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Comparison of semi-infinite and finite clouds effects for the external exposure dose calculation in Level 3 SUPSA and MUPSA

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INTRODUCTION

- MACCS (MELCOR Accident Consequence Code System) Code
  - MACCS is used for the purpose of improving safety through realistic evaluation [1]. MACCS reflects phenomena of radioactive decay, deposition due to rainfall or surface roughness. When calculating exposure dose, MACCS assumes the finite cloud model.
- PAVAN code
  - PAVAN provides the methodology for licensing and regulation to the nuclear power plant [2]. PAVAN does not take into account this realistic phenomena. When calculating exposure dose, PAVAN assumes the semi-infinite cloud model.

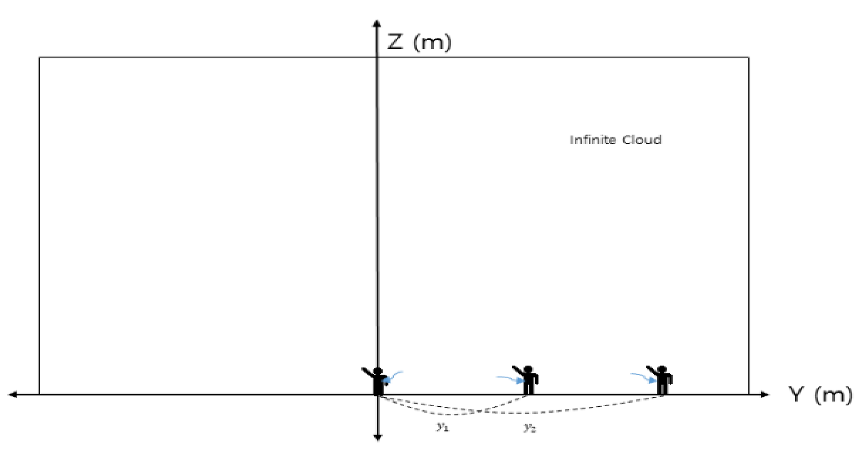

Fig. 1. Gamma rays effect of semi-infinite cloud

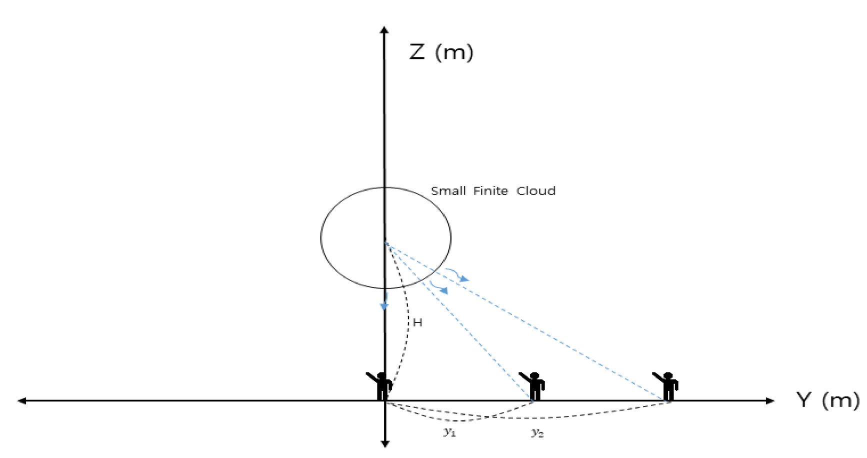

Fig. 2. Gamma rays effect of small finite cloud

- MURCC (multi-unit radiological consequence calculator) code
  - This study is to compare two results of external exposure dose to semi-infinite cloud model and finite cloud model using the MURCC code [3].

METHODS

- Dose calculation of semi-infinite cloud model

- $\boldsymbol{Cld\ Dose_{organ}(x,y) = Cldfac \times \sum_{i=1}^{N} AirCon_i(x,y,0) \times DC_{i,organ}}$
- When people exist in the semi-infinite cloud, this people is homogeneously affected by gamma rays [4].

