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Radiological Accident Assessment of Naturally Occurring Radioactive Material Waste

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1. Introduction

In 2018, it was reported in mass media that a specific mattress model of bedding product had relatively emitted a high level of radon gas. Nuclear Safety and Security Commission (NSSC) in Korea, together with the related specialized organizations, investigated this issue, measured some samples, and confirmed that a specific bedding mattress emitted radon gases at a level that was higher than the radiation exposure limit for the general public and that was of concern in public health. As a result of evaluating the radiation exposure to mattress users, it appeared that the limit value set by the regulation 'The Act on Protective Action Guidelines against Radiation in the Natural Environment' could be significantly exceeded above 1 mSv per year, depending on the products. Therefore, NSSC ordered the supplier to remove the mattress from the consumer product and recover the manufacturing defect in a product that may harm its users. 'The Act on Protective Action Guidelines against Radiation in the Natural Environment' was partially changed in January, 2019. The main contents included the prohibition of consumer products containing naturally occurring radioactive materials (NORM) to be used as body contact products such as beds, accessories, and etc., for a long period of time, regardless of whether the annual exposure dose limit of 1 mSv per year might be satisfied. Since the event of radon-emitting bed mattress, NSSC confirmed that anion powder had been applied to the cover fabric inside the corresponding mattress using radon measuring instrument. It was found that the anion powder was manufactured and processed by monazite which relatively contained high levels of natural radioactive materials [1]. It was assumed that the collected radon mattresses were kept in a certain storage facility and had a sudden fire accident. This study was performed to ensure that the estimated doses from accidental releases of NORM meet the protective criteria of the general public through the atmospheric dispersion analysis.

2. Methods and Results

HotSpot health physics code of National Atmosphere Release Advisory Center at Lawrence Livermore National Laboratory was used to assess the total effective dose equivalent (TEDE) in this study [2]. The atmospheric dispersion model used by HotSpot was a first order approximation of the radiation effects associated with the short-term atmospheric discharge of radioactive materials. In fact, it was designed for near-surface releases, short-range dispersion, and short-term emission in unobstructed terrains and simple meteorological conditions. HotSpot can estimate the dispersal of radioactive materials using the Gaussian plume model, since the adequacy of this model for making initial dispersion estimates or worst-case safety analyses has been tested and verified for many years. The general Gaussian dispersion equation can be expressed as follows.

$$C(x,y,z)=\frac{Q}{2u\pi\sigma_y\sigma_z}\exp\left(\frac{-y^2}{2\sigma_y^2}\right)\left[\exp\left(\frac{-(z-H)^2}{2\sigma_z^2}\right)+\exp\left(\frac{-(z+H)^2}{2\sigma_z^2}\right)\right] \quad (1)$$

where,
C = concentration at a given position (μgm^{-3}),
Q = source emission rate (gs^{-1}),
x = downwind (m),
y = crosswind (m),
z =vertical direction (m),
u = average wind speed (ms^{-1}) at the H,
H = height of the release (m),
σ_y and σ_z are the standard deviations of the concentration distribution and frequently referred as dispersion coefficients. The values of σ_y and σ_z are usually determined based on the stability of the atmosphere.

HotSpot codes are reasonably accurate for a timely initial assessment. HotSpot code can produce a consistent output for the same input assumptions and minimize the probability of errors associated with reading a graph incorrectly. Its unique advantages as a radiological emergency response code include some capabilities to model the dispersal of radioactive materials due to a fire, explosion, and etc. in order to display contamination levels in units that emergency responders are familiar with, and to provide a plot of the area contaminated. Through an analysis of the environmental impact of radioactive materials in the event of an accident, one can estimate how much radiation can be exposed to the people [3]. The radioactive concentration analysis of the monazite mattresses confirmed that the composition ratio of uranium and thorium was 1:10. There was a total of 410,000 mattresses using monazite, 205 tons of wastes after mattresses were dismantled, and the volume of radon mattresses collected was 8,005 m^3, and the total amount of radioactivity was 843×10^6 Bq/m^3. It was assumed that radon mattresses collected at a storage facility had a fire accident. As shown in Table I, the average wind speed in a certain city was 4.758 km/h (1.321 m/s) and the dominant wind direction was southwest.

Table I: Monthly wind speed at a certain city in 2019

Month	Wind speed (km/h)	Month	Wind speed (km/h)
January	4.3	July	5.4
February	4.7	August	4.3
March	5.8	September	4.7
April	5.8	October	4.0
May	5.8	November	4.0
June	4.3	December	4.0

The main result of this study was presented in TEDE graph in Fig. 1. It was found that maximum TEDE was estimated to be 1.6×10^{-2} mSv at a distance of 16 km from the release point. As shown in Fig. 1, the dose increased at 100 m from the time of the initial fire accident, and the maximum dose was reached at about 16 km, and then gradually decreased. It was shown that up to the distance of 16 km from the source, the dose was lower than the recommended value of 1 mSv per year for the protection of general public.

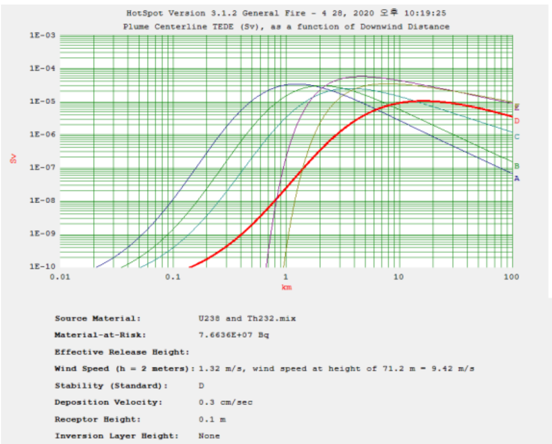

Fig. 1. Plume centerline dose (Sv) as a downwind distance.

3. Conclusion

This study was conducted to assess the radiation risks associated with the release of radionuclides into the atmospheric environment following a fire accident in the management storage facility of radon mattress. The estimated dose was lower than that recommended by the international organizations. The results of this study can be used to help prepare a plan for the mitigation of possible fire accidents and to respond to such events associated with large quantities of consumer products containing NORM.

Acknowledgement

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REFERENCES

[1] J.K. LEE, White paper on safety management of consumer products affected by naturally occurring radioactive substance, The Korean Association for Radiation Protection, 2019.
[2] S.G. Homann and F. Aluzzi, HotSpot Health Physics Codes Version 3.0 User's Guide, Lawrence Livermore National Laboratory, 2014.
[3] Interim results of investigation on mattresses detected with radioactive radon, Nuclear Safety and Security Commission, 2018.