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Radiological Environmental Effects of Hypothetical Nuclear Accidents in Northeast Asia

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1. Introduction

Nuclear power plants (NPPs) around Northeast-Asia neighboring countries such as Japan, South Korea and China have developed huge concerns towards the public after the major nuclear accident at Fukushima in 2011. With aid of lessons learned from previous NPP accidents, radiological consequence analysis could be investigated and predicted for analysis of hypothetical accident. Analysing NPP of other neighbouring countries would be useful to calculate risks towards the public and environment in South Korea by using computerized software. In this study, NANAS (Northeast Asia Nuclear Accident Simulator) developed by Nuclear Safety and Security Commission (NSSC) in Korea was used to quantify the offsite radiological consequences and to examine the emergency protective measures for the general public in South Korea as it was developed specifically for Northeast Asia regions [1]. Dose assessments were determined in accordance with distance of dispersion and visualized through map projection and charts for specific regions. In this research scope, a few groups of radioactive nuclides (noble gases, halogens and alkali metals) were chosen in which considered to be released to the surroundings. NANAS consisted of three modules including source-term estimation, atmospheric dispersion prediction and dose assessment. For the prediction of atmospheric dispersion, NANAS used puff and lagrangian particle model embedded in HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model. HYSPLIT has been commonly used and worked best to calculate long range dispersion of radionuclides. Atmospheric dispersion was calculated by inputting several factors affecting the hypothetical accident such as source term, direction of release and atmospheric stability [2]. Simulation and analysis of dispersion of radioactive nuclides from NPP in China were investigated in order to study the impact towards South Korea peninsula for a hypothetical accident scenario. Furthermore, the results of simulation could facilitate offsite emergency planning for the public in general.

2. Methods and Results

Several important parameters were set up to simulate the radiological impact assessment of radioactive nuclides to the environment using NANAS.

2.1 Release point

In this study, a release point was chosen from Hongyanhe unit 4 NPP in China. This plant located in Donggang Town, Wafangdian in the Liaoning Province of China and it was a CPR1000 reactor. Hongyanhe unit 4 achieved first criticality on 5 March 2016, was connected to the grid on 1 April 2016, and entered commercial operation on 20 September 2016. This reactor was one of the closest reactors in distance to South Korea in which related to the main objective of this research scope, to analyse the risks towards public and environment. As shown in Fig. 1, 5 NPP reactors in Northeast Asia were found to be closed to South Korea.

Fig. 1. Nearest nuclear power plants surrounding South Korea.

2.2 Time and source term

In this study, simulations of NANAS using Fukushima accident source term was conducted for all four seasons as shown in Table I.

Table I: Source term used for the simulation

Nuclides	Total activity (Bq/h)
I-131	4.30E+12
I-132	2.83E+11
I-133	1.72E+06
Cs-134	2.43E+12
Cs-136	2.37E+11
Cs-137	2.32E+12

This option of hypothetical accident could be set manually using NANAS input deck of 7 days' simulation. Furthermore, GDAS meteorological data were used for the first week of July 2018 (for summer season) and first week of October 2018 (for autumn season) which could be freely downloadable from National Oceanic and Atmospheric Administration (NOAA). Consecutively, for winter and spring season, GDAS meteorological data for the first week of January 2019 and April 2019 were inputted, correspondingly. Deposition covered for a total 7 days of simulation according to each specific season with 3 hours' interval.

2.3 Deposition

During summer, spreading of nuclides could be seen in Fig. 2 directed to the northern area from the Hongyanhe NPP and did not affect South Korea.

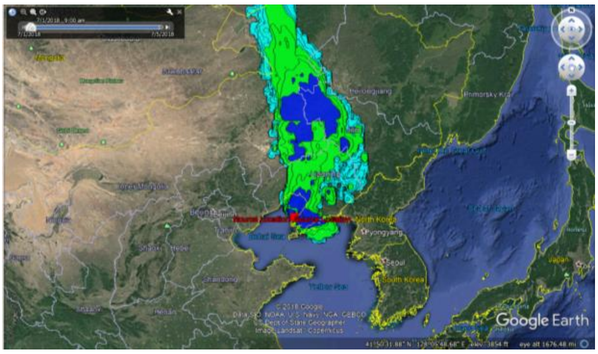

Fig. 2. Calculated deposition patterns for summer season (Google Earth 2018).

During autumn, spreading of radionuclides covered cities in South Korea as shown in Fig. 3. The wind-blown in the North-west direction from the point and affected South Korea for the first two days and spread to the north and south part of Korea.

