A Case Study for Clearance of Activated Carbon Waste Using RESRAD Computer Code

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1. Introduction

Radioactive substances exceeding the value of deregulation concentration are detected in the waste activated carbon generated in domestic nuclear power plants or facilities. Consequently, it is classified as a radioactive solid waste because it is difficult to clearance, more than dozens of drums generating every year. According to previous research cases, ^{3}H from the waste activated carbon source ports secured a technology that satisfies the clearance concentration limit. However, in some cases, it is difficult to apply it in the actual field as it exceeds the clearance concentration limit. Moreover, since this problem is aggravated during the decommissioning of the nuclear power plants, it is necessary to prepare effective countermeasures considering the problem of the cost. Therefore, this study evaluates whether waste activated carbon is clearance using the RESRAD code and seeks efficient reduction of the cost measures in the future.

2. Evaluation Methodology

2.1 RESRAD Code

The RESRAD code, developed by the US ANL(Argonne National Laboratory), evaluates the radiological impact on upper residents due to residual radioactive substances in the contaminated site and the satisfaction of site recycling standards after the nuclear power plant decommissioning. It also evaluates the risk associated with radiation exposure through analysis of exposure route and models approaches to individuals or groups exposed to radiation.

2.2 Selection of Scenario

Scenario selection should precede evaluating the exposure dose by waste activated carbon. The RESRAD code can be selected through various exposure channels as shown in Figure 1. In this study, worker scenarios were selected and considering the direct exposure from radionuclides, respiration of suspended dust, respiration of radon and radon decay products, and exposure routes for contaminated soil intake.

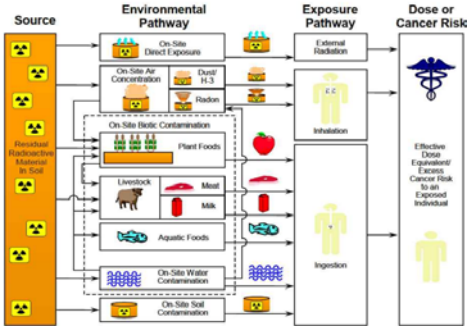

Fig 1. RESRAD exposure pathway[1].

2.3 RESRAD Code Input Factor

Since it is extremely difficult to secure input factors that accurately reflect the characteristics of the landfill site, some factors were evaluated by selecting conservative values that reflect domestic characteristics. Table 1 shows a list of RESRAD code site characteristics factors[1].

Table 1. Site characteristics factor

Classification	Input Factor
Physical factor	Concentration of radionuclides, Type and area of contaminated areas, etc.
Hydrological factor	Fountain area, Porosity, Hydraulic conductivity, Soil b-parameter, etc.
Geological factor	Distribution coefficient, Leaching rate, Solubility, etc.
Meteorological factor	Wind speed, Precipitation, Erosion rate, Evapotranspiration coefficient, etc.
Consumption factor	Ingestion, Inhalation rate, Storage period, Pumping rate, etc.

2.3.1 Source Term.

In case of the source term of the waste activated carbon, ^{3}H, ^{14}C, ^{131}I and γ nuclides are included. In case of ^{131}I, the half-life was very short at 8 d, and γ nuclides was excluded from the evaluation because it was less than the MDA(Minimum Detectable Activity) value. Therefore, In this study, ^{3}H and ^{14}C were selected as RESRAD code source terms. Information on the ^{3}H and ^{14}C source terms is described in Table 2.

Table 2. Waste activated carbon source term[2]

Source term	Half-life	Activity (Bq/g)
^{14}C	5,730 y	45.5
^{3}H	12.3 y	226

Among the nucleation treatment technologies studied and developed in previous studies, the vacuum & heat treatment(600 torr, 270 °C) method, which has the highest nucleation concentration removal rate of ^{3}H and ^{14}C, was used. However, both ^{3}H and ^{14}C exceeded the clearance permission concentration, and dose evaluation was performed after vacuum & heat treatment.

3. Evaluation Result

As shown in Table 3, In the prior study, ^{3}H with initial concentration 226 Bq/g, was possible to be removed by 99.8 % at 600 torr and 0.38 Bq/g after treatment at 270 °C. However, In case of ^{14}C, 600 torr was performed and 12.4 Bq/g was treated at 270 °C, which did not satisfy the clearance permission concentration of ^{14}C.

Table 3. Changes in nuclide concentration during vacuum & heat treatment

Nuclide	Before processing	After processing	Clearance permission concentration
^{14}C (Bq/g)	45.5	12.4	1
^{3}H (Bq/g)	226	0.38	100

In case of annual individual doses, the initial 0.240 μSv/y satisfies the expected annual exposure dose of 10 μSv/y for individuals, and Table 4 shows that the dose value satisfies the expected total annual exposure dose of 1 man·Sv/y for the group.

Table 4. Results of individual and collective dose in vacuum & heat treatment

Vacuum & heat treatment	Before processing	After processing	Clearance permissible doses
Individual (μSv/y)	62.75	0.240	10
Collective (man·Sv/y)	0.00433	Less than 0.001	1

When observing changes in radiation over time, both ^{3}H and ^{14}C, which were selected as radionuclides for the evaluation of radiation sources in the radioactive waste, satisfied the clearance permissible doses. After a period of five years, the radiation levels showed negligible values. As indicated in Table 5, the exposure resulting from the clearance (landfill) of radioactive waste through vacuum and heat treatment is determined to be at a very low level.

Table 5. Evaluation results of vacuum and heat treatment

Nuclide	Instantly	5 years	30 ~ 1000 years
^{14}C (μSv/y)	0.134	Less than 0.001	Less than 0.001
^{3}H (μSv/y)	0.1047	Less than 0.001	Less than 0.001

4. Conclusion

To assess the clearance compliance of radioactive waste, a dose assessment was conducted using RESRAD. The individual and collective doses from clearance were both found to be within acceptable limits. However, the concentration of ^{14}C appeared to be at levels that do not meet the criteria using the current decontamination technology. Therefore, it is evident that a decontamination technology for ^{14}C capable of achieving removal rates equivalent to the its rates for ^{3}H needs to be developed. However, an apparent inconsistency arises with the 5,730 year half-life of ^{14}C. This discrepancy is attributed to the particle like behavior of carbon and hydrogen within the RESRAD code, where they permeate deep into the soil, following groundwater flow, and exhibit transport characteristics that extend beyond the existing contaminated area. Future dose assessments over an extended period will be conducted, taking into account further studies on the transport characteristics of ^{3}H and ^{14}C in the environment.

5. Acknowledgments

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