Effect of the Duration of Meteorological Data Collection on the Atmospheric Dispersion Assessment

Yoo-mi Choi, Eun-hee Kim*
Nuclear Engineering Dept., Seoul National Univ., 1 Gwanak-ro, Gwanak-gu, Seoul, 151-744, Korea
**Corresponding Author: eunhee@snu.ac.kr*

1. Introduction

In Korea, Nuclear Safety Commission noticed that at least 1-year meteorological data should be used in assessing the environmental effect by gas release during normal operation for a construction permit of nuclear facility and 2-year meteorological data should be used for an operating license [1]. Recently, the revaluation of derived release limit for HANARO was performed by employing 5-year meteorological data [2].

The atmospheric dispersion factor χ/Q is defined as the ratio of the radioactivity concentration χ in air to the activity release rate Q from a source stack. The χ/Q informs the environmental impact of radioactive gas release from nuclear facilities. In case of continuous radioactive gas release from a nuclear facility under normal operation, the wind direction, wind speed and atmospheric stability determine the dispersion of the released radioactivity.

This study regards the duration of meteorological data record for a prospective assessment of the environmental impact of gas release from Kori nuclear power plant under normal operation. We compared the atmospheric dispersion factors obtained by employing the meteorological data from 2- and 5-year durations with the corresponding values obtained by employing yearly meteorological data in the period of 2001 to 2008.

2. Methods and Results

2.1 Calculation of Long-term Atmospheric Dispersion Factor

Since meteorological state keeps changing, the atmospheric dispersion factors should be estimated on the basis of a long-term data on meteorological condition. In this study, the CAP88-PC (version 3.0; EPA National Computer Center in Research Triangle Park, NC) program was used to calculate long-term average atmospheric dispersion factor. The program employs a modified Gaussian plume equation given by [3]

$$\chi(x,y,z;H)=\frac{Q}{2\pi\sigma_y\sigma_z\mu}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right]+\exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\} \qquad (1)$$

where $\chi(x,y,z;H)$ is the radioactivity concentration [Ci/m^3] in air at a downwind distance x [m], a crosswind distance y [m], and a vertical distance z [m]. Q is the radioactivity release rate [Ci/sec] from a stack; H is the effective stack height [m]; and μ is the wind speed [m/s]. The parameters σ_y and σ_z are horizontal and vertical dispersion coefficient [m], respectively. Dispersion coefficients are determined by the atmospheric stability classified according to the vertical temperature gradient.

Applying the equation (1), the atmospheric dispersion factor at ground level (z=0) averaged for 22.5° sector in horizontal direction becomes: [3]

$$\frac{\chi}{Q}=\frac{1}{0.15871\pi x\sigma_z\mu}\exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \qquad (2)$$

The input data for CAP88-PC simulation is the joint frequency distribution table of wind speed class, wind direction, and atmospheric stability class derived from meteorological data in the site of interest. Figure 1 shows the wind roses of yearly meteorological data from 2001 to 2008 in Kori site. The stack height was assumed to be 58 m, which was the same as the height of wind monitoring. The other conditions such as temperature, absolute humidity, stack diameter and release rate were set at the default values provided in the program. The χ/Q values were calculated at distances of up to 20 km from the stack in all the sectors of horizontal direction.

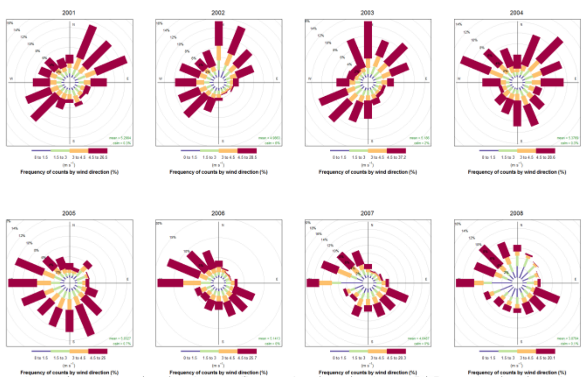

Fig. 1. Annual wind roses in Kori site recorded at 58m from 2001 to 2008.

2.2 Wilcoxon sign ranked test

The comparison of the atmospheric dispersion factors based on the meteorological data collected from different durations was made by employing the Wilcoxon sign ranked test. The 2- and 5-year data sets were compared with the data sets based on every yearly meteorological record. The statistical analysis program was R version 3.3.2. The null hypothesis was that there was no significant difference between the χ/Q values from 2- or 5-year meteorological data and the yearly meteorological data. Table I lists the p-values of the test at distances of every 1 km up to 20 km. The p-values were rounded to two significant figures. At 95% confidence level, one can judge with a p-value less than 0.05 that there is a significant difference between the χ/Q values based on 2- or 5-year data and the yearly meteorological data. The shaded cells in Table I have the p-values larger than 0.05. The cells belonging to 2002-2003 period group have the largest number of yearly data for p-values greater than 0.05 whereas the cells belonging to 2003-2004 period group have all the yearly data for p-values less than 0.05. Regarding the cells belonging to 5-year period groups, the largest number of shaded cells was counted in the 2001 to 2005 period group whereas the smallest shaded cells in the 2004 to 2008 group. Table II lists the p-values of the test at distances of every 1 km up to 10 km. The distribution of shaded cells in Table II is not the same as but similar to that in Table I.

