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Study on Institutional Control Period for Near Surface Disposal Facilities Considering Inadvertent Intruder Scenarios

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Abstract

As for safety assessment of a radioactive waste disposal facility, radiation dose to inadvertent intruders is evaluated according to scenarios related to intruder's postulated activities at the disposal site after the end of Institutional Control Period(ICP). Simple trench and Below Ground Vault(BGV) are considered for this study as alternative disposal systems, and different scenarios are applied to each disposal type. The results show that 300 years of ICP is needed for simple trench and 100 years for BGV. Even for BGV, concentration of long-lived radioactive nuclides should be limited considering degradation of BGV after 300 years.

1. Introduction

Currently, two distinctively different ICPs are adopted by most countries with operational near-surface disposal facilities[1]. Namely, 100 years of ICP is applied in USA and Canada. To the contrary, Japan and many EU countries such as France and Spain are using 300 years of ICP. The purpose of this paper is to show a generic methodology for determination of a minimum duration of ICP required from the viewpoint of safety assessment for near-surface disposal facility of LILW.

For the purpose of this study, it is assumed that the effective dose equivalent to an inadvertent intruder after loss of institutional control should be limited to 100 mrem per year for chronic radiation exposure for disposal facility[1,2,3]. This dose limit for a disposal site is used to determine maximum concentrations of radionuclides that would be acceptable for disposal. This paper presents a study on ICP for both simple trench and BGV based on intruder exposure scenarios developed by DOE. The GENII computer code[4] which has been widely used for human intrusion scenario assessment[1] is used to calculate the equivalent dose rates to intruder considering many pathways and scenarios that cause radiation exposure to human. Some food data of present Korean are used to consider internal exposure to the intruder.

2. Scenario Descriptions

Exposure assessment always requires the invocation of scenarios for potential human exposure[2,5]. For this study, eight basic intruder scenarios are postulated which are believed to reasonably describe potential intruder events. Figure 1 describes the intruder scenarios. Each intruder scenario involves a number of exposure pathways and assumptions. In the drilling and post-drilling scenarios either for water wells or for mineral exploration, a little volume of waste is brought to the surface and discarded. It results in external exposure from the drilling activity and the soil mixed with excavated waste and causes internal exposure from dust of contaminated soil. The scenarios for excavation and post-excavation are similar to the drilling and post-drilling scenarios. The exposure pathways for excavation and post excavation scenario are also same as for drilling and post drilling scenario but total amount of waste postulated to be brought to surface is much larger than that of drilling scenario. According to four residential agricultural scenarios, intruders are assumed to build homes and grow food crops and cattle over the disposal site. Exposure pathway in agricultural scenarios is mainly ingestion of cultivated foods in the disposal site.

To become credible, scenarios by which a person is postulated to be exposed to contaminants from waste must reflect a range of waste disposal configurations such as depth and types. In this study simple trench or BGV are divided by absence or presence of a intruder resistance system. In this sense, only two scenarios, drilling and post-drilling, are assumed to occur regardless of depth of covering soil and type of disposal, while excluding the other scenarios in case of BGV.

3. Calculation Model

The calculation model for this study is illustrated in Figure 2. A 5 m thick layer of soil is placed over 5 m deep trench at the disposal zone of 300 m by 300 m. One important assumption on the calculation model is that there will be intruder resistance system such as a thick concrete slab for BGV which will isolate the disposed waste from human intrusion. In this study, drilling and post-drilling scenarios are considered for BGV calculation immediately after repository closure for the reason already mentioned in Section 2, which is illustrated in Table 1. GENII computer code is used, and some ingestion parameters are revised to consider food ingestion habit for Korean.

The inventories of 14 radionuclides for simple trench and BGV are conservatively selected from the radionuclide inventory used for rock-cavern disposal facility[6] to show the effect of long-lived radionuclide. Table 2 shows inventory, concentration and half-life of radionuclide in a generic near-surface disposal facility

4. Results and Discussion

The dose rate for trench as a function of ICP is described in Figure 3. For trench disposal, the dose rate does not become less than dose limit of 100 mrem/yr for disposal site even after 300 years of ICP. Since the ICP longer than 300 years is not recommendable for a disposal site, trench disposal is inadequate for the conservatively assumed inventory of radionuclides from the viewpoint of ICP. For BGV, the dose rate as a function of ICP is illustrated in Figure 4. The exposure dose rate during 300 years of ICP is far below the dose limit for disposal site. Intruder resistant system in BGV is required to last at least 300 years for class B & C type waste in 10CFR61. If we assume pessimistically that BGV fails after 300 years, dose rate becomes higher than the dose limit after 300 years. Therefore, the exposure dose rate exceeding the dose limit after 300 years should be cut down by controlling the concentration of long-lived radioactive nuclides. The dose rates from BGV for 300 years after repository closure are illustrated in Figures 5 and 6 for each scenario and radionuclide. In Figure 5, the excavation and post-excavation cases are dominant scenarios for external exposure, while garden A for internal exposure. Figure 6 shows that long-lived radionuclides such as Nb^{94},

Tc^{99} and Cs^{137} should be restricted by half of the inventory listed in Table 2 to meet the dose limit for disposal site.

