# Assessment of Inhalation Dose for Decontamination Worker of Contaminated Soil on Decommissioning Site in Korea

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## 1. Introduction

Decommissioning of nuclear facilities is one of the main issues in the Korean nuclear industry. Decontamination of a decommissioning site is necessary to reuse the site. In the course of the decontamination of the site, workers are exposed to radiation through various pathways from the contaminated soil. Therefore, the assessment of exposure dose for workers is needed to protect workers from the risk of radiological exposures.

The purpose of the present study is to assess the inhalation dose for workers who will occupy themselves in the decontamination work of contaminated soil on the decommissioning site of nuclear facilities in Korea.

## 2. Methods and Results

### *2.1 Equation for calculation of Inhalation Dose*

The internal exposure dose due to inhalation of suspended particles from the contaminated soil is calculated by the following equation [1]:

$$E_{inh} = DC_{inh}\, t_e\, f_d\, f_c\, C_{soil}\, M_{dust}\, V' e^{-\lambda t_1} \frac{1-e^{-\lambda 2}}{\lambda t_2} \quad (1)$$

Where,

- $E_{inh}$ [Sv/y] is the committed effective dose in a year;
- $DC_{inh}$ [Sv/Bq] is the dose coefficient for inhalation;
- $t_e$ [h/a] is the exposure time;
- $f_d$ [dimensionless] is the dilution factor;
- $f_c$ [dimensionless] is the concentration factor of specific activity in the fine fraction;
- $C_{soil}$ [Bq/kg] is the contaminated soil concentration;
- $M_{dust}$ [kg/m$^3$] is the dust load in air or mass loading factor;
- V' [m$^3$/h] is the breathing rate;
- $\lambda$ [1/a] is the radioactive decay constant;
- $t_1$ [a] is the decay time before the start of scenario;
- $t_2$ [a] is the decay time during the scenario;

In Eq. 1, the breathing rate and working time are the characteristic data of each country. Thus, it is necessary to use the Korean date for such input date for a realistic assessment.

### *2.2 Procedures for decontamination work of soil*

The procedure of decontamination work of soil is summarized in Fig. 1. The kinds of work involved in radioactive soil decontamination are as follows: soil removal with an excavator, transporting of contaminated soil, soil collecting, loading/unloading of soil, crane operation, and landfill management. The work intensity according to work was classified into the two groups. Excavator operation, transportation and crane operation are classified into light works; while soil collection and load/unload, and landfill management are classified into heavy works.

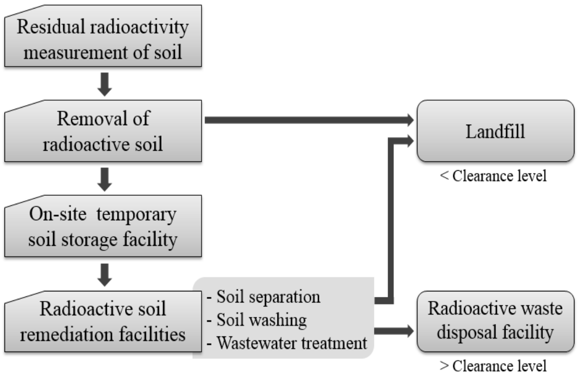


Fig. 1. Schematic work procedures of soil decontamination

### *2.3 Breathing rate for Korean Workers*

Table I shows the consumption time depending on the activity for a Caucasian worker in daily life, which was taken from the ICRP (International Commission on Radiological Protection) publication 66 [2].

Table I: Physical activity and consumption time of Caucasian worker in daily life

| Activity | Exercise level | | Time, h |
|---|---|---|---|
| Sleep | | | 8 |
| Occupational | Light work | Light exercise | 5.5 |
| | | Rest, sitting | 2.5 |
| | Heavy work | Light exercise | 7 |
| | | Heavy exercise | 1 |
| Non-occupational | Rest, sitting | | 4 |
| | Light exercise | | 3 |
| | Heavy exercise | | 1 |

The representative breathing rate for a Korean worker was estimated by combining the measured respiration rates of Korean [3] with the consumption time of worker depending on the activity proposed by the ICRP 66 [2]. The estimated breathing rate for a Korean worker, together with the ICRP breathing rates for light (1.2 m$^3$/h) and heavy work (1.68 m$^3$/h) for comparison, is plotted in Fig. 2. Each box of Korean data shows the distribution of estimated breathing rate for a worker from 25th to 75th percentiles. The straight line inside the box indicates the median value. It can be seen that the 95th percentile of Korean breathing rates is less than that of the ICRP in both light and heavy works.

