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ARTICLE

Analysis of Nuclear Accidents in Neighboring Countries of Korea

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Recent accident at Fukushima nuclear power plant in Japan raised a great concern about the safety of nuclear power plants and the radiological consequences. About twenty percent of the operating power plants in the world are located in north-east Asia. Nuclear accident is not a domestic matter but an international matter especially among neighboring countries. The purpose of this study is to understand the general behavior of the radiological materials and the radiation dose in Korea resulted from a nuclear accident in neighboring countries of Korea. We selected a nuclear power plant unit respectively from China and Japan. We suppose a severe accident releasing radiological materials to the environment and performed a plume dispersion simulation using HYSPLIT4, considering the seasonal weather. The results show that the radiation exposure doses in the most pessimistic case could reach the nuclear emergency level in Korea, such as the indoor sheltering and the restriction on food consumption and drinking water for the public, which is based on the ICRP recommendation. The long-range plume dispersion model for the decision supportive system should be established and improved in near future.

KEYWORDS: radiological emergency, radiation exposure dose, atmospheric dispersion, HYSPLIT

I. Introduction

About twenty percent of nuclear power plants in operation in the world are located in north-east Asia and it is expected that the number of nuclear power plants in Asia will be increasing as the electricity consumption increases more and more. Especially, China has an ambitious plan to construct over 100 nuclear power plants in the coming years. Because most of operating nuclear power plants in Asia are located in three countries such as China, Korea and Japan, the radiological risk to the public and the environment from the severe accidents is also increased. In Korea, most of the studies on the radiological consequences were oriented into the short range effect surrounding nuclear power plants until now. Meanwhile, Fukushima accident, which is considered as the worst case since the Chernobyl accident in 1986, occurred in 2011 and it is expected to be defined as level 7 after the IAEA International Nuclear and Radiological Scale (INES). This accident also aroused people the fact that the nuclear accident is not only a domestic matter but a trans-boundary matter among neighboring countries. So, the estimation of the long-range plume dispersion such as its trajectory, its air and ground concentration and doses to the public became to be very important and the establishment of long-range dispersion modeling system is strongly needed in near future. Using HYSPLIT4 (Hybrid Single-Particle Lagrangian Integrated Trajectories) developed by National Oceanic Atmospheric Administration (NOAA) in U.S, this study estimates the radiological consequences to Korea from the accidents in neighboring countries such as China and Japan.

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II. Radiological Consequences

HYSPLIT4 [1,2] is a complete system for computing simple air parcel trajectories to complex dispersion and deposition simulations. The initial development was a result of a joint effort between NOAA and Australia's Bureau of Meteorology. Some features include improved advection algorithms, updated stability and dispersion equations, and continued improvements to the graphical user interface. The dispersion of a pollutant is calculated by assuming either puff or particle dispersion. The model can be run interactively on the Web through the READY system or the code executable and meteorological data can be downloaded to a Windows. The registered PC version is complete with no computational restrictions, except that users must obtain their own meteorological data files. In this study HYSPLIT registered PC 4.9 version was used for the radiological materials trajectory.

Using the concentrations calculated by HYSPLIT, the doses are assessed as followings.

$$D_c = Q_{air} \times DCF_{cs} \quad \text{: cloud shine} \quad (1)$$
$$D_g = Q_{air} \times DCF_{gs} \quad \text{: ground shine} \quad (2)$$
$$D_i = Q_{air} \times DCF_i \times BR \quad \text{: inhalation} \quad (3)$$

where, D_c, D_g and D_i are doses from cloud shine, ground shine and inhalation respectively,

Q_{air} is the radioactivity concentration in air (Bq),
DCF_{cs}, DCF_{gs} and DCF_i are the dose conversion factors from cloud shine, ground shine and inhalation respectively,
BR is the inhalation rate (m^3/s)

Finally, the total dose can be calculated by

$$D_{tot} = D_c + D_g + D_i \quad (4)$$

The first nuclear power plant to be simulated is Tianwan in China, which is located about 600 km from south-western coast of Korea. It has 2 operating units of VVER type reactor, operating with 1000 MWe. The second nuclear power plant simulated is Shimane in Japan, which is located about 300km from south-eastern coast of Korea. It has 2 operating units of BWR type reactor.

Hypothesis for the estimation of radiological consequences is as follows. For the case of Chinese nuclear accident, the radiological materials started to be released at 0 o'clock, November 7th in 2010 as UTC time. The release height was about 50 m-AGL. We supposed a steam generator tube rupture accident. The source term consists of ^{131}I and ^{137}Cs, all of which are released during one hour with the rate of 1,000 g/hr and 50,000 g/hr respectively. This estimation of source term is based on the Probabilistic Safety Assessment report on Wooljin nuclear power plant on Korea and could be very conservative considering the amount of released radiological materials and its release duration.

