Numerical Simulation of a Tracer Experiment at the Wolsong Nuclear Site

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1. Introduction

Many field tracer diffusion experiments have been carried out in order to judge the effectiveness and availability for computer programs that analyze the air dispersion of radioactive materials released by environmental nuclear facilities. Few tracer experiments are implemented under weather conditions that are disadvantageous to air dispersion of the radioactive materials at the site of a nuclear facility. By comparing the concentration of a tracer measured under weather conditions that are disadvantageous to the dilution of radioactive materials released from the Wolsong Nuclear Power Plant, with the concentration of a tracer calculated using an air dispersion model, it is possible to evaluate the characteristics of the air concentrations of radioactive materials estimated with an air dispersion model, which can then be used in an environmental impact analysis of radioactive materials.

Therefore, a field dispersion experiment has been carried out to figure out the behavioral characteristics of the tracer under weather conditions that are disadvantageous to the dilution of radioactive materials released from the Wolsong Nuclear Power Plant site in Korea. In addition, through a comparison of the tracer concentrations estimated by the Gaussian plume model with measurements, this study checked the degree of conservative estimation for the Gaussian plume at the Wolsong nuclear site in Korea.

2. Methods and Results

2.1 Tracer Experiment

The field dispersion experiment was performed at the Wolsong Nuclear Power Plant. The Wolsong Nuclear Power Plant is located in a coastal area by the East Sea. The field dispersion experiment was conducted for an hour from 22: 30 on December 3, 2013, and SF_6 was used as the tracer. 150 sampling points were selected along with the roads, and samplers were allocated. Sampling was done at 10-minute intervals, and the concentrations were then analyzed using a gas chromatographer.

2.2 Air dispersion model

This study used the Gaussian plume model, and simulated a tracer dispersion to check the behavioral characteristics of radioactive materials at the Wolsong Nuclear Power Plant. Assuming that radioactive materials are continuously emitted at an identical rate for a certain period of time, the concentration of radioactive materials can be calculated based on the following Gaussian Plume model [1, 2].

$$C(x,y,z)=\frac{Q}{2\pi\sigma_y\sigma_z u_H}\exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left[\exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right)+\exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right)\right] \quad (1)$$

C : Air concentration of tracer (g/m^3), Q : Emission rate (g/s), σ_y, σ_z: Horizontal and vertical diffusion coefficients according to atmospheric stability (m), x : Downwind distance from the emission point (m), y : Vertical distance from the central line of the plume (m), u_H : Mean wind speed at the effective release height (m/s)
H: Effective release height (m). Pasquill-Gifford curve was used for the horizontal and vertical diffusion coefficients based on atmospheric stability.

2.3 Modeling of the Tracer Dispersion

Fig. 1 shows the distribution of tracer concentrations estimated using the meteorological data and emission rate. Fig. 1(a) used the meteorological data of one-minute intervals and Fig. 1(b) used the meteorological data of five-minute intervals. Fig. 1(a) shows the air concentrations of the tracer using the meteorological data of one-minute intervals. The maximum value was shown at a point that was 1,602m distant from the emission point in a southeast direction, and the value was 9.43E-6 g/m^3. On the other hand, Fig. 1(b) shows the air concentrations of the tracer using the meteorological data of five-minute intervals. The maximum value was shown at a point that was a distance of 1,594m from the emission point in a southeast direction and the value was 1.28E-5 g/m^3, which was higher by about 35% than the maximum value when meteorological data of one-minute intervals was used. This was because the low wind speed, which was less than 2.5 m/sec for 5-minute intervals, was distributed at a relatively higher level than at one-minute intervals. Looking at the sampling location indicated by the "+" mark in Fig. 1, the maximum value is located on the sea, which means a failure in sampling the maximum value. On the other hand, because the tracer sampling was conducted on the line that connects the emission point and the location of the maximum point, it was deemed that the captured sample in the connected line showed the maximum value among all samples.

