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Development on Dose Assessment Model of Northeast Asia Nuclear Accident Simulator

Juyub Kim*, Juyoul Kim, Sukhoon Kim, Seunghee Lee, Taebin Yoon
FNC Technology Co., Ltd., 32F, 13, Heungdeok 1-ro, Giheung-gu, Yongin, Korea
**Corresponding author: yubjoo@fnctech.com*

1. Introduction

Currently, over 100 reactors are in operation or under construction in neighboring countries of Korea such as China, Japan and Taiwan [1]. As learned from Fukushima Daiichi Nuclear Accident, a nuclear accident occurred in overseas may affect people within the country and thus the emergency response system should be organized to consider it. In order to support the emergency response system, the simulator for overseas nuclear accident is under development including source-term estimation, atmospheric dispersion modeling and dose assessment. The simulator is named NANAS (Northeast Asia Nuclear Accident Simulator).

For the source-term estimation, design characteristics of each reactor type should be reflected into the model. Since there are a lot of reactor types in neighboring countries, the representative reactors of China, Japan and Taiwan have been selected and the source-term estimation models for each reactor have been developed, respectively [2]. For the atmospheric dispersion modeling, Lagrangian particle model will be integrated into the simulator for the long range dispersion modeling in Northeast Asia region.

In this study, the dose assessment model has been developed considering external and internal exposure.

2. Methods

Human body is affected by radioactive material through external and internal pathways of the body. The external exposure is composed of cloudshine and groundshine. Cloudshine and groundshine are exposure pathways from radioactive plume and contaminated soil, respectively. The internal exposure is made up of inhalation and ingestion.

2.1 External exposure

As a result of atmospheric dispersion modeling, the average concentrations of radionuclides in air (Bq/m^3) and ground (Bq/m^2) are printed out for each point. These outputs are used as an input of the dose assessment and dose conversion factors are also used as an input.

For external exposure, it is assumed that the receptor is exposed by semi-infinite cloud and infinite ground surface. Shielding effect is ignored on both pathways for conservatism. Exposure doses from cloudshine and groundshine are calculated by Equation (1) and (2), respectively.

$$D_{cl} = 10^3 \times T_e \times \sum_i (C_{a,i} \times DCF_{cl,i}) \quad (1)$$
$$D_{gr} = 10^3 \times T_e \times \sum_i (C_{g,i} \times DCF_{gr,i}) \quad (2)$$

where,
D : exposure dose (mSv)
T_e : exposure time (sec)
$C_{a,i}$: average air concentration of nuclide i (Bq/m^3)
$C_{g,i}$: average ground concentration of nuclide i (Bq/m^2)
$DCF_{cl,i}$: dose conversion factor of nuclide i for cloudshine (Sv/sec per Bq/m^3)
$DCF_{gr,i}$: dose conversion factor of nuclide i for groundshine (Sv/sec per Bq/m^2)

2.2 Internal exposure

Inhalation pathway uses the average concentrations of radionuclides in air and breathing rate of the receptor to calculate the exposure dose. Exposure dose from inhalation is calculated as Equation (3).

$$D_{in} = 10^3 \times BR \times T_e \times \sum_i (C_{a,i} \times DCF_{in,i}) \quad (3)$$

where,
D : exposure dose (mSv)
BR : breathing rate (m^3/sec)
T_e : exposure time (sec)
$C_{a,i}$: average air concentration of nuclide i (Bq/m^3)
$DCF_{in,i}$: dose conversion factor of nuclide i for inhalation (Sv/ Bq)

Compared to three other pathways, ingestion pathway is quite complicated. Amount of radionuclide in each food is estimated from the average concentration in air and ground surface with transfer coefficients considering radioactive decay. In this model, ingestion pathway is ignored for simplification.

3. Development of Dose Assessment Model

The dose assessment model is based on GUI (Graphical User Interface) and developed by C# language. The model is integrated into the simulator and Figure 1 shows the main screen of NANAS. Information of reactors in China, Japan and Taiwan such as location and power are predefined into database and they are shown as yellow pins on the map in Figure 1.

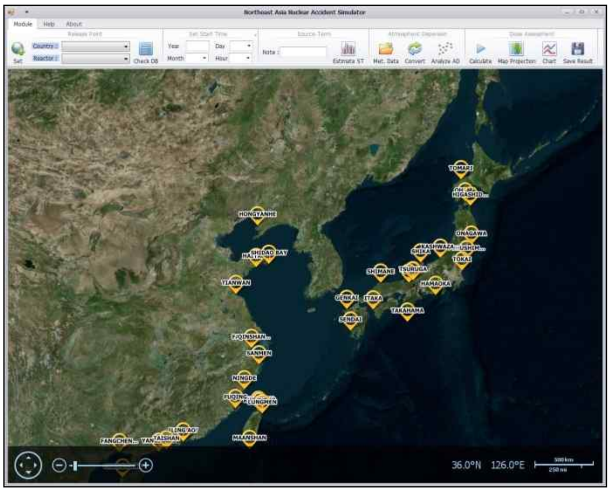

Fig. 1. Main Screen of NANAS

Except the concentration of radionuclide, all inputs such as dose conversion factors for each nuclide are stored in database as a format of MDB file.

