A Study on the Effect of Consideration of Plume Meander Model on the Off-Site Consequence

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Introduction

A research project has been carried out since 2019 to verify that the operating facilities handling radioactive materials on the site of the Korea Atomic Energy Research Institute (KAERI) are satisfied with the domestic nuclear safety goals through the risk profile assessment. A risk profile can be derived from the level 1/2/3 Probabilistic Safety Assessment (PSA) [1].

We are focusing on the off-site consequence analysis of severe accidents, which is technically level 3 PSA area. Preliminary MACCS2 (MELCOR Accident Consequence Code System 2) input model for the level 3 PSA on the KAERI site has been developed in the previous study [2]. Most of the MACCS2 model parameters are defined by the user and those input parameters can make a significant impact on the results. A parametric study is currently being performed to identify the relative importance of the values of each input parameters. This paper focuses on the analysis of the effect of the plume meander model, which is one of the main input terms of the atmospheric dispersion (ATMOS) module, on the off-site consequence.

Material and Methods

Plume meander model in MACCS2 code

MACCS/WinMACCS version 4.0.0, released to the public in 2020 [3], was used in this study. Plume meander effect is responsible for most of the total horizontal plume dispersion in weak winds and strong stability. There are three options for plume meander model in MACCS2 code.

- Original MACCS model
- U.S. NRC Regulatory Guide 1.145 model
- None

The original MACCS plume meander model only accounts for the effect of the release duration. The NRC Reg. Guide 1.145 plume model assumes one-hour duration plume segments and accounts for the effects of stability class and wind speed [3].

Input parameters

MACCS2 input parameters for the KAERI site were obtained from the previous study [2]. In Jang et al. (2021) [1], the release characteristics of radioactive materials of HANARO facility were divided into four categories. Among four source term categories (STCs), early ground release (STC2) and early release through chimney (release height: 74.31 m) (STC3) were selected as calculation conditions for this study. Preliminary source term data for Beam Tube Break (BTLOCA) Accident at HANARO was obtained from Lee et al. (2021) [4]. The values recommended in MACCS2 code were applied as input variables for the plume meander model

Results and Discussion

Ground-level air concentrations and centerline ground concentrations of Cs-137 were calculated for ground level release and release through chimney (Figure 1 and 2). Radionuclide ground-level air concentration (Bq·s/m^3) represents the centerline ground-level integrated air concentration from the plume segment averaged over the spatial interval's length. And, radionuclide centerline ground concentration (Bq/m^2) means the centerline ground concentration after passage of the plume averaged over the spatial interval's length.

In the case of ground release (Figure 1), it was evaluated that there was almost no difference in the results between the case where the original MACCS plume meander model was considered and the case where the meander effect was not considered.

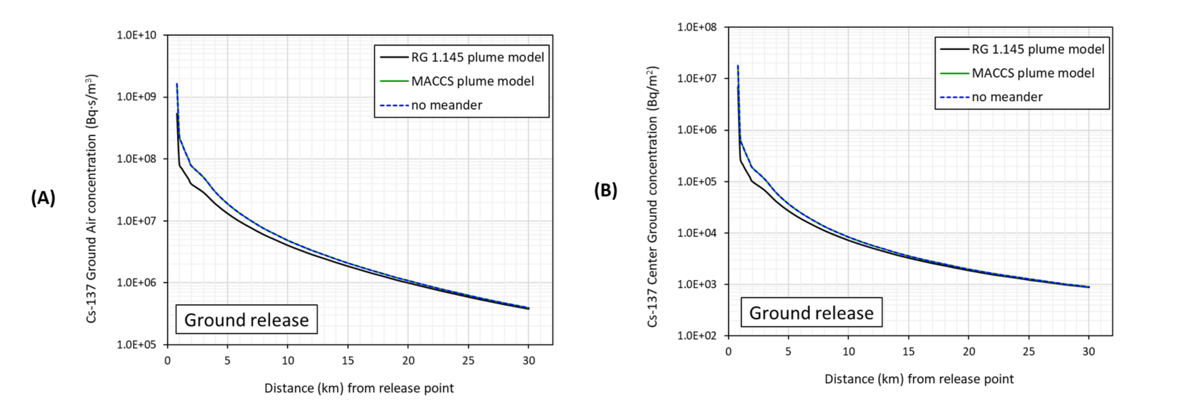

Fig 1. (A) Ground air concentration (Bq·s/m^3) and (B) center ground concentration (Bq/m^2) of Cs-137 for ground release (mean value)

At a short distance within 2 km from the release point, the results of no meander case was approximately 2-3 times larger than that of the NRC Reg. Guide 1.145 plume meander model, and this difference decreased as the distance increased.

In the case of chimney release (Figure 2), elevated (stack) release, the concentration values were calculated to be higher in the order of no meander case, the original MACCS plume meander model, and the NRC Reg. Guide 1.145 plume meander model at a relatively short distance from the release point. The result of the original MACCS plume meander model was evaluated to be approximately 0.8 less than that of no meander case, regardless of the distance.

