Application of Statistical Method to LLRW Transportation Management

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1 Introduction

In Japan, the Low Level Radioactive Waste (LLRW) arising from nuclear power plants, which are currently stored at power plant sites, will be sent to the Low Level Radioactive Waste Disposal Center.
LLRW consists of homogeneous waste such as concentrated liquid waste solidified with cement and other medium, non-combustible heterogeneous waste such as filter sludge, metal scraps and concrete, ashes after incineration of combustible waste, and others. Firstly the homogeneous waste will be transported for disposal, and heterogeneous waste will follow. Upon these transports, it is necessary to confirm that the waste packages satisfy all the requirements specified in transport regulations. Considering the large number of waste packages to be transported, it is necessary to establish a systematic and efficient method for inspection and confirmation.

2 Inspection Items and Method for Confirmation

(1) Inspection items and concept for confirmation

It is prospected that almost all of the LLRW generated of Japanese nuclear power plants would be classified as Industrial Packages (IP) specified in IAEA Regulations. (1985 Edition).

The following methods are proposed for confirmation of the items required by IAEA Regulations (1985 Edition):

① Actual measurement of radiation level, surface contamination and weight, and visual inspection can be performed for each of the packages.

② Document checking can be employed for confirmation of items such as homogeneity, general requirements and mechanical strength. For these items, data variation among packagings can be considered to be sufficiently small, and evidential data showing the compliance with regulations can be prepared beforehand for packages produced by a certain specific process.

③ For specific activity, which does not fall into either category ① or ②, a method shall be established for proper confirmation.

(2) Problems regarding the evaluation of radioactivity of each packaging

Since LLRW contains numerous radionuclides, the total activity of packagings shall be evaluated by comparing the value with A_2 of the waste which is derived by the following formula :

$$A_2\ (\mathrm{mixture}) = \frac{1}{\sum_i \frac{fi}{Ai}}$$

fi : Compositional ratio of radioactivity for nuclide i.

Ai : A_2 of the nuclide i.

In other words, it is necessary to determine the radioactivity of each nuclide contained in the waste, and its ratio to the total activity. Regarding this matter, the following problem should be noted.

— In Japan, from the view point of disposal, maximum specific activity for C-14, Co-60, Ni-63, Sr-90, Cs-137 and all α in the waste are specified in regulations and shall be confirmed. However, in order to confirm the compatibility with transport regulations, some other radionuclides shall be taken into account.

— Furthermore, for non-combustible heterogeneous waste, it is difficult to pre-determine the nuclides contained in them.

(3) Method for evaluation of radioactivity

Taking into consideration the above problem, a simplified method for evaluation of radioactivity is proposed here for the purpose of certifying compliance of packages with transport regulations.

① For C-14, Co-60, Ni-63, Sr-90, Cs-137, all α, and furthermore H-3, Ni-59, Nb-94, Tc-99 and I-129, the results obtained at the evaluation for disposal purpose will be applied.

② In order to evaluate activities from other nuclides (e.g. Mn-54, Co-58, Ce-144, etc.), following steps are taken: The activity of the entire packaging is obtained by Co-60 conversion from its actually measured surface dose rate. From this amount, the activity of γ nuclides mentioned in ①, also derived by Co-60 conversion, will be subtracted. The result would give the activity of "other β, γ nuclides," in Co-60 converted form.

③ Since effective energy of Mn-54 and Co-58 (0.84MeV/dis and 0.82MeV/dis respectively) classified as "other β, γ nuclides" are sufficiently smaller than that of Co-60 (2.5MeV/dis), there is a possibility of under-estimating the actual activity. For this reason, the activity of "other β, γ nuclides" will be corrected at this stage by multiplication of an appropriate correction factor. Also, for A_2 of them, the general value for β, γ emitters (0.02TBq, 0.5Ci) will be used.

④ By adding the amount of activity for 11 nuclides mentioned in ① and other β, γ emitters mentioned in ②, the total activity is obtained.

