Evaluation of Offsite Dose from Landfill Disposal and Incineration of Household Waste Containing Naturally Occurring Radioactive Materials

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1. Introduction

Long-lived radioactive elements like uranium, thorium, and potassium, as well as their decay products, are all examples of naturally occurring radioactive materials (NORMs). They are abundant in natural rocks and minerals in the earth's crust. [1]. These NORMs are found in a wide range of applications, from residential to industrial, and their activity concentration (AC) can be increased or concentrated as a result of human activities and industrial processes. [2]. NORM exposure can occur via the external pathway, in which the source remains outside the body, or via the internal pathway, in which radioactive material is absorbed into the body through inhalation, ingestion, or absorption. This does not have the same acute and severe consequences as exposure to high levels of radiation from man-made sources. Chronic exposure that exceeds the general public's exposure guidelines or occurs in the absence of proper safety precautions may have long-term consequences, such as the development of certain cancers. [3]. Consumer products (CPs) containing NORMs are used both directly and indirectly in our daily lives, and they are discarded uncontrollably in landfills alongside other household wastes. The public is exposed to a significant amount of radiation as a result of this unauthorized disposal. A consumer product is defined as a device or manufactured item into which radionuclides have been purposely integrated or created by activation, or that generates ionizing radiation, and which can be marketed or made available to the general public without regulatory control after the sale [4]. Because of the uncontrolled supply to the public and the disposal of these goods after use, the IAEA considers ubiquitous CP to be beyond effective regulatory control. The accumulation of such materials at a waste disposal facility could constitute a radiological danger, and should be submitted to dose assessment to ensure that landfill personnel and the general public are not exposed to uncontrolled radiation [4]. In this study, we conducted offsite dose evaluation to the public resulting from landfill disposal and incineration of household waste containing NORMs in Korea. The Korea Nuclear Safety and security Commission Notice No. 2014-3 states that all exempt wastes can be incinerated, recycled, or disposed of in landfill sites [5]. The European Commission's 147 guidelines for the regulatory control of CPs containing radioactive substances divided CPs into three categories: existing products, which are currently being manufactured and are readily available for public use; novel products, which require authorization from the competent authority; and historic products, which are not currently being manufactured but could be manufactured in the future [6].

2. Materials and Method

2.1 Activity Concentration of NOMRs CPs

Data containing specific ACs of various CPs containing NORMs were obtained from Korea Nuclear Safety and Security Commission (NSSC) and were grouped into combustible and noncombustible CPs containing NORMs each with AC below and above 1 Bq/g. The mean specific activity for various product concentration ranges was obtained and statistically analyzed using an interval plot for ^{238}U, ^{232}Th, and ^{40}K with a 95% confidence interval for the mean of each product for different concentration ranges. ACs of combustible and noncombustible CPs containing NORMs were used as input data to RESRAD codes in Bq/g to determine the exposure dose to offsite residents at a landfill disposal facility. The 95% confidence interval for the mean specific ACs of all radionuclides in question is summarized in Figure 1.

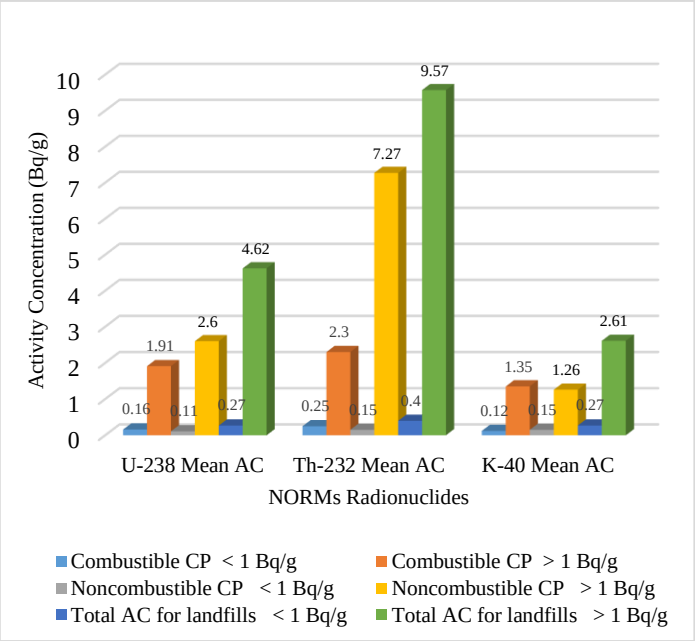

Figure 1. 95% confidence interval for the mean activity concentration of ^{238}U, ^{232}Th, and ^{40}K.

2.2 Dose Assessment Scenarios

Dose assessment Scenario diagram for the disposal of CPs containing NORMs is shown in Figure 2.

