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Statistical Approach for Derivation of Quantitative Acceptance Criteria for Radioactive Wastes in Near-Surface Disposal Facility

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ABSTRACT

Statistical analysis by using the Latin Hypercube Sampling(LHS) is conducted to derive the radionuclide concentration limit for low- and intermediate-level radioactive waste disposal facility. In this statistical analysis, Post Drilling and Post Construction scenario are mutually competing scenarios to determine radionuclide concentration in comparing with the previous study of deterministic approach, where Post Construction scenario appeared as a most limiting candidate scenario. As an alternative performance assessment, a new assumption considering the depth of disposal facility is introduced. This assumption resulted in that concentration limit of Nb-94, Tc-99 and I-129 are increased about 4~4.5 orders of magnitude in both Construction and Post Construction scenario. In this case, Post Construction scenario is no longer the limiting scenario to derive the concentration limit of disposal facility. Post Drilling scenario as a limiting case, in this study, shows that most gamma-emitting radionuclides such as H-3, C-14, Co-60, Nb-94 and Cs-137 show elevated values of limit concentration. And non-gamma emitting radionuclides such as Sr-90, Tc-99 I-129, Ni nuclides (gamma-emitting), and alpha-emitting radionuclides show lower values than the case of previous deterministic study.

1. Introduction

Radioactive wastes need to be safely managed in a regulated manner, compatible with internationally agreed principles and standards. The disposal method chosen for the low- and intermediate-level waste (LILW) should be commensurate with the hazard and longevity of the waste. Near surface disposal is an option used by many countries for the disposal of radioactive waste containing short-lived radionuclides and low concentrations of long-lived radionuclides. The term ‘near surface disposal’ encompasses a wide range of options, including disposal in engineered structure at ground level, disposal in simple trenches a few meters deep, disposal in engineered concrete vaults, and disposal in rock caverns several tens of meters below the surface.

In 1995, the International Atomic Energy Agency (IAEA) published the Principles of Radioactive Waste Management(1). This document states that the objective of radioactive waste management is ‘*to deal with radioactive waste in a manner that protects human health and the environment how and in the future without imposing undue burdens on future generations*’. Thus the application of the near surface disposal option requires the implementation of measure that will provide protection of human health and the environment since improperly managed radioactive waste would result in adverse effects to human health and the environment now and in the future.

Based on the Latin Hypercube Sampling (LHS), in this study, statistical approach is introduced and conducted an extension of our previous published work(2,3). Due to the difficulties to deal with the uncertainty of multiple parameters of GENII(4), which is dose assessment code developed by PNL, statistical package program called GENII-LHS is developed by authors. In this study, probabilistic performance assessment is conducted by introducing the continuous distribution of input random parameters into GENII(4).

International approaches to derive quantitative acceptance criteria are summarized in section 2 and in section 3 previous works of authors(2,3) is reported briefly. From Section 4, statistical approaches with GENII-LHS and results will be discussed finally.

2. Approaches To Derive Quantitative Acceptance Criteria

A number of approaches could be used to derive quantitative acceptance criteria for disposal of radioactive waste to near surface facilities. It is important that the chosen approach should be (1) relevant, (2) adequate, (3) understandable, and (4) credible(5).

In previous studies(6,7), which have been undertaken to derive the limit values of radionuclide concentrations, the safety assessment approach has been found to be most useful. The Safety Guide on Safety Assessment for Near Surface Disposal(8) notes that the '*result of safety assessment are an important means for determining inventory and/or concentration limit for specific radionuclides in the waste and provide one way for developing waste acceptance requirements for the near surface repository*'. The safety assessment approach has been developed and applied in a several ways for the assessment of near surface facilities(2,3,9-11).

Recently, IAEA Co-ordinated Research Program(CRP) on Improvement of Safety Assessment Methodologies for Near Surface Disposal Facilities (ISAM)(10,11) is providing a critical evaluation of the safety assessment approach. And the key component of the safety assessment approach were also identified and synthesized.

Synthetic procedure is developed in consistent with international recommendations on the structure and content of performance assessments by authors(2,3). In the study of authors(3), main four steps consisted of (1) assessment context, (2) scenario selection, (3) model formulation and (4) assessment and determination are set up and considerations within each step are identified from six reference human intrusion scenarios for a conceptually designed concrete vault type disposal facility.

