Study on the method of estimating the source term and accumulation of radioactive waste in consideration of the operating history of a nuclear power plant

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1. Introduction

The safety of disposal must be ensured before radioactive waste can be disposed of. To this end, the source term and accumulation of radioactive waste must be estimated, and accordingly, Korea is regulating them by presenting and establishing/revising relevant laws, ordinances and notifications. In particular, the Ministry of Science and Technology Notification No. 01-32 "Criteria for Reception of Low and Intermediate Level Radioactive Waste," which is in the process of being revised, presents the direct/indirect estimation method with proven validity as a method of estimating radionuclide accumulation. Currently, nuclear power plants in Korea have been using the gamma spectrometry method (HPGe) as the direct measurement method since 2004 to estimate the quantity of the radionuclide, and utilizing the Scaling Factor (SF) as the indirect measurement method to estimate other nuclides. However, it is impossible to use this nuclide analysis system for the diverse types of existing drums other than the 200ℓ drum (Uljin Plant No. 1; 2000ℓ concentrated waste concrete drum, Gori Plant No. 1; 1200ℓ concentrated waste repackaging concrete drum, etc.).[1,2,3] Therefore, this study developed the program for estimating the radionuclide accumulation of radwaste using the material balance method, one of the indirect methods, and performed application evaluation on the basis of the data from commercial nuclear power plants.

2. Methodology and Results

2.1 Methodology

Radioactive materials generated in a nuclear reactor circulate through the systems together with the nuclear reactor coolant, and they are collected after they go through such processes as decontamination in each of the purification systems and the radwaste processing systems.[4] If the input/output concentration and decontamination factor of nuclide I (DFti) are known, it can be expressed as shown in Formula (1).

$$A_i = \frac{Ci}{\lambda_i} \times (1 - \frac{1}{DFt_i})FL \times (1 - e^{-\lambda_i t}) \qquad (1)$$

where,

$A_i(t)$: Concentration of the radionuclide I accumulated per unit time (Ci)

C_i : Concentration of the radionuclide flowing into the system (Ci/ℓ)

λ_i : Half period of radionuclide I (s^{-1})

DF_{ti} : Decontamination factor of the purification system

Fl : Incoming flux of the system (ℓ/s)

Formula (1), a method of calculating the cumulative radioactivity, utilizes the average decontamination factor (DF$_{ti}$) technique. Its errors are too big to be applied to actual nuclear power plants as the decontamination factor of each purification system varies constantly over time.[1] Therefore, this study developed a program for estimating the cumulative radionuclide, an improvement over the existing method based on the instantaneous decontamination factor which calculates the cumulative volume of the radionuclide in each purification system over a short period of time. To assess the applicability of this program, the data from the Rancho-seco plant in the US was used as input data, and the data from Gori Plant No. 4 during the shutdown water chemistry control was used input data to compare it with the nuclide removal estimation technique.

2.2 Results

The data from Rancho Seco Plant in the US dated from January 3, 1979-February 28, 1979 was selected, and the CVCS Co-60 nuclide concentration measurement data and the DF measurements of each purification system were used to estimate the cumulative radionuclide in the purification system.[5]

Fig.1 and Fig.2 illustrate the operating conditions at shutdown and startup, and the cumulative Co-60 nuclide in the CVCS purification system.

First, Fig.1. shows a sharp increase of the radionuclide accumulation caused by the increased input/output concentration in the demineralizer due to the chemical changes, such as the shutdown water chemistry control. DF_2 is the decontamination factor of the purification system calculated by correcting the input/output concentration, and the total radioactivity of Co-60 accumulated in the Purification Ix (purification system) during this period is 59.66Ci. (Table 1)

Fig.2 illustrates the change in DF_2 and radionuclide accumulation caused by the abrupt changes in the input/output concentration of the nuclide due to the startup characteristics and shorter unplanned outage.