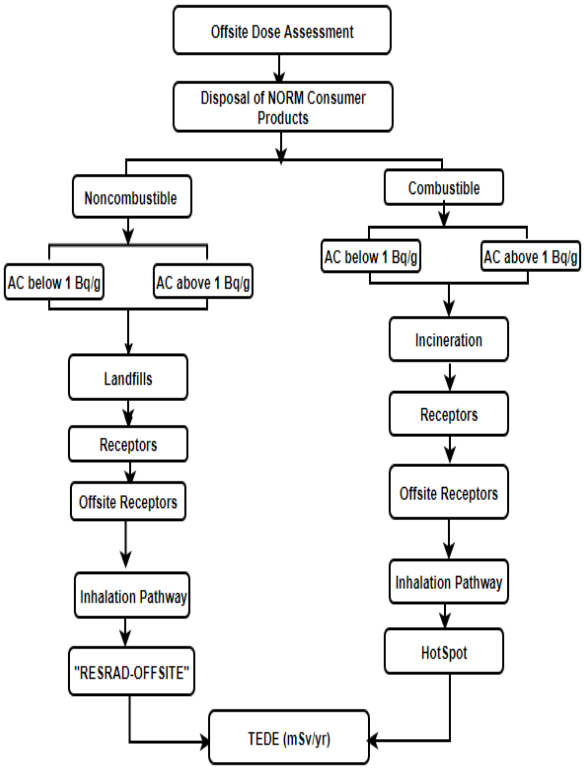

Figure 2. Summary of the Dose assessment scenario for the disposal of NORM added consumer products.

2.3 RESRAD-OFFSITE Computer code

RESRAD-OFFSITE evaluates the radiological dose and excess cancer risk to an individual who is exposed while living or working in or near a radionuclide-contaminated area [7]. The code numerically computes the concentration, dose, and risk progressively over time. To evaluate offsite radiological dose using RESRAD-OFFSITE, we assumed an offsite resident scenario, where a person resides within the vicinity of a landfill but does not consume any food or water from the contaminated site and the only exposure pathway considered is inhalation of radon or thoron being the gaseous decay products of ^{238}U and ^{232}Th respectively. The code uses a Gaussian plume model, where the radionuclide concentration and plume remain constant over time.

2.4 HotSpot Computer code

The HotSpot Health Physics Codes were developed to provide emergency responders and planners with a fast, field-portable set of software tools for evaluating radioactive material incidents [8]. Atmospheric dispersion models are designed for near-surface releases, short range (less than 10 km) dispersion, and short-term (less than 24 hours) release durations. HotSpot codes provide a first-order approximation of radiation effects due to the atmospheric release of radionuclides. The code evaluates any incidents involving radioactive substances so that the first responder can take appropriate measures to respond to the incidents.

3. Results and Discussion

3.1 RESRAD-OFFSITE

The total dose rate (mSv/y) from RESRAD-OFFSITE with activity concentration ranges below and above 1 Bq/g is presented in figure 3.