3. Conclusion

Influence of the duration of meteorological data collection on short-term atmospheric dispersion factors was previously studied [4]. In this study, long-term dispersion factors were assessed to investigate the influence of the duration of meteorological data collection on the assessment of environmental impact by gas release from Kori nuclear power plant under normal operation. We counted how many yearly meteorological conditions would be represented by 2 or 5 years of long-term data collection. The distribution of shaded cells in Tables I and II indicated that some of the yearly meteorological condition could be properly represented by the conditions averaged over 2- or 5-year durations. Overall, 5 years of meteorological data collection seems more preferable to represent the yearly meteorological condition in assessing the environmental impact by gaseous release from Kori site during the period of 2001 to 2008.

Table I: The p-values of Wilcoxon paired test for atmospheric dispersion factors at the same locations of up to 20 km

	2-year period group							5-year period group			
	01-02	02-03	03-04	04-05	05-06	06-07	07-08	01-05	02-06	03-07	04-08
2001	3.4E-01	4.6E-01	4.8E-04	2.5E-01	5.9E-03	1.2E-03	3.7E-07	2.3E-01	2.2E-02	5.6E-03	9.5E-04
2002	5.2E-01	4.7E-01	2.1E-03	5.7E-02	4.2E-02	3.0E-03	1.0E-06	2.6E-01	3.6E-01	3.6E-02	3.2E-03
2003	1.0	6.2E-01	2.7E-04	3.1E-02	6.8E-01	7.9E-02	3.0E-05	2.6E-01	3.6E-01	8.1E-01	2.2E-01
2004	1.3E-06	1.1E-06	2.5E-06	7.0E-06	1.8E-05	1.4E-06	1.7E-10	8.3E-07	8.9E-07	8.0E-08	1.3E-08
2005	3.4E-01	3.8E-01	2.3E-02	2.9E-04	1.9E-04	1.9E-07	2.1E-14	6.3E-02	2.3E-01	1.8E-01	6.0E-05
2006	2.4E-02	1.4E-01	9.6E-04	1.1E-07	4.1E-04	2.6E-13	4.8E-14	7.9E-03	9.5E-03	1.5E-01	2.2E-01
2007	2.6E-04	1.4E-03	2.9E-06	1.6E-10	1.9E-11	4.1E-11	8.6E-02	2.0E-05	3.2E-06	6.1E-07	2.0E-05
2008	8.7E-13	3.1E-12	2.6E-19	2.5E-20	2.2E-10	6.9E-05	1.9E-01	3.6E-19	3.8E-23	1.7E-19	5.2E-14

Table II: The p-values of Wilcoxon paired test for atmospheric dispersion factors at the same locations of up to 10 km

	2-year period group							5-year period group			
	01-02	02-03	03-04	04-05	05-06	06-07	07-08	01-05	02-06	03-07	04-08
2001	1.5E-01	5.9E-02	3.7E-06	1.6E-01	1.6E-03	2.1E-03	1.1E-05	5.2E-01	2.6E-02	4.6E-03	1.8E-03
2002	5.6E-02	3.9E-01	1.0E-02	3.5E-01	1.4E-02	1.0E-03	9.1E-06	6.8E-01	1.2E-01	6.2E-03	5.4E-04
2003	5.0E-02	6.4E-01	1.8E-01	6.6E-01	5.7E-01	5.9E-02	2.1E-04	1.7E-01	7.7E-01	4.7E-01	1.3E-01
2004	2.6E-26	1.0E-25	2.8E-26	3.8E-26	8.9E-19	7.6E-22	8.1E-32	6.6E-27	5.3E-27	1.9E-28	6.9E-30
2005	9.4E-02	1.3E-01	6.9E-03	7.9E-04	2.8E-05	5.6E-08	1.2E-11	2.4E-02	8.3E-02	2.7E-01	7.4E-05
2006	4.5E-02	1.2E-01	1.8E-03	1.2E-05	1.2E-04	1.4E-15	3.1E-15	3.2E-02	4.0E-02	8.0E-01	5.4E-03
2007	7.7E-04	7.9E-04	4.3E-06	9.5E-09	1.3E-11	3.0E-12	7.4E-01	8.9E-05	1.4E-05	6.6E-06	1.6E-04
2008	7.5E-09	1.5E-08	2.8E-15	2.3E-13	3.6E-06	4.9E-03	8.8E-01	3.1E-13	1.5E-16	7.4E-12	1.0E-06

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