3. Near-Surface Facility and Human Intrusion Scenario

3.1 Near-Surface Disposal Facility

For the assessment of human intrusion scenarios, a hypothetical near-surface disposal facility has been conceptualized based on the conceptual design study of the near-surface disposal facility for LILW in Korea(12). The disposal facility is composed of heavily engineered vaults that are conservatively represented by homogenizing the content. This facility can accommodate the different types of vaults and locate into the ground, the approximate dimensions of the disposal facility are 250m by 250m. The depth of vault is assumed to be 8m. The final disposal cover will be constructed after the disposal vaults in a disposal area of 400,000 drums capacity are completely filled.

3.2 Human Intrusion Scenario

Reference intruder scenarios were identified based on the review of well-established ones considered in other countries and/or organizations such as US NRC(13), US DOE(14), OECD/NEA(7), IAEA(5), Japan(15), France and Spain(16) for near-surface disposal. Six kinds of scenarios as potential intruder events, called in this paper as (1) Drilling, (2) Post Drilling, (3) Road Construction, (4) Post Construction, (5) Housing & Gardening, and finally (6) Farming scenarios, were selected as applicable for the vault type facility.

'Drilling scenario' is that the intruder drills a well at the top of the facility. In this scenario, it is assumed that drilling is to penetrate the waste vault and any engineered barriers. 'Road Construction' scenario assumes that the intruder constructs a road directly over a waste disposal site. Waste packages and engineered barriers are assumed to be completely degraded and mixed together during the construction work time. 'Post Drilling' and 'Post Construction' scenarios are the extension of 'Drilling' and 'Road Construction' scenario, though house construction scenario is ruled out in the main scenario categories due to small scale of construction comparing with 'Road Construction' scenario. 'Housing & Gardening' scenario is considered as equivalent as residential scenario. 'Farming' scenario is similar to 'Housing & Gardening' scenario except that the former has longer intruder occupancy time and larger contaminated area than the latter.

The radiological impact on the intruder directly depends on the institutional control period. In the base case assessment work(3), human intrusion into the disposal facility is assumed to occur at time after loss of institutional control of 300 years, in other words just after the end of passive institutional control period. Also, we applied 0.1 rem/yr as a performance objective in the base case. The exposure pathway parameters of each scenario have been defined based on extensive literature review (5,7,13,14) as summarized in Table 1, in which the up-to-date ingestion input parameters are used with the consideration of consumption habit for Korean(17).

Table 1 Characteristic parameters of Selected Human Intrusion Scenario(2,3)