As a result of dose assessment, effective dose and thyroid dose for each point are printed out by time step. The domain is limited as the region of Korean Peninsula and assessment points include major cities. Also, NANAS has the feature of chart drawing and map projection for dose results.

4. Sample Run

4.1 Source-term and Dispersion

The release point of sample run was set to Hongyanhe Unit 1 in China which is CPR1000 reactor type. 2,000 cm^2 of LOCA (Loss Of Coolant Accident) on cold leg and station blackout were postulated for 16 hours. The activities of 52 nuclides released into the environment were calculated by the source-term estimation model of NANAS. Figure 2 shows the output of source-term estimation for major nuclides such as Xe-133, I-131, Cs-137 and so on. Xe-133 recorded the most activity and it was released about 1.09E+07 TBq in total.

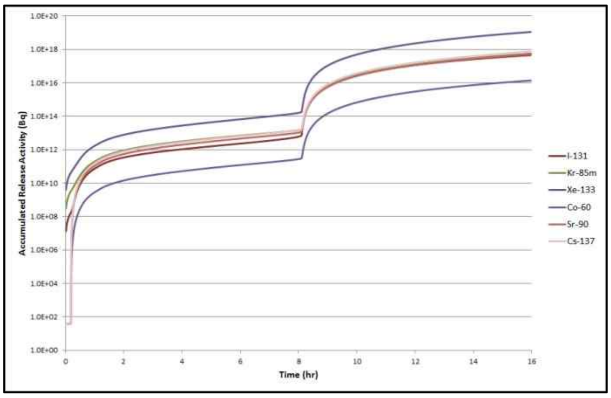

Fig. 2. Result of Source-term Release

GDAS meteorological data was used for the atmospheric dispersion model and the start time of calculation was set as 22 February 2016. The calculation period for atmospheric dispersion was set to 24 hours.

4.2 Result

For 24 hours, the maximum values of effective dose and thyroid dose were calculated as 1.09×10^{-3} mSv and 1.17×10^{-3} mSv, respectively. Figure 3 shows map projection on the result of dose assessment at the end of calculation time. The result shows that the major wind direction is west wind at the moment, so that the North Korea region is mainly affected by hypothetical accident.

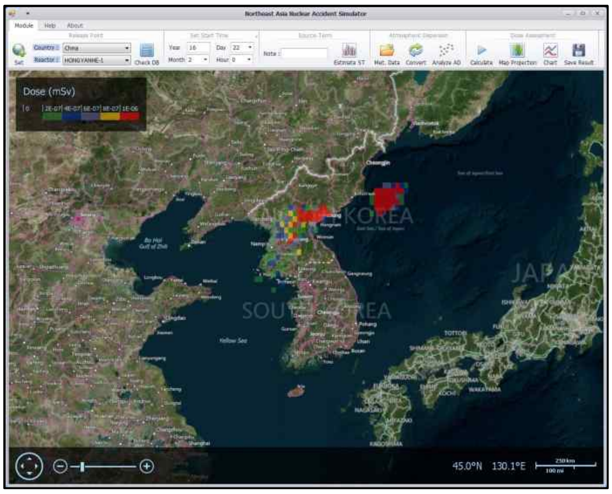

Fig. 3. Result of Dose Assessment

5. Conclusions

The dose assessment model has been developed as a part of the overseas nuclear accidents simulator which is named NANAS. It addresses external and internal pathways including cloudshine, groundshine and inhalation. Also, it uses the output of atmospheric dispersion model (i.e. the average concentrations of radionuclides in air and ground) and various coefficients (e.g. dose conversion factor and breathing rate) as an input. Effective dose and thyroid dose for each grid in the Korean Peninsula region are printed out as a format of map projection and chart. Verification and validation on the dose assessment model will be conducted in further study by benchmarking with the measured data of Fukushima Daiichi Nuclear Accident.

In addition to the dose assessment model, source-term estimation and atmospheric dispersion models were integrated into the simulator system. Therefore, the simulator system would swiftly simulate the whole process of hypothetical nuclear accident in neighboring countries including release of radioactive materials, atmospheric dispersion and radiological exposure.

The integrated simulator system would be utilized as training tool for emergency response staff and support the decision making of public protection.

ACKNOWLEDGMENTS

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