Comparison Study on Dose Estimation among Consequence Analysis Codes

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1. Introduction

Sandia National Laboratories have developed MACCS (MELCOR Accident Consequence Code System) and its graphical user interface implemented version, WinMACCS, for U.S. NRC (Nuclear Regulatory Commission) to simulate the impact of nuclear power plant accident on the surrounding environment, supporting Level3 probabilistic safety assessments. Also, U.S. NRC has RASCAL (Radiological Assessment System for Consequence AnaLysis) for rapid assessment of an accident of nuclear facility to provide information for decision-making such as where the public should evacuate to. The individual Dose at the certain distance from the nuclear power plant is evaluated and compared with these codes and simple calculation utilizing HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory model) developed by NOAA's (National Oceanic and Atmospheric Administration) air resources laboratory which is considered as alternative atmospheric transport model of MACCS [1].

2. Methods and Inputs

To give unity to 3 models, only the emergency phase is considered for individual dose calculation with EARLY module in MACCS, Source Term to Dose module in RASCAL. The other functions are not used. WinMACCS 3.11.2 and RASCAL4.2 are used for dose estimation. This section describes the input or method chosen that is related to all 3 models.

2.1. Sources and Release assumptions

As the purpose of this estimation is to compare the result of 3 different model which uses a different system, assumptions and acquire the relative characteristic of them, radioactive source and release feature is simplified and designed for unity of inputs.

To ease the difficulty of calculation, only two radioactive materials, I-131 and Cs-137, are considered. It is assumed that they are released from where Shin-Kori nuclear power plant No.1 and 2 are positioned and midnight on 3rd of August 2017 is selected for release start time considering westerlies.

Plume is segmented into 3 parts. The number of segmentation is chosen considering the input limit of RASCAL. Each part contains 80%, 15% and 5% of release done until 72 hours. Release fraction of source term 8 which failure mode is late containment failure with leakage is selected.

2.2. Transport

The 3 models are equipped with different modeling method to deal with the transport of nuclides and its input required. The inputs for them are provided considering its own feature. For MACCS and RASCAL, the weather data inputs are acquired from KMA (Korea Meteorological Administration). The weather data during 2017 at Kijang, Busan which is proximate to Shin-Kori NPPs is provided for MACCS because it needs weather data only at release point. This weather data is collected through actual observation for the prevention of disaster. For RASCAL, additionally, the forecast weather data called "DongNae Forecast" of KMA from 1st of August to 4th of August, at 35 areas which is the maximum number of weather data RASCAL can utilize are applied [2,3]. Forecast data is chosen to apply dense weather data and the areas are selected considering even distribution in the region which covers 80km far from the release point. Table I shows the areas selected for additional weather data for RASCAL. To calculate the stability of the atmosphere, rawinsonde data at Pohang and Changwon are utilized and the option that uses decrease of temperature as altitude is elevated is chosen. HYSPLIT utilizes its own data set from NOAA. Table I shows the name and representative location of district chosen for additional weather forecast to RASCAL.

For MACCS and HYSPLIT input for deposition, only dry deposition is considered because there was no precipitation around 3rd of August 2017. Deposition velocity is chosen referring to NUREG/CR-7009, assuming mono particle size. As RASCAL calculates the amount of deposition without additional input, deposition velocity is not provided [2,4].

2.3. Dose pathway and Calculation

To match the dose pathway between the models, it is assumed that people will be exposed to the radionuclide through only groundshine, cloudshine, and Inhalation. To stick with this assumption, arbitrary inputs are given to MACCS to neglect inhalation dose by resuspended radionuclide from ground and skin dose deposition [4].

As RASCAL consider groundshine dose for 4 days, it is applied in a same way to other models [2].

Table I. District chosen for RASCAL weather data

District	Latitude	Longitude
Jangseongpo	34.880	128.735
Chilsan-seobu	35.197	128.860
Saengrim	35.335	128.866
Danjang	35.518	128.875
Muan	35.479	128.647
Jungang	35.330	129.035
Habuk	35.465	129.098
Uichang	35.249	128.638
Jungang	35.158	128.634
Gyeongsan Dongbu	35.796	128.774
Yongseong	35.793	128.887
Sannaee	35.742	129.054
Geoncheon	35.832	129.115
Naemnam	35.737	129.224
Woedong	35.733	129.337
Yangnam	35.683	129.447
Seomyeon	35.880	129.061
Ahngang	35.966	129.235
Cheonbuk	35.873	129.287
Yeongcheon Dongbu	35.975	128.952
Unmun	35.700	128.939
Gaknam	35.616	128.653
Cheongdo	35.659	128.768
Ocheon	35.961	129.405
Janggi	35.911	129.516
Jeonggwan	35.324	129.203
Jangahn	35.322	129.260
Myeonryun	35.236	129.087
Jangrim1	35.057	128.966
Jungjae2	35.141	129.194
Seosaeng	35.366	129.318
Onsan	35.412	129.320
Onyang	35.414	129.264
Beomseo	35.553	129.215
Hakseong	35.550	129.327

With nuclide concentration calculated by HYSPLIT, FGR-12 cloudshine, groundshine dose conversion factors and ICRP-60 inhalation dose conversion factors which RASCAL provides are utilized to calculate doses. FGR-13 dose conversion factors of effective dose to whole body are selected for MACCS input.