The total radioactivity of Co-60 accumulated in Purification lx (purification system) during this period is 2.25Ci. (Table 1)

Next, to confirm whether the technique developed in this study is appropriate, the data from Gori Plant 4 (during the 9th PM period), a commercial nuclear power plant in Korea, was used to conduct a comparative analysis. The data from a previous study concerning the nuclide removal in the purification system during the shutdown water chemistry control, and the related estimation technique (SCALP) were used.[6]

As shown in Table 2, the result of comparing the accumulation-based technique to the nuclide removal estimation method shows that the measurements by the nuclide removal estimation technique and the technique developed in this study were 2165.43Ci, and 2140.64Ci respectively, and the relative error was less than 1%.

3. Conclusion

This study developed the technique for estimating the source term and accumulation to ensure the safety of radwaste disposal, and assessed its applicability. The program developed in this study was used to analyse and evaluate the data from commercial nuclear power plants. The result shows that it is possible to quantitatively estimate the accumulation in the purification system on the basis of the input/output concentration and decontamination factor (DF) of the purification system for the selected nuclide and the operating conditions during this period. For quantitative estimation of nuclide accumulation in the future, estimation must be done on the basis of sufficient actual measurement data of the relevant system in commercial nuclear power plants. In addition, the scaling factor (SF) must be utilized to explore ways to estimate hard-to-measure nuclides (DMT nuclide), and applicability must be assessed on the basis of the verification of the actual measurement data of the radwaste of commercial nuclear power plants.

Acknowledgment

References

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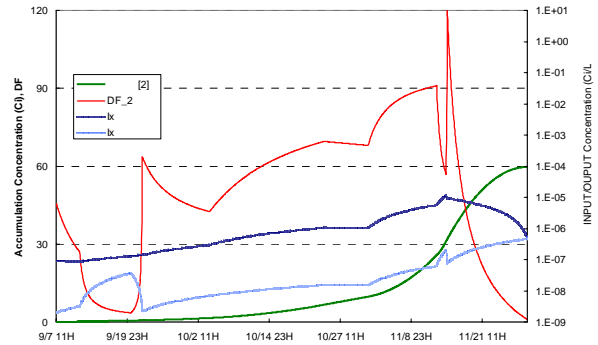
Fig 1. Input/output concentration, DF variations and radionuclide accumulation of the CVCS purification system (shutdown)
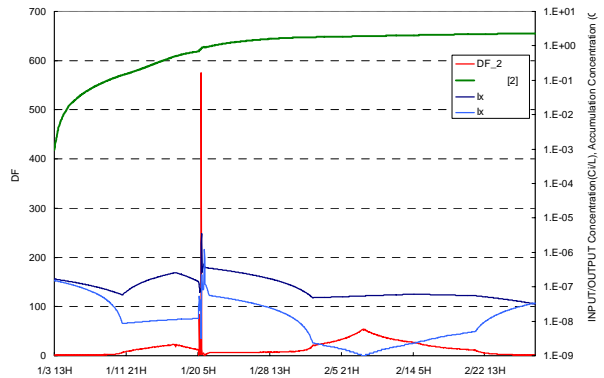

Fig 2. Input/output concentration, DF variations and radionuclide accumulation of the CVCS purification system (startup, shorter unplanned outage

Table 1. Co-60 accumulation in the CVCS purification system

Unit: Ci

Purification system	Normal operation - shutdown (Sept. 7-Dec. 19, 1978)	Startup - normal operation (Jan. 3-Feb. 28, 1979)
1 Letdown Filter	248.5	1.45
2 Purification Ix	59.66	2.256
3 Makeup Filter	0.123	-0.27

Table 2. The result of comparing the radionuclide removal estimation technique and the radionuclide accumulation estimation technique

Estimated radionuclide	Removal (Ci)	Accumulation (Ci)	Relative error
Co-58	2,165.43	2,140.64	0.9%

- Period: Apr. 5-15, 1996
- Relative error: criterion for estimating the removal
- Target system: Chemistry and volume control system
- Purification system: demineralizer