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Simulation of the Dispersion of Radioactive Effluents over the Kori site using Field Tracer Experiment

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Field tracer experiments have been conducted at the Kori nuclear site for the purpose of analyzing the site-specific atmospheric dispersion characteristics and validating a real-time radiological dose assessment system FADAS. Field tracer experiments were performed for three years from 2000 to 2002. Tracer gas SF_6 was released at the top of the meteorological tower of the site and sampled by 140 automatic sequential gas samplers. The samplers were disposed at sampling points along the traffic roads around the site. The coordinates of all the sampling points were investigated by GPS. The concentration of the sampled gas was analyzed by gas chromatography. And the measured concentration distribution was compared with the distribution simulated by FADAS. During the experiments, meteorological data was measured at several sampling points including the release point. The measured meteorological data were used for the numerical simulation by FADAS. The comparative study between the measured and the simulated concentration was conducted. Due to the effects of the complex terrain of the Kori site, the degree of agreement between the measure and the simulated concentration is somewhat lower than that of the site of a flat terrain. The analysis of the site-specific field tracer experiment provides the useful information for the realistic application of an atmospheric dispersion model for a nuclear site.

KEYWORDS : atmospheric dispersion, field tracer experiment, meteorological data

I. Introduction

Ensuring radiation safety is essential for a continuing nuclear industry. The defence-in-depth policy is adopted in a nuclear power plant. Emergency planning is one part of the defence-in-depth for minimizing the radiological consequences resulting from a nuclear accident[1]. To estimate the trajectory of the released radioactive materials and the following radiological dose is the basis of emergency planning. Atmospheric dispersion of radioactive materials is dependent on the environmental characteristics. Therefore it is required to develop a site-specific radiological dose assessment system.

A real-time radiological dose assessment system FADAS (Following Accident Dose Assessment System) has been developed[2,3]. FADAS has been used as a basic tool for providing the function of the atmospheric diffusion and the radiological dose assessment for the national radiological emergency preparedness system CARE (Computerized technical Advisory system for Radiological Emergency) since 1998[4]. FADAS is composed of several modules; a mass-consistent wind field module for generating a wind field using several measured wind data, a random-walk dispersion module for calculating the distribution of the radioactive materials in the atmosphere, and a dose estimation module in which the volume-equivalent numerical integration method is used for assessing the external gamma exposure given from the randomly distributed radioactive materials[5].

Large-scale field tracer experiments have been conducted over nuclear power plant sites in Korea since 1996[3]. These experiments have been conducted for analyzing the site-specific atmospheric dispersion and the applicability of FADAS to the sites. There are four nuclear sites in Korea. Younggwang site is located in the west side and the others (Kori, Wolsung, Ulchin) are located in the east side. Younggwang site is relatively flat compared with the others located in the east side. From 2000 to 2002, six field tracer experiments had been conducted at the Kori site. A tracer gas SF_6 was released at the top of the meteorological tower of a 58 m height. Tracer gas was sampled by 140 automatic sequential air samplers and the concentration was analyzed using a gas chromatography. During the experiments, meteorological data was measured at several points with the measuring equipment such as a portable wind system, Air Sonde and SODAR. The measured wind data was used as the input data of FADAS for the numerical simulation of the concentration distributions of the tracer gas. The comparative study between the measured and the simulated concentration was conducted. The analysis of the site-specific field tracer experiment provides essential information for the realistic application of an atmospheric dispersion model.

Due to the lack of space, the results of the 4th experiment among the six experiments conducted at the Kori site was described. The reasons why the 4th experiment was selected are the low missing rate of air sampling and the simple pattern of the measured meteorological data during the experiment.

This paper describes the process and results of the 4th tracer experiment among the six conducted at the Kori site. The analyzed environmental characteristics of the site and the comparative study between the measured and the simulated are reported.

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II. Experimental Details

1. Description of Kori Site

The Kori site is located at the bottom of the protrusion and is surrounded by the sea on three sides, with bordering land on the north side as shown in **Figure 1**. In this figure, the bold lines represent the traffic roads on which the air samplers were disposed. Along the lines, about 140 automatic gas samplers were disposed for sampling.

Weather conditions are important in field experiments. Annual wind data of the Kori measured in 2000 was analyzed and represented as wind rose as in **Figure 2**. The prevailing winds are from the northwest. The seasonal averaged wind speeds are 5.1 m/sec in spring, 4.7 m/sec in summer, 4.3 m/sec in autumn and 4.3 m/sec in winter. The annual average wind speed on the other three sites is about 3 m/sec.