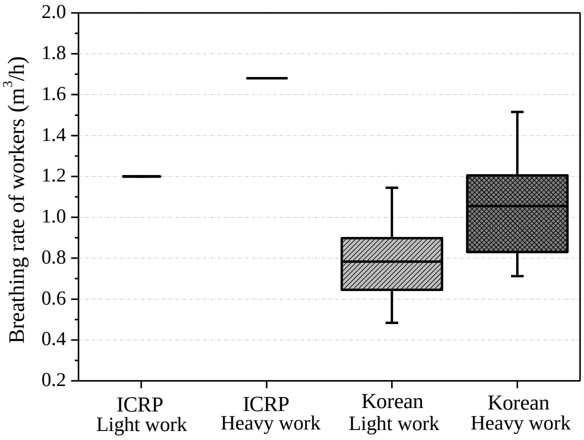


Fig. 2. Comparison of the breathing rate of workers in ICRP recommendation with Korean

*2.4 Annual Exposure Time for Korean Workers*

As listed in Table II, the annual exposure time for each work is defined since the degree of radiation exposure varies depending on the work characteristics. The range between a quarter of a working year (realistic assumption) and a full working year (low probability assumption) of workplace scenarios in the IAEA/SRS 44 was applied for exposure time in the present study. Therefore, this study assumed an annual working time of three months and the monthly working hours, according to the type of work extracted from the data of the Korean Statistical Office (KSO) (2017) [4]. It is assumed that W1, W2 · W4, and W3 correspond to the environmental restoration industry, construction industry, transportation industry of the KSO data, respectively. Meanwhile, the exposure time of W5 was taken from the landfill scenario in the IAEA/SRS 44 [1]. In the present study, inhalation dose for W3 was not considered since the inhalation dose for a driver could be negligible during the transportation of the packed soil.

Table II: Annual exposure time according to the types of work

| Group | Types of work | Exposure time |
|---|---|---|
| W1 | Excavator operation | 570.9 h/a |
| W2 | Soil collection, load and unload | 533.4 h/a |
| W3 | Transportation | 274.0 h/a |
| W4 | Crane operation | 533.4 h/a |
| W5 | Landfill management | 450.0 h/a |

*2.5. Inhalation Dose Assessment for workers*

Inhalation dose for a worker was calculated by using Eq. 1. It was assumed that Cs-137 were deposited in the decommissioning site with a deposition density of 50,000 Bq/m$^2$, which is corresponding to the soil activity concentration of 16.67 Bq/kg. The other input values used in the estimation of the inhalation dose are summarized in Table Ⅲ. The default value of RESRAD [5] and the values with the low probability case of the landfill scenario in the IAEA/SRS 44 [1] were applied.

Fig. 3 shows the effect of breathing rate on inhalation dose. The inhalation dose appeared to increase in the order of W4, W1, W5, and W2. In the case of collection and load/unload work of soil (W2), the inhalation dose of a worker was estimated to be 2.62E-8 μSv based on the ICRP breathing rate. By using the 50th and 95th percentiles for the breathing rate of Korean, the estimated inhalation doses were 1.63E-8 and 2.45E-8 μSv respect-tively, which are equivalent to 62.8 % and 90.2 % of the ICRP result, respectively. The result indicates that, if the ICRP breathing rate is used, the inhalation dose is likely to be slightly overestimated than actual situations of Korea.

Table Ⅲ: Input parameter values used in dose assessment

| Parameter | | Value | Unit | Ref. |
|---|---|---|---|---|
| $DC_{inh}$ | Dose coefficient for inhalation | 6.70E-9 | Sv/Bq | [6] |
| $f_d$ | Dilution factor | 1 | - | [1] |
| $f_c$ | Concentration factor of specific activity in fine fraction | 4 | - | [1] |
| $d_r$ | Effective depth of the layer | 2 | m | [5] |
| $\rho_s$ | Contaminated soil density | 1.50E+3 | kg/m$^3$ | [5] |
| $M_{dust}$ | Dust concentration in air | 2.00E-7 | kg/m$^3$ | [5] |
| $\lambda$ | Radioactive decay constant | 2.31E-2 | 1/a | [6] |
| $t_1$ | Decay time before scenario start | 0 | a | [1] |
| $t_2$ | Decay time during the scenario | 1 | a | [1] |

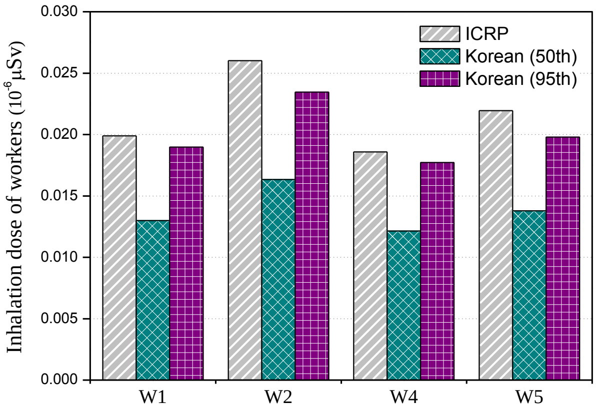


Fig. 3. Comparison of estimated inhalation dose according to the types of work and breathing rate values

## 3. Conclusions

The inhalation dose for a decontamination worker on decommissioning site was assessed by using the Korean characteristic data. The calculated dose appeared to be overestimated when using the breathing rate proposed by the ICRP, which means that the use of domestic data is necessary for a realistic dose assessment. In future work, the dose assessment of decontamination workers on the Kori #1 decommissioning site will be comprehensively performed by considering detailed scenarios as well as other exposure pathways.

## 4. Acknowledgments

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