In the case of the NRC Reg. Guide 1.145 plume meander model, it was about 0.4 to 0.7 times lower than that of no meander case at a short distance within about 5 km, and the difference decreased as the distance increased, and it was evaluated as low as about 0.95 to 0.96 at a distance of 30 km.

According to Figure 1 and 2, the release height is one of the important factors determining the degree of meander effect. Figure 3 shows plume cross-wind size (m). Meandering widens the plume in cross-wind direction (i.e., increases horizontal dispersion) and thus decreases the plume centerline concentration.

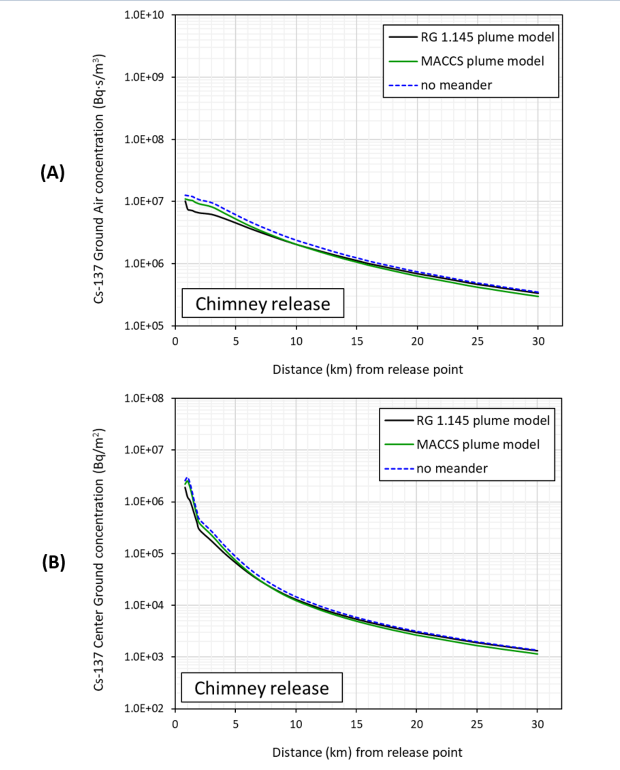

Fig 2. (A) Ground air concentration (Bq·s/m^3) and (B) center ground concentration (Bq/m^2) of Cs-137 for the release through chimney

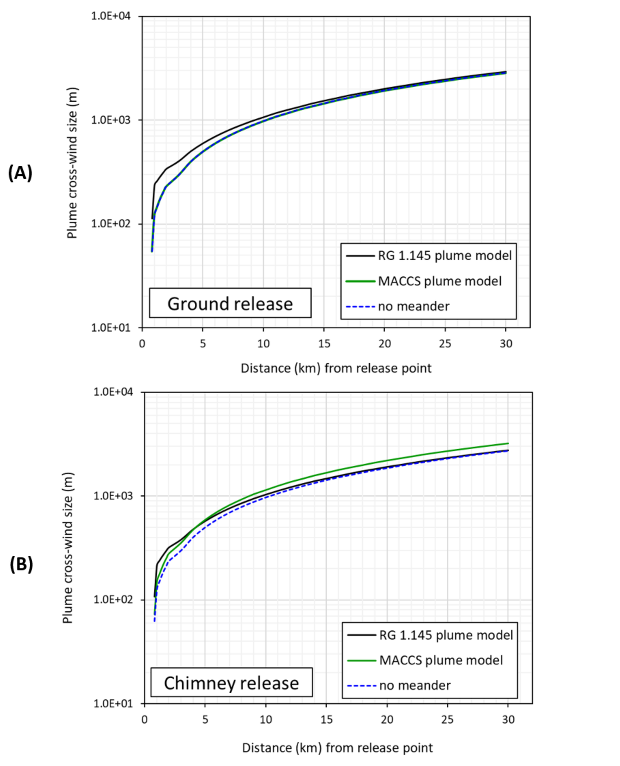

Fig 3. Plume cross wind size (m) of (A) Ground release and (B) chimney release (mean value)

The original MACCS plume model is a time-dependent model that was used in the old version of the MACCS code, and is no longer recommended to apply. This study also shows that the atmospheric results of this model were independent of distance or weather conditions. In SOARCA project, the plume meander effect was not taken into account. They considered applying the NRC Reg. Guide 1.145 plume meander model, but it would have had a very small effect even on the estimated doses for the closest residents to the release point [5, 6]. This is because, as already confirmed in this study, Reg. guide 1.145 plume meander model only affects the plume characteristics at relatively short distances.

Conclusion

This study was conducted to analysis the effect of considering the plume meander model on the atmospheric dispersion results in MACCS2 code. These results would not be applicable to every case of the nuclear accidents, because only the limited calculation was performed with KAERI-specific data. This paper could be used as basic material for our research project.

References

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