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Level 3 MUPSA at 9 Unit Nuclear Site using MACCS2 and MURCC Codes

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1. Introduction

The occurrence of severe accidents exceeding the design basis accident (DBA) became reality recently at the Japan's Fukushima NPPs. The Nuclear Safety and Security Commission (NSSC) amended the law in order to submit the management plan to serious accidents about the probabilistic safety assessment (PSA) [1, 2].

PSA is the important way to provide insight of individual event probability and total safety about all scenarios that may occur at the NPPs. Peoples of all around the world have re-recognized importance of PSA.

Construction to NPPs of SK 3 and 4 unit was completed in republic of Korea. And Construction to NPPs of SK 5 and 6 unit has been being done recently. Most of NPPs in republic of Korea are located more than least two NPPs on one site. The construction of multiple NPPs on one site is the important issue in the industry of PSA.

In the study, we used the MURCC code developed by the PSA laboratory of the Sejong University. It is code to aggregate nuclide concentration and convert from aggregation of nuclide concentration to dose calculation result about the amount of released nuclides in the air [3, 4]. We compared with result of radioactive concentration of air about the center of mass (COM) method and multiple location (ML) method.

We assumed m that is the number of accident scenarios about the NPP if NPPs are the same plant. And N is the total number of NPPs on one site. COM method is $m \times m \times \cdots \times m = m^n$. COM method has to aggregate to 8760 dose results of each 1 hour about 1 year. But ML method is $m + m + \cdots + m = n \times m$. ML method can convert from aggregation of nuclide concentration calculated as 8760 weather data to dose calculation result. It is fast and underestimate to calculate dose for PSA Level 3 field.

2. Methods

The process of calculating concentrations is as follows:

1. Source term calculated by the RASCAL 4.3.3 code [5]. The amount of radionuclides are calculated by the code option, such as the accident scenario, emission pathway, weather, and thermal power about the each NPP.
2. As result of source term calculation, we can get information about the amount and kinds of radionuclides each NPP. And it was entered to the input of ATMOS module to MACCS2. So MACCS2 was calculated value of nuclides concentration in the air, horizontal atmospheric diffusion coefficient about the plume centerline [6, 7].
3. It was entered to calculate result of concentration and horizontal atmospheric diffusion coefficient into MURCC code. And MURCC calculates aggregation nuclide concentration and converts from aggregation of nuclide concentration to dose calculation result about the amount of released nuclides in the air.

Fig. 1 shows processing to calculation of the concentration of nuclides using MURCC code.

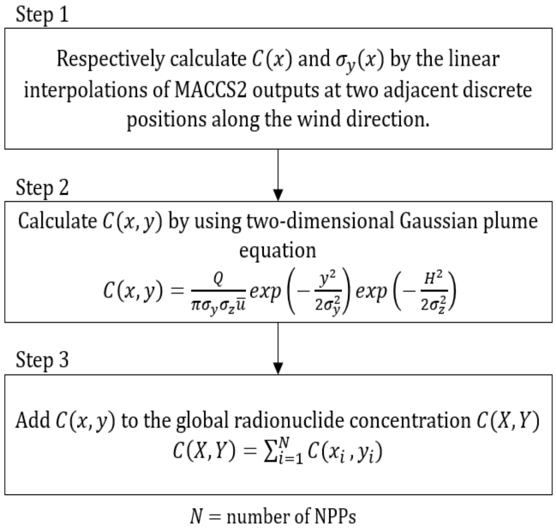

Fig. 1. Procedure of MURCC code [3, 4]

First, we calculated the concentration of Cs-137 in the air at K and SK about 9 units of NPPs as COM method and ML method.

Second, we calculated the concentration of Cs-137 in the air at K about 3 units of NPPs as COM method and ML method.

Third, we calculated the concentration of Cs-137 in the air at SK about 6 units of NPPs as COM method and ML method.

