The Homogeneity Test and Analysis for Solidified Specimen of Low and Intermediate Level of Radioactive Wastes

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1. Introduction

Homogeneity test and proof for the solidified specimen of low and intermediate level of radioactive wastes, which is required for safe radioactive waste management by regulation and KORAD, is one of the acceptance criteria for conformity assessments for waste disposal.

In order to show the homogeneity in this study, the uranium-contained specimen that is solidified using Calcium Aluminate Cement (CAC) solidification agent for sludge type of precipitate in KNFC was used. The homogeneity of these specimens based on radioactivity was conducted based on ANOVA (Analysis of Variance) in KS A ISO GUIDE 35 [1].

2. Radioactivity measure

2.1 The preparation of specimen

The total specimens of 30 out of 37 prepared from drum of NF-2017-B01-0009, NF-2017-B01-0010, and NF-2017-B01-0011 for conformity test in Apr. 29th, 2017, excluding specimens for thermal cycle test, leaching test and immersion test, are used, and those are solidified according to the TPI-34-52 [3].

2.2 Radioactivity concentration measurement

The total radioactivity concentration is gained by dividing U-235 specimen's activity by weight.
HPGe(High-Purity Germanium detector) was used to measure the radioactivity for specimen containing U-235 as in Fig. 1.

Fig. 1. HPGe.

3. Homogeneity and variance assessment

3.1. The selection of group

For ANOVA analysis, more than 2 groups of specimens are prepared. Thus, 30 specimens prepared in Section 2.1.2 are allocated into 3 groups of 10 specimens as in Table 1 and 2 just as manufacturing order.

Table 1. Grouping for Specimen No.

Group 1	Group 2	Group 3
LS-2017042901-C	LS-2017042914-C	LS-2017042924-LC
LS-2017042902-C	LS-2017042915-C	LS-2017042925-S
LS-2017042903-C	LS-2017042916-C	LS-2017042926-C
LS-2017042904-C	LS-2017042917-C	LS-2017042927-C
LS-2017042906-C	LS-2017042918-C	LS-2017042928-C
LS-2017042907-C	LS-2017042919-S	LS-2017042929-C
LS-2017042908-C	LS-2017042920-C	LS-2017042930-C
LS-2017042909-C	LS-2017042921-C	LS-2017042931-C
LS-2017042910-C	LS-2017042922-C	LS-2017042932-C
LS-2017042913-S	LS-2017042923-TC	LS-2017042935-S

Table 2. Grouping for Concentration Activity [Unit : Bq/g]

Group 1	Group 2	Group 3
9.6514E+00	1.0231E+01	1.0339E+01
9.8950E+00	1.0585E+01	1.0205E+01
9.9829E+00	1.0647E+01	1.0518E+01
9.8752E+00	1.0465E+01	1.0215E+01
1.0564E+01	1.0251E+01	1.0104E+01
1.0471E+01	1.0782E+01	1.0269E+01
1.0324E+01	1.0377E+01	1.0275E+01
1.0528E+01	1.0501E+01	1.0562E+01
1.0671E+01	1.0539E+01	1.0468E+01
1.0562E+01	1.0489E+01	1.0465E+01

3.2 The analysis of variance

The homogeneity of radioactivity concentration among 3 groups are identified by assessing if the average and distribution of the measured radioactivity concentration values of 3 groups are same or similar.

a) Hypothesis establishment

- Null hypothesis: the average and distribution of 3 groups is the same (the concentration of radioactivity is homogeneous)
- Alternative hypothesis: the average or distribution of 3 groups is not the same (the

concentration of radioactivity is not homogeneous)

b) Hypothesis testing

The established hypothesis calculates the F ratio, F critical value and P-value

Total variance of SST(ST) is calculated through formula-1.

$$SST(S_T) = \sum_{i=1}^{k}\sum_{j=1}^{n}(y_{ij} - \overline{y})^2 \tag{1}$$

Where,

y_{ij} : measured value (i: group number, j: number within group)

$\overline{y}$: total average

k : the number of groups

n : the number of data element within group

Thus summarizing the total variance of SST(ST) can be expressed as the sum of the variation between group (SSA(SA)) and the variation within group (SSE(SE)).

$$SST(S_T) = \sum_{i=1}^{k}\sum_{j=1}^{n}(y_{ij} - \overline{y}_i)^2 + \sum_{i=1}^{k}\sum_{j=1}^{n}(y_{ij} - \overline{y})^2$$

= SSE(SE) + SSA(SA) (2)

The degree of freedom (DF) of variation is defined as follows;

DF for total variation: $\Phi_T = kn - 1$

DF for variation between groups: $\Phi_A = k - 1$

DF for variation within groups: $\Phi_E = k(n-1)$

The F ratio is calculated through dividing the average for variation between groups (VA) by the average for variation within groups (VE) as in formula-3.

$$F_{ratio} = \frac{V_A}{V_E} \tag{3}$$

Where,

$V_E = \frac{SSE(S_E)}{\Phi_E}$, $V_A = \frac{SSE(S_A)}{\Phi_A}$

We can find the F critical value in F-table for α=0.05 using the DF for variation within groups and DF for variation between groups

In this study, the F critical value is 3.35 because DF for variation between groups is 2 and DF for variation within groups is 27 in 95% of confidence interval of 3 groups that have 10 elements. Using F ratio, F critical value and P-value based the analysis above, one of the null and alternative hypothesis is selected. If F ratio is less than F critical value, and P-value is bigger than 0.05, them null hypothesis is selected. And if F ratio is bigger than F critical value, or P-value is less than 0.05, then alternative hypothesis is selected.

3.3 The assessment of analysis

If null hypothesis is selected, assessing that specimens prepared during the solidification process is homogeneous in the concentration of radioactivity. And if alternative hypothesis is selected, assessing that specimen prepared during the solidification process is not homogeneous in the concentration of radioactivity.

Using the radioactivity measurement values of 3 groups of homogeneity test specimen in 3.1, Microsoft excel's statistical analysis tool for the analysis of variance is used to analyze one-way ANOVA. The Table 3 shows summary of calculation, and Table 4 shows the results of one-way ANOVA.

Table 3. Summary of Calculation (Group 1, 2 and 3)

Groups	Count	Sum	Average	Variance
Group 1	10	102.5245	10.25245	0.133431821
Group 2	10	104.867	10.4867	0.028772011
Group 3	10	103.42	10.342	0.023527778

Table 4. One-way ANOVA results

Source of Variation	Between Groups	Within Group	Total variation
Sum of square	0.279434517	1.671584485	1.951019002
DF	2	27	29
Mean square	0.139717258	0.061910536	
F ratio	2.256760582		
P-Value	0.124080129		
F critical value	3.354130829		

4. Conclusions

As a result of One-way ANOVA using the radioactivity measurement values of 3 groups of homogeneity test specimen, F ratio (2.256760582) is less than F critical value (3.354130829), and P-value (0.124080129) is bigger than 0.05.

Thus null hypothesis is conclusively selected to assess that the test specimens solidified during solidification process are homogeneous.

REFERENCES

[1] KS A ISO GUIDE 35: 2010, Certification of reference materials - General and statistical principles

[2] KS Q ISO 13528: 2014, Statistical methods for use in proficiency testing by interlaboratory comparisons

[3] TPI-34-52, The plan and procedure for solidification of sludge type of radioactive waste from fuel manufacturing (KNFC internal)