2. Release and Sampling of tracer gas

Field experiments were conducted at the Kori site during 2000 and 2002. **Table 1** represents the information on the tracer gas release and the sampling of each experiment in detail. Sulfur hexafluoride (SF_6) which is extremely stable in the environment was used as a tracer gas[6]. And the other reasons to use the gas are reasonable cost, easy-to-sample and high sensitivity to electron capture detector (ECD). Release rate of the tracer gas was calculated considering the background concentration of SF_6 in the atmosphere and the detection limit of the gas chromatography[7].

For theses experiments, automatic sequential air samplers were designed and manufactured as shown in **Figure 3**.

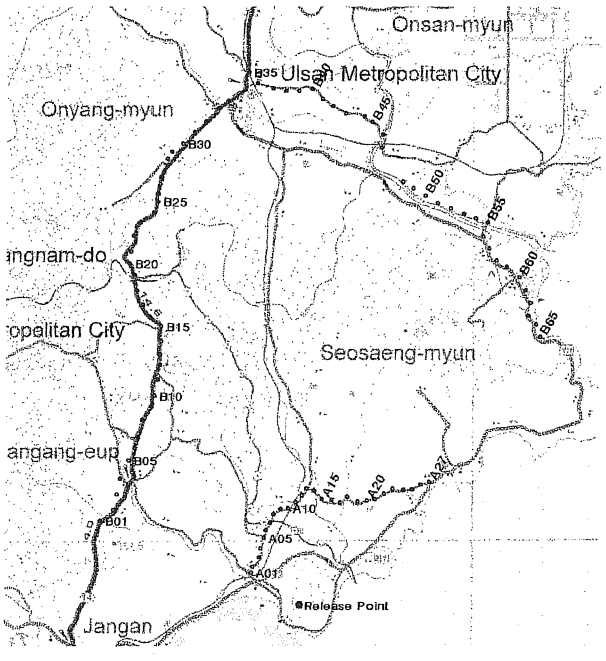

Fig. 1 Map of the Kori site (x-y : 14 x 15 km^2) (A and B line represents the inner and the outer sampling line, respectively.)

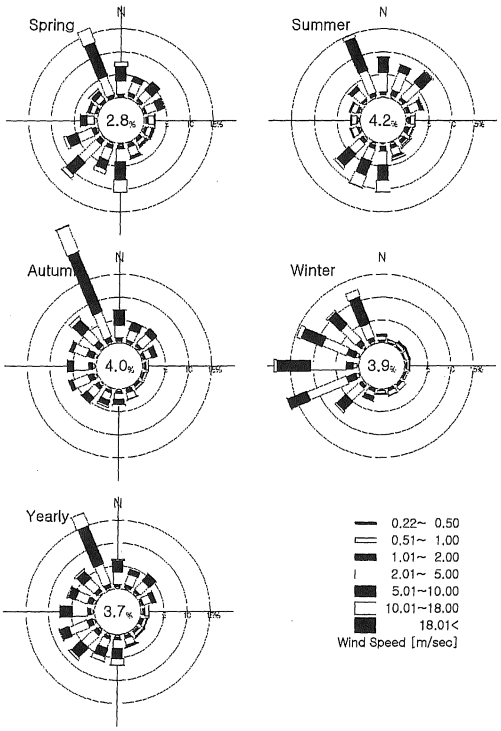

Fig. 2 Wind rose of Kori Site

The automatic sequential air sampler is composed of three main parts; air distributor, control module, and the support which includes the intake and the case. An air distributor supplies the sampled tracer gas to each sample bag according to the sampling protocol. The control module is a printed circuit board with which the starting time and the duration of sampling, and the rate of intake are programmed. Saran bags were used for sampling the tracer gas. Each sampler contained six Saran sampling bags. The duration of sampling per each sample bag was set to 10 minutes.

Table 1 Details of the field experiments

No	Date	Release	Sampling	Release Rate (kg/hr)	Total (kg)
#1	2000/ 06/07	11:30-13:00 13:00-13:30 13:30-15:17	14:00-15:00	37.35 62.25 124.50	309.18
#2	2000/ 06/08	10:30-13:00	12:00-13:00	66.53	166.33
#3	2001/ 05/31	12:30-16:00	15:00-16:00	75.97	265.91
#4	2001/ 10/16	10:00-13:30	12:30-13:30	78.21	273.74
#5	2002/ 05/21	11:30-13:30 13:30-15:30	14:30-15:30	50.22 100.44	301.33
#6	2002/ 05/22	12:00-15:30 15:30-15:43 15:43-15:54	15:00-16:00	108.12 81.09 54.06	405.91