<table>
<tr><th colspan="5" rowspan="2">Parameter</th><th colspan="6">Scenario / parameter value</th></tr>
<tr><th>Drilling</th><th>Road construction</th><th>Post Drilling</th><th>Post Construction</th><th>Housing & gardening</th><th>Farming</th></tr>
<tr><td rowspan="6">Near-field parameter</td><td colspan="4">Inventory disposed years prior to beginning of intake period (yr)</td><td>300</td><td>300</td><td>300</td><td>300</td><td>300</td><td>300</td></tr>
<tr><td colspan="4">LOIC occurred n years prior to beginning of intake period</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="4">Fraction of roots in upper soil (top15cm)</td><td>0.00</td><td>0.00</td><td>1.00</td><td>1.00</td><td>0.99</td><td>0.99</td></tr>
<tr><td colspan="4">Fraction of roots in deep soil</td><td>0.00</td><td>0.00</td><td>0.00</td><td>0.00</td><td>0.01</td><td>0.01</td></tr>
<tr><td colspan="4">Manual redistribution (m3/m2)</td><td>5.7E-3</td><td>9.0E-2</td><td>2.3E-4</td><td>3.0E-2</td><td>0.0E+0</td><td>0.0E+0</td></tr>
<tr><td colspan="4">Source area for external dose modification factor (m2)</td><td>100</td><td>1250</td><td>1250</td><td>1250</td><td>1250</td><td>1250</td></tr>
<tr><td rowspan="3">Waste form</td><td colspan="4">Waste form/package half life</td><td>0.0E+00</td><td>0.0E+00</td><td>0.0E+00</td><td>0.0E+00</td><td>0.0E+00</td><td>0.0E+00</td></tr>
<tr><td colspan="4">Thickness of buried waste (m)</td><td>8.00</td><td>8.00</td><td>8.00</td><td>8.00</td><td>8.00</td><td>8.00</td></tr>
<tr><td colspan="4">Depth of soil overburden (m)</td><td>4.50</td><td>4.50</td><td>4.50</td><td>4.50</td><td>4.50</td><td>4.50</td></tr>
<tr><td>External exposure</td><td colspan="4">Hours of exposure to ground contamination</td><td>4.0E+01</td><td>9.0E+01</td><td>3.2E+03</td><td>3.2E+03</td><td>3.2E+03</td><td>5.8E+04</td></tr>
<tr><td rowspan="3">Inhalation</td><td colspan="4">Hours of inhalation exposure per year</td><td>1.0E+00</td><td>9.0E+01</td><td>4.4E+03</td><td>4.4E+03</td><td>4.4E+03</td><td>6.6E+03</td></tr>
<tr><td colspan="4">Resuspension model
1-mass loading, 2- anapauugh</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td colspan="4">Mass-loading factor (g/m3)</td><td>1.00E-04</td><td>1.00E-03</td><td>1.00E-04</td><td>1.00E-04</td><td>1.00E-04</td><td>1.00E-04</td></tr>
<tr><td rowspan="5">Plants ingestion</td><td>Food type</td><td>Grow time (d)</td><td>Yield (kg/m2)</td><td>Holdup (d)</td><td colspan="6">Consumption rate (kg/yr)</td></tr>
<tr><td>Leaf. Veg.</td><td>60</td><td>4.52</td><td>1</td><td rowspan="4">NA</td><td rowspan="4">NA</td><td>31.7</td><td>31.7</td><td>31.7</td><td>31.7</td></tr>
<tr><td>oth. veg.</td><td>90</td><td>4.53</td><td>14</td><td>24.5</td><td>24.5</td><td>24.5</td><td>24.5</td></tr>
<tr><td>Fruits</td><td>155</td><td>1.13</td><td>14</td><td>16.6</td><td>16.6</td><td>16.6</td><td>16.6</td></tr>
<tr><td>Grains</td><td>150</td><td>0.36</td><td>14</td><td>NA</td><td>NA</td><td>NA</td><td>47.1</td></tr>
<tr><td rowspan="5">Animal food ingestion</td><td colspan="2">Food type</td><td colspan="2">Holdup (d)</td><td colspan="6"></td></tr>
<tr><td colspan="2">Meat</td><td colspan="2">7</td><td rowspan="4">NA</td><td rowspan="4">NA</td><td rowspan="4">NA</td><td rowspan="4">NA</td><td rowspan="4">NA</td><td>33.1</td></tr>
<tr><td colspan="2">Poultry</td><td colspan="2">3</td><td>22</td></tr>
<tr><td colspan="2">Milk</td><td colspan="2">1</td><td>63</td></tr>
<tr><td colspan="2">Eggs</td><td colspan="2">3</td><td>8</td></tr>
</table>

In the previous work of authors(3), it is found that ‘Post Construction’ scenario results in the most limiting radionuclide concentration, and the major contributing radionuclides to the resulting dose are Nb-94, Tc-99 and I-129. For the alpha-emitting nuclides, ‘Road Construction’ scenario becomes the contributing scenario as well.

As an effort to dealing with the uncertainty, the effects of significant data and parameters are briefly investigated by calculating the different cases for the same scenarios. In the parametric study, the difference of concentration limits would be small in most cases within an order of magnitude, even through the effect of variations of soil dilution factor and average dust loading is more significant than those of consumption rate and exposure time.

4. Statistical Approach of Performance Assessment

4.1 Latin Hypercube Sampling Theory

In this study, sampling of probabilistically defined parameters is conducted using the Latin Hypercube

Sampling (LHS) approach. The LHS approach is a stratified sampling strategy that permits the central tendency of the output distribution to be established using far fewer realizations than needed when applying simple random sampling of the input distribution such as Monte Carlo simulation.

To illustrate how the specific values of a variable are obtained in a LHS, consider the following example. Suppose it is desired to obtain a LHS sample of size $n = 5$ from a normal distribution with a mean of 5.0 and a variance of 2.618 as indicated in Fig. 1.

