Proceedings of the Korean Nuclear Society Autumn Meeting

Seoul, Korea, October 1998

Calculation of Accumulated Energy Ratio in Paraffin Waste Form of Radioactive Liquid Concentrate Considering Various Packing Configuration

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Abstract

Monte Carlo simulations are performed to calculate accumulated energy ratio on various configurations of paraffin waste form, which is required to accurately estimate gas generation in radioactive waste as well as material embrittlement by radiolytic decomposition during disposal or storage. Through the simulation, two factors which mainly affect the accumulated dose are identified: one is a geometric factor according to disposal configuration and the other is a material factor from backfilling conditions. To quantitatively express the effect of these factors, accumulated energy ratio in a single drum to that of various configuration of paraffin waste form is calculated. The geometric factor varies in the range from 0.8 to 1.3, On the other hand, material factor dose not much varied ranging from 1.05 to 1.2.

1. Introduction

Currently, paraffin is used in most of Korean nuclear power plants as a binding material for liquid radioactive concentrate waste instead of cement. As a part of disposal safety assessment effort, gas generation by radiation has studied. However, most of the methods available were developed for application to TRU waste or HLW. A representive of these models is developed by USDOE for TRU waste which calculated an accumulated energy ratio in a single drum using a conventional point kernel method as a function of photon energy strength.[1]

In our study for radiolytic gas generation from paraffin waste form, accumulated energy in paraffin waste form should be calculated especially considering disposal configuration. In this paper, differences in accumulated energy are compared between a single drum and a group of drums in various disposal configuration which interact and interfere radiation each other. The DOE model could not calculate the difference quantitatively. For this reason, a new method considering actual disposal configuration is developed to exactly postulate the amount of gas generation by radiolysis in a disposal facility. Accumulated energy ratio in paraffin waste form stacked in the disposal facility is calculated by Monte Carlo simulation. It is compared with the calculation results obtained from a single drum model to find out the geometric factor from disposal configurations. Monte Carlo simulations are carried out also to estimate accumulated energy ratio according to backfilling conditions.

2. Calculation Models for Paraffin Waste Form

The amount of energy accumulated by irradiated materials depends on the type of radiation and the absorption coefficient of the material. For this reason, it can be assumed that most of the energy from alpha and beta radiation is deposited in the paraffin waste form along with very low energy gamma ray. The degree of interaction is described by gamma ray mass absorption coefficient which is a function of material density. Instead of theoretical density of the waste form(1.33g/cm3), actual density(1.245g/cm3) is used for the calculation considering actual mixing process. In the waste form, the other important factor in assessing the amount of gamma energy that is deposited in the mixed waste is geometric configuration which can be applied to actual disposal configurations (main object of this study is to find out these factors according to various geometric configurations). In many configurations of stacked drums, radiation energy escaping from drums affects each other. On the other hand, the drums can be self-shielding sources for each other. For these reasons, the accumulated energy in drum may be increased by significance. Sole drum and stacked configuration models are illustrated in Figure 1.

Especially, the drums in center region of the calculation model (c) of Figure 1 can be assumed as sole drum case in infinite array, which means that maximum accumulated energy ratio is expected in this configuration. The average energy spectrum of gamma ray source in paraffin waste form is described in Table 1 based on non-destructive assay data of three waste drums in Kori nuclear power plant. As a Monte Carlo simulation tool, MCNP4B[2] is used in these calculations.

3. Calculation Results

Comparison of results between from DOE model and from MCNP4B calculation for sole drum case as a function of source energy is illustrated in Figure 2. As shown in Figure 2, accumulated energy ratio of DOE model is much higher than that of MCNP4B calculation in very low energy region because DOE model can not consider mass attenuation behavior of photon below 0.04 MeV. Since average energy of gamma ray from paraffin waste form is usually higher than 0.8 MeV, DOE model postulates the accumulated energy ratio in sole drum conservatively.

Comparison of average accumulated energy ratio between DOE model for sole drum and MCNP4B for 4 x 2 x 1 configuration is illustrated in Figure 3 and Figure 4 according to backfilling condition. The trend in Figure 3 is similar to in Figure 2, but difference in accumulated energy ratio becomes larger. The difference in accumulated energy ratio in concrete backfill condition is less than in air condition.

Figure 5 and Figure 6 show comparison of accumulated energy ratio between DOE model for sole drum and MCNP4B for 4 x 4 x 3 configuration according to backfilling condition. In Figure 5, the accumulated energy ratio varied in the range from 0.8 to 1.3, which means more gas generation can be expected from stacked configurations than from sole drum for the same radioactivity. Figure 7 shows comparison of accumulated energy ratio for various configuration models on 0.835 MeV photon that is average energy of photon of three paraffin waste drums from the non-destructive assay data.

4. Conclusion

The calculated geometric factor for 4 x 4 x 3 rectangular disposal configuration is as large as 1.3 at the high energy region for no backfill condition and is 1.2 for concrete backfill. Based on the above calculation and results, it can be concluded that effect from geometric factors considering packing configurations of waste drums should be considered to realistically evaluate the gas generation or material embrittlement by radiation degradation. From the calculation of backfilling condition, concrete backfilling has an advantage from an aspect of accumulated energy in waste drum.