Figure 1 and **2** show the radioactive materials trajectory and the radiological concentration change of ^{131}I with time. The concentration represents the relative values to 1 Bq/m^3 of source term. Because of the westerly wind from China to Korea, the trajectory from China shows a rather straight line and the earliest the radiological materials can arrive in Korea is in 18 hours.

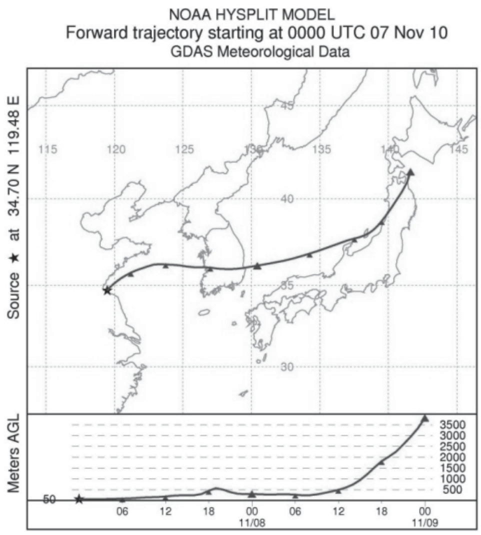

Fig. 1 Trajectory analysis for an accident in China.

For the case of Japanese nuclear accident, the radiological materials started to be released at 18 o'clock, April 10th in 2010 as UTC time. We supposed the same source term as in the case of China for convenience's sake and for the comparison of doses with the case of China.

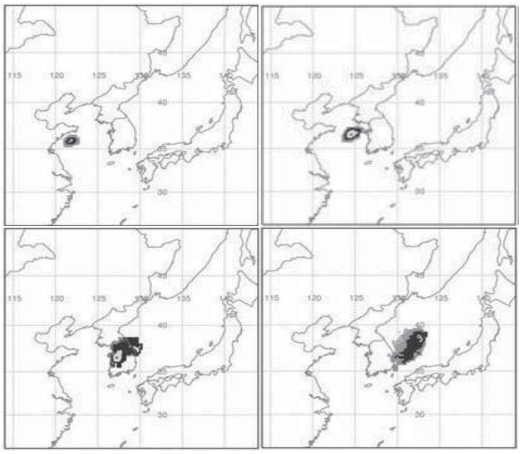

Fig. 2 Radiological concentrations following time change for an accident in China.

Figure 3 and **4** show the radioactive materials trajectory and the radiological concentration change of ^{131}I with time. On the other hand, the trajectory from Japan does not show a straight line, rather a rising curve which comes from the complex wind field produced by upward and downward winds between Korea and Japan. The earliest the radiological materials can arrive in Korea is about in 2 days, which is much longer than in the case of China.

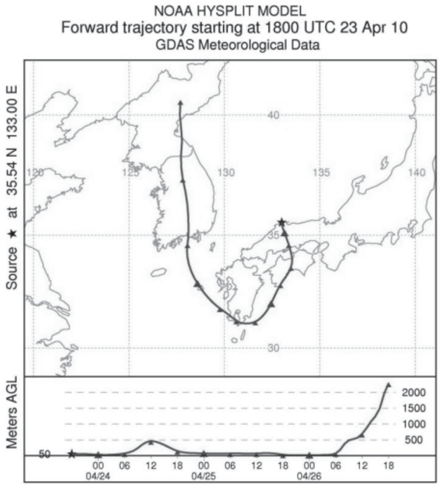

Fig. 3 Trajectory analysis for an accident in Japan.

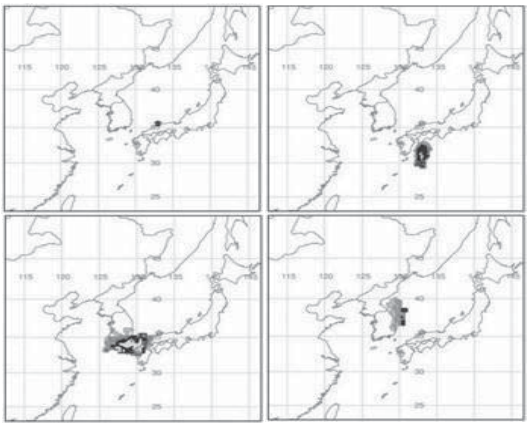

Fig. 4 Radiological concentrations following time change for an accident in Japan.