The density characteristics of the normal distribution allow for the definition of the equal probability intervals. These intervals are shown in Fig. 1 in terms of a density function. The next step is to randomly select an observation within each of the intervals. This selection is not done uniformly within the intervals shown in Fig. 4, but rather it is done relative to the PDF distribution being sampled (in this case, the normal distribution). This is equivalent to uniform sampling form the quantiles of the distribution (equivalent to sampling the vertical axis of the CDF) and then inverting the CDF to obtaining the actual distribution values that those quantiles represent.

Therefore, to get the specific values, $n = 5$ numbers are randomly selected from the standard uniform distribution (uniformly distributed between 0 and 1). Let these be denoted as U_m, where m = 1,2,3,4,5. These values will be used to select distribution values randomly from within each of the $n = 5$ intervals. To accomplish this, each of the random numbers U_m is scaled to obtain a corresponding cumulative probability, P_m, so that each P_m lies within the mth interval. Thus, for this example with $n = 5$,

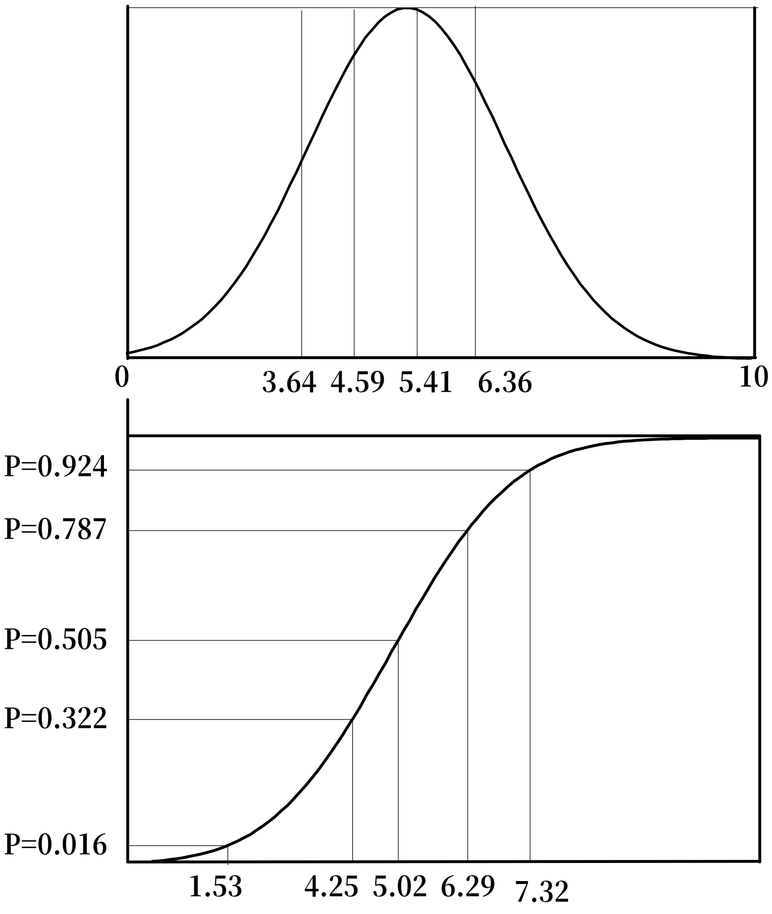

Figure 1 Interval endpoints used with a LHS of size 5 (top) and specific values of *X* selected through the inverse of the distribution function (bottom)

$$P_m = \left(\frac{1}{5}\right) U_m + \left(\frac{m-1}{5}\right) \tag{1}$$

This ensures that exactly on probability, P_m, will fall within each of the five intervals (0, 0.2), (0.2, 0.4), (0.4, 0.6), (0.6, 0.8) and (0.8, 1.0). The values P_m are used with the inverse normal distribution function to produce the specific values to be used in the final LHS. Note that exactly one observation is taken each interval shown in Fig. 1. The entire process is shown in Table 2. Fig. 2 makes it clear that when obtaining a LHS, it is easier to work with CDF for each variable. Fig. 1 shows how one input variable having a normal distribution is sampled with LHS. This procedure is repeated for each input variable, each time working with the corresponding CDF.

Table 2 One possible selection of values for a LHS of size n = 5 from a *N*(5, 2.618).