3. Application and Results

3.1 Information of location and thermal power of NPPs

We can get the satellite image and information of the location and distance of each NPP on one site using Google Earth [8].

Fig. 2 contains information of the location of the K, SK units of NPPs and COM of the site. The P represents location lived human. The location of K unit 1 of NPP was based to the layout about the site of K and SK. But the K unit 1 of NPP was permanently shut down in 2017. So it was excluded to calculate location about the COM at the site. We can know distance of each unit of NPPs through the satellite images of the site. Then we should calculate the location of COM calibrating with the thermal power about the site.

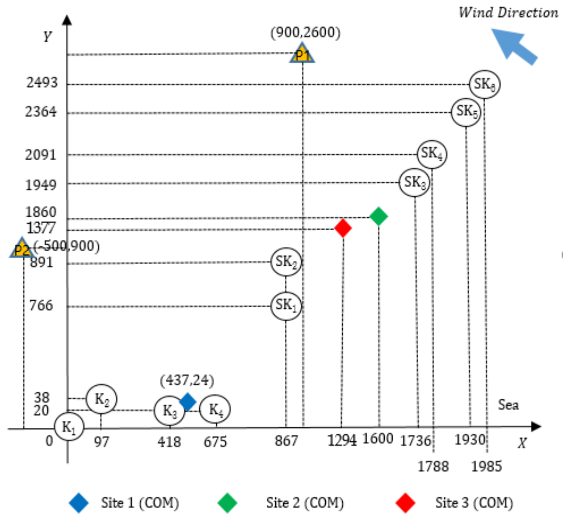

Fig. 2. Layout of K and SK on the site

Table 1 represents information of the location and thermal power about each unit of NPPs. Also it is included information of the location of COM and lived human city about the site.

Table 1. Information of location and thermal power

Location	X (m)	Y (m)	P_{th} (MWth)
K 2	97	38	1,876
K 3	418	20	2,912
K 4	675	20	2,912
SK 1	867	766	2,815
SK 2	867	891	2,815
SK 3	1,736	1,949	3,983
SK 4	1,788	2,091	3,983
SK 5	1,930	2,364	3,983
SK 6	1,985	2,493	3,983
Site 1 (COM)	437	24	N/A
Site 2 (COM)	1,600	1,860	N/A
Site 3 (COM)	1,294	1,377	N/A
P1	900	2,600	N/A
P2	-500	900	N/A

3.2 Information of weather on the site

When we calculate concentration of each NPP using the MACCS2 code, we applied constant weather option about the K and SK unit of NPPs.

When we aggregate concentration of all NPPs using the MURCC code, we set wind direction as south-east on the site.

3.3 Severe accident scenario and emission path

We assumed the scenario of severe accident that is the loss of coolant accident (LOCA) using RASCAL 4.3.3. It was assumed that the reactor was shut down immediately after the loss of coolant accident (LOCA). And the core was not recovered due to the failure of the core cooling system.

Radioactive nuclides released due to break the containment building into the air. It is fail to protect human and environment by the dose of nuclides. And this volume of leakage assumed 100 %/volume about the most serious accident.

3.4 Concentration of Cs-137 in the air (K and SK)

We calculated aggregation concentration of Cs-137 in the air at the K and SK unit 9 of NPPs and compared results of two cases with COM and ML method.

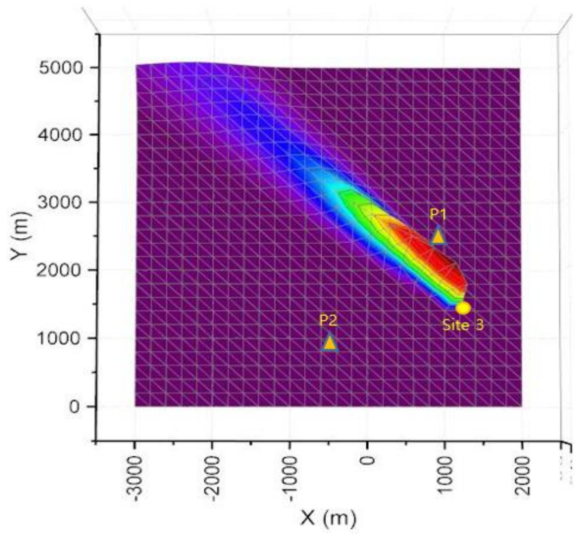

Fig. 3. Concentration about the K and SK (COM)

