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A Parametric study of MELCOR Accident Consequence Code System 2 (MACCS2) Input Values for the Predicted Health Effect

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1. Introduction

Recently, the importance of Probabilistic Safety Assessment (PSA) was reminded as becoming a reality of severe accident caused by the extreme disaster, especially level 3 PSA. The model and computer code for probabilistic accident consequence analysis are essential elements for level 3 PSA. The various probabilistic accident consequence analysis codes, MACCS2 (US), COSYMA (EU), OSCAAR (Japan), CONDOR (UK), ARANO (Finland), and LENA (Sweden), had been developed in the 1970s to the 1990s [1] by reflecting their national characteristics.

The MELCOR Accident Consequence Code System 2, MACCS2, has been the most widely used through the world among the off-site consequence analysis codes. MACCS2 code is used to estimate the radionuclide concentrations, radiological doses, health effects, and economic consequences that could result from the hypothetical nuclear accidents [2]. Most of the MACCS model parameter values are defined by the user and those input parameters can make a significant impact on the output. A limited parametric study was performed to identify the relative importance of the values of each input parameters in determining the predicted early and latent health effects in MACCS2.

2. Materials and Methods

2.1. Overview of MACCS2 code [2, 3]

MACCS2 models the transport, dispersion, deposition, and radioactive decay of radioactive materials released to the atmosphere. The atmospheric module is based on the straight-line Gaussian plume model with Pasquill-Gifford dispersion parameters. Seven exposure pathways are considered: cloudshine, groundshine, direct and resuspension inhalation, ingestion of contaminated food and water, and deposition on skin. Protective measure actions are also considered as means to mitigate the extent of the exposures. The health effects and economic costs are estimated as a final step.

The user may choose a number of MACCS2 input data and parameter values which have an impact on the output. Input data and parameters required in MACCS2 are provided below.

- Atmospheric data: geometry, radionuclides, release description, wet and dry deposition, dispersion parameters, plume meander, plume rise, wake effects, meteorological sampling, initial and boundary conditions.
- Dose data: Dose conversion factors, population data, organ definition data, shielding and exposure data, evacuation zone data.
- Environmental pathway data: groundshine, resuspension, regional characteristics, food and water ingestion, food chain.
- Emergency response data, economic data, etc.

2.2. Kori nuclear power plant [4]

We performed MACCS2 calculation on the hypothetical nuclear accident in Kori-site. The calculations were performed with 16 compass sectors of 22.5° out to a distance of 50 km.

The core inventory data of 3,412 MWth, end-of-cycle, pressured water reactor (PWR) (supplied by D.E. Bennett) [2] was used as the source term data. The scaling factor of 0.505 was applied to adjust the core inventory for power level (thermal power level of Kori-1: 1,732 MWth).

The hourly recorded meteorological data of Kori site in 2013 was obtained from Korea Meteorological Administration (KMA). Weather bin sampling method (METCOD 2) was used to select multiple weather sequences. Surface roughness length was specified as 100 cm (surface type: suburban) to take account of the terrain feature [3].

The site and population data of Busan and Ulsan in 2013 were used and taken from Statistics Korea. It was assumed that 95% of people residing within 30 km from Kori-site were evacuated, and that the 5% of people remained behind.

2.3. Selected input values for parametric analysis

The source term specifies the release characteristics of by defining a number of input parameters. It is necessary to compare their predictions for source terms with different release characteristics. A several combinations of the selected parameter values pertaining to the atmospheric source term, release height (0, 20, 50, and 100 m) and release duration (2, 12, and 24 h), were analyzed in this study. Only direct exposure pathways were considered except the ingestion of contaminated food and water for calculating the population weighted risk of early- and latent cancer-fatalities.

3. Results and Discussions

Population weighted risk of early fatality was calculated for four different release heights as a function of distance from Kori-site (Figure 1): 0, 20, 50, and 100 m. The predicted value of population weighted risk of early fatality decreased with increasing the release height, as presented in Figure 1. In graphs, no value means that the predicted risk is calculated as zero. However, the release height (0 ~ 100 m) gave no significant effects on the risk of latent cancer fatality for people residing within 50 km from Kori-site.

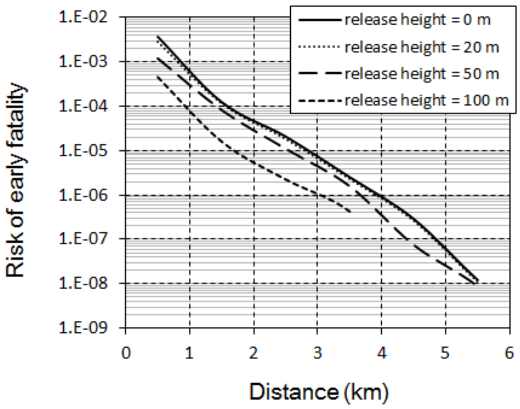

Fig. 1. Risk of early fatality (mean values) for the different release height as a function of distance from Kori-site. Assuming 95% of people residing within 30 km from Kori-site are evacuated, and 5% of people remain behind.