Interval Number m	Uniform (0,1) Random No. U_m	Scaled Probability With in the Interval $P_m = U_m(0.2 + (m-1)(0.2)$	Corresponding Standard normal Value from the Inverse Distribution	Corresponding ***N***(5, 2.618) Observation within the Intervals
1	0.080	0.016	-2.144	1.529
2	0.610	0.322	-0.462	4.252
3	0.525	0.505	0.013	5.021
4	0.935	0.787	0.796	6.288
5	0.620	0.924	1.433	7.319

A computer program, GENII-LHS, is developed to generate multiple realizations of uncertain variables and to interface with GENII, a dose assessment code which is widely used in the assessment of human intrusion scenarios.

4.2 Manual Redistribution Factors

Transport of radioactive materials from the deep soil or contaminated waste compartment to the surface soils may occur via human distribution of a site. This can be modeled simply using a manual redistribution factor in this study. The manual redistribution factor relates the resultant surface soil concentration, in Ci/m^2, to the initial surface concentration, in Ci/m^3 by definition (18). According to the Table 1, which is used in out previous work(3), manual redistribution is allocated for drilling scenario (including ‘Drilling’ and ‘Post Drilling’ scenarios) and construction scenario (‘Road Construction’ and ‘Post Construction’ scenarios).

Park et al.(3) reported in their work that the ‘Post Construction’ scenario is resulted in the most limiting radionuclide concentration due to the highest values of manual distribution factor such as 0.03 in Table 3.

At this point, we would like to take an alternate assumption for the performance assessment. Both in ‘Road Construction’ and in ‘Post Construction’ scenario, the intruder cannot intrude directly or indirectly the disposal site because that disposal site is located below the depth where the construction program can excavate. Waste package and engineered barriers are assumed to be remained during the construction period of human intruders.

Based on this assumption of construction scenario, ‘Post Construction’ scenario is anticipated that it cannot act as a leading and/or limiting scenario further more to derive the concentration limit of disposal facility among selected six human intrusion scenarios. After all, the manual redistribution factor is allocated only for drilling related scenario such as ‘Drilling’ and ‘Post Drilling’ scenario.

4.3 Random Input Variables

As for four human intrusion scenarios which are related with drilling and construction, random input variables are selected based on the result of our previous work(3) and listed in Table 3. Table 3 also shows the distribution type and accompanying statistical properties, which are selected for this study, such as mean, standard deviation, minimum and maximum.

According to the assumption discussed in section 4.2, in Table 3, manual distribution factors for both scenarios in ‘Construction’ and in ‘Post Construction’ are changed from the value used in our previous work(3) to nearly zero values.

Table 3 Random Input Variables and Distribution Type for Human Intrusion Scenario

Scenario	**Description of Random Variables**	**Type of Distribution**	**Mean**	**Standard Deviation**	**Min.**	**Max.**
Drilling Scenario	Manual Redistribution	Log N	0.0057	0.002	-	-
	Depth of soil overburden, m	Uniform	4.5	-	4.0	5.0
	Exposure time: Plume (hr)	Normal	1.0	0.3	-	-
	Exposure time: Soil Contamination (hr)	Normal	40.0	12.0	-	-
	Mass loading factor (g/m3)	Log N	0.0004	0.0002	-	-
Road Construction Scenario	Manual Redistribution	Log N (Const.)	0.09 (~ 0.0)	0.045	-	-
	Depth of soil overburden, m	Uniform	4.5	-	4.0	5.0
	Exposure time: Plume (hr)	Normal	90.0	30.0	-	-
	Exposure time: Soil Contamination (hr)	Normal	90.0	30.0	-	-
	Mass loading factor (g/m3)	Log N	0.001	0.0005	-	-
Post Drilling Scenario	Manual Redistribution	Log N	0.00023	0.00012	-	-
	Depth of soil overburden, m	Uniform	4.5	-	4.0	5.0
	Exposure time: Plume (hr)	Normal	3200.0	1000.0	-	-
	Exposure time: Soil Contamination (hr)	Normal	3200.0	1000.0	-	-
	Mass loading factor (g/m3)	Log N	0.0001	0.00005	-	-
	Consumption rate: Leaf Vegetable (kg/yr)	Normal	32.0	16.0	-	-
	Consumption rate: Root Vegetable (kg/yr)	Normal	24.5	12.5	-	-
	Consumption rate: Fruit (kg/yr)	Normal	16.6	8.5	-	-
	Consumption rate: Grain (kg/yr)	Normal	0.0	0.0	-	-
Post Construction Scenario	Manual Redistribution	Log N (Const.)	0.03 (~ 0.0)	0.015	-	-
	Depth of soil overburden, m	Uniform	4.5	-	4.0	5.0
	Exposure time: Plume (hr)	Normal	3200.0	1000.0	-	-
	Exposure time: Soil Contamination (hr)	Normal	3200.0	1000.0	-	-
	Mass loading factor (g/m3)	Log N	0.0001	0.00005	-	-
	Consumption rate: Leaf Vegetable (kg/yr)	Normal	31.7	16.0	-	-
	Consumption rate: Root Vegetable (kg/yr)	Normal	24.5	12.5	-	-
	Consumption rate: Fruit (kg/yr)	Normal	16.6	8.5	-	-
	Consumption rate: Grain (kg/yr)	Normal	0.0	0.0	-	-