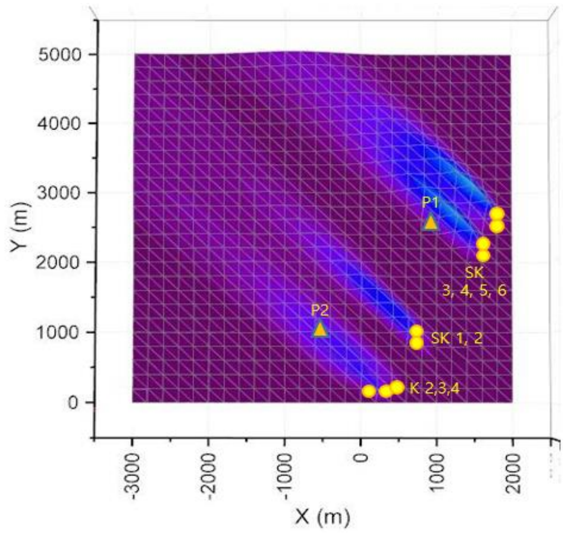

Fig. 4. Concentration about the K and SK (ML)

Fig. 3 shows concentration of Cs-137 in the air at the site 3 (COM). The maximum concentration of Cs-137 in the air is 3.13e+13.

Fig. 4 shows concentration of Cs-137 in the air at the K and SK unit 9 of NPPs (ML). The maximum concentration of Cs-137 in the air is 7.28e+12.

Table 2. Concentration of Cs-137 in the air at the P1, P2

Location	Concentration (COM)	Concentration (ML)
P1	1.70E+13	3.72E+11
P2	0.00E+00	5.83E+00

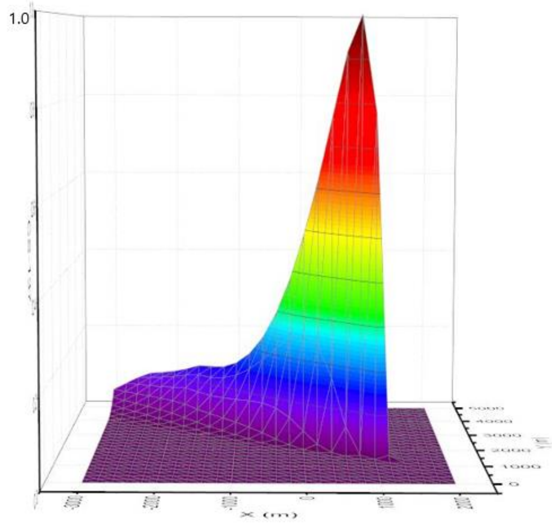

Fig. 5. Normalized Concentration about the K and SK (COM)

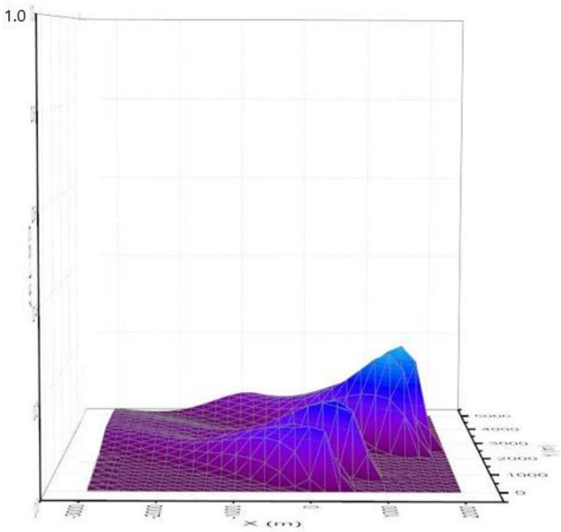

Fig. 6. Normalized Concentration about the K and SK (ML)

