Safety Assessment for the Landfill Disposal of Solidified Cement Wastes

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1. Introduction

The decommissioning of a nuclear power plant is becoming an important issue after the Kori 1 unit was decided to shutdown permanently in 2017 in Korea [1]. For the safe management of decommissioning wastes the radiological safety has to be secured. In this study, we made the safety assessment for the landfill disposal of concrete powder wastes solidified by the magnesium potassium phosphate cements (MKPC) [2]. We used the RESRAD-ONSITE code for the estimation of exposure doses resulting from the landfill disposal of these wastes [3]. In addition, we made sensitivity analyses for the input parameters of cover material to obtain useful insights for the detail design of a landfill site.

2. Methods and Results

2.1 Solidified Concrete Waste

The concrete powder wastes generated from the decommissioning of a nuclear power plant were solidified by MKPCs to immobilize wastes. Co and Cs ions are added as contaminants into a mixture of simulated concrete powder wastes and MKPCs. The size of a solidified waste specimen are as follows: 1.3 cm in diameter, 2.6 cm in height, 2.532 g/cm^3 in density. The composition of 50 wt% of simulated concrete powder waste (SCPW) specimen is summarized in Table 1.

Table 1. Composition of solidified waste specimen [2]

Component	Percentage (wt.%)
SCPW	50
MgO	10.07
KH_2PO_4	22.66
H_2O	14.68
H_3BO_3	0.5
$CsNO_3$	0.58
$Co(NO_3)_2 \cdot 6H_2O$	0.87
$Sr(NO_3)_2$	0.63
Total	100

2.2RESRAD-ONSITE Code

The estimation of exposure doses was made by RESRAD-ONSITE Ver. 7.2 code which is a computer model designed to estimate radiation doses and risks from residual radioactive materials. It has been used widely by many government agencies and institutions in several countries including Korea as well as the USA. The exposure pathways for the critical population group in the RESRAD-ONSITE code are a direct exposure to external radiation from contaminated soil material, internal doses from the inhalation of airborne radionuclides and the ingestion of plant foods, meat and milk, drinking water, fish, and contaminated soil as shown in Figure 1.

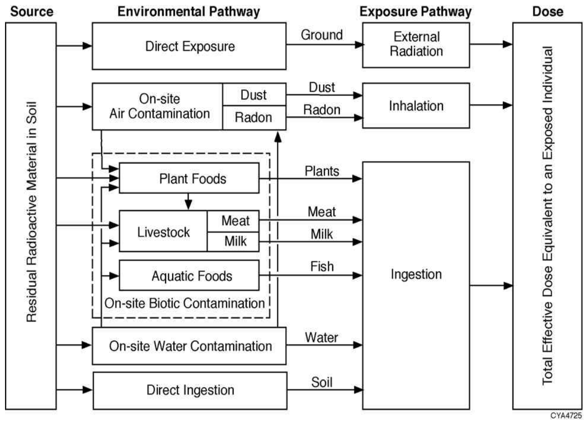

Fig. 1. Exposure pathways considered in RESRAD code.

2.3 Input data

Most input data are derived from the references and the data for the primary contamination zone and the cover are summarized in Table 2. We assumed that the radioactivity of Co and Cs in the solidified waste specimen as one tenth of the upper threshold radioactivity values of them that can be classified as very low-level radioactive wastes. In addition, we assumed that the radionuclides of Co and Cs are ^{60}Co and ^{137}Cs, respectively. Therefore, we use 1.0 Bq/g for the radioactivity concentration of both ^{60}Co and ^{137}Cs.

Table 2. Input data for the primary contamination zone and the cover

Parameter	Unit	Value
Area of contaminated zone	m^2	14,250
Thickness of contaminated zone	m	16
Length parallel to aquifer flow	m	600
Depth of cover	m	0.5
Density of cover material	g/cm^3	1.6
Erosion of contaminated zone	m/yr	0.001
Total porosity of contaminated zone	-	0.15
Field capacity of contaminated	-	0.2

zone		
Hydraulic conductivity of contaminated zone	m/yr	100
Evapotranspiration coefficient	-	0.68
Wind speed	m/sec	2.1
Precipitation	m/yr	1.7
Runoff coefficient	-	0.2
Watershed area for nearby stream or pond	m^2	1,000,000
Humidity in air	g/cm^3	8.0

2.4 Estimation of Exposure Doses

The exposure doses resulting from the landfill disposal of concrete powder wastes solidified by the MKPCs are shown in Fig. 2. As shown in this figure, even at the time of disposal, the total exposure doses do not exceed 0.1 mSv/yr which is the safety goal for the regulation of the low- and intermediate-level radioactive waste repository. Exposure doses decrease with time and they become negligible at the time of 300 years that is the institutional period of a radioactive waste repository in Korea.