4.4 Results and Discussions

Fig. 2 shows the result of statistical approach taken in the study with the data used in our previous work(3). In Fig. 2, the distributions of ‘Post Drilling’ scenario show lower concentration limits than those of ‘Drilling scenario’, and the distributions of ‘Post Construction’ scenario also show lower concentration limits that those of ‘Construction’ scenario for all radionuclides. These results are because of higher values of manual redistribution factors of ‘Post Drilling’ and ‘Post Construction’ scenarios than those of ‘Drilling’ and ‘Construction’ scenario. These higher values of manual redistribution factors result in higher values of annual effective dose equivalent(AEDE) on which concentration limits, in turn, inversely depend.

When we consider the appropriate and/or limiting scenario, the lowest value of a radionuclide acts as an important role to derive the concentration limit. Tc-99 and I-129 show the lowest value in distributions of ‘Post

Drilling’ scenario and Nb-94 shows the lowest value in distribution of ‘Post Construction’ scenario. In our previous study of deterministic approach(3), ‘Post Construction’ appeared as a most limiting candidate scenario to derive the radionuclide concentration. In this statistical approach, ‘Post Drilling’ and ‘Post Construction’ scenario are mutually competing for scenario selection depending on which radionuclide is more important in performance assessment processes.

As discussed in section 4.2, alternate assumption is introduced to check out further both the competing human intrusion scenarios of ‘Post Drilling’ scenario and ‘Post Construction’ scenario. Introduction of a new assumption and repeated assessment are the typical strategy of performance assessment to obtain the common assurance for the utmost results. In this sense, it is assumed that human intruder cannot excavate the disposal site during the (road) construction program because that disposal location is situated below the construction area.

Fig. 3 shows the result of concentration limit obtained by considering new assumption. In case Nb-94, Tc-99 and I-129 which are the candidate radionuclides to determine the radionuclide concentration limit, the values are increased about 4~4.5 orders of magnitude in both ‘Construction’ and ‘Post Construction’ scenario. Concentration limit of remaining radionuclides are also increased same magnitude of candidate radionuclides. As expected in section 4.2 ‘Post Construction’ scenario is no longer the limiting scenario to derive the concentration limit of disposal facility.

Therefore, ‘Post Drilling’ scenario can play a role as limiting scenario instead of ‘Post Construction’ scenario. In Table 4, the calculated radionuclide concentration limits of ‘Post Drilling’ scenario are compared to those in the existing foreign regulations and/or near-surface disposal facilities. The result of previous deterministic study is also compared with that of this study.

From the distributions of concentration limit in statistical calculation, lower values for each radionuclide are selected as a limiting concentration in this study (See Table 4). When we compare the concentration limits between previous and this study, most gamma-emitting radionuclides such as H-3, C-14, Co-60, Nb-94 and Cs-135 show elevated values of limit concentration. And non-gamma emitting radionuclides such as Sr-90, Tc-99 I-129, Ni nuclides (gamma-emitting), and alpha-emitting radionuclides show lower values than the case of previous study.