To deal with nuclide concentration in HYSPLIT, it is assumed that person would get cloudshine doses from average concentration between altitude 0m and altitude 10m height and person would inhale average concentration between altitude 0 m and 2 m considering the average height of people. It is expected that people get cloudshine dose and inhalation dose when the nuclide stays at the certain location. Also, decay of nuclide after deposition to the ground is considered for groundshine calculation. It is assumed a person who stands at the location where trajectory passes would get maximum doses relatively.

3. Results

The maximum doses at 3, 5, 20, 26 and 30 km are estimated with 3 models described as mentioned at the previous section. Fig. 1 shows the maximum doses calculated by 3 models and Table II shows their relative errors based on the outcome of MACCS.

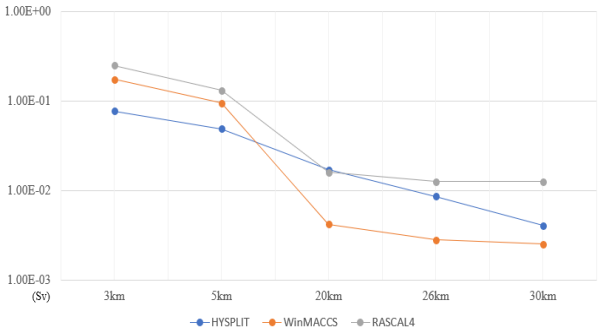

Fig. 1. The maximum doses from Cs-137, I-131 utilizing MACCS, RASCAL and HYSPLIT at certain distance.

Table II: Relative errors of maximum doses calculated by HYSPLIT and RASCAL based on MACCS outcome

Model	Distance	Error(MACCS)
HYSPLIT	3km	-55.93%
	5km	-48.63%
	20km	305.24%
	26km	206.95%
	30km	61.73%
RASCAL	3km	43.26%
	5km	37.67%
	20km	279.12%
	26km	347.79%
	30km	399.34%

At all over the certain distances, RASCAL estimates dose higher than the other 2 models. The relative error based on MACCS outcome reaches around 400% at 30km. The calculation outcome utilizing HYSPLIT estimates the lowest quantity of dose at relatively near the release point and 2nd highest at far points.

The relative error of HYSPLIT based on MACCS outcome reaches more than 200% and get similar relatively at 30km. The maximum dose estimated at 20km by RASCAL and HYSPLIT shows the almost same outcome. The reason why this trend is expected is that they use the same basic transport model which is lagrangian-trajectory gaussian puff model at that location and same dose conversion factors. But RASCAL does consider the shielding factors at early-phases [2,6].

Also, doses calculated by RASCAL at near points show relatively low error comparing with far points. It is expected that this trend can be observed because RASCAL uses gaussian plume model at near points as same as MACCS [2,5,6].

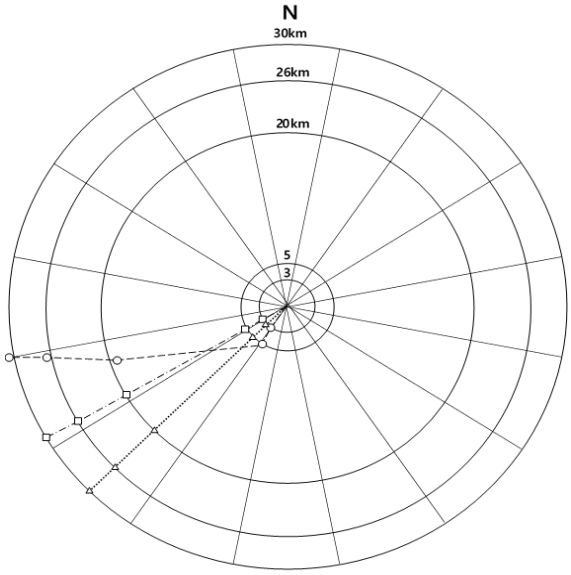

Fig. 2. The location where the maximum doses are estimated. (Circle: RASCAL, Square: HYSPLIT, Triangle: MACCS)

Because the trajectory of puff in HYSPLIT is assumed to cause maximum dose, the line with squares is the trajectory expected by HYSPLIT. As shown in Fig. 2, The line with circles at 3km and 5km far from release point are estimated by plume model of RASCAL and the other 3 circles are estimated by puff model. Circles estimated by puff model does not exactly match with the line that shows the distance because the range of distance is given to get the maximum dose.

The outcome of MACCS covers the region of South-South-West and generally RASCAL and HYSPLIT trajectory exists at South-West region. RACAL's trajectory is more biased to west comparing with HYSPLIT.

4. Conclusion

In this study, the individual doses are estimated utilizing WinMACCS 3.11.2, RASCAL 4.2 and HYSPLIT. The atmospheric transport model of HYSPLIT is applied to get concentration data and the dose is calculated with simple assumptions.

The absolute values of dose came out from the study are insufficient to measure the risks or other engineering works considering Level3 probabilistic safety assessment because of assumptions and inputs made to ease the difficulty of calculation. But as they are compared with the other outcome from different models, it would help to understand the purpose of models and differences between the models.

Acknowledgements

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