Population weighted risk of early and latent cancer fatality was calculated for three different release durations as a function of distance from Kori-site (Figure 2 and 3): 2, 12, and 24 h. Total released radionuclide inventories (Bq) of plume were identical for those conditions.

Early fatality risk decreased as the duration of the release is getting longer (Figure 2). In Figure 3, the predicted population weighted risk of latent cancer fatality for 2 hour release was higher than those of 12 and 24 hour releases within a 30 km radius from Kori-site. On the other hand, there was no significant difference on the region beyond 30 km radius from Kori-site (Figure 3). These results were affected by the initiation time and the area of emergency protective measures.

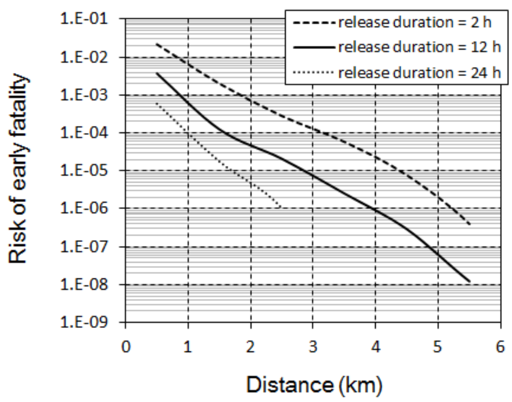

Fig. 2. Risk of early fatality (mean values) for the different release duration as a function of distance from Kori-site. Assuming 95% of people residing within 30 km from Kori-site are evacuated, and 5% of people remain behind.

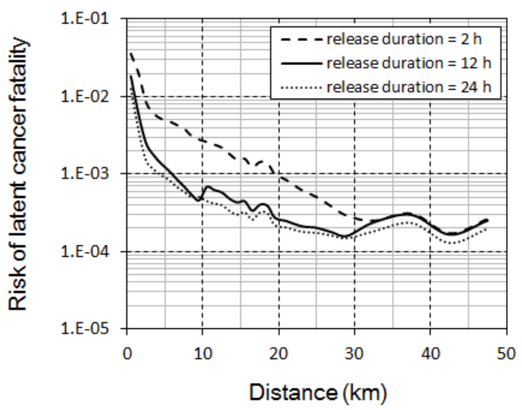

Fig. 3. Risk of latent cancer fatality (mean values) for the different release duration as a function of distance from Kori-site. Assuming 95% of people residing within 30 km from Kori-site are evacuated, and 5% of people remain behind.

Figure 4 (A) and (B) show the cancer fatality risk of non-evacuating and evacuating cohorts, respectively. In the calculation, the beginning time of the off-site evacuation and the evacuation zone were defined as 1300 seconds after the accident initiation and within 30 km radius from Kori-site, respectively.

According to the results, the influence of input parameters related to source term on the predicted health effect depends on the numerous factors (ex: the time point, the region, and the types of emergency protective measures; threshold doses for health effects or emergency protective measures; health effect model and coefficients; health effect type considered as the endpoint, etc.) It means that the predicted health effects are intricately and simultaneously affected by the various input parameters.

(A)

(B)

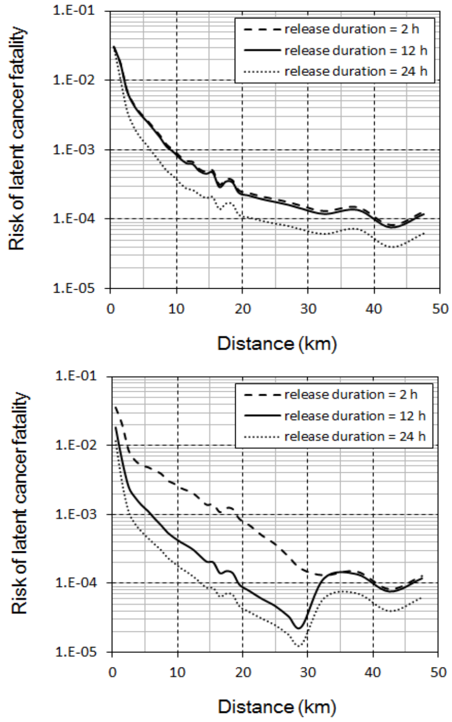

Fig. 4. Risk of latent cancer fatality (mean values) for (A) non-evacuating people and (B) evacuating people for the different release durations as a function of distance from Kori-site.

4. Conclusions

This study addressed the sensitivity of input parameter values pertaining to the atmospheric source term in the predicted health effects in the population residing around Kori-site. These results would not be applicable to every case of the nuclear accidents, because only the limited calculation was performed with Kori-specific data. The endpoints of the assessment were early- and latent cancer-risk in the exposed population, therefore it might produce the different results with the parametric studies for other endpoints, such as contamination level, absorbed dose, and economic cost. Accident consequence assessment is important for decision making to minimize the health effect from radiation exposure, accordingly the sufficient parametric studies are required for the various endpoints and input parameters in further research.

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