Table 4 Comparison of Radionuclide Concentration Limit of foreign regulations, previous study and this study

Radio-Nuclide	Japan	France	Spain	US(Class C)		Previous Study [3]		This Study		
	Conc. Limit (Bq/t)	Conc. Limit (Bq/t)	Conc. Limit (Bq/t)	Conc. Limit (Bq/t)	Conc. Limit (Ci/㎥)	Conc. Limit (Bq/t)	Conc. Limit (Ci/㎥)	Conc. Limit [Min.] (Bq/t)	Conc. Limit [Mean] (Bq/t)	Conc. Limit [Max.] (Bq/t)
H-3	-	-	9.07E+11	-	-	3.53E+22	1.43E+12	2.24E+23	1.25E+24	2.74E+24
C-14	3.70E+10	2.0E+11	1.81E+11	1.97E+11	8.0E+00	1.17E+13	4.76E+02	1.37E+14	6.13E+14	1.37E+15
Co-60	1.11E+13	5.0E+13	4.54E+13	-	-	6.86E+23	2.78E+13	6.02E+24	1.01E+25	2.90E+25
Ni-59	3.30E+09	-	5.72E+10	-	-	8.51E+10	3.45E+00	7.71E+09	1.61E+10	5.48E+10
Ni-63	1.11E+12	1.2E+13	1.09E+13	1.73E+13	7.0E+02	3.21E+11	1.30E+01	2.24E+10	4.65E+10	1.64E+11
Sr-90	7.40E+10	9.1E+10	8.26E+10	1.73E+14	7.0E+03	1.30E+10	5.26E-01	9.14E+08	1.93E+09	6.67E+09
Nb-94	-	1.2E+08	1.09E+08	-	-	9.50E+06	3.85E-04	1.12E+08	3.58E+08	7.25E+08
Tc-99	-	1.0E+09	9.07E+08	7.43E+10	3.0E+00	5.60E+07	2.27E-03	1.76E+06	3.70E+06	1.30E+07
I-129	-	4.6E+07	4.17E+07	1.97E+09	8.0E-02	5.03E+07	2.04E-03	1.54E+06	3.30E+06	1.12E+07
Cs-137	1.11E+12	3.3E+11	3.00E+11	1.13E+14	4.6E+03	2.47E+10	1.00E+00	1.54E+11	2.61E+11	7.71E+11
Alpha	5.55E+08	-	3.36E+09	-	-	1.30E+08	5.26E-03	1.12E+08	2.19E+08	8.22E+09

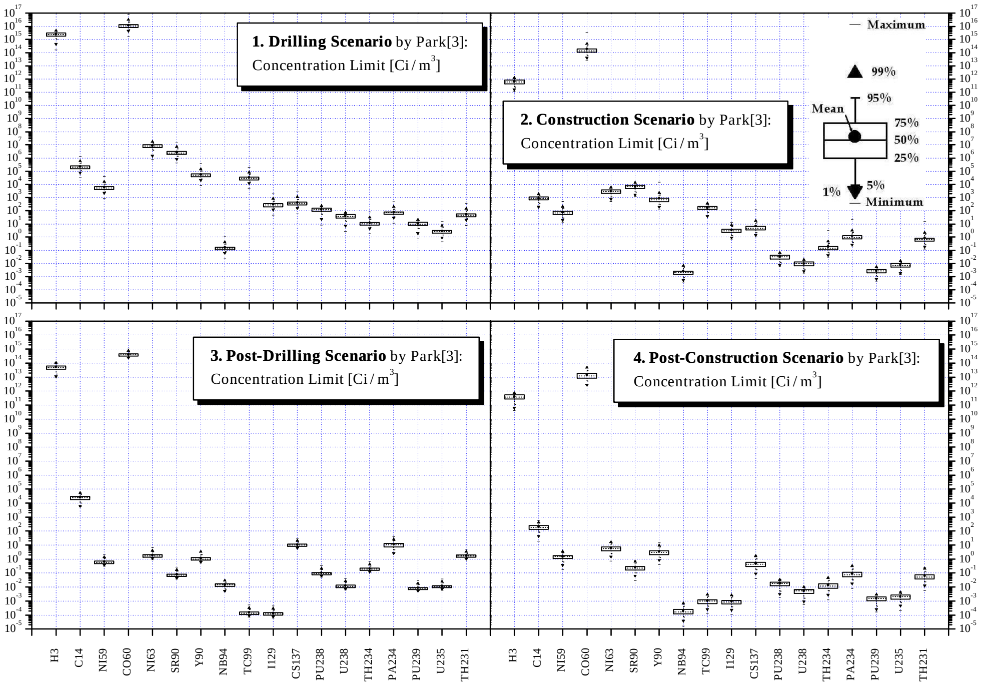

Figure 2 Statistical Results of Concentration Limit with the Data used in Previous Work(3)

