Analysis of Parameters Used to Calculate Radiation Dose to Handlers during Radioactive Material Transportation

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ABSTRACT*: According to high-level radioactive waste management basic plan in Korea, the intermediate storage facility will be constructed. Risk assessment techniques during radioactive material transportation should be prepared for the construction of the intermediate storage facility. The objective of this study was to estimate radiation doses to the handlers by analysis of parameters used for radiation dose calculation. The INTERTRAN code was used to calculate radiation doses. Initially, the INTERTRAN code results were verified by comparing calculation results based on simple empirical formula. Calculation of radiation doses was performed by changing the average distance from source to handler. Radiation doses to handlers were 5.0×10^{-4} person-Sv for 2 m, 3.3×10^{-4} person-Sv for 3 m, 2.5×10^{-4} person-Sv for 4 m, and 2.0×10^{-4} person-Sv for 5 m. The shielding factor had effect on radiation dose. In INTERTRAN code, the radiation doses to the public and transport personnel are calculated using the shielding factor. However, the shielding factor is not taken into account for handlers. The shielding factor is related to the package size and the distance from source to person. Therefore, this study was implemented by changing the package size and the distance from source to handler. To get realistic dose estimates, the shielding factor should be also considered for the handlers. This study will be implemented to estimate the realistic value of handler dose. Furthermore, this study will contribute to develop transportation risk assessment techniques.*

KEYWORDS*: Transportation, Risk Assessment, INTERTRAN, Handler, Radiation Dose*

I. INTRODUCTION

According to high-level radioactive waste management basic plan in Korea, the intermediate storage facility will be constructed. Risk assessment techniques during radioactive material transportation should be prepared for the construction of the intermediate storage facility. There is growing interest in evaluating potential radiation exposures due to the transportation. A few computer codes, including INTERTRAN and RADTRAN are commonly used for the risk assessment of the transportation. The computer codes can be used to calculate radiation doses to transport personnel, handlers, and the public (Ref. 1). Radiation doses to handlers are relatively high compared to the other exposure groups. However, such studies have not been performed in Korea. The objective of this study was to estimate radiation doses to the handlers by analysis of parameters used for radiation dose calculation.

II. MATERIALS AND METHODS

The INTERTRAN code was used for this study. The calculation of the handler dose was classified into three ways depending on the package size (Ref. 2). The calculation was automatically determined in the code by comparing the specified package dimension with preset size limits. In this study, transportation was assumed to be performed once a year. It was assumed that five workers handled one package per shipment and they were exposed for an hour. The workers were assumed to handle once per shipment. The typical package dimension was 2 m. The dose rate value measured at 1 m from the package surface was 0.1 mSv per hour. The average distance from source to handler had the most effect on calculating the handler dose. So, calculations were performed by changing the average distance from source to handler. To verify the INTERTRAN code, the INTERTRAN code results were compared with calculation results based on simple empirical formula. Calculation results were compared while changing the package size from 0.3 m to 3 m.

Radiation dose to the handlers due to the transportation of small packages could be calculated with an empirical formula (Ref. 3):

$$D_{small} = PPS \cdot SPY \cdot TI \cdot K_h \cdot N_h \qquad (1)$$

where PPS is number of packages per shipment, SPY is number of shipments per year, TI is transport index, K_h is dose conversion factor per handling per TI (2.5×10^{-6} person-Sv per handling per TI), and N_h is average number of handlings per shipment. It was assumed that a handling was defined as the entire process of moving a package from one location to another.

The handling of medium sized packages such as drums might require more than one handler. In this case the handler dose was calculated by specifying a distance, number of handlers, and exposure time:

$$D_{medium} = Q_1 \cdot PPS \cdot SPY \cdot PPH \cdot T_h \cdot N_h \cdot \frac{K_0 \cdot TI}{r^2} \qquad (2)$$

where Q_1 is unit conversion factor, PPH is number of exposed persons per handling, T_h is exposure time, K_0 is dose conversion factor per TI for point source, and r is average distance from source to handler. The values assigned for these parameters in the INTERTRAN code are given in Table I.

TABLE I. Assigned parameter values in the INTERTRAN code (Ref. 2)

Package size	r (m)	T_h (hr)	PPH
Small ($x\leq0.5$)	Use an empirical formula		
Medium ($0.5<x\leq1$)	1	0.25	2
Large ($x>1$)	2	1	5

In the case of large packages such as spent fuel casks, radiation dose to handlers was calculated in a similar way as for medium sized packages. However, the exposure distance was shorter compared to the medium-sized packages. It made the assumption of a point source inappropriate. In this case line source geometry was assumed:

$$D_{large} = Q_1 \cdot PPS \cdot SPY \cdot PPH \cdot T_h \cdot N_h \cdot \frac{K_0' \cdot TI}{r} \qquad (3)$$

where K_0' is dose conversion factor per TI for line source.

III. RESULTS AND DISCUSSIONS

Table II shows the calculation results by the INTERTRAN code and empirical formula. Radiation doses to the handlers were calculated using Eq. 1 for package sizes of 0.3 m and 0.5 m, Eq. 2 for 0.8 m and 1 m, and Eq. 3 for 2 m and 3 m. All the calculation results by the code and empirical formula were the same.

TABLE II. Calculation results by the INTERTRAN code and empirical formula

Package size (m)	Handler dose (person-Sv)	
	By INTETRAN code	By empirical formula
0.3	2.5×10^{-5}	2.5×10^{-5}
0.5	2.5×10^{-5}	2.5×10^{-5}
0.8	9.8×10^{-5}	9.8×10^{-5}
1	1.1×10^{-4}	1.1×10^{-4}
2	5.0×10^{-4}	5.0×10^{-4}
3	6.3×10^{-4}	6.3×10^{-4}

Table III shows radiation doses to handlers by the average distance from source to handlers using the INTERTRAN code. In this study, Eq. 3 was used in the INTERTRAN code because the typical package dimension was 2 m (large package).

TABLE III. Radiation doses to handlers by the exposure distance

Average distance from source to handler (m)	Handler dose (person-Sv)
2	5.0×10^{-4}
3	3.3×10^{-4}
4	2.5×10^{-4}
5	2.0×10^{-4}

IV. CONCLUSIONS

Radiation doses to handlers were estimated by analysis of parameters used for radiation dose calculation. Among the parameters, the shielding factor had effect on radiation dose. In INTERTRAN code, the radiation doses to the public and transport personnel are calculated using the shielding factor. However, the shielding factor is not taken into account for handlers. The shielding factor is related to the package size and the distance from source to person. Therefore, this study was implemented by changing the package size and the distance from source to handler. To get realistic dose estimates, the shielding factor should be also considered for the handlers. This study will be implemented to estimate the realistic value of handler dose. Furthermore, this study will contribute to develop transportation risk assessment techniques.

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