- Dose calculation of finite cloud model

- $\boldsymbol{Cld\ Dose_{organ}(x,y) = Cldfac \times \sum_{i=1}^{N} AirCon_i(x,0,H) \times DC_{i,organ} \times Finfac(x,y)}$
- Finite cloud exists as the certain height and size in the air [4].

$Cld\ Dose_{organ}(x,y)$ = External exposure dose to human organs $[Sv]$
$Cldfac$ = Shielding factor of cloud shine $[Unitless]$
$AirCon_i(x,y,0)$ = Ground level air concentration $[Bq \times sec/m^3]$
$DC_{i,organ}$ = Dose coefficient of external exposure $[Sv/sec/Bq/m^3]$
$AirCon_i(x,0,H)$ = Centerline air concentration $[Bq \times sec/m^3]$
$Finfac(x,y)$ = Finite cloud dose correction factor $[Unitless]$
i = Nuclide
N = Number of nuclides

- Ratio of finite to semi-infinite cloud dose

- The finite cloud dose correction factor is the ratio of finite to semi-infinite cloud dose [4].
- $Finite\ cloud\ dose\ correction\ factor = \frac{D(x,y,0)}{D_\infty(x,0,H)}$

$D(x,y,0)$ = Dose of semi-infinite cloud $[Sv]$
$D_\infty(x,0,H)$ = Dose of finite cloud $[Sv]$

	$\sqrt{y^2+z^2}/\sqrt{\sigma_y\sigma_z}$ (a)					
$\sqrt{\sigma_y\sigma_z}$ (b)	0	1	2	3	4	5
3	0.020	0.018	0.011	0.007	0.005	0.004
10	0.074	0.060	0.036	0.020	0.015	0.011
20	0.150	0.120	0.065	0.035	0.024	0.016
30	0.220	0.170	0.088	0.046	0.029	0.017
50	0.350	0.250	0.130	0.054	0.028	0.013
100	0.560	0.380	0.150	0.045	0.016	0.004
200	0.760	0.511	0.150	0.024	0.004	0.001
400	0.899	0.600	0.140	0.014	0.001	0.001
1000	0.951	0.600	0.130	0.011	0.001	0.001

Table. 1. Finite cloud dose correction factor [5]

$\sqrt{y^2+z^2}/\sqrt{\sigma_y\sigma_z}$ = Distance to cloud centerline and receptor [unitless]
$\sqrt{\sigma_y\sigma_z}$ = Diffusion parameter [m]

- Calculation process to the MURCC code

- Source term is calculated using the RASCAL code .
- Information of the amount and kinds of nuclides of the single NPP should input into the ATMOS module of MACCS [1].
- MACCS output file of this single NPP should input into MURCC code. And finite cloud dose correction factor option of MURCC code decide on/off to calculate the external exposure dose [3].

- NPP Model

- APR-1400

- Scenario and release pathway

- The scenario of severe accident is assumed the LTSBO (long-term station black out). The reactor core was not recovered due to the failure of the core cooling system.
- Percent leakage volume per time assumed 100 % vol/h in order to the scenario of most serious accident.

- Weather

- Atmospheric stability is D.
- Wind speed is 4m/h.
- Precipitation is zero.
- Temperature and relative humidity are general.