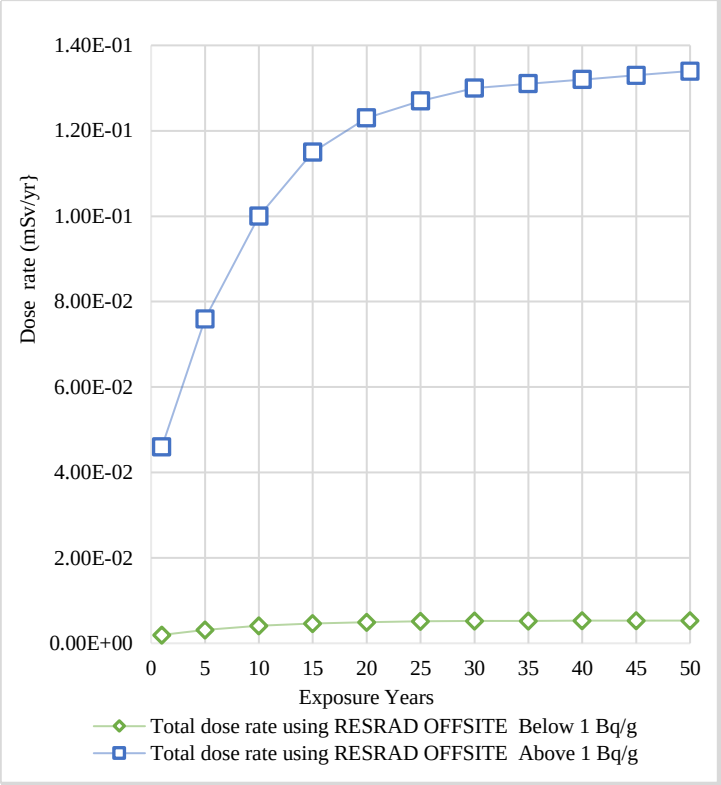

Figure 3. Dose from the RESRAD-OFFSITE scenario

The only exposure pathway considered was the inhalation of radon and thoron decay products of NORMs over a 50-year modeling period. The input data for both range of activity concentration were used along with other default RESRAD parameters. The total dose for both categories of AC were determined with the highest dose of 5.32e-03 mSv/y for AC below 1 Bq/g and 0.134 mSv/y for AC above 1 Bq/g, respectively. This dose is below the recommended ICRP public dose limit of 1 mSv/y, Results of the evaluation for RESRAD-OFFSITE with AC below and above 1 Bq/g proves that it is safe for individuals to reside within a vicinity of a dump site as offsite residents.

3.2 *HotSpot Code with AC Below 1Bq/g*

AC below 1000 Bq/kg alongside receptor height of 5 m was used in the evaluation with effective release height of 7 ft from the release point, with sun high in sky atmospheric stability and wing speed of 2.24 mph, wind speed of 10 m/s and wind direction of 270 and breathing rate of 3.33E-04 m^3/sec were used for the analysis. The result of offsite dose evaluation for AC below 1 Bq/g is presented in Figure 4.

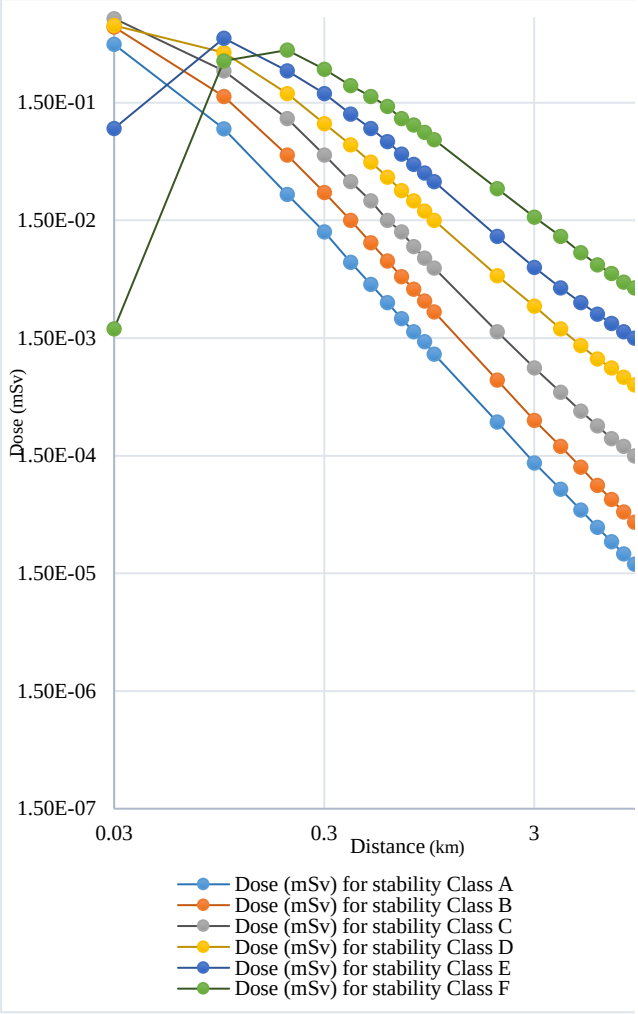

Figure 4. Dose from the HotSpot code for AC below 1 Bq/g

From Figure 4, the highest dose for stability class A is 0.47 mSv at a distance of 0.03 km from the release point for AC below 1000 Bq/kg. The dose dispersed throughout a 10 km radius of the release site is influenced by the stability class, receptor height, lengthy sampling period, and the effect of climatic variables examined in the study. As a result, people living within 10 kilometers of the incineration tents are thus exposed to a higher dose from inhaling contaminated air caused by the gaseous decomposition of NORMs included in the burned garbage than those living further away.

3.3 HotSpot Code with AC Above 1Bq/q

AC above 1000Bq.kg alongside other input parameters used in Figure 4 were employed for dose evaluation and the results is presented in Figure 5.