5. Conclusion

With a view to show a generic methodology to determine the ICP, the estimation of exposure dose resulting from human intrusion is carried out according to reasonable scenarios. From the results, BGV that isolates disposed waste from most of human activities is an appropriate disposal system from the viewpoint of ICP. Even for BGV, the concentrations of long-lived radionuclides should be controlled well enough to consider degradation of BGV after 300 years. The derived limits on radionuclide concentrations from human-intrusion scenarios are intended to serve as a basis of design condition of disposal facility that also takes into account site-specific waste classification system. This study provides useful information in comparing the importance of the scenarios and radionuclides. In most cases, the human intrusion scenarios are assessed deterministically. Therefore, uncertainty and sensitivity analyses on parameters will be carried out to thoroughly evaluate the potential impact on performance assessment results.

References

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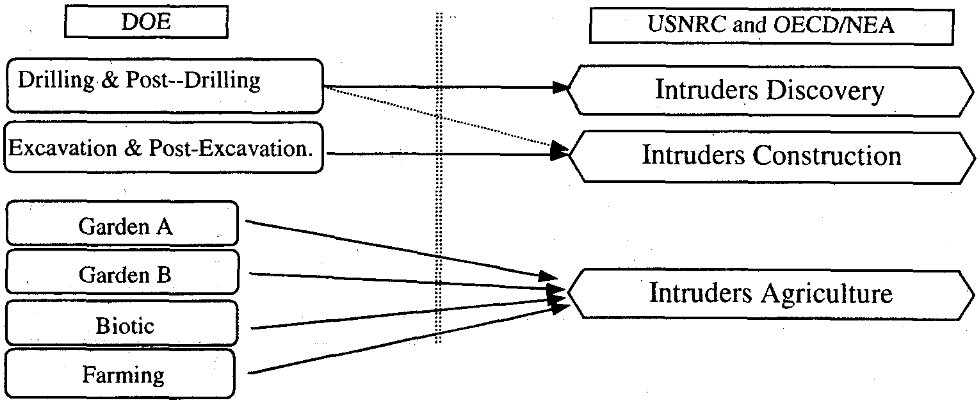
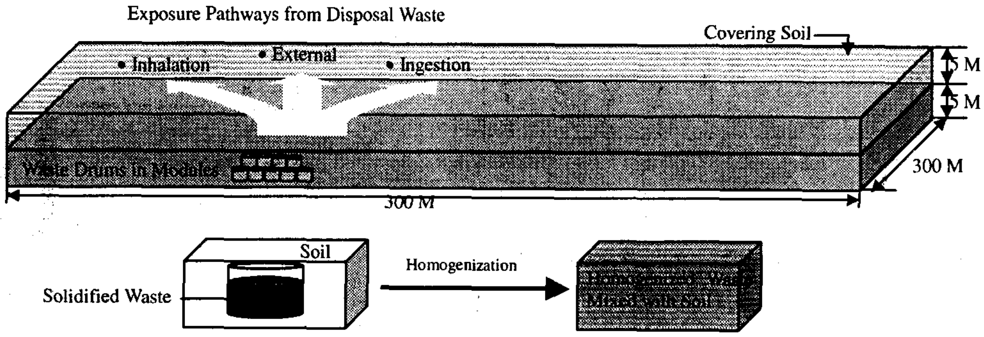


Figure 1. Intruder Scenarios on Disposal Site after Institutional Control Period



(a) Actual Solidified Waste in Drum Model (b) Homogenized Calculation Model

Figure 2. Comparison of Actual and Homogenized Models for GENII Calculation

Types / Institutional Control Period / Scenarios	Simple Trench (No Intruder Resistance Cover)			Below Ground Vault (With Intruder resistance Cover)		
	100	200	300	100	200	300
Drilling	O	O	O	O	O	O
Post-Drilling	O	O	O	O	O	O
Excavation	O	O	O		X	O
Post-Excav.	O	O	O	X	X	O
Garden A	O	O	O	X	X	O
Garden B	O	O	O	X	X	O
Biotic	O	O	O	X	X	O
Farming	O	O	O	X	X	O

