A Scaling Factor Estimation Program for Low-level Radioactive Waste - 11427

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ABSTRACT

Before radioactive waste can be accepted for disposal, its radionuclide concentration should be determined. The radioactivity of gamma nuclides can be measured directly by RAS (Radioactive waste Assay System), but that of alpha or beta nuclides requires an indirect method, such as scaling factor. Manual calculation of the scaling factor is time consuming and allows for the possibility of human error. In this regard, KHNP has developed a computer program to calculate the scaling factor for alpha or beta nuclides in radioactive waste drums. Once the drum is identified, the program automatically acquires information such as plant, generating data, waste stream, etc., and then calculates scaling factors. RAS can then use the result to estimate the inventory of alpha and beta nuclides. To verify the program, test cases were produced for waste streams of nuclear power plants, and the calculated values were in a good agreement with the estimated values. The program was installed in plants, where it successfully generated the scaling factors for waste drums which are currently awaiting delivery to the disposal site. It is expected that the program will play a key role in the characterization of radioactive waste from nuclear power plants in accordance with the Korean waste acceptance criteria for disposal.

INTRODUCTION

According to the regulations for transferring low-level radioactive waste to disposal facilities, the radionuclide inventory of the radioactive waste to be disposed must be estimated before disposal.

The radionuclides in the waste consist not only of easy-to-measure nuclides emitting gamma rays, but also difficult-to-measure (DTM) nuclides emitting alpha or beta particles. The radioactivity of the former can be measured directly by RAS, but that of the latter can only be estimated through an indirect method, such as scaling factors [1].

Based on analysis of the correlation between DTM nuclides and key nuclides, it is determined that activation products and transuranic nuclides are related to Co-60, whereas fission products are related to Cs-137. The manual estimation of scaling factors is time consuming and vulnerable to human error. In this regard, KHNP developed a computer program to calculate the scaling factor of radioactive waste.

For developing the plant- and waste-stream specific scaling factors, plants were classified into 7 groups according to plant types, and the waste streams into 7 groups, including dry active waste, spent resin from primary system, spent resin from secondary system, spent filter, evaporated bottom, sludge, and spent fuel rack.

Because the scaling factors depend on plants and waste streams, the program is developed to acquire the relevant information about the waste automatically through drum identification. After the scaling factor is estimated, it is imported to RAS (Radioactive waste Assay System), which then calculates the inventory of alpha and beta nuclides.

The program has initially been set to calculate the scaling factor for plant grouping, statistical methods, outlier elimination, and nuclides. These options can only be changed by a limited number of people, due to data security. The program also has a unique function for decay correction for the time difference between waste generation and shipment.

DEVELOPMENT

The program was developed in the following sequence: user requirement, software requirement specification, software design description, software test plan, implementation, integration, and test. Verification and validation according to IEEE 1012 was performed during all development steps.

The program is installed in the main computer of RAS. When waste drums are put on the RAS conveyor, the program generates files containing scaling factors of the wastes and RAS uses those files to calculate the radionuclide inventory. RAS and the program should use the same protocol for data communication.

The program is written in visual C++ language and uses Microsoft foundation class library in a working environment of WINDOWS 2000 and XP.

Identification of waste drum

Each drum is assigned a 16-digit identification number which contains the information of the site, plant unit, waste stream, production year, and serial number. The program identifies the drum to acquire the relevant information for the scaling factor calculation. To prevent human error, an internal algorithm checks for incorrect data.

Database

The data is stored in a Microsoft Access database to allow for simple updates needed for estimating the scaling factors. The database is composed of tables which contain user information, radiochemistry analysis data, nuclide information, plant grouping, waste stream classification, scaling factor estimation options, standard t distribution value, transuranic nuclide option and outlier elimination option, etc.

Because these figures can directly affect the estimation of scaling factors, only a limited number of designated persons will have access to the database.

Scaling factor estimation

After the information required to estimate the scaling factors is identified, associated radiochemistry analysis data are deducted from the database.

When the correlation coefficient between the DTM nuclide and the key nuclide is greater than or equal to 0.6, then the log linear regression method is applied. The method uses logarithm data of radioactivities of DTM nuclides and key nuclides, as in the following equation:

$$\log(A_{DTM}) = m \times \log\left(A_{key}\right) + b$$

where A_DTM = the radioactivity of DTM nuclide, A_key = the radioactivity of key nuclide, m = the slope of the regression equation, b = the intercept of the regression equation.

