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Case Study - US NRC「Concentration Averaging and Encapsulation Branch Technical Position, Revision 1」

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1. Introduction

In Korea, radioactive wastes are classified as high-level, intermediate-level, low-level, and very low-level waste according to the heat generation rate and radioactivity concentration.[1] Different disposal constraints apply to each waste. Radioactive wastes currently being disposed of are mainly low-level radioactive wastes (LLW) and are delivered to Korea Radioactive Waste Agency (KORAD) in accordance with the national radioactive waste management policy. And they are disposed of permanently to the underground repository which cave disposal method was applied to. To dispose of LLW, waste generators are performing complicated preparation procedures such as sorting and repacking by waste type and characterization of each package under severe regulations. In this process, there are many difficulties in waste generation places such as increasing radiation exposure of workers and generation of secondary waste.

Meanwhile, in USA, LLW are classified as three classes (A, B, and C) under the regulation of US NRC and different disposal constraints are applied to each waste class. This waste classification system is developed to protect inadvertent intruder who intrudes onto the disposal site after the 100-year institutional control period ends and interact with the waste from receiving unsafe exposure to radioactivity.

In this study, we reviewed the position of LLW disposal in US NRC through the review of "Concentration Averaging and Encapsulation Branch Technical Position(CA BTP), Revision 1"[2], a report published by NRC, and summarized the technical position of concentration averaging, which is a major issue in this document. By comparing this technical position with the domestic radioactive waste handling process, we intend to improve the efficiency of the permanent disposal system for LLW in progress.

2. Definition of Key Terminology

2.1 Blendable Waste

According to NRC, the radioactive waste is divided into one of two categories, blendable waste or discrete items. If the waste meets either of the following criteria, it can be defined as blendable waste.

- the waste can be physically mixed to create relatively uniform radionuclide concentrations or
- the waste is not expected to contain durable items with significant activity.

Ion-exchange resins, filter media, evaporator bottom concentrates, soil, ash, contaminated trash are the example of blendable waste.

2.2 Discrete Items

Activated metals, sealed sources, cartridge filters, contaminated materials, and components incorporating radioactivity into their design are the example of discrete items.

Items belonging to these waste types are considered discrete items because they are expected to be durable and often have relatively high amounts or concentrations of radioactivity.

2.3 Concentration averaging

Concentration averaging is a mathematical averaging of the radionuclide activities in waste over its volume or mass. NRC' s technical positions of concentration averaging are described in this document, CA BTP.

It is designed to answer such as : “How much waste above the class limits is permissible in a waste mixture?” and “How much more concentrated than the limit can a portion of this waste be?” and “Over what volume are these concentrations to be measured?”.

Licensees should perform concentration averaging while complying with the constraints described in the CA BTP.

3. Technical Position of Concentration Averaging for Blendable Waste

3.1 Single Blendable Waste

If a waste package contains a single blendable waste stream, an average radionuclide concentration may be based on its total activity in the package divided by the volume or mass of the waste in the package. There are many averaging constraints as follows.

- If a waste container is more than 90% full of waste by volume, a nominal interior volume of the container may be used.
- If a container is less than 90% full, the actual waste volume or mass should be used.
- In case of the absorbed liquid, the original volume or mass of the liquid waste before absorption should be used.
- If an activity of small concentrated sources of gauges(less than 3.7MBq) that may be mixed with contaminated trash, it can be averaged over the trash volume.

3.2 Multiple Blendable Waste

Multiple blendable waste streams of the same waste type can be combined in the same container without blending. In this case, if the Table I thresholds are not exceeded, the waste dose not need to be blended and the radionuclide concentrations can be averaged as a single waste stream. But, if the thresholds are exceeded, the waste must be blended and a demonstration of adequate blending is needed.

Table I: Thresholds for Demonstrating Adequate Blending

Characteristics of Most concentrated influent Waste Stream	Volume of Mixture in $m^3(ft^3)$		
	Class A Mixture	Class B Mixture	Class C Mixture
Sum of fractions less than 10	No limit	No limit	No limit
Sum of fractions between 10 and 20	No limit	No limit	50 (1800)
Sum of fractions between 20 and 30	60 (2100)	No limit	20 (700)
Sum of fractions between 30 and 50	20 (700)	No limit	6 (210)
Sum of fractions between 50 and 100	6 (210)	40 (1400)	2 (70)

3.3 Determining Thresholds for Adequate Blending

The way to determine thresholds for adequate blending which are specified in Table I is as follows.