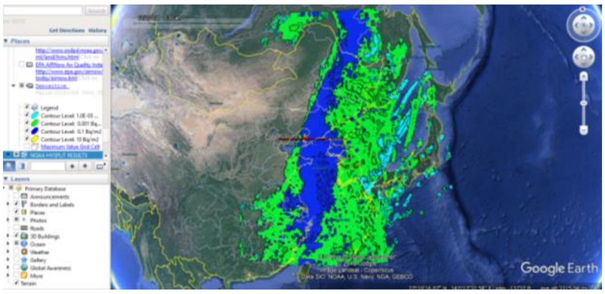

Fig. 3. Calculated deposition patterns for autumn season (Google Earth 2018).

During winter, spreading of radionuclides dispersed into South Korea affecting most cities as wind could be seen blown to the east and south part from the release point in China.

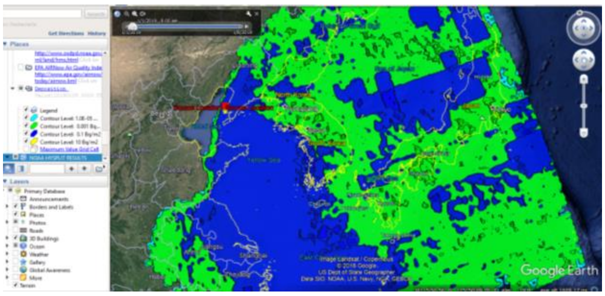

Fig. 4. Calculated deposition patterns for winter season (Google Earth 2019).

From Fig. 4 shown, even some cities in Japan were affected during this season. During spring, spreading of radionuclides distributed in direction towards the whole South Korea peninsula and Japan as shown in Fig. 5.

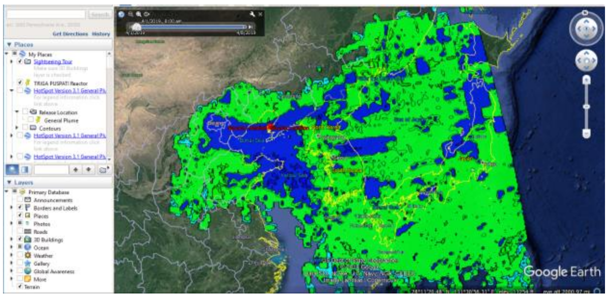

Fig. 5. Calculated deposition patterns for spring season (Google Earth 2019).

2.4 Dose assessment

After calculating the dose affecting the environment in South Korea, the results could be seen for each season separately in figures below. Note that only during summer, chart of dose assessment was not available as deposition of nuclides did not affect South Korea.

Fig. 6. Integrated effective dose with time at Seoul during autumn.

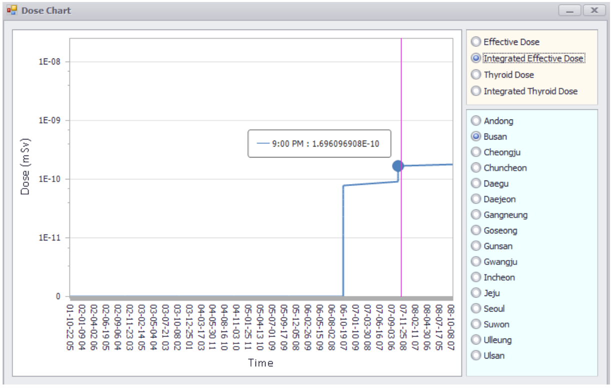

Fig. 7. Integrated effective dose with time at Busan during autumn.

As shown in Fig. 6 and 7, maximum value of integrated effective dose calculated were around $4.74{\times}10^{-7}$ mSv at approximately day 3 of simulations at Seoul and $1.69{\times}10^{-10}$ mSv at approximately day 6 of simulations at Busan.

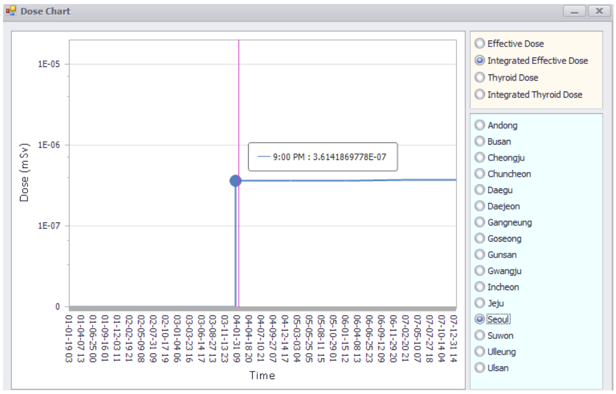

Fig. 8. Integrated effective dose with time at Seoul during winter.