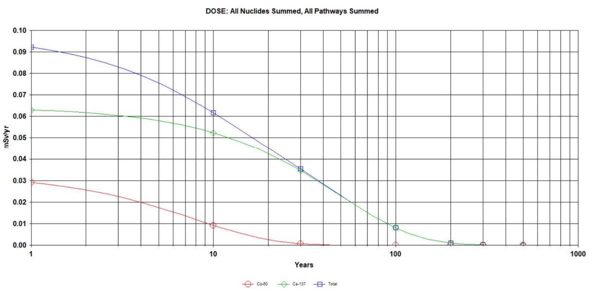

Fig. 2. Exposure doses as a function of time.

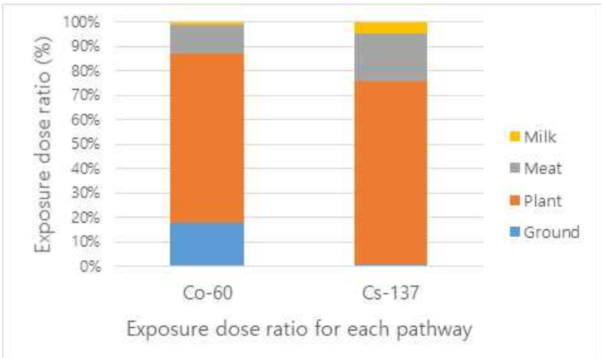

Fig. 3. Exposure doses as a function of time.

The contribution of each exposure pathway to the total exposure doses at 30 years are shown Fig. 3. The most important pathway is the ingestion of plants for both ^{60}Co and ^{137}Cs because plants above the contaminated areas may be affected by them directly. The second important pathways are the external exposure from the ground for ^{60}Co and the ingestion of meat for ^{137}Cs, respectively.

2.5 Sensitivity Analyses

We made sensitivity analyses for the input parameters of cover because the cover of a landfill site plays very important roles such as securing the mechanical stability of a landfill site, reducing the internal exposure doses by restricting the release of radionuclides to the atmosphere, and restricting the inflow of precipitation into the disposal area. According to the sensitivity analysis results for the cover depth, the total exposure doses and exposure doses for each pathway decreases as the cover depth increases. Especially, the exposure dose for the ingestion of soil occurs only for the case of cover depth of 0.1 m, which means that there are no exposure doses from the ingestion of soil if the cover depth is greater than 0.1 m. As the cover depth decreases, the important exposure pathway is the external exposure from the ground because the radionuclide may release to the ground surface due to a small cover depth.

And the total exposure doses increase as the erosion rate of cover material increases because the radionuclides may release to the ground surface due to the fast erosion of cover material. The exposure dose from the ingestion of soil occur only for the case of erosion rate of 0.1 m/yr due to the fast release of radionuclide to the ground surface. And there are no exposure doses from the ingestion of soil for erosion rate value of smaller than 0.1 m/yr.

As the density of cover material changed, only the external exposure dose from the ground surface changed. As the density of cover material increases the external exposure dose from the ground surface decreases. Therefore, the increase of the density of cover material may restrict the release of radionuclide to the ground surface, however, it may not affect the transport of radionuclides to foodstuffs.

3. Conclusions

To check the disposal feasibility of a solidified concrete powder wastes with MKPCs in terms of radiological safety, we estimated exposure doses resulting from the disposal of them into a landfill site with RESRAD code. We found out that total exposure doses are below 0.1 mSv/yr that is the safety goal for the low- and intermediate-level radioactive waste repository. In addition, they satisfied the waste acceptance criteria such as compressive strength and leachability index. Therefore, the solidified concrete powder wastes with MKPCs containing ^{60}Co and ^{137}Cs can be disposed of into a landfill site safely. In addition, we made sensitivity analyses for the input parameters of cover material because the cover of a landfill site is a very important component to secure the mechanical stability and to restrict the release of radionuclides to the environment. The results of sensitivity analyses can be used as useful insights on the detail design of a landfill site for the disposal of very low-level decommissioning wastes.

REFERENCES

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[3] S. Kamboj, E. Gnanapragasam, and C. Yu, “User’s guide for RESRAD-ONSITE Code, Version 7.2”, ANL/EVS/TM-18/1, 2018.