⑤ By comparing this total activity with A_2 of the mixture derived from above-mentioned formula, the compliance with either LSA- II (up to 10^{-4} A_2/g) or LSA- III (up to $2 \times 10^{-3} A_2/g$) will be evaluated.

The entire flow of this process is shown in Fig. 1.

3 Study on Applicability of the sampling inspection

The other measure to systematize the inspection prior to the shipment of large amount of LLRW may be the sampling inspection.

As a sampling inspection method, the applicability to the "Single Sampling Inspection Plans Having Desired Operation Characteristics by Variables" specified in JIS (Japan Industrial Standard) is assessed.

It is assumed that the probability for a "good quality lot" with fraction defective below Po to be rejected should be kept as small as α, and the probability for a "bad quality lot" with fraction defective greater than P_1 to be accepted shall be kept as small as β. To determine whether a lot is acceptable or not, the mean value of surface dose rate measurements of n samples randomly taken from each lot will be obtained, and the acceptability of this value will be checked by the following formula:

$$\overline{X} < Xu = Su - K\sigma$$

where

$\overline{X}$: Mean value obtained at sampling inspection

$\overline{X}u$: Upper acceptable value for $\overline{X}$

Su : Upper acceptable value

k : Acceptance constant

σ : Variance

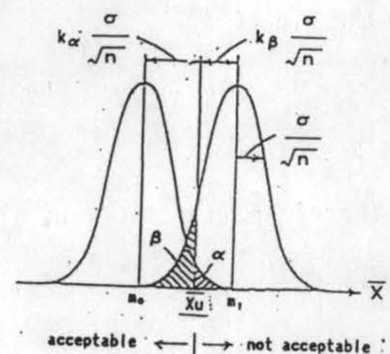
in addition that,

$$k = K_{p_0} - \frac{K_\alpha}{\sqrt{n}} = K_{p_1} + \frac{K_\beta}{\sqrt{n}}$$

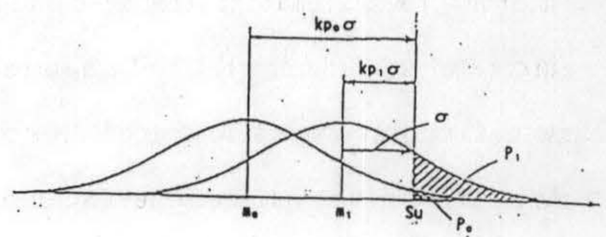
$$k_\alpha = \frac{X_u - m_0}{\sigma / \sqrt{n}}$$

$$-k_\beta = \frac{X_u - m_1}{\sigma / \sqrt{n}}$$

distribution of mean value



distribution of lot



where

m_0 : Mean value for good lot

m_1 : Mean value for bad lot

n : Sample size

K_{p_0} : Critical value of fraction defective P_0 which would give inspection results exceeding Su.

K_{p_1} : Critical value of fraction defective P_1 which would give inspection results exceeding Su.

Following is the example of the application of this method for the surface dose rate inspection. In this example, Sample size n and mean value $\overline{X}u$ obtained at the sampling inspection are determined.

Su : log (2mSv/hr) ; 2mSv is the upper radiation level for the package when not under exclusive use.

P_0 : 0.3%

α : 5% which is used for the general industries

β : 10% which is also used for the general industries.

P_1 an σ : parameters

Fig 2 shows the relation among P_1, σ, n and $\overline{X}u$. Followings are obvious from the figure :

- Variance σ is most important and gives more influence to $\overline{X}u$ than P_0, P_1, α and β.
- Therefore, the sampling inspection may be applicable for a lot having small σ.

4 Conclusion

In order to systematize the inspection of large amount of LLRW for the purpore of confirming that the waste package satisfies all the requirements specified in transport regulations, the evaluation method for the radioactivity of waste and the applicabilty of a sampling inspection method were studied.