First, determine the intended waste class of blended product. Then, take the most concentrated influent waste stream and divide it by the concentration limit which are specified in 10CFR Part61 tables(TableⅡ and Ⅲ)for that radionuclide, based on the waste class of the final blended product. And sum the fractions over all the radionuclides in the influent waste stream. According to the sum of fractions and intended waste class, the threshold for adequate blending in Table I can be determined.[3]

TableⅡ: Concentration Value of Long-lived Radionuclides

Radionuclide	Concentration (Ci/m^3)
C-14	8
C-14 in activated metal	80
Ni-59 in activated metal	220
Nb-94 in activated metal	0.2
Tc-99	3
I-129	0.08
Alpha emitting transuranic nuclides with half-life greater than 5 years	100(nCi/g)
Pu-241	3500(nCi/g)
Cm-242	20000(nCi/g)

TableⅢ: Concentration Value of Short-lived Radionuclides

Radionuclide	Concentration (Ci/m^3)		
	Col. 1	Col. 2	Col. 3
Total of all nuclides with less than 5 year half-life	700	No limit	No limit
H-3	40	No limit	No limit
Co-60	700	No limit	No limit
Ni-63	3.5	70	700
Ni-63 in activated metal	35	700	7000
Sr-90	0.04	150	7000
Cs-137	1	44	4600

4. Technical Position of Concentration Averaging for Discrete Items

4.1 Single Discrete Items

Individual discrete items may be classified based on the activity of their radionuclides divided by the volume or mass of the item. If an individual item is encapsulated, the concentration may be averaged over the volume or weight of the final waste form.

4.2 Mixture of Discrete Items

4.2.1. Using Screening Criteria(conservative and optional)

If each item has an activity less than 37 MBq(1mCi), the radionuclide activities may be divided over the volume of the entire mixture.

But, if any item has an activity greater than 37 MBq, the mixture may be conservatively classified according to the item with the highest classification.

4.2.2 Not Using Screening Criteria

In case that screening criteria are not used, the concentration averaging constraints should be used for classifying a mixture of items. If an item in the mixture cannot meet the constraints described in this section, the item should be removed from the average and classified as an individual item.

When licensees use concentration averaging constraints, they can apply an activity limit or concentration limit.

1) Applying an activity limit

- For primary gamma-emitting radionuclides(Co-60, Nb-94, Cs-137 ; subject to averaging constraints because of the hazard they could present to an intruder handling a discrete item of waste), the activity limits are TableⅣ limits.

TableⅣ: Recommended Activity Limits of Primary Gamma Emitters Potentially Requiring Piecemeal Consideration in Classification Determinations

Nuclide	Waste Classified as Class A	Waste Classified as Class B	Waste Classified as Class C
^{60}Co	5.2 TBq (140 Ci)	No limit	No limit
^{94}Nb	37 MBq (1 mCi)	37 MBq (1 mCi)	37 MBq (1 mCi)
^{137}Cs	266 MBq (7.2 mCi)	27 GBq (0.72 Ci)	4.8 TBq (130 Ci)

The TableⅣ limits should be applied using a sum of fractions. When using 'sum of fraction rule', Items larger than 280cc (0.01 ft^3) may be treated individually.

However, items smaller than 280cc should be grouped together. That is, the sum of fractions should be based on the total inventory of each primary gamma-emitting radionuclide in the items smaller than 280 cc (0.01ft^3).

- For radionuclides of concern that are not primary gamma emitter, the activity limits are TableⅤ limits.

TableⅤ limits are applied separately to each radionuclide in each item (i.e., the sum of fractions is not applied).

TableⅤ: Recommended Activity Limits of Radionuclides Other Than Primary Gamma Emitters Potentially Requiring Piecemeal Consideration in Classification Determinations

Nuclide	For Waste Classified as Class A or B	For Waste Classified as Class C
^{3}H	0.3 TBq (8 Ci)	No limit
^{14}C	0.04 TBq (1 Ci)	0.4 TBq (10 Ci)
^{59}Ni	0.15 TBq (4 Ci)	1.5 TBq (40 Ci)
^{63}Ni	0.26 TBq (7 Ci)	55 TBq (1500 Ci)
Alpha-emitting transuranic(TRU) waste with half-life greater than 5 years(excluding ^{241}Pu and ^{242}Cm)	111MBq (3 mCi)	1.1 GBq (30 mCi)

2) Applying a concentration limit

- For primary gamma-emitting radionuclides, if the primary gamma-emitting radionuclides are classification-controlling, the appropriate concentration limit is the "Factor of 2" concentration limit.[1] However, if the primary gamma-emitting radionuclides are not classification-controlling but are radionuclides of concern, the appropriate concentration limit is the "Factor of 10" concentration limit. The Factors of 2 and 10 are applied separately to each radionuclide in each item, irrespective of size.