Figs. 5 and 6 represent the concentration of Cs-137 in the air at the site 3 (COM) and the K and SK unit 9 of NPPs (ML) as 3D. It is normalized to 1 based on the maximum value of concentration about the result of COM method. It is different about 4.3 times.

3.5 Concentration of Cs-137 in the air (K)

We calculated aggregation concentration of Cs-137 in the air at the K unit 3 of NPPs and compared results of two cases with COM and ML method.

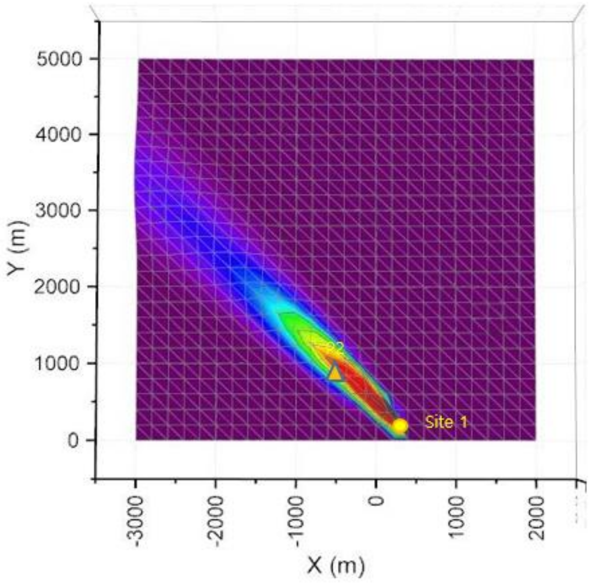

Fig. 7. Concentration about the K (COM)

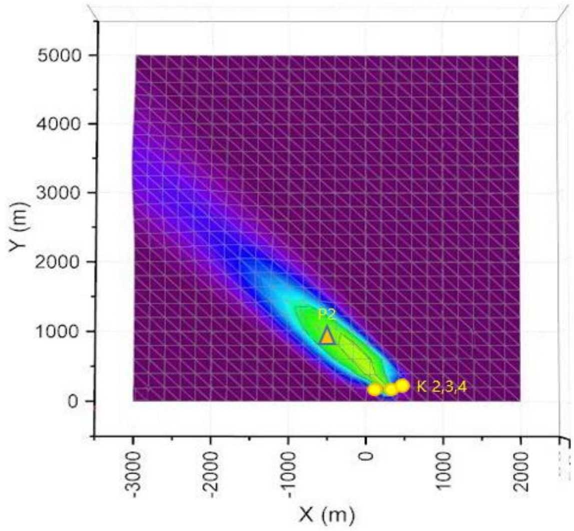

Fig. 8. Concentration about the K (ML)

Fig. 7 shows concentration of Cs-137 in the air at the site 1 (COM). The maximum concentration of Cs-137 in the air is 2.53e+13.

Fig. 8 shows concentration of Cs-137 in the air at the K unit 3 of NPPs (ML). The maximum concentration of Cs-137 in the air is 7.28e+12.

Table 3. Concentration of Cs-137 in the air at the P1, P2

Location	Concentration (COM)	Concentration (ML)
P1	0.00E+00	0.00E+00
P2	4.71E+12	3.23E+10

3.6 Concentration of Cs-137 in the air (SK)

We calculated aggregation concentration of Cs-137 in the air at the SK unit 6 of NPPs and compared results of two cases with COM and ML method.