For the evaluation of radioactivity of waste, the method proposed in this paper is to combine the results obtained by Co-60 conversion of surface dose rate of LLRW, and the activity data obtained for the purpose to confirm the compliance with disposal requirements. Concerning the sampling inspection, an applicability of the "Single Sampling Inspection Plans Having Desired Operation Characteristics by Variables" has been assessed.

Although the application seems possible, further study is required in order to establish a method to detemine values for P_0, P_1, α and β.

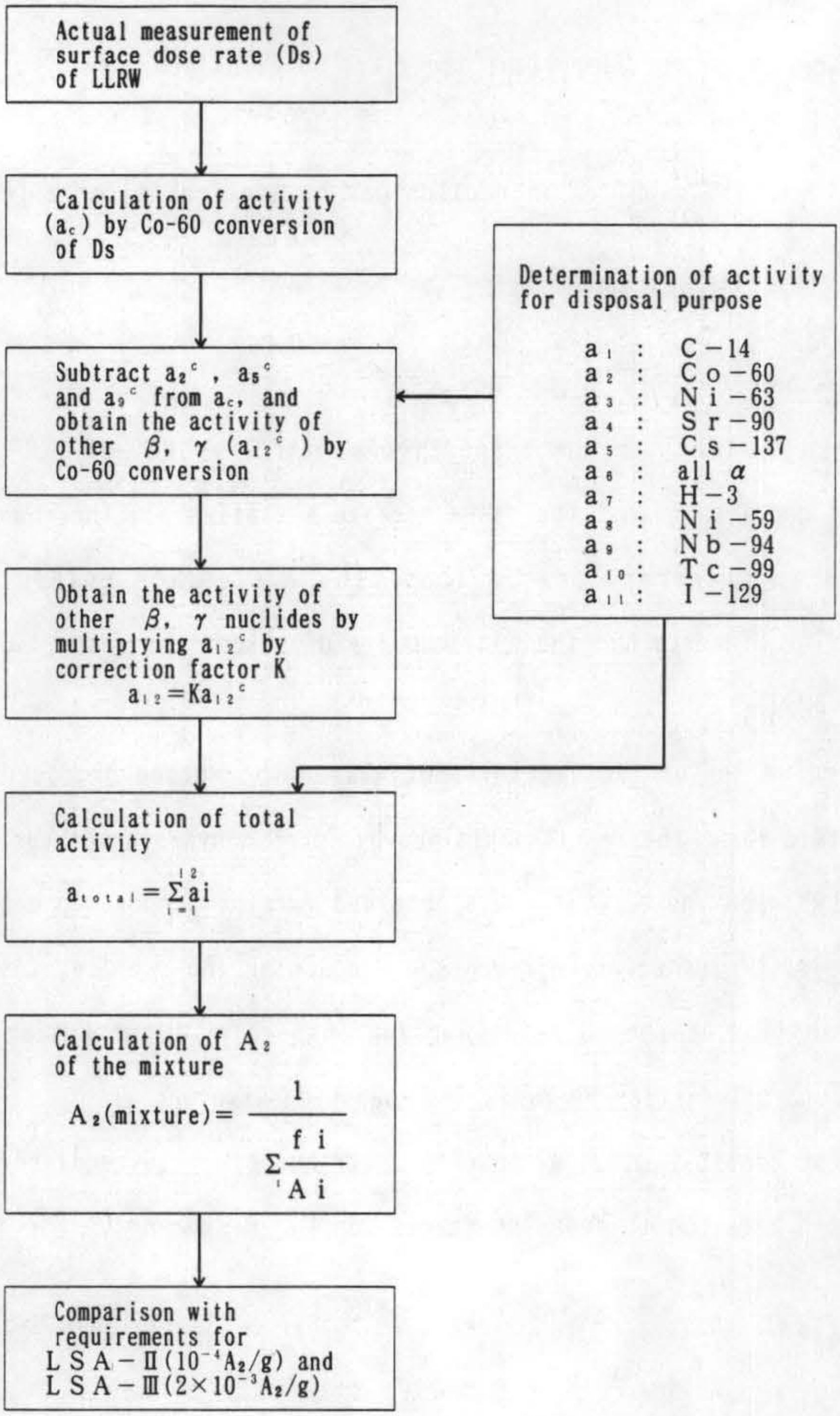


Fig. 1 Method for Evaluation of Radioactivity

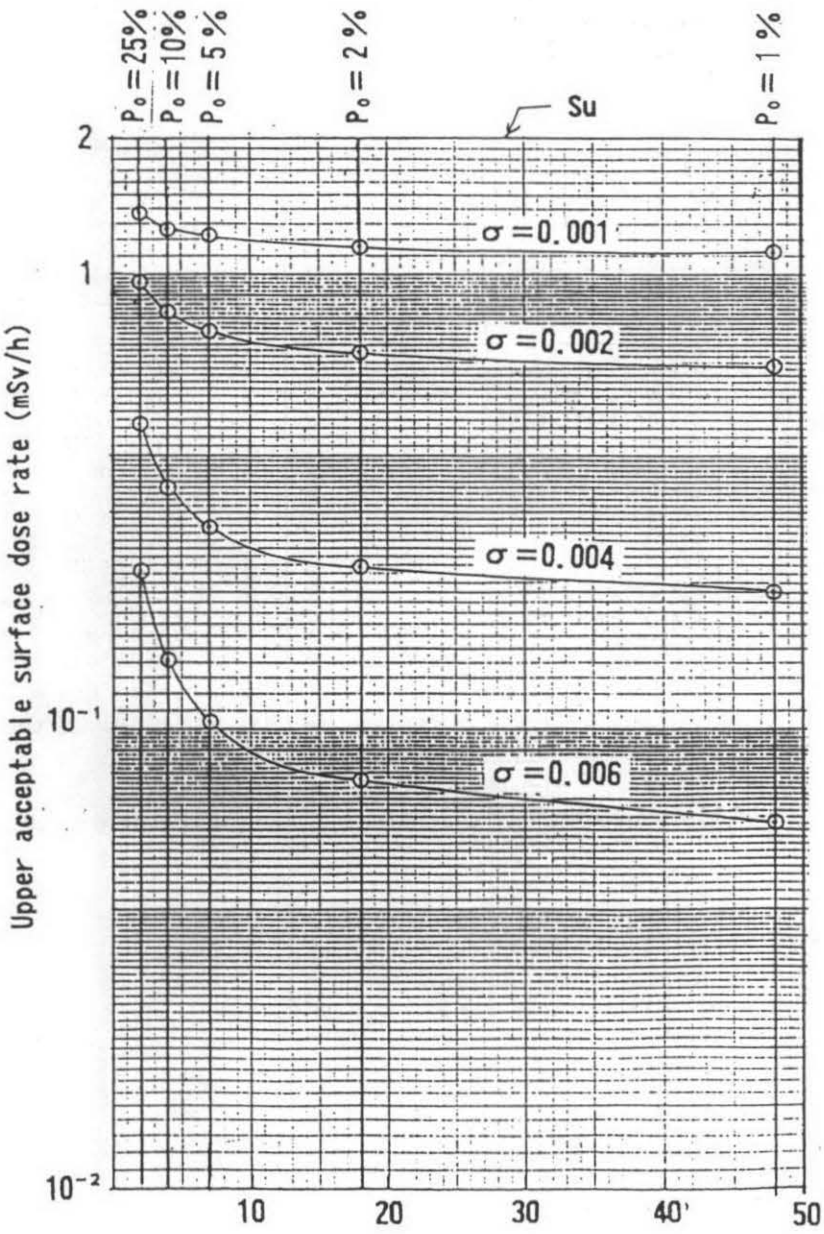


Fig. 2 Relationship between the Number of Samples and Upper Acceptance Value when the Surface Dose Rate is 2mSv/h