Carbon-14 Inventory Optimization Process for LILW Silo Repositories in a Normal Scenario by Adopting Triangular Distribution Function

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1. Introduction

For the disposal of low- and intermediate-level radioactive waste (LILW), a silo type repository is currently being operated in Gyeongju.

In our previous work, we developed the safety assessment model for LILW disposal system by using Monte Carlo based program, Goldsim, and evaluated the radiological effect in terms of annual dose rate.

Based on the safety assessments, carbon-14 (C-14) appeared as a radionuclide which dominantly contributes to the maximum annual dose rate [1] as reported in other study [2]. Therefore, the inherent uncertainties of C-14 related input data (i.e. solubility, distribution coefficient, etc.) may highly affect the reliability of safety assessment. Moreover, C-14 inventory, calculated from the scaling factor, necessarily involves uncertainty as well.

In this framework, the triangular distribution function is adopted to examine the effect of variation in C-14 inventory on the safety assessment results. In addition, the estimation of the safety margin and optimization process for C-14 inventory has also been achieved.

2. Model Description

2.1 Performance assessment module of silo repository

The figure below indicates a schematic diagram of the modelled silo and a part of performance assessment module of silo repository. Radioactive wastes are stored in 200-L waste drum and repacked in the concrete waste box.

From a conservative point of view, we presume that the silo is fully saturated with groundwater and waste drum loses its credibility immediately after its closure.

Once the silo is saturated with groundwater, radionuclides can be released from the damaged waste drum and diffused to engineered barrier system (EBS). The released radionuclides are transported through the fractures in the geosphere and migrate to the biosphere. Finally, they affect human and environment radiologically.

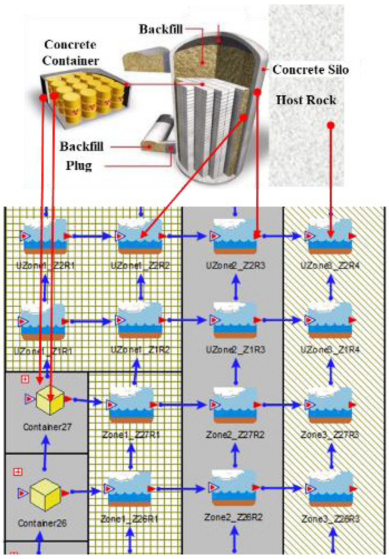

Fig. 1. Schematic diagram of modelled silo and performance assessment module.

2.2 Application of triangular distribution function to C-14 inventory in silo repository

In general, the normal distribution function and the triangular distribution function are widely used to represent the variation of data. In the case of the normal distribution function, both ends of which are unbounded, often samples outliers. On the other hand, the triangular distribution function can fix the exact boundary conditions. Therefore, the reasonable modeling results are achievable.

In this study, the triangular distribution function for the C-14 inventory is adopted to implement the variation of the inventory. The lower limit, upper limit, and the distribution center are set as 10^3 Bq, 10^{23} Bq, and 10^{13} Bq, respectively.

3. Modeling Result

For six silos, each C-14 inventory is randomly generated from the triangular distribution function and simulated 500 iterations. Fig. 2 illustrates the annual dose rate of all realizations. Within a few tens of years after closure, there are no significant differences in the annual dose rate among the iterations. This is because C-14 normally releases into biosphere in the next decades after closure. On the other hand, a hundred years after closure, C-14 inventory shows high sensitivity versus the annual dose rate.

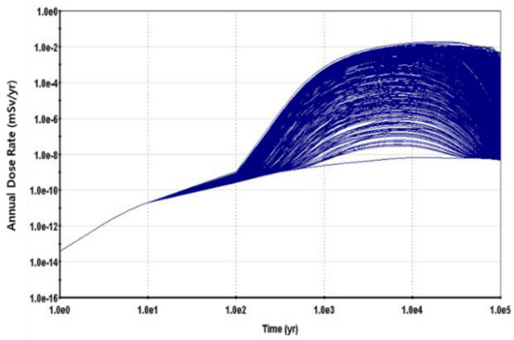

Fig. 2. Annual dose rate obtained from 500 simulations.

The maximum annual dose rates are also calculated from each simulation, as described in Fig. 3. The black dots indicate the maximum annual dose rates obtained from each simulation. The red dot represents the maximum annual dose rate which is calculated with actual C-14 inventory (1.7×10^{14} Bq) that is expected to be disposed of in the silo.

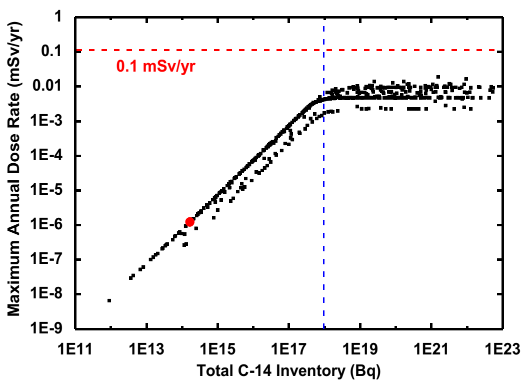

Fig. 3. Maximum annual dose rate according to C-14.

As can be seen in Fig. 3, the maximum annual dose rate becomes increasing until the total C-14 inventory is reached to nearly 5×10^{18} Bq and after that, the slope of the graph is dulled and saturated. The solubility of carbon is fixed, there is no increase in the discharge rate of C-14, even though its inventory increases at these inventories. Accordingly, the maximum annual dose rate is not increased either. However, the maximum annual dose rate is still lower than the safety limit, 0.1 mSv/yr, although the maximum annual dose rate reaches the highest value.

In addition, the inventory margin for C-14 is calculated to be 5×10^{18} Bq, almost 30,000 times higher than the actual total C-14 inventory.

4. Conclusions

In our modeling environment, it was observed that the maximum annual dose rate reaches the highest value and does not exceed the safety limit when the inventory of C-14 becomes greater than 5.11×10^{18} Bq.

The margin of the C-14 inventory of silo is estimated to be nearly 30,000 times higher than that of originally planned to be disposed. Thus, the silo repository would be maintaining its safety even if the repository additionally disposes C-14 contaminated radioactive wastes at least several thousands of times higher than the original inventory. Moreover, based on the great inventory margin of the silo repository, it is expected to ensure its safety despite of uncertainties of C-14 related input data.

5. Acknowledgement

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REFERENCES

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