RESULTS AND DISCUSSIONS

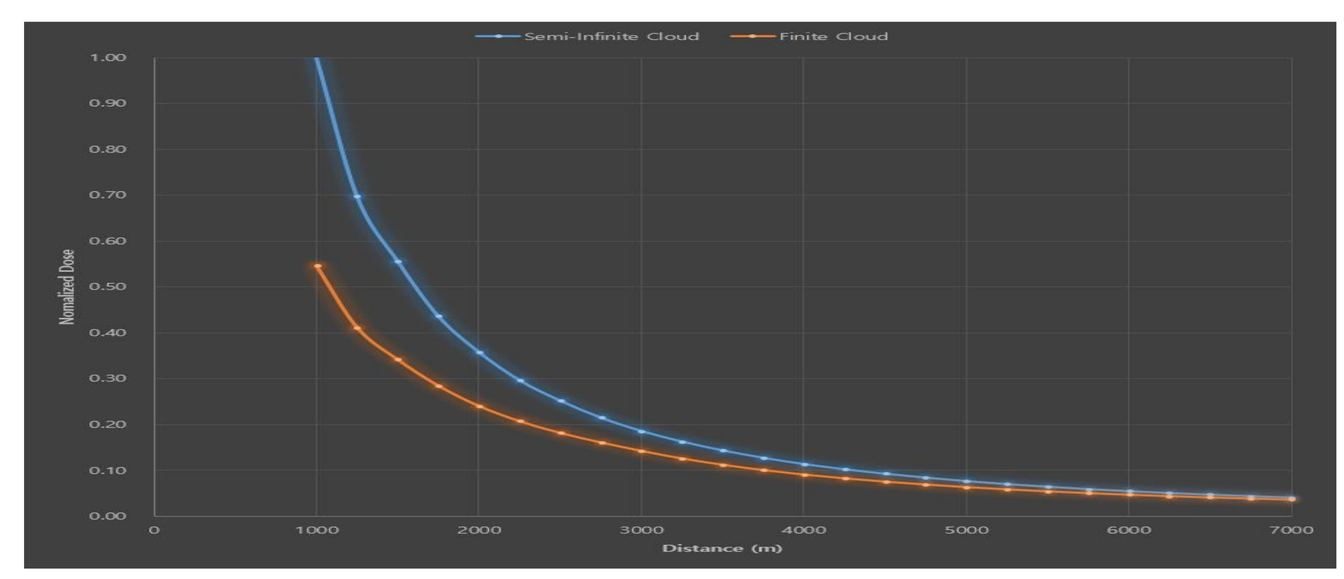

Fig. 3. Comparison of centerline dose to semi-infinite and finite cloud

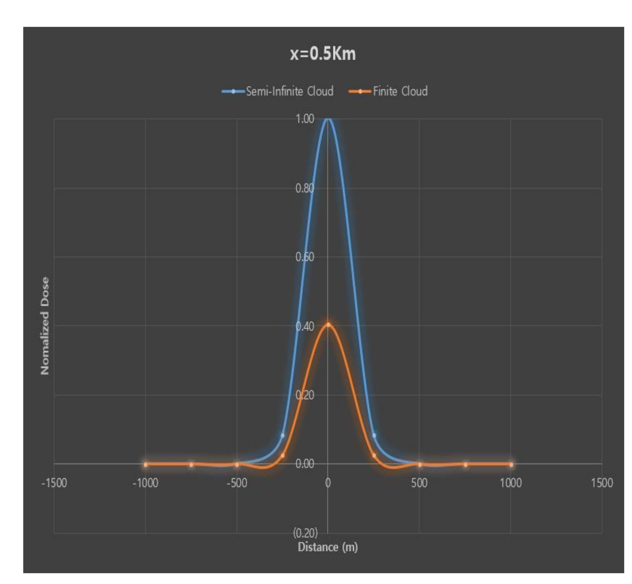

Fig. 4. Comparison of dose (0.5km)