If the correlation coefficient is less than 0.6, then the geometric mean is applied[2]. The geometric mean method uses an arithmetic average of the logarithm data of the radioactivities of DTM nuclides and key nuclides, as in the following equation:

$$\mathbf{A_{DTM}} = \mathbf{SF} \times \mathbf{A_{key}}$$

where SF is the scaling factor determined as follows:

$$\log(SF) = \left(\frac{1}{\mathbf{n}}\right) \sum \log\left(\frac{\mathbf{A_{DTM}}}{\mathbf{A_{key}}}\right)$$

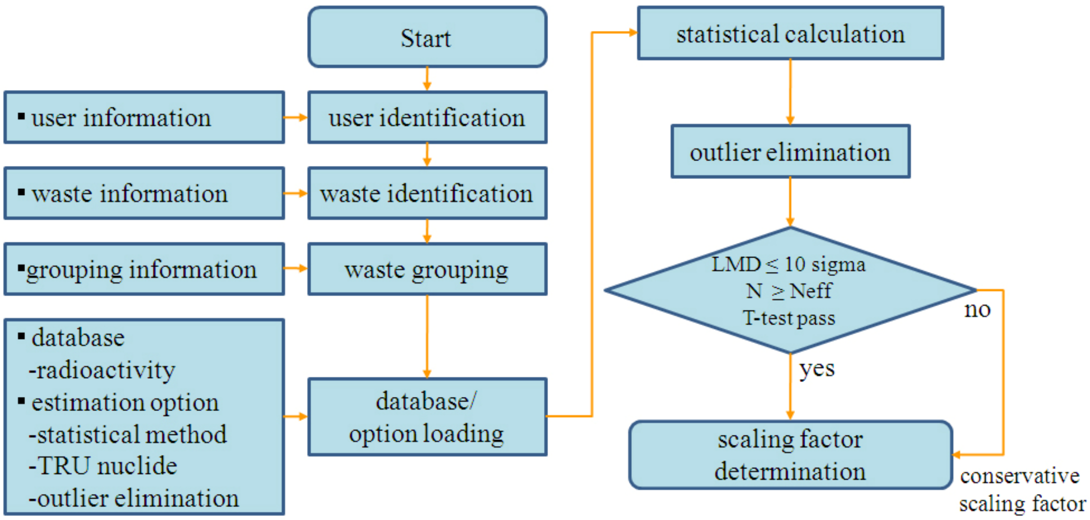
where n is the number of radiochemistry data used for calculating scaling factors.

Any radiochemical data which have not passed a t-test with a 95% confidence level are eliminated from the calculation of scaling factors.

Conservative scaling factor

If calculated scaling factors do not meet the following criteria, then conservative values are applied[3]:

- The number of data used for determining scaling factors is less than that of statistically effective data
- Standard deviation of scaling factors is higher than 10
- Data set does not pass the t-test for confidence level of 95%. Here, the t value is



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Flow of estimation

The flow chart of the scaling factor estimation program is as shown in Fig. 1. The results of scaling factors are produced in the form of electronic files to be used for RAS.

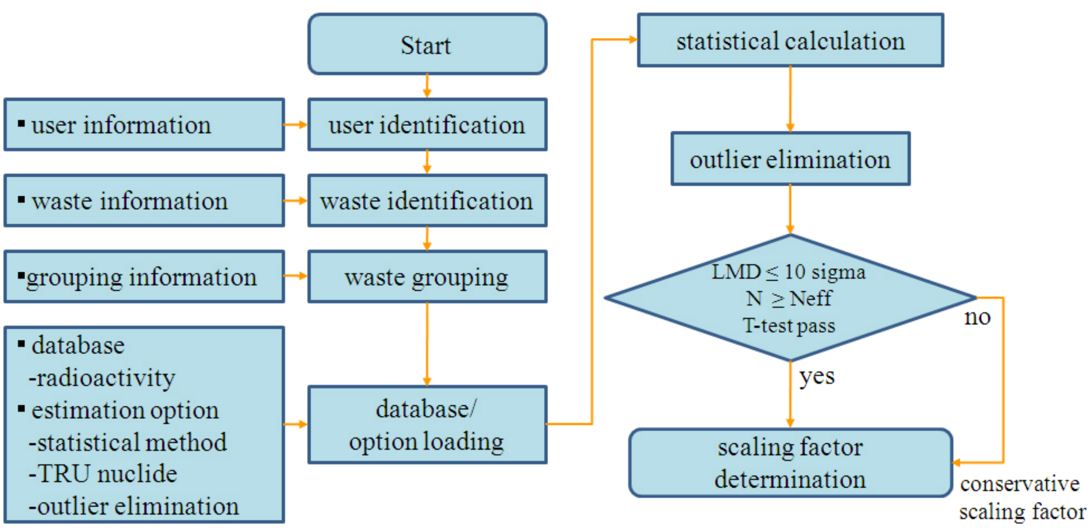

Fig. 1. A flow chart of the scaling factor estimation program for low- level radioactive waste

TEST

For verification and validation of the program, the following tests were made for A and B nuclear power plants.

- unit and integration test of API block and branch
- user interface tests: login, display and control on the monitor
- functional tests: calculation, database control and file generation

The results showed that the values calculated by the program are in a close agreement with the licensed values and that each function has been properly implemented.

The program was installed in the A plant and successfully generated scaling factors for wastes which are currently awaiting delivery to the disposal site. It is expected that the program will play a key role in the characterization of radioactive waste from nuclear power plants in accordance with disposal regulations.

CONCLUSION

A scaling factor estimation program was successfully developed, tested, and installed at KHNP nuclear power plants. Radioactive waste inventory can be evaluated in accordance with the associated disposal criteria in order to transfer to radioactive waste disposal facility.

REFERENCE

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3. James N. Miller and Jane C. Miller," Statistics and Chemometrics for Analytical Chemistry," 2000.