Development of Re-Packaged Drum Radioactivity Estimation Method – 14158

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ABSTRACT

Since their commercial operation of the late 1970s the nuclear power plants (NPP) in Korea have generated radioactive waste. The radioactive waste has been stored in on-site interim storage facilities. To reduce the radioactive volume and to improve storage conditions, super-compactors were commissioned. Typically, two or three 200 L drums were compacted by super-compaction and placed in re-packaged drums.

NPPs should deliver the radioactive wastes being temporarily stored at their on-site facilities to the radioactive waste disposal site that will be operated soon. To ensure wastes disposal safety, waste characteristics should be identified before their disposal. The characterization of radioactive waste is most important for disposal. A method to estimate radioactivity of the re-packaged drum containing 2 compressed waste drums generated at different times as been developed. In the estimation of total radioactivity of the re-packaged drum, the activity from gamma emitters was estimated using the data measured by drum nuclide analyzer and the activities from alpha and beta emitters were estimated by applying scaling factors.

To estimate the activities of the drums that were generated at different times, the activity estimation timing was set to the initial date in reckoning and activities of the drums were calibrated by considering their generation times and radionuclides' decay times. The results show that there were cases that the radioactivity of the older drum is higher than other drums and vice versa. That seems to be different between half-lives of key nuclides and difficult to measure (DTM) nuclides in applying the scaling factor. It is essential to identify radiological characteristics of the radioactive wastes before their final disposal to ensure the disposal safety. Considering that the radioactive waste disposal facility is under construction, the method to estimate the radioactivity of the waste drums as exactly as possible should be developed. This study is expected to be applied for characterizing re-packaged waste drums and other various waste packages.

INTRODUCTION

Many kinds of radionuclides are found in radioactive waste. Radionuclides that cannot be measured in a gamma nuclide analysis is able to determine the radioactivity using scaling factor method. The scaling factor method is indirect method for identifying radioactivity of DTM nuclides based on the activity of gamma emitting nuclides.

Dry active waste (DAW) produced from the Korean NPPs is generally packaged in steel drums. The types of radioactive waste packages in South Korea include general steel drums (200 liters), shielded drum, re-packaged drums (320 liters), concrete drums, and the high integrated containers (HIC). Since there were many kinds of the production process of waste packages, radioactivity should be analyzed depending on characteristics of each drum. Two or three compressed drums were placed in a re-packaged 320 L drum. Compressed drums are not analyzed before the super compaction and have different generation days. Therefore a process to measure radioactivity of a re-packaged drum which is generated by super compaction of two drums is needed considering compressed drum generation time, half life, applying scaling factor etc. In this study I have developed a method for estimating the radioactivity of such drums.

METHOD

In this study, it is assumed that a re-packaged drum contains two compressed drums. Key nuclide of radioactive waste that is obtained by gamma spectrometer measurements and alpha-beta radioactivity is obtained by applying a scale factor. The total radioactivity of re-packaged drum is calculated by sum of gamma, alpha and beta radioactivity.

By applying a scale factor to calculate the radioactivity formula as follows:

$$A_{DTM} = A_{Key} \times S.\ F \qquad \text{(Eq. 1)}$$

Where, A_{DTM}: DTM nuclides Activity,
A_{Key}: nuclides Activity,
S. F: Scaling Factor

Two compressed drum has different generation time. Let call the older compressed drum 'Drum-1' and call the other 'Drum-2' respectively.

Radioactivity calculation Method

A. Radioactivity calculation for re-packaged drums.

(1) Select the key nuclide
- Co-60 and Cs-137 are the key nuclides and alpha-beta radionuclides are DTM nuclides.

(2) Assay re-packaged drum radioactivity
- Key nuclides radioactivity is obtained using gamma analyzer.

(3) Calculate key radionuclide radioactivity on compressed drum generation day.
- Key nuclides radioactivity from (2), calculates radioactivity of key nuclides of compressed drum generation day.
- calculates each key nuclide radioactivity of two compressed drums

(4) Each DTM nuclide radioactivity of two compressed drums are obtained using scaling factor on compressed drum generation day.

(5) Calculate DTM nuclides radioactivity on analysis day from (4)

(6) Key nuclides and DTM nuclides radioactivity is obtained at the time of re-packaged.

(7) Two radioactivities are obtained by summing the radioactivity of each Drum-1 and Drum-2 because of the difference of re-packaged drum generation day.

(8) Select the high radioactivity
- Due to the radioactive decay time of the difference between the two drums, radioactivity gap occurs.

B. Derived radioactivity for re-packaged drum

(1) Calculation of key nuclide for re-packaged drum
^{60Co}A : Activity measured of Co-60
$^{137Cs}A$: Activity measured of Cs-137

(2) Calculation of key nuclides activity for compressed drum when generated.

