere, (5) provision of an environmental database, and (6) nuclear safeguards. Typical monitoring parameters include temperature (heat), water level, pore-water and moisture content (groundwater), rock pressure, fractures, displacement and deformation (stress), water quality chemistry and dissolved component (chemistry). They can be measured using proven equipment and methods such as wireless and non-intrusive monitoring techniques.

Directly accessing the waste packages for the purpose of monitoring could negatively affect the long-term performance of engineered barriers. One way to solve this problem is to build a pilot facility (demonstration facility) at another site set apart from the actual disposal site and implement monitoring there. The pilot facililty proposed by the "Expert Group on Disposal Concepts for Radioactive Waste" of Switzerland is a small-scale facility which is different from test facility (in-situ rock laboratory) in terms of representative amount of real waste. The pilot facility provides information to confirm the performance of the repository system, and also allows the early detection of any deviations from the expected evolution.

National low-level waste management program of the United States published a report containing 16 key radionuclides that are judged by the NRC to most likely contribute significantly to the radiation exposures estimated from a performance assessment of a proposed commercial LLW disposal facility. They are ^{3}H, ^{14}C, ^{60}Co, ^{59}Ni, ^{63}Ni, ^{90}Sr, ^{94}Nb, ^{99}Tc, ^{129}I, ^{137}Cs, ^{237}Np, ^{238}U, ^{239}Pu, ^{241}Pu, ^{241}Am, ^{242}Cm. They are almost consistent with concentration limits of radionuclides for disposal of No. of Notices of the MOST; 2009-37 except gross alpha radioactivity (TRU) and ^{238}U [2]. Four radionuclides, such as ^{3}H, ^{14}C, ^{99}Tc and ^{129}I, are identified as special considerations by the NRC in terms of ensuring that performance objectives for long-term environmental protection are met for disposal of commercial LLW. They are very mobile in groundwater, and their main route to enter the human body is by either ingestion or inhalation.

2. Method and Result

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.

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

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

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

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

where k is time lag, n length of time-series, $\overline{X}$ and $\overline{Y}$ 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 trend is defined as:

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

where

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

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

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

Tritium concentration in air and rainwater which is one of terrestrial indicator around disposal facility is respectively plotted during pre-operation phase (3 years) as shown in Figure 1. One interesting finding is that tritium concentration in rainwater continuously increases with time from 2008 to 2010, so continuous attention should be paid to determine whether accumulation of tritium within living organism is going on or not [3].

3. Conclusions

The response of environmental radioactivity of tritium around disposal facility 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 due to the operation of neighboring nuclear plants. Non-parametric trend analysis of tritium concentration in rainwater shows an 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.

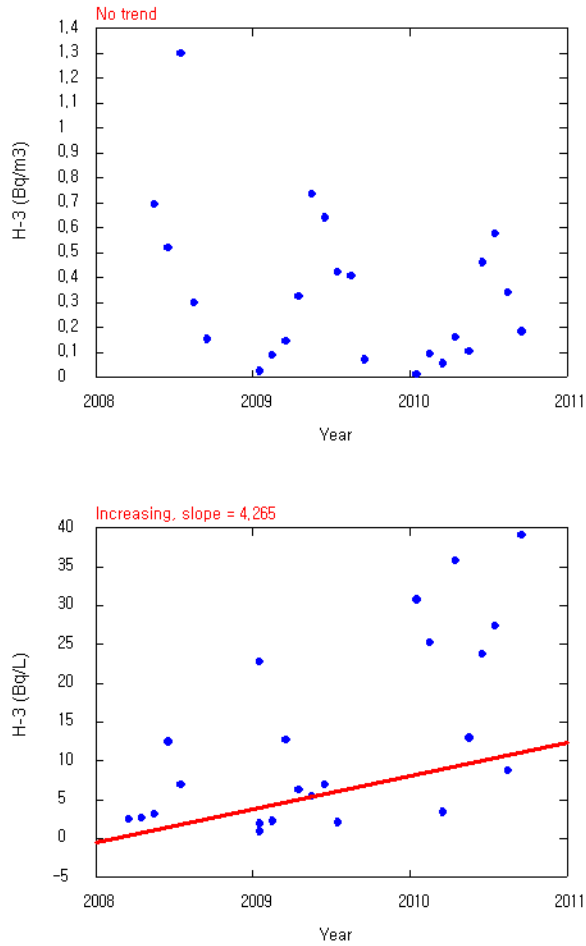

Fig. 1 Trend of H-3 in air (top) and rainwater (bottom) during pre-operation phase of disposal facility

Acknowledgment

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REFERENCES

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[2] No. 2009-37 (MEST.waste.007) of Notice of the Ministry of Education, Science and Technology, “Acceptance Criteria for Low- and Intermediate-Level Radioactive Waste”
[3] Korea Institute of Nuclear Safety, Annual Report on the Environmental Radiological Surveillance and Assessment around Nuclear Facilities (2010).