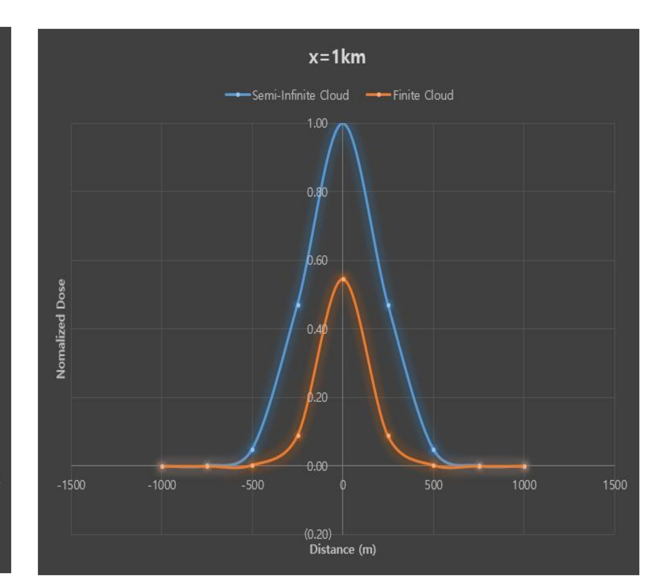

Fig. 5. Comparison of dose (1km)

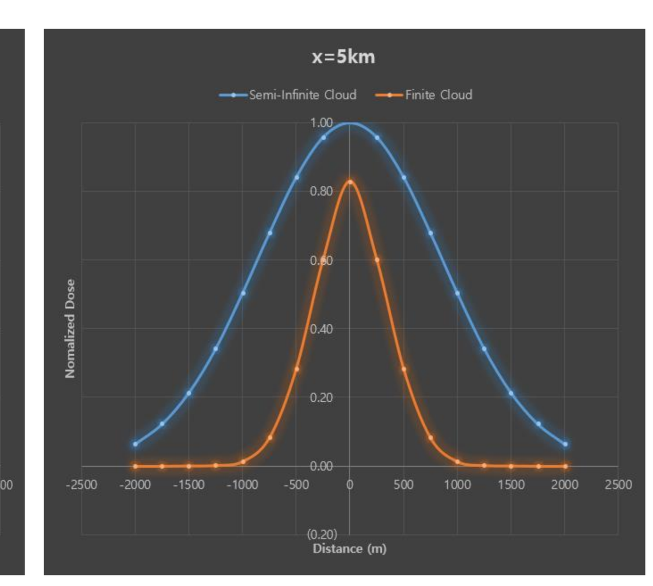

Fig. 6. Comparison of dose (5km)

- Result

- The two cases of semi-infinite and finite cloud model differed by 0.45 at x=1.0 km. The difference is large when it is close to the source of the cloud.
- The two cases of semi-infinite cloud and finite cloud model differed by 0.56 at x=5.0 km and y=0.5km. The difference is small when it is close to the source of the cloud.

CONCLUSIONS

- Conclusions

- The results of calculating dose of semi-infinite cloud model showed the more conservative result than dose of finite cloud model.
- Quantitative safety objectives for NPPs have not been established in Korea. If these quantitative safety targets are legislated as mandatory regulations, dose of finite cloud model is calculated accurately and realistically by reflecting this factor. The effect that satisfies the quantitative safety target will be expected.
- When calculating the external exposure dose for Level 3 MUPSA, the value larger than 5 sigma must be added to the table. Because, the external exposure dose for L3 MUPSA must be calculated from the centerline to the far distance.

REFERENCES

1. D. Chanin, M. L. Young, J. Randall, and K. Jamali, “Code Manual for MACCS2: Volume 1, User’s Guide”, NUREG/CR-6613, 1998
2. U.S.NRC, PAVAN: “An Atmospheric-Dispersion Program for Evaluating Design-Basis Accidental Releases of Radioactive Materials from Nuclear Power Stations”, NUREG/CR-2858, 1982
3. W. S. Jung, H. R. Lee, J. R. Kim, G. M. Lee, “Development of MURCC code for the efficient multi-unit level 3 probabilistic safety assessment,” Nuclear Engineering and Technology, 2020
4. D. H. Slade, “METEOROLOGY AND ATOMIC ENERGY”, TID-24190, U. S. ATOMIC ENERGY COMMISSION, pp. 337-346, 1968
5. D. L. Strange, “Models Selected for Calculation of Doses, Health Effects and Economic Costs due to Accidental Radionuclide Releases from Nuclear Power Plants, NUREG/CR-1021”, NRC, pp. 6-1 - 6-15, 1980