Figure 5 shows the environmental radioactivity monitoring system installed in Korea and the locations for the dose assessment by the simulation for each case. Table 1 and 2 also summarize the doses assessed from ^{131}I and ^{137}Cs in the location represented in the **Figure 5**. Total effective dose is assessed by summing the contribution from the external dose by ^{137}Cs and the internal dose by ^{131}I. The maximum dose in the case of China was estimated to be about 41.5 mSv in the ‘E’ area because of the high concentration of the ^{131}I, while the maximum dose in the case of Japan was about 0.45 mSv in the ‘F’ area.

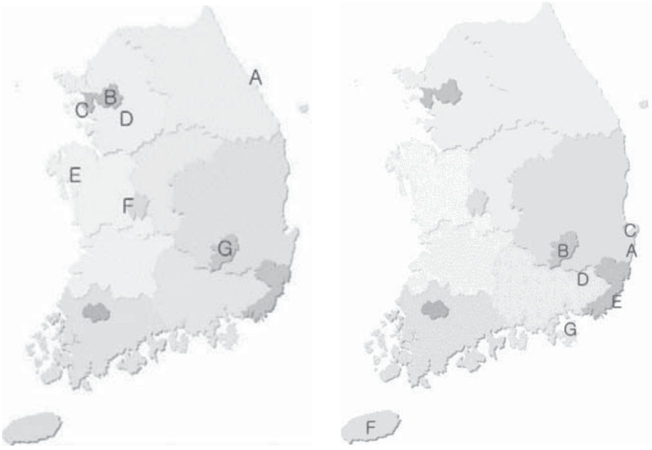

Fig. 5 Dose assessment locations for accidents in China (left) and Japan (right).

III. Conclusion

The radiological consequences estimated by HYSPLIT4 for the accidents in neighboring countries of Korea, China and Japan, show that the severe accidents from China could be more serious to Korea than those from Japan, because of the direct westerly wind from China to Korea. Consequently, the arrival time of radioactive materials is relatively short and the worst accident in China can result in the indoor sheltering, eventually even the temporary evacuation of people in terms of emergency response.

On the other hand, the radiological consequences from the accidents in Japan could be reduced by the local complex wind field between two countries and the arrival time of radioactive materials is also prolonged. The limitation of food consumption or drinking water would be also necessary for both cases, based on the ICRP recommendation[3]. It should be also considered that the source used for the simulation is taken from the most severe case, so that the calculated dose could be very pessimistic and conservative. Also, because the atmospheric dispersion model can normally show from 100% to a few 1000% errors, the estimation results should be always confirmed and assimilated by the real field measurement data.

Finally, the emergency planning and response until now is normally based on the one severe accident in a nuclear power plant site. As a lesson learned from Fukushima accident, we should also take into account of the multi-units accidents in one site to strengthen the emergency planning and response in the future.

References

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3) “Protecting people against radiation exposure in the event of a radiological attack”, ICRP 96 publication, 2004

Table 1 Dose assessed for an accident in China.

Doses (mSv)	Locations						
^{131}I	A	B	C	D	E	F	G
Whole body dose	4.22E-03	1.35E-01	1.61E-01	3.86E-01	1.50E-00	1.56E-02	2.22E-03
Thyroid dose	6.41E-01	1.62E+00	2.61E+00	1.89E+00	4.14E+01	2.40E+00	7.03E-01
^{137}Cs							
Whole body dose	3.03E-04	1.55E-02	1.71E-02	5.88E-02	3.68E-01	4.27E-03	2.81E-04
Thyroid dose	1.42E-03	3.96E-04	8.71E-03	9.63E-03	1.09E-01	4.87E-03	1.20E-02
Total effective dose	6.42E-01	1.62	2.62	1.90	41.5	2.40	7.15E-01

Table 2 Dose assessed for an accident in Japan.

Doses (mSv)	Locations						
^{131}I	A	B	C	D	E	F	G
Whole body dose	6.91E-03	1.97E-04	1.61E-02	6.95E-03	3.31E-02	4.96E-02	4.80E-03
Thyroid dose	3.38E-02	6.59E-05	1.07E-01	2.78E-02	2.21E-01	3.51E-01	1.90E-01
^{137}Cs							
Whole body dose	2.16E-02	3.59E-04	4.03E-02	8.61E-03	4.97E-02	3.51E-02	7.04E-02
Thyroid dose	1.47E-03	2.42E-06	2.85E-03	2.26E-04	3.68E-02	9.56E-03	1.22E-02
Total effective dose	6.37E-02	6.24E-04	1.66E-01	4.32E-02	3.40E-01	4.45E-01	3.20E-01