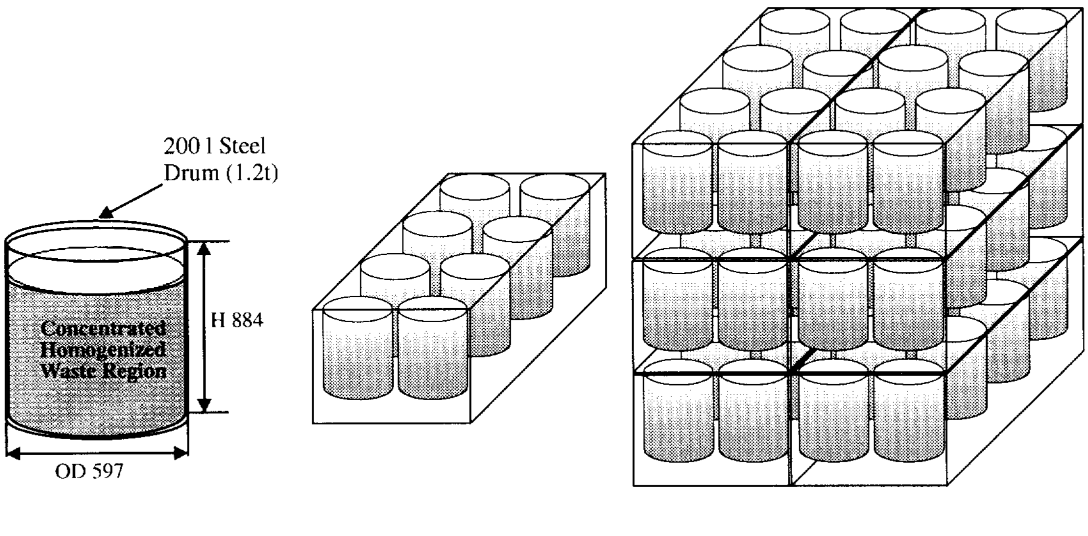
The accumulated energy ratio obtained from the MCNP4B simulation considering packing configurations will be used in our future assessment. This study will provide useful information in considering the importance of the geometric configuration in disposal especially from the viewpoint of gas generation by radiation degradation. Therefore, more study on other parameters such as dimensional factor in other geometric configurations will be carried out to throughly evaluate the actual disposal situation for performance assessment of disposal facilities.

References

1. Frank G. Smith, 1988, "A Computer Model of Gas Generation and Transport within TRU Waste Drums", DE89 002387.
2. J.F. Breismeistet, et al., 1996, "MCNP-A General Monte Carlo N-Particle Transport Code Version 4B, LA-12625-M.

Radiation Sources	Emission Energy (MeV)	Normalized Spectrum	Emission Rate per Ci (Bq)
Cs-134	5.630E-01	0.01169	4.3253E+08
Cs-134	5.690E-01	0.02088	7.7256E+08
Cs-134	6.050E-01	0.13644	5.0483E+09
Cs-137	6.620E-01	0.30430	1.1259E+10
Cs-134	7.960E-01	0.11834	4.3786E+09
Cs-134	8.020E-01	0.01211	4.1481E+08
Co-58	8.110E-01	0.14251	5.2729E+09
Mn-54	8.350E-01	0.00739	2.7343E+08
Co-60	1.173E+00	0.12108	4.4800E+09
Co-60	1.332E+00	0.12108	4.4800E+09
Cs-134	1.365E+00	0.00418	1.5466E+08
Total	0.837 MeV(Averaged)	1.00000	3.7000E+10

Table 1. Photon Source and Energy Spectrum from Paraffin Waste Form for MCNP Simulation.



(a) Sole drum model (b) 4 x 2 x 1 configuration (c) 4 x 4 x 3 configuration

Figure 1. Drum Configuration Models for Calculation

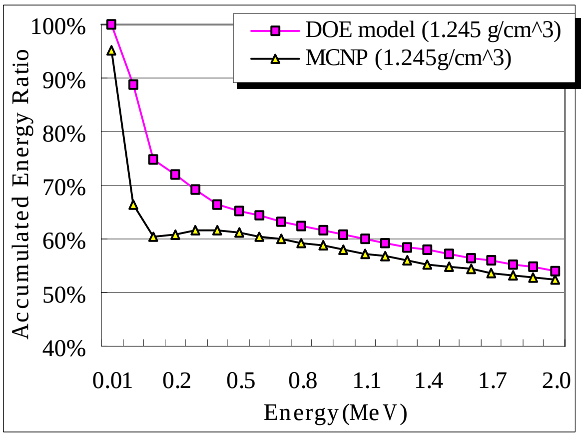


Figure 2. Comparison of Accumulated Energy Ratio between DOE Model and MCNP Calculation for Sole Drum Case.