O : Considering
X : No Considering

Table 1. Intruder Scenarios for Disposal Site causing Exposure Dose to Human

Radio Nuclides	Ci/m³ (waste form)	Ci/m³ (Disposal Facility)	$T_{1/2}$ (year)
H^3	5.82E-03	9.32E-04	1.24E+01
C^{14}	5.55E-03	8.89E-04	5.73E+03
Co^{60}	8.32E-01	1.33E-01	5.27E+00
Ni^{59}	1.38E-02	2.21E-03	7.50E+04
Ni^{63}	4.22E-01	6.75E-02	9.60E+01
Sr^{90}	1.07E-02	1.72E-03	2.91E+01
NB^{94}	3.32E-04	5.32E-05	2.03E+04
Tc^{99}	4.51E-04	7.22E-05	2.13E+05
I^{129}	2.61E-05	4.17E-06	1.57E+07
Cs^{137}	4.61E-01	7.37E-02	3.00E+01
U^{235}	7.50E-08	1.20E-09	7.04E+08
U^{238}	2.64E-07	4.23E-08	4.47E+09
Pu^{238}	1.08E-04	1.72E-05	8.77E+01
Pu^{239}	2.22E-04	3.55E-05	2.41E+04

Table 2. Total Inventories of Radioactive Nuclides for GENII Calculation

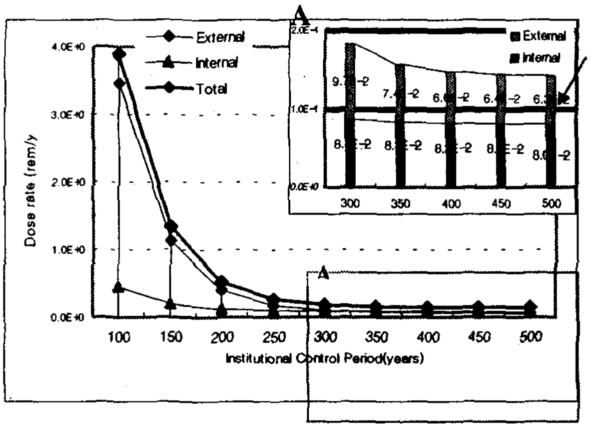


Figure 3. The dose rate to intruder as a function of ICP for Simple Trench

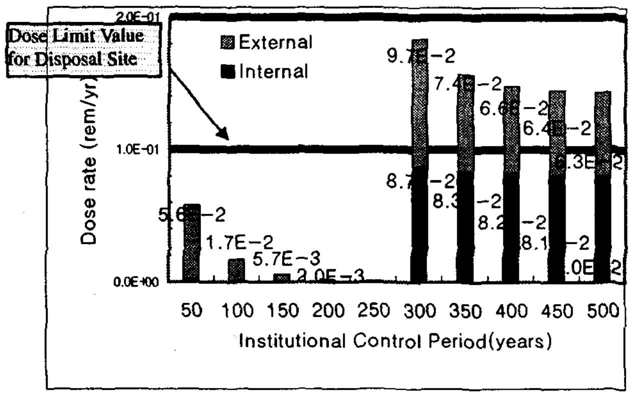


Figure 4. The dose rate to intruder as a function of ICP for BGV

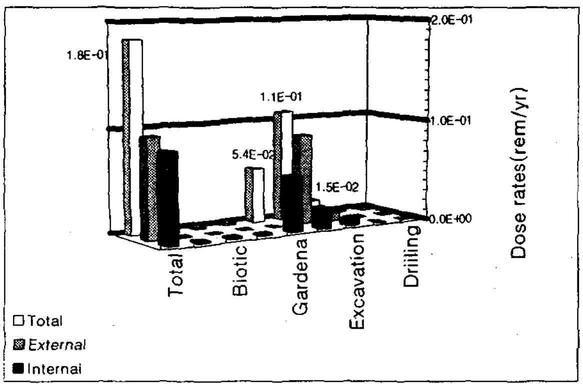


Figure 5. The dose rate according to intruder scenarios at 300 year

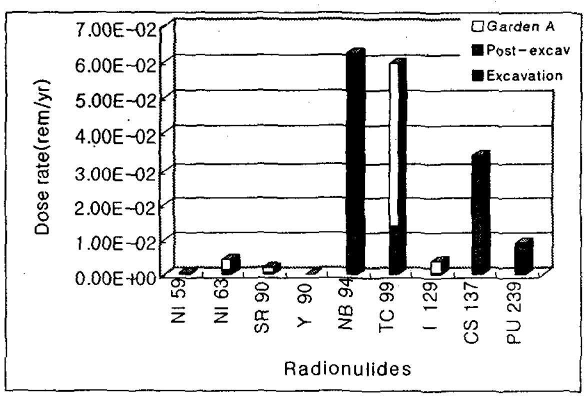


Figure 6. The dose rate according to radionuclides at 300 year