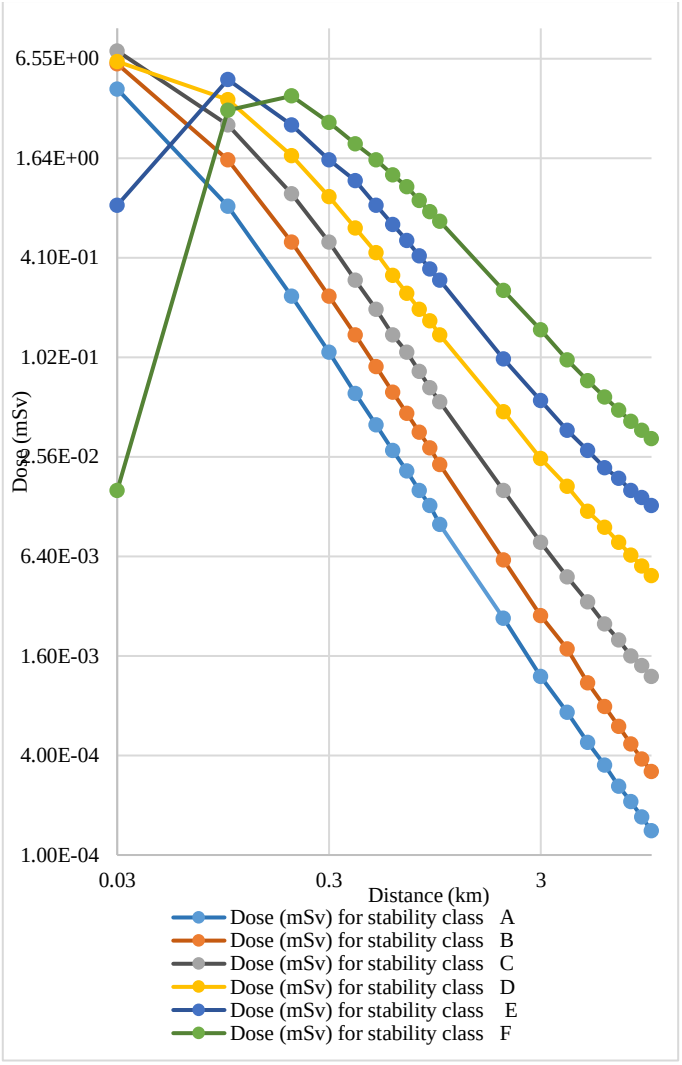

Figure 5. Dose from the HotSpot code for AC Above 1 Bq/g

From Figure 5, the highest dose at a distance of 0.03 km from the release point for ACs above 1000 Bq/kg for stability classes A, B, C and D are 4.30E00 mSv, 6.10E00 mSv, C is 7.30E00 mSv and 6.30E00 mSv respectively which are above the ICRP-recommended public dose limit of 1 mSv/y. The dose shown in Figure 5 is much higher than the dose shown in Figure 4 because of the high AC above 1000 Bq/kg. People who live within 10 kilometers of the incinerator are more susceptible to higher exposure dosages.

4. Conclusion

Using relevant dose assessment methods, such as RESRAD-OFFSITE and HotSpot computer codes, offsite dose evaluation to the public resulting from landfill disposal and incineration of household waste containing NORMs was calculated in this paper. Combustible and noncombustible CPs were identified in household trash containing NORM-added CPs. These were then divided into two groups depending on the AC range (below and above 1 Bq/g). All the results were below 1 mSv/yr and as a result it is safe for people to reside within the vicinity of landfill. Nevertheless, the responsible authorities must implement a protection

measure for residents residing near the incinerator and landfill site for their own safety and well being. This is due to the emission of gaseous NORM decay, which pollutes the atmosphere and causes large inhalation doses.

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REFERENCES

[1] A. E, Agency, Management of NORM Residues - IAEA-TECDOC-1712. 2013.
[2] Jeong, J. et al. Estimation of exposure doses for the safe. No 2018. May, 1–9, doi: 10.1093/rpd/ncy041.
[3] Dwipayana, C. A. W.; Moersidik, S. S.; Pratama, M. A. Estimation radiation dose from operation of petroleum NORM waste disposal in landfill using TSD-DOSE. J. Phys. Conf. Ser. 2020, 1572 (1), doi: 10.1088/1742-6596/1572/1/012031
[4] International Atomic Energy Agency. Radiation Safety for Consumer Products. IAEA Safety Standard Series No: SSG-36, 2016.
[5] Hui-Gyeong, K.; Sang-Wook, H.; Su-Ri, P.; Byung-Jick, K. Safety assessment on the incineration disposal of regulation exempt waste by RESRAD code. J. Radiol. Sci. Technol. 2018, 41 (1), 67–73, doi: 10.17946/JRST.2018.41.1.67.
[6] European Commission Radiation protection 147. Handb. Part. Detect. Imaging 2012, 203–235, doi: 10.1007/978-3-642-13271-1_10.
[7] Yu, C. User's manual for RESRAD-OFFSITE code version 4 (Vol I). *Argonne Natl. Lab.***,** *1*.
[8] De Andrade, E. R. et al. HotSpot health physics codes used as a tool for managing excess risk on radiological emergencies. *Rad. Oncol.*, 1–7.