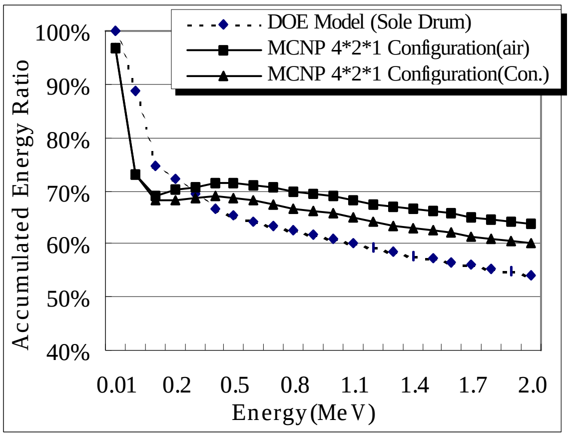


Figure 3. Comparison of Accumulated Energy Ratio between DOE Sole Drum Model and MCNP 4*2*1 Configuration Simulation.

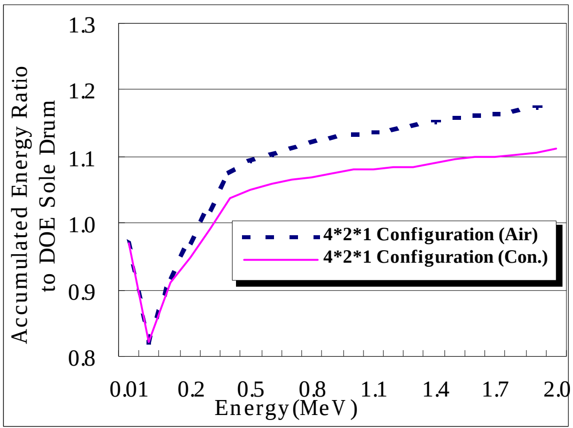


Figure 4. Comparison of Differences on Accumulated Energy Ratio between DOE Sole Drum Model and MCNP 4*2*1 Configuration according to Air and Concrete Backfill Conditions.

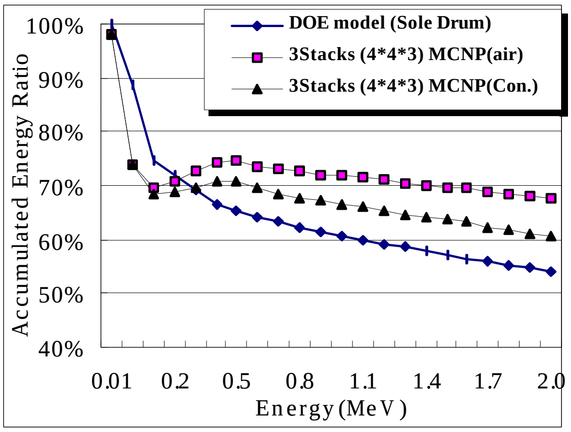


Figure 5. Comparison of Accumulated Energy Ratio between DOE Sole Drum Model and MCNP 4*2*3 Configuration Simulation.

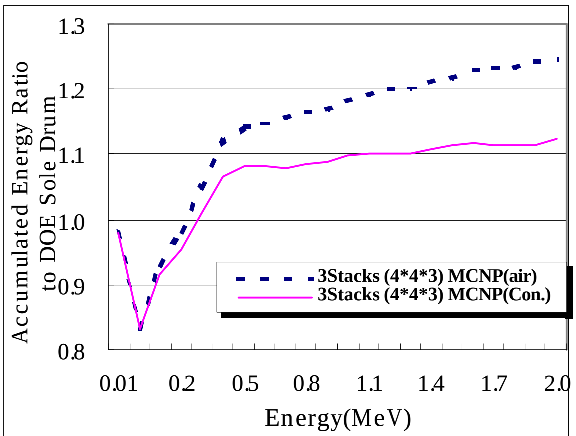


Figure 6. Comparison of Differences on Accumulated Energy Ratio between DOE Sole Drum Model and MCNP 4*4*3 Configuration According to Air and Concrete Backfill Conditions.

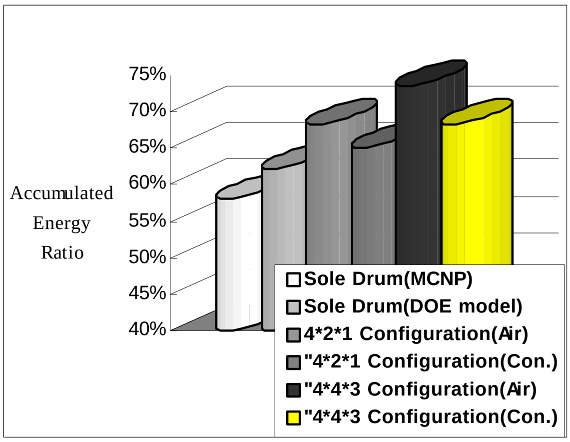


Figure 7. Comparison of Accumulated Energy Ratio between DOE Sole Drum Model and various MCNP Configurations and Backfill Conditions for 0.835 MeV Photon.