- Decay formula : $A = A_0 e^{-\lambda t}$
  $^{60Co}A_0 = {}^{60Co}A/e^{-\lambda t}$
  $^{137Cs}A_0 = {}^{137Cs}A/e^{-\lambda t}$

(3) Calculation of DTM nuclides activity for compressed drum when generated.
$^{DTM}A_0 = {}^{60Co\ or\ 137Cs}A_0 \times$ S. F(Scaling Factor)

(4) Calculation of DTM nuclides activity for re-packaged drum when generated.
$^{DTM}A = {}^{DTM}A_0 e^{-\lambda t}$
eg, $^{3H}A = {}^{3H}A_0 e^{-\lambda t}$

(5) Calculation of compressed drum when generated.
(a) $^{DTM}A_1 = {}^{DTM}A_{10} e^{-\lambda t1}$
(b) $^{DTM}A_2 = {}^{DTM}A_{10} e^{-\lambda t2}$

(6) At (5), compare (a) and (b), and choice the higher value.

○ Key unclides Activity : (a) = (b) (same value)
○ DTM unclides Activity
- $^{DTM}A_1 > {}^{DTM}A_2 = {}^{DTM}A_1$
- $^{DTM}A_1 < {}^{DTM}A_2 = {}^{DTM}A_2$

(7) Calculation for re-packaged drum radioactivity

Total activity = Key nuclides radioactivity + DTM nuclides radioactivity

DISCUSSION

The effects of radiation on the half-life for radioactivity

A. Radioactivity decay curve in case of Co-60

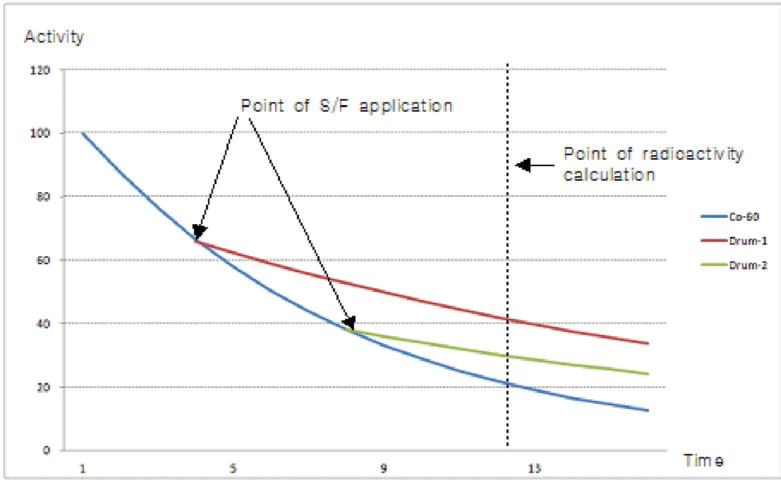

Fig. 1. Decay scheme of Co-60 and Drum-1 and 2.

In case that key nuclide is Co-60, Fig.1 shows the radioactivity of Drum-1 and Drum-2. In this graph, the half-life of Co-60 (5.3 years) is shorter than the half-life of the DTM nuclides. Co-60 decay curve can be seen that it is reduced earliest and Drum-2 radioactivity decay more rapidly. When applying the scaling factor, it is possible to know that Drum-1 radioactivity is decayed more slowly than Drum-2 radioactivity. This is what when evaluating the radioactivity on the basis of the measurement point, the older drum radioactivity showing higher.

B. Radioactivity decay curve in case of Cs-137(DTM nuclide has a half-life that is longer than the half-life of key nuclide)

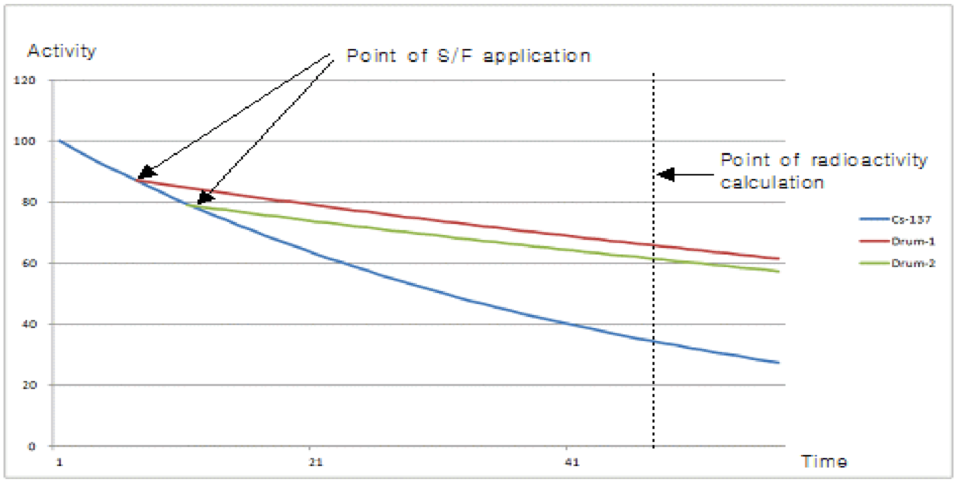

Fig. 2. Decay scheme of Cs-137 and Drum-1 and 2.