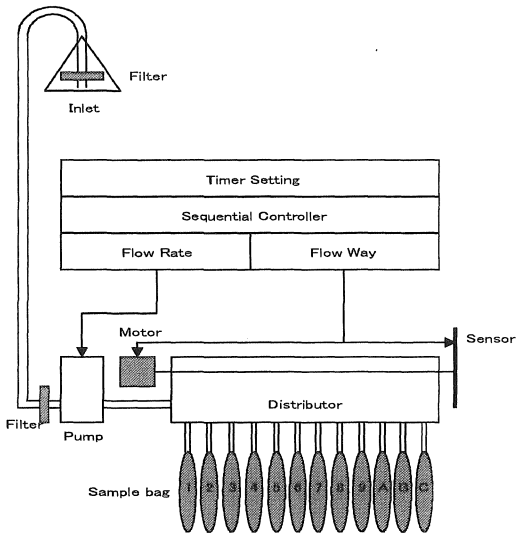

Fig. 3 Schematic diagram of Air Sampler

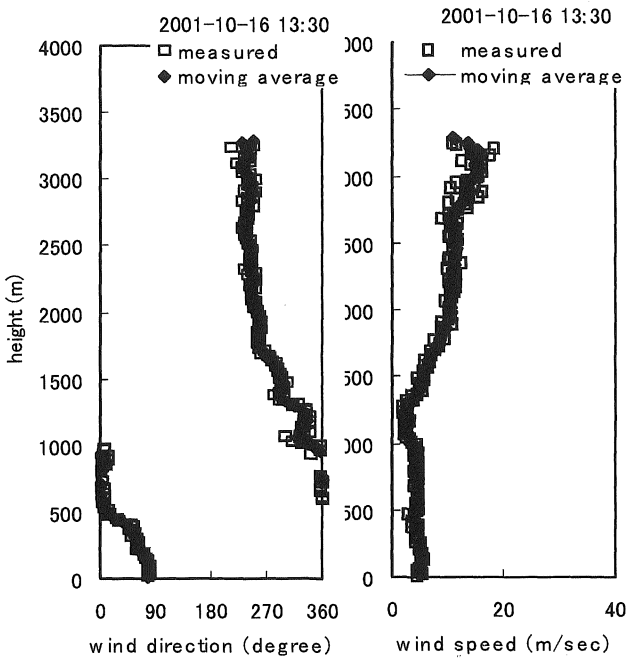

Fig. 4 Profile of wind direction and speed

The sampling points were selected along the two arc line of the roads around the site and the coordinates of each point were investigated by GPS. In the case of the Kori experiment, the radius of arc lines are about 1.5 ~ 4 km for inner (A-) line and 5 ~ 13 km for outer (B-) line.

3. Measurement of Meteorological Data

Meteorological data measured over the domain of the field experiment is important for the realistic simulation of the atmospheric dispersion of the released tracer gas. Meteorological data such as wind speed, wind direction, temperature and humidity were measured using the SODAR, Air Sonde system and portable wind systems. **Figure 4** represents the profile of the wind data measured using the Air Sonde system in October 2001. It shows the drastic change of wind direction at a 1 km height. **Table 2** represents the meteorological data measured at the meteorological tower of the Kori site. It shows that the prevailing wind was blown from East with low wind speed of about 2 m/sec. And neutral condition of atmospheric stability was represented during the experiment.

The measured meteorological data were used for generating wind fields over the domain of the experiment using FADAS.

III. Results and Discussion

For the simulation of the dispersion of the released tracer gas, the domain was considered to consist of the cell with the size of $\triangle x = \triangle y = 1$ km, and $\triangle z = 30$ m. The σ - coordinate system was adopted in this simulation to consider the effects of topography. **Figure 5** shows the simulated result of the distribution of the released tracer gas in the case of the 4th experiment.

Figure 6 represents a figure of the measured and the simulated concentration distribution along the inner line of the 4th experiment. In this figure, the horizontal line and the vertical line represent the angle from the north direction and the concentration of SF_6, respectively. It shows a good agreement in the angle in which a peak concentration is represented. The good agreement between the measured and the simulated concentration distribution is due to the simple pattern of the meteorological data during the experiment.

The comparative study shows that a good agreement between the measured and the simulated concentration is obtained in the case of the experiment over a flat terrain. In the case of a flat terrain, the realistic wind fields might be generated with the wind data measured at several points.