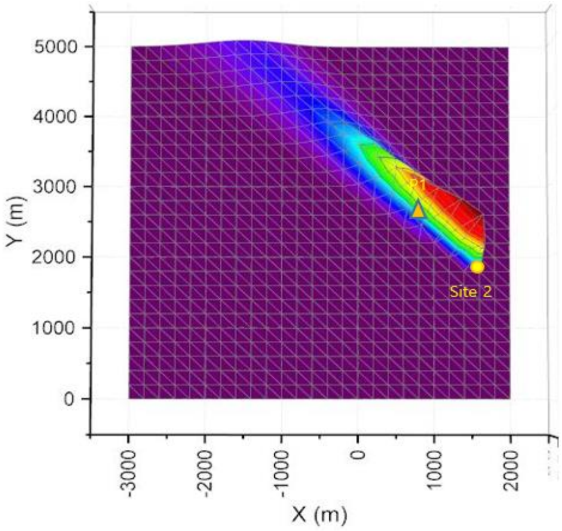

Fig. 9. Concentration about the SK (COM)

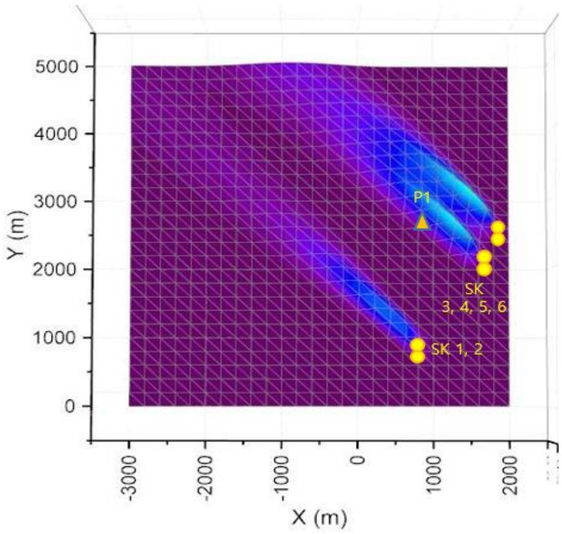

Fig. 10. Concentration about the SK (ML)

Fig. 9 shows concentration of Cs-137 in the air at the site 1 (COM). The maximum concentration of Cs-137 in the air is 8.79e+12.

Fig. 10 shows concentration of Cs-137 in the air at the K unit 3 of NPPs (ML). The maximum concentration of Cs-137 in the air is 3.98e+12.

Table 4. Concentration of Cs-137 in the air at the P1, P2

Location	Concentration (COM)	Concentration (ML)
P1	1.70E+13	2.35E+12
P2	0.00E+00	5.82E+00

Table 5 shows the maximum concentration of Cs-137 in the air about the each case. Most of result of the COM and ML method are approximately different about 10 times.

Table 5. Maximum value of concentration

Case	Concentration (Max)
K (COM)	*8.79533e+12*
K (ML)	*3.98478e+12*
SK (COM)	*2.53091e+13*
SK (ML)	*7.28081e+12*
K and SK (COM)	*3.13329e+13*
K and SK (ML)	*7.28081e+12*

4. Conclusions

Using the MURCC code, this study compared the concentration of Cs-137 in the air at the site with COM and ML method.

In summary, this study is as follows:

1. The concentration of the COM method is more than the concentration of the ML method. COM method is overestimated concentration on the site. It is recommended to calculated concentration through the ML method. It provides the realistic result in order to select the plan of Exclusive Area Boundary (EAB) and Low Population Zone (LPZ) for emergency response plan.
2. We assumed m that is the number of accident scenarios about the NPP if NPPs are the same plant. And N is the total number of NPPs on one site. COM method is $m \times m \times \cdots \times m = m^n$. COM method has to aggregate to 8760 dose results of each 1 hour about 1 year. But ML method is $m + m + \cdots + m = n \times m$. When we calculate concentration on the site, aggregation concentration using MURCC code is more efficient. It just converts from aggregation concentration to dose calculation.

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