In case that key nuclide is Cs-137, Fig.2 shows the radioactivity of Drum-1 and Drum-2. In this graph, the half-life of Cs-137 (30.3 years) is shorter than the DTM nuclides half-life, Cs-137 decay curve can be seen that it is reduced earliest and Drum-2 radioactivity decay more rapidly. When applying the scaling factor, it is possible to know that Drum-1 radioactivity is decayed more slowly than Drum-2 radioactivity. This is what when evaluating the radioactivity on the basis of the measurement point, the older drum radioactivity showing higher.

C. Radioactivity decay curve in case of Cs-137(DTM nuclide has a half-life that is shorter than the half-life of key nuclide)

In case that key nuclide is Cs-137, Fig. 3 shows the radioactivity of Drum-1 and Drum-2. In this graph, the half-life of Cs-137 (30.3 years) is longer than the Sr-90(DTM nuclide) half-life (28.9 years), Cs-137 decay curve can be seen that it is reduced latest and Drum-1 radioactivity decay more rapidly. When applying the scaling factor, it is possible to know that Drum-2 radioactivity is decayed more slowly than Drum-1 radioactivity. This is what when evaluating the radioactivity on the basis of the measurement point, the older drum radioactivity showing lower.

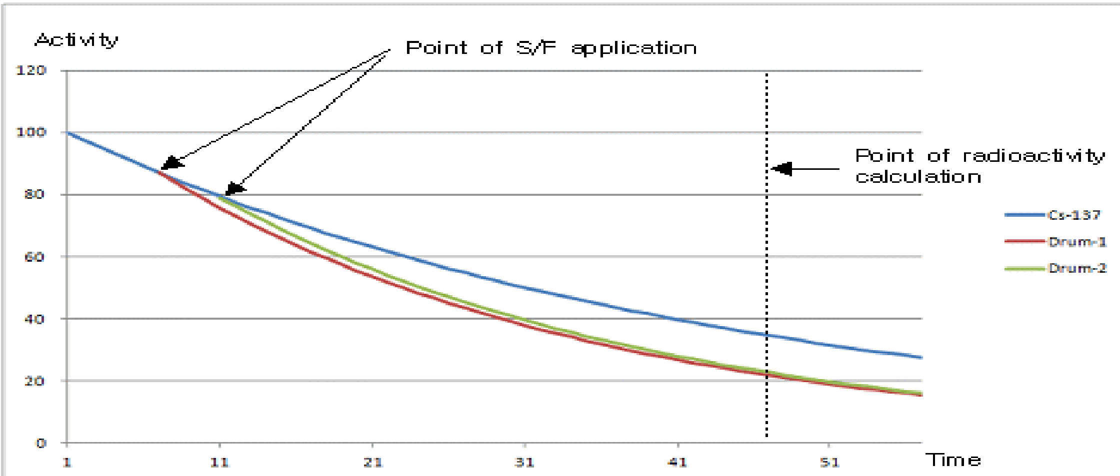

Fig. 3. Decay scheme of Cs-137 and Drum-1and2.

Calculation of Radioactive of Re-packaged Drum

A. Radioactivity calculation for Co-60

Table I is a value obtained by calculating the radioactivity of the drum generated day in radioactivity of Co-60 as measured by nuclide analysis. H-3 radioactivity is calculated by applying the scaling factor.

Table II. Result of Radioactivity calculation for Co-60 & H-3

Drum	G-day	A-day	Elapsed days	Co-60 Activity at G-day (Bq/g)	Co-60 Activity at A-day (Bq/g)	H-3 Activity at G-day (Bq/g)	H-3 Activity at A-day (Bq/g)	Total Activity at A-day (Bq/g)
Drum-1	2005.03.22	2007.12.04	987	0.17321	0.12140	0.34816	0.29898	0.46956
Drum-2	2005.08.25	2007.12.04	831	0.16375	0.12140	0.32914	0.28953	0.45054

* G-day : Generation day, A-day: Assessment day
** Elapsed days : Elapsed days between G-day and A-day
*** H-3 Scaling factor : 2.01E+00
*** I-129 Scaling factor : 3,9E-04
*** Sr-90 Scaling factor : 1.61E-02

The total radioactivity of nuclide analysis is a value obtained by summing the radioactivity of H-3 and Co-60. For this reason, it was confirmed that the radioactivity of the Drum-1 is 4.05% higher than the radioactivity Drum-2 (0.46956 Bq/g Vs.0.45054 Bq/g) to determine the radioactivity of each of the drums.

