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Risk Analysis of Fukushima Accident using MACCS2

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1. Introduction

It has been three years since Fukushima Daiichi accident had occurred. Many efforts have been done for a restoration, however, radioactive materials are still released resulting in a crucial additional damage to a human health and economics and the scale of damage is not much evaluated. Therefore, an estimation of damage degree caused by the released radioactive materials right after a nuclear accident is essential to cope with additional radioactive problems.

Here, we report the risk analysis of Fukushima Daiichi accident using MELCOR Accident Consequence Code System 2 (MACCS2), which is the Nuclear Regulatory Commission's (NRC's) code for evaluating off-site consequences. It is used in level-3 Probabilistic Risk Analyses (PRA), for planning purposes, for cost-benefit analyses and so on [1]. The purpose of this study is to estimate radiological doses and health risks of Fukushima Daiichi accident through short- and long-term of lifetime using MACCS2.

2. Methods

MACCS2 analysis was performed to estimate the health effects, radiological doses, health risks, and economic costs which were caused by releases of radioactive materials to the atmosphere.

There are three modules in MACCS2 which are classified as ATMOS, EARLY, and CHRONC module. Firstly, the ATMOS module performs modeling and calculations, which consider dispersion and transport to the atmosphere and wet and dry deposition on the ground of radioactive materials. The ATMOS module uses Gaussian plume model for atmospheric dispersion of radionuclides. All of the source term data are included in the ATMOS module. Secondly, the EARLY module calculates impacts on the emergency phase. The EARLY module considers deterministic effects and mitigative actions based on the emergency phase results. Finally, the CHRONC module is for intermediate- and long-term phases and uses food chain model to obtain ingestion doses. The analysis period depends on the aim of calculation and can be changed by user [2].

In this study, core inventory and release fraction of Fukushima Daiichi NPP were estimated by released amounts, which were calculated by MELCOR, in four days after the accident occurred [3]. The released amounts of the radioactive materials are multiplication of core inventory and release fraction. Here we assumed that the release fraction was one, indicating that the released amounts were same with the core inventory.

Population data was based on population density at neighboring prefectures (i.e. Fukushima, Miyagi, and Ibaraki) of Fukushima NPP in 2010 from the Japanese National Statistical Office. The region within 80 km radius from Fukushima Daiichi NPP was divided by 10 concentric circles with different radius. The angular divisions of the region were sixteen with an angle of 22.5 degrees. Meteorological data with 8,760 records in 2010 was taken from the Japanese Meteorological Agency. The weather records include the wind direction, wind speed, precipitation and atmospheric stability. The atmospheric stability was conservatively assumed.

3. Results and Discussion

3.1 Comparison with measured doses

World Health Organization (WHO) has measured internal exposure doses on the thyroid for 1,080 children within 39~45 km region (i.e. Kawamata town, Iitate village, and Iwaki city) from Fukushima Daiichi NPP and on whole body for inhabitants in 20~45 km region (i.e. Kawamata town, Iitate village, and Namie) on March 2011. Thyroid doses based on the measurements were less than 10 mSv and whole body doses especially exposed by Cs-134 and Cs-137 were less than 1mSv. However, in vivo measurements were limited to internal exposure from inhalation [4].

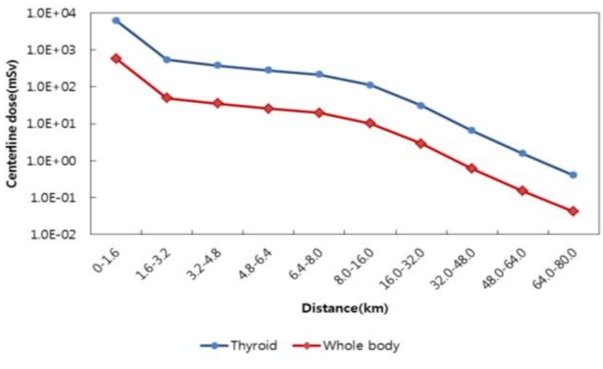

Fig. 1 Estimated doses as a function of distance from the release point. The centerline dose represents the maximum dose to an individual directly under the plume.

Occupational exposure doses of emergency workers of Fukushima Daiichi NPP were also assessed. The dose ranges of the emergency workers for thyroid and whole body were, respectively, 5~11,800 mSv and 6~590 mSv.

The maximum dose was from less than 1% workers, having worked very close to the Fukushima Daiichi NPP [5].