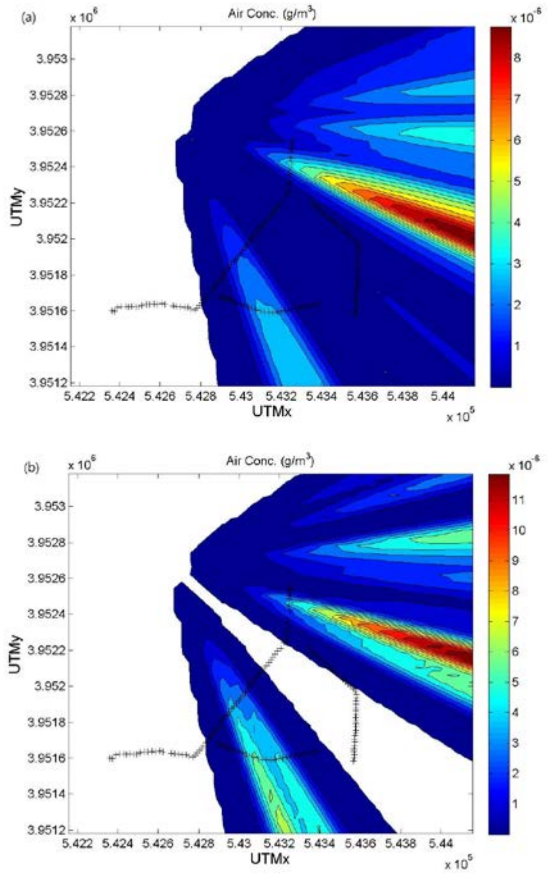

Fig. 1. Estimation of the tracer concentrations using the Gaussian plume model: (a) meteorological data of one-minute intervals, and (b) meteorological data of five-minute intervals.

Fig. 2 shows the air concentrations of the sampled tracers on the main road of the Wolsong nuclear site, located vertically in the wind direction, and the estimated concentration using the Gaussian plume model. In both cases of the meteorological data used, one-minute intervals and five-minute intervals, are shown in bimodal form. This was because the two major plumes were located on the sampling points. Overall, it was deemed that the estimated air concentrations of the tracer, indicated using the meteorological data at one-minute intervals, are closer to the measurements. However, the concentration of the tracer that was sampled at a low peak was significantly different that the estimated concentrations by the Gaussian plume model based on the meteorological data of both one-minute intervals and five-minute intervals. We assumed it was because the nuclear reactor buildings and accessary buildings are located between the sampling point of the first peak and the emission point. According to Jeong et. al. [3], Canepa [4], and Mavroidis et. al. [5], if the buildings, which are obstacles for a plume pass, are located in the central line of the plume, the concentration of pollutants would increase more at the leeward side of the buildings owing to the plume stagnation. However, the farther the plume moves away

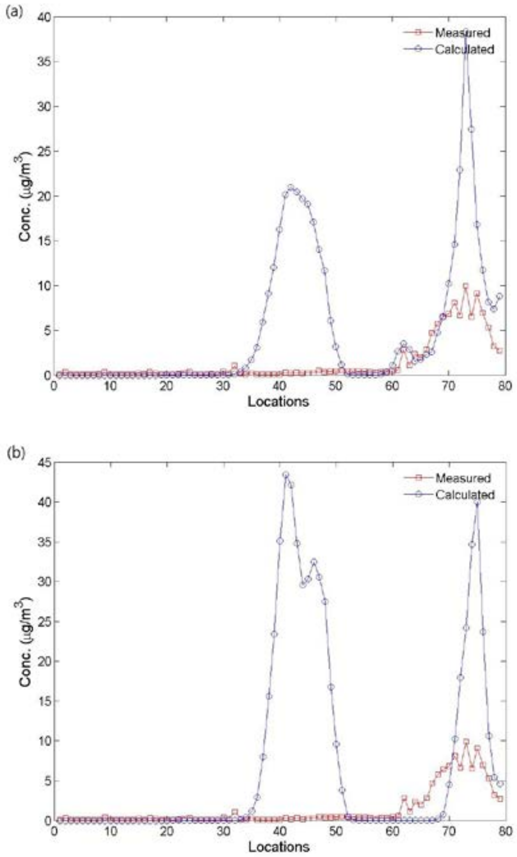

Fig. 2. Comparison of the measurements with the estimated concentrations using the Gaussian plume model: (a) meteorological data of one-minute intervals, and (b) meteorological data of five-minute intervals.

from the buildings, the lower the concentration of the pollutants will be owing to the "wake phenomenon" of the plume. This study also showed the wake phenomenon being present when the plumes passed through the nuclear reactor buildings and auxiliary buildings, all of which led to a very low concentration of pollutants at the sampling points.

3. Conclusions

A tracer dispersion experiment using an SF_6 trace was implemented to determine the dispersion characteristics of radioactive materials at the Wolsong Nuclear Power Plant site in Korea. Based on meteorological data and the emission rate of the tracers, this study estimated the tracer concentrations using a Gaussian plume model, and then compared it with the measurement to check the conservative estimation of the Gaussian plume model. The measured concentrations of the tracer tends to be lower than the concentrations estimated by the Gaussian plume model overall. Most computer programs that estimate the air dispersion of radioactive materials to obtain the licensing approval for a nuclear power plant in Korea are at present based on a Gaussian plume model equation. Therefore, a radiological environmental impact assessment on radioactive materials using such computer programs has sufficient conservatism in assessing the health risk of the residents near a nuclear power plant.

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