B. Radioactivity calculation for Cs-137 is Key nuclide (Cs-137 & I-129)

Table **III** is a value obtained by calculating the radioactivity of the drum generated day in radioactivity of Cs-137 as measured by nuclide analysis. I-129 radioactivity is calculated by applying the scaling factor.

Table IV. Result of Radioactivity calculation for Cs-137& I-129

Drum	**G-day**	**A-day**	**Elapsed days**	**Cs-137 Activity at G-day (Bq/g)**	**Cs-137 Activity at A-day (Bq/g)**	**I-129 Activity at G-day (Bq/g)**	**I-129 Activity at A-day (Bq/g)**	**Total Activity at A-day (Bq/g)**
Drum-1	2005.03.22	2007.12.04	987	0.11108	0.10440	0.0004	0.000433	0.10044433
Drum-2	2005.08.25	2007.12.04	831	0.11000	0.10440	0.0004	0.000428	0.10044429

The total radioactivity of nuclide analysis is a value obtained by summing the radioactivity of I-129 and Cs-137. For this reason, it was confirmed that the radioactivity of the Drum-1 is 0.0004% higher than the radioactivity Drum-2 (0.10044433 Bq/g Vs.0.100044429 Bq/g) to determine the radioactivity of each of the drums.

C. Radioactivity calculation for Cs-137 is Key nuclide (Cs-137 & Sr-90)

Table Ⅲ is a value obtained by calculating the radioactivity of the drum generated day in radioactivity of Cs-137 as measured by nuclide analysis. Sr-90 radioactivity is calculated by applying the scaling factor.

Table III. Result of Radioactivity calculation for Cs-137& Sr-90

Drum	**G-day**	**A-day**	**Elapsed days**	**Cs-137 Activity at G-day (Bq/g)**	**Cs-137 Activity at A-day (Bq/g)**	**Sr-90 Activity at G-day (Bq/g)**	**Sr-90 Activity at A-day (Bq/g)**	**Total Activity at A-day (Bq/g)**
Drum-1	2005.03.22	2007.12.04	987	0.11108	0.10440	0.00179	0.00125	0.10565
Drum-2	2005.08.25	2007.12.04	831	0.11000	0.10440	0.00177	0.00131	0.10571

The total radioactivity of nuclide analysis is a value obtained by summing the radioactivity of I-129 and Cs-137. For this reason, it was confirmed that the radioactivity of the Drum-1 is 0.06% higher than the radioactivity Drum-2 (0.10044433 Bq/g, Vs. 0.100044429 Bq/g) to determine the radioactivity of each of the drums.. It was possible to confirm that the radioactivity of Drum-2 is higher in the case of Co-60.

CONCLUSIONS

Super-compactor was facilitated to reduce waste volume and NPP tried to improve the storage space in the radioactive waste storage. In other words, re-packaged drums were produced by reducing two or more 200 L drums to one 320 L drum. Re-packaged drums have been generated by special treatment of super compaction and contain two or three compressed drums that were not estimated radioactivity. In radioactivity analysis, if the shape of the drums is different, radioactivity is also different, so appropriate nuclide investigation methods are necessary depending geometric conditions of the drums and the structure of the contents.

In this study, a method for calculating radioactivity of the re-packaged drum that was generated in nuclear power plant has been developed. This can be used as an example of estimation of radioactivity for waste disposal. For radioactivity estimation of re- packaged drum, how to apply the scaling factor for compressed drums. Compressed drum generation time is effective on. Currently, it's time to dispose of radioactive waste that has occurred so far nuclear power plant in Korea. The most important element is the radiation histological characterization of radionuclide and radioactivity for the safety of long-term disposal more than anything in terms of disposal. The radioactive waste can be classified as waste of various types depending on content material. Physical and chemical properties of the packaging container will be influence on radioactive analysis. In this study, the influence of the factors that affect the radiation and the development of the method for measuring the radioactivity of re-packaged drum. In addition, the graph of decay curve shows the influence of the half-life and application time of scaling factor.

Therefore, the results of this study, it can be applied to practice of radioactivity calculations re-packaged drum and can be applied also to radiation investigation of radioactive waste of various packages in the future.

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