Table 2 Meteorological data measured at the release point

Time	Wind Direction *	Win. Speed (m/sec)	Atmospheric. Stability
10:00	82.4	1.13	B
10:15	83.8	1.40	D
10:30	65.8	0.81	B
10:45	82.7	1.53	D
11:00	84.7	1.72	B
11:15	86.7	1.86	D
11:30	91.9	1.49	D
11:45	91.2	1.42	D
12:00	95.4	2.30	D
12:15	107.7	1.22	D
12:30	92.4	2.33	D
12:45	87.1	2.35	D
13:00	94.9	2.15	D
13:15	85.7	2.31	D

(*: Azimuth angle, N=0,E=90,S=180,W=270)

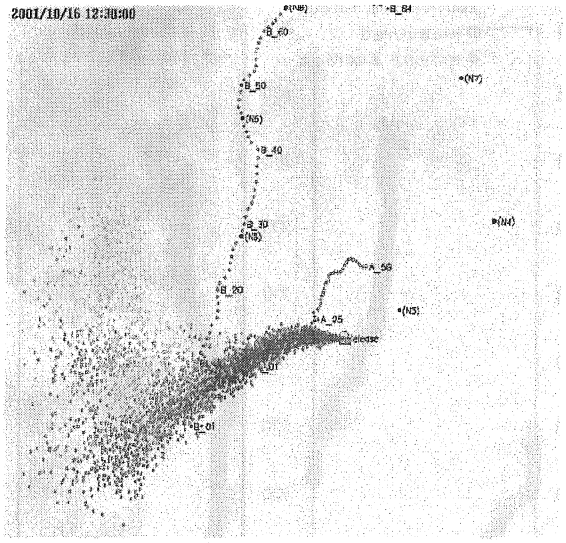

Fig. 5 Simulated distribution of the released tracer gas

But in the case of a complex terrain, it is difficult to generate the realistic wind field with the measured meteorological data. Therefore, for the experiments over the complex terrain, obtaining enough wind data is essential for the realistic estimation of the atmospheric dispersion of the tracer gas.

Ⅳ. Conclusions

The methodology and the results of the field tracer experiment conducted at the Kori nuclear power plant site was reported. Field tracer experiments were conducted at the Kori site for the purpose of analyzing the site specific atmospheric dispersion characteristics. The concentration distributions along the arc lines on which the automatic gas samplers were positioned were analyzed using a gas chromatography. The measured atmospheric concentration distribution was compared with the distribution simulated by a real-time radiological dose assessment system FADAS.

The Kori site is located at the bottom of the protrusion and three sides are bordered by the sea. The measured wind data showed a complicated pattern compared with those obtained at the Younggwang site of flat terrain. Due to the complicated wind conditions, the degree of agreement between the measure and the simulated concentration at the Kori site is somewhat lower than at the Younggwang.

The analysis of the site-specific field tracer experiment provides the essential information for the realistic application of an atmospheric dispersion model for a nuclear site. And the technology developed through the experiments could be used in non-nuclear fields such as the safety assessment of chemical facilities.

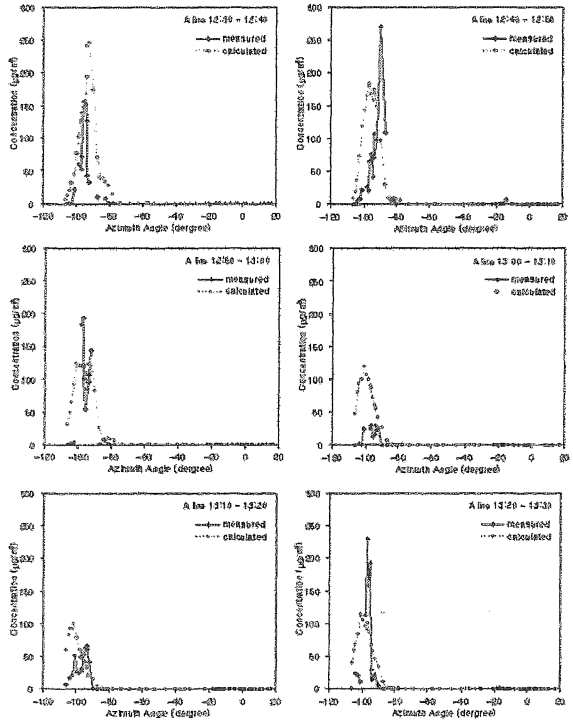

Fig. 6 Concentration distribution along the inner line (A-line). (Azimuth angle "0" represents the North)

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