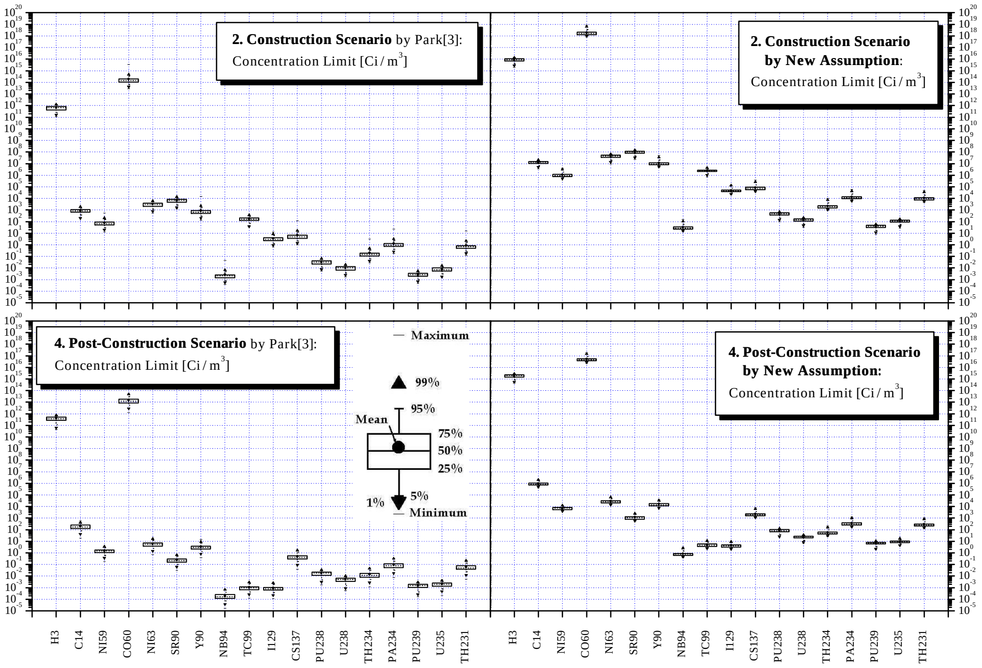

Figure 3 Statistical Results of Concentration Limit with the Data used in our Previous Work(3) and New Assumption for Construction and Post Construction Scenarios

5. Conclusion and Recommendations

Statistical approaches by programming the Latin hyper Cube Sampling theory are conducted to derivate the radionuclide concentration limit for low and intermediate radioactive waste disposal facility.

In our previous study of deterministic approach(3), Post-Construction appeared as a most limiting candidate scenario to derive the radionuclide concentration. In this statistical approach, Post-Drilling and Post-Construction scenario are mutually competing for scenario selection according to which radionuclide is more important in performance assessment processes.

As a standard strategy of performance assessment, a new assumption of disposal facility is introduced. This assumption resulted in that, in case Nb-94, Tc-99 and I-129 which are the candidate radionuclides to determine the radionuclide concentration limit, these values are increased about 4~4.5 orders of magnitude in both Construction and Post Construction scenario. Concentration limit of other radionuclides are also increased same magnitude of candidate radionuclides. Therefore, Post Construction scenario is no longer the limiting scenario to derive the concentration limit of disposal facility.

Post Drilling scenario as a limiting case, in this study, shows that most gamma-emitting radionuclides such as H-3, C-14, Co-60, Nb-94 and Cs-135 show elevated values of limit concentration. And non-gamma emitting radionuclides such as Sr-90, Tc-99 I-129, Ni nuclides (gamma-emitting), and alpha-emitting radionuclides show lower values than the case of previous deterministic study.

In the viewpoint of utility for radioactive disposal management, the elevated values of gamma-emitting radionuclides is favorable because that the gamma-emitting radionuclides from the operation of nuclear power plant (NPP) have occupied most portion of radioactive waste. By contrary, in the viewpoint of regulation body, concentration limit is strictly imposed for non-gamma radionuclides from the beginning of radioactive waste classification process.

Results of this study are one possible case by introducing new assumption of performance assessment and further calculation and detailed consideration of concentration limit should be continued. Specially, food consumption rate of Korea should be considered and repeated calculation will be implemented. All of this information of performance assessments should be considered simultaneously with additional future issues such as ethical limitation, political restriction of current situation, etc.

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