- For radionuclides of concern that are not primary gamma emitter, licensees may choose the Factor of 10 concentration limit. And radionuclides that are not represented in TableⅣ or Ⅴ, the Factor of 10 concentration limit should be applied.

For applying a concentration limit, 10CFR Part 61 concentration limit(TableⅡ and Ⅲ) are used.

[1] "Factor of 2" concentration limit means that the concentration of each primary gamma-emitting nuclide in each item should be less than 2 times the classification limit for that nuclide.

4.2.3. Encapsulation of discrete items

If discrete items are encapsulated, following constraints should be adapted.

- Containers up to 9.5 m^3 (331 ft^3) may be used if the minimum waste loading [2] is at least 14 percent. But, for waste loadings less than 14 percent, the maximum volume or mass should be 0.2 m^3 or 500kg. And the minimum solid volume or mass used to encapsulate waste should be sufficient to make handling the radioactive waste by an inadvertent intruder prohibitively difficult.

- The constraints on the amount of radioactivity or concentrations of individual encapsulated items are similar to those that apply to mixtures of discrete items.

The description is addressed in Section 4.2.

- The maximum amount of any radioactive waste that should be encapsulated in a single disposal container is that which, when averaged over the waste and the encapsulating media, does not exceed the maximum concentration limits for Class C waste defined in 10CFR 61.55.

- Multiple items may be encapsulated together, so long as the final encapsulated package meets the other criteria described herein.

5. Comparing with Domestic Standards

Differences of technical position regarding LLW management between the US and Korea, which were confirmed through the report review, are as follows.

First, a difference of the waste classification. In Korea, wastes are classified as high-level, intermediate-level, low-level and very low-level radioactive waste if it belongs to the concentration range of a legal classification standard.[4] However, in case of the US, wastes are classified as high-level, low-level radioactive waste and Atomic Energy Act(AEA) section 11e.(2) byproduct material. Also, LLW is classified into four categories, class A, B, C and greater than class C (GTCC) LLW, according to the conditions regulated by US NRC.[1]

Second, a difference of the waste type. In Korea, radioactive waste is divided into major categories such as combustible wastes and non-combustible wastes, and then classified further by the contents of the waste. However, the NRC divides waste into two categories, blendable waste and discrete items, depending on their radiological characteristics. For example, contaminated trash currently being disposed of are classified by the contents (vinyl, plastic, paper, etc.) in Korea, but they are treated as same blendable waste in the US.

Third, the possibility of blending or concentration averaging for multiple waste streams. The NRC states that if multiple waste streams are combined in a same container while meeting the averaging or blending constraints presented in this report, the radionuclide concentrations can be averaged and if needed, waste can be blended without a separate classification. It can be seen that there is a difference from the domestic standard that the same waste type and waste stream should be included in one container and blending or concentration averaging of multiple waste streams is not permitted.

6. Conclusions

In this study, we reviewed a technical position of the NRC report for disposal of LLW. From reviewing the position of NRC, it can be concluded that the regulations on the classification and characterization of wastes in Korea are stronger than those in the US. However, this causes excessive human, cost, time difficulties and radiation exposure of workers in preparing for the current disposal. Therefore, in order to efficiently dispose of LLW, it is necessary to carefully examine the disposal cases and technical positions of developed countries such as the US and compare them with domestic constraints. In particular, additional study will be needed to find ways to improve the efficiency and safety of LLW disposal.

REFERENCES

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[4] Nuclear Safety and Security Commission, Notice No.2014-003, “Regulation on classification and self-disposal of radioactive waste”.
[5] Chang-Lak Kim, David S. Kessel, “U.S. Policy and Current Practices for Blending Low-Level Radioactive Waste for Disposal”, Journal of Nuclear Fuel Cycle and Waste Technology Vol.14, No.3, pp.235-243.

[2] Waste loading means volume of waste divided by the total volume, including encapsulating material.