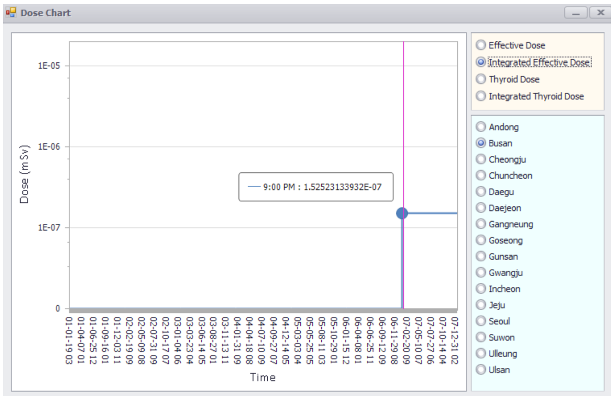

Fig. 9. Integrated effective dose with time at Busan during winter.

From Fig. 8 and 9, the value of integrated effective doses calculated at day 4 and 6 of simulations were $3.61{\times}10^{-7}$ mSv and $1.52{\times}10^{-7}$ mSv for Seoul and Busan cities during winter, respectively. Only two main big cities, one in the northern part (Seoul) and one in the southern part (Busan) were considered in this study as the deposition pattern could be seen covering the whole region of South Korea as shown earlier in Fig. 4. Wind direction during winter was found to move in the direction of in between south and east from west of Hongyanhe unit 4 NPP.

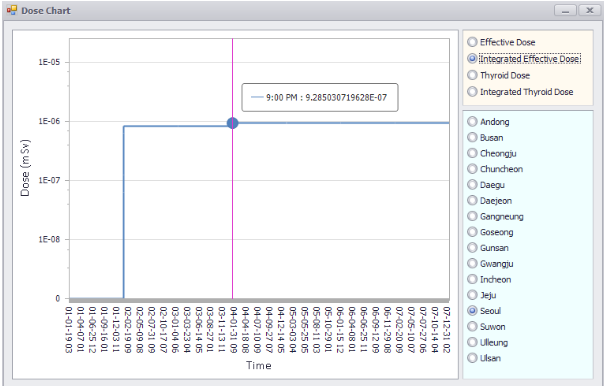

Fig. 10. Integrated effective dose with time at Seoul during spring.

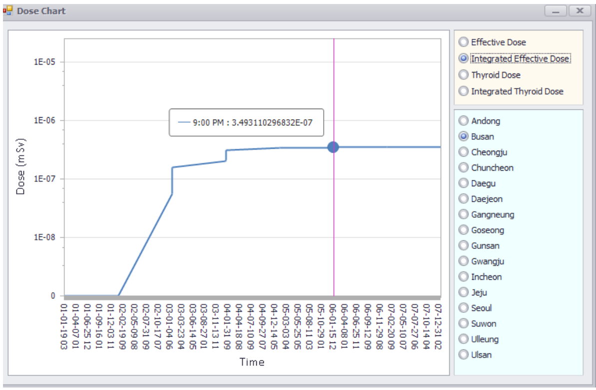

Fig. 11. Integrated effective dose with time at Busan during spring.

From Fig. 10 and 11, the value of integrated effective doses calculated were $9.28{\times}10^{-7}$ mSv and $3.49{\times}10^{-7}$ mSv for Seoul and Busan cities at day 4 and 6 of simulations during spring, respectively. The pattern observed was similar to winter in terms of deposition of nuclides spreadness. For the same reason, these two major cities were analysed and compared. As shown before in Fig. 5, spreading of nuclides affected Japan almost entirely and this contributed to higher dose reading in Busan during spring because wind direction was blown towards the south-east region.

3. Conclusions

For each season, it was found that spring posed the highest integrated effective doses of $9.28{\times}10^{-7}$ mSv and $3.49{\times}10^{-7}$ mSv in Seoul and Busan cities at day 4 and 6 of simulations. Consecutively, during winter, the value of integrated effective doses calculated were $3.61{\times}10^{-7}$ mSv and $1.52{\times}10^{-7}$ mSv for Seoul and Busan cities. However, during autumn, maximum value of integrated effective dose was around $4.74{\times}10^{-7}$ mSv at day 3 of simulations at Seoul city. According to simulation runs conducted in NANAS for 7 days using Fukushima source term with release point from Hongyanhe unit 4 NPP for summer, autumn, winter and spring, the likelihood of severity of accidents were coming from spring, autumn and winter season. During these season, major regions in South Korea with higher reading in Seoul areas were expected to pollute in case of accident and dispersion of radionuclides spread by the wind direction started from west towards in between south and east directions. Furthermore, according to the standards that have been enacted by the NSSC, urgent public protective actions of evacuation for short term protection should be carried out if the dose exceeded the limit of 50 mSv for 7 days but in this study the two highest doses calculated were 9.28×10^{-7} mSv during spring and 4.74×10^{-7} mSv during autumn at Seoul city which were very small and considered safe. In conclusion, these results could be used as an extra data to be compared with other research study to improve future research development and could help the offsite radiological consequence analyses in case of nuclear accidents in South Korea.

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