In this study, the emergency exposure of the inhabitants was estimated using MACCS2. The doses were limited to internal exposure from inhalation except for ingestion. Atmospheric dispersion of the radioactive materials was modeled by Straight-line Gaussian plume model. From Fig. 1, it was found that the estimated thyroid doses were about 6.4 mSv in 32~48 km region and the whole body doses were about 1.7 mSv within 16~48 km region. The monitored thyroid doses were higher than the estimated thyroid doses since targets were different. Targets were children for measurement and adults for estimation, and children are more sensitive than adults, resulting in higher doses [6]. However, when the estimated doses were compared with the monitored doses, the comparison was qualitatively conducted and a scope of both estimated and monitored doses was limited to inhalation exposure.

Thus, MACCS2 analysis was performed to estimate lifetime health risks, considering all exposure pathways such as cloudshine, groundshine, ingestion, inhalation, and skin deposition.

3.2 Health risk assessment

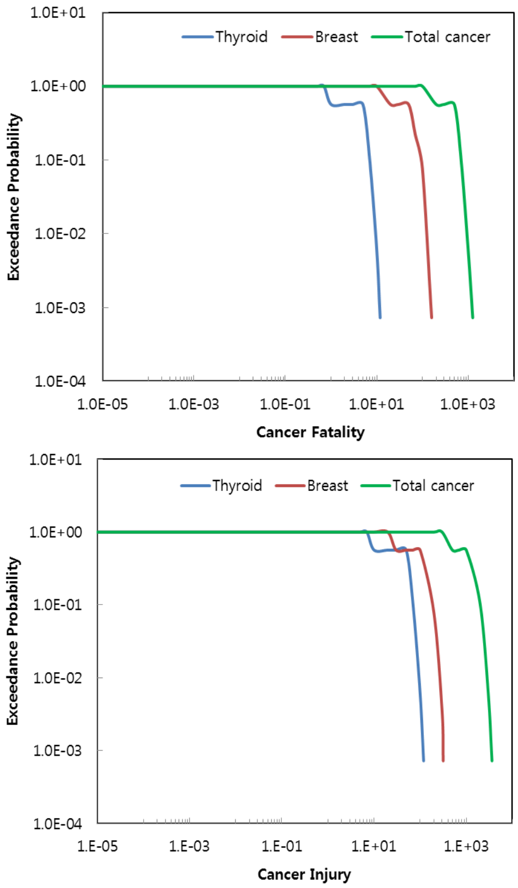

Fig. 2 The Complementary Cumulative Distribution Function (CCDF) of cancer fatality (top) and injury (bottom).

The probability was 0.567, causing more than one case of thyroid cancer fatality and 20 cases of breast cancer, respectively. In addition, both occurrence rates of more than 10 cases of thyroid cancer injury and 30 cases of breast cancer injury were 0.567.

Table 1: The population doses in exposure pathways

Exposure pathway		Population dose [man·mSv]
Emergency-term		1.40E+06
Long-term	Groundshine	6.97E+06
	Resuspension	0.03E+06
	Water ingestion	1.24E+06
	Milk ingestion	0.03E+06
	Grain ingestion	0.06E+05
	Other ingestion	0.08E+06
	Decontamination	0.43E+06
Total		1.02E+07

The population doses in the region were calculated, considering direct exposures, the ingestion of food and water, and decontamination work in table 1. The estimated average individual dose was 4.76 mSv, calculated by dividing the total population dose by the population in the region.

4. Conclusion

In summary, the health risk for inhabitants near Fukushima Daiichi NPP has been evaluated by considering the long term radiation effect using MACCS2 code. The result indicates that the occurrence and death rate of the cancer have been increased by the radioactive materials released from Fukushima Daiichi accident. The result obtained in this study may provide new insights for taking action after the nuclear reactor accident to mitigate the released radioactive materials and to prepare the countermeasure.

REFERENCES

[1] C.R. Molenkamp, N.E. Bixler, C.W. Morrow, J.V. Ramsdell, Jr., J.A. Mitchell, Comparison of Average Transport and Dispersion Among a Gaussian, a Two-Dimensional, and a Three-Dimensional Model, NUREG/CR-6853, 2004.

[2] Chanin, D., M.L. Young, and J. Randall, Code manual for MACCS2: Volume 1, User's Guide, Sandia National Laboratory, Albuquerque, USA, 1997.

[3] Nuclear Emergency Response Headquarters Government of Japan, Report of Japanese Government to IAEA Ministerial Conference on Nuclear Safety - Accident at TEPCO's Fukushima Nuclear Power Stations, 2011.

[4] World Health Organization, Preliminary Dose Estimation from the Nuclear Accident after the 2011 Great East Japan Earthquake and Tsunami, 2012.

[5] World Health Organization, Health Risk Assessment from the Nuclear Accident after the 2011 Great East Japan Earthquake and Tsunami based on a Preliminary Dose Estimation, 2013.

[6] George G. Killough, Keith F. Eckerman, Age and Sex-specific Estimation of Dose to a Normal Thyroid From Clinical Administration of Iodine-131, NUREG/CR-3955, 1986.