Research Paper

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A Study on Annual Atmospheric Dispersion Factors Between Continuous and Purge Releases of Gaseous Radioactive Effluents

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Radioactive materials from nuclear power facilities can be released into the atmosphere through various channels. Recently, the dispersion of radioactive materials has become critical issue in Korea after Kori Unit 1 and Wolsong Unit 1 were permanently shut down. In this study, annual atmospheric dispersion factors were compared based on the continuous release and purge release using the XOQDOQ computer program, a method for calculating atmospheric dispersion factors at commercial nuclear power stations. The meteorological data analyzed in this study was based on the Shin Kori nuclear power meteorological tower which has the largest operating nuclear power plants in Korea, for three years (from 2008 to 2010). The analysis results of the dispersion factor of the radioactive material release obtained using the XOQDOQ program showed that the difference between the continuous release and purge release was within two times. This study will be valuable helpful for revealing the uncertainty of the predictive atmospheric dispersion factor to achieve regulation.

Keywords: Purge release, Continuous release, Gaseous radioactive effluent, Atmospheric dispersion factors

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1. Introduction

1.1 Background

Although an issue of releasing radioactive materials has been treated importantly from the start of operation Kori Unit 1 to its shut down in 2017, it is recent to get attention to the dispersion of radioactive materials to atmospheric since people became interested in environmental issues with their life enhancing.

To protect people and regulate from the exposure of radioactivity, the governmental decision process is normally conducted at the early stages of facilities and activities for which it is foreseen that an assessment of their possible impact on the environment are necessary. It is calculated conservatively to protect the public and the environment from radiological hazards applying ALARA.

Nuclear Safety Security Committee (NSSC) of Korea has noticed and regulated the factors including Derived Air Concentration (DAC) and Annual Limit of Intake (ALI) at Exclusion Area Boundary (EAB) of the nuclear facilities [1]. The gaseous radioactive material is released to the atmosphere in various channels, for instance, vents of the reactor and auxiliary building and gaseous radioactive waste system [2]. And the gaseous radioactive effluent affecting the atmospheric dispersion factors is divided into the anticipated purge release from reactor building and constant release from auxiliary building [3].

1.2 Research Subject

In normal operating nuclear power plants in Korea, the XOQDOQ computer program is used to calculate the atmospheric dispersion factor for gaseous radioactive material as per the Regulatory Guide 1.111. According to the computer program, calculations of purge and continuous release are available and continuous release is assumed in general. However, in reality, both continuous and purge releases are simultaneously done in normal operation in a nuclear power plants. Because of that, a questionable point can be raised that the values may be underestimated if continuous release is used instead of the purge release even in meteorological stable conditions.

In this study, the variation of the atmospheric dispersion factor values was analyzed based on annual purge time and compared to ones of continuous release. The meteorological data from 2008 to 2010 at Kori and Wolsong sites was used to compare with the atmospheric dispersion factors computed in the current method under the same meteorological condition.

2. Material and Method

2.1 Evaluation of Atmospheric Dispersion

To evaluate the capability of atmospheric dispersion, the XOQDOQ computer program was applied to calculate the annual averaged atmospheric dispersion factors. The program has been developed in U.S. NRC to provide an independent atmospheric dispersion evaluation of continuous or purge releases of radiological material at commercial nuclear power reactors and relevant nuclear facilities [4].

Calculation of long-term or annual average values of the atmospheric dispersion factor is divided into ground release and elevated release. It is assumed to be ground release when the height of radioactive materials release is lower than twice the height of adjacent structures, in case of vent or penetration [5].

2.1.1 Continuous Ground Release

Ground level release concentrations were calculated using the following two equations [3]. The atmospheric dispersion factor was determined greater value among (1) and (2) due to the conservative approach.

$$\frac{X}{Q}(x, k) = \frac{2.032}{x} RF(x, k) \sum_{ij} DP_{ij}(x, k)\, DC_i(x)\, f_{ij}(k) \left[u_i(\sigma_{zj}^2(x) + CD_z^2/\pi)^{1/2}\right]^{-1} \quad (1)$$

and

$$\frac{X}{Q}(x, k) = \frac{2.032}{x} RF(x, k) \sum_{ij} DP_{ij}(x, k)\, DC_i(x)\, f_{ij}(k) [\sqrt{3} u_i\, \sigma_{zj}(x)]^{-1} \quad (2)$$

where $\frac{X}{Q}$: Atmospheric dispersion factor of continuous release ($sec \cdot m^{-3}$)

x: Down-wind distance (m)

i: i th wind speed class

j: j th atmospheric stability class divided into 7 classes [Regulatory Guide 1.23]

k: k th wind-direction class

u^i: Middle of the point value of the i th wind speed class ($m \cdot s^{-1}$)

σ_{zj} (x): Vertical plume spread for stability class j at distance x (m)

f_{ij} (k): Joint probability of occurrence of the ith wind speed class, jth atmospheric stability class, and kth wind direction sector

RF (x,k): Correction factor for recirculation and stagnation at downwind distance x at kth wind direction class

DP_{ij} (x,k): Reduction factor due to plum depletion at distance x for the j th wind speed class, jth atmospheric stability class, and kth wind direction class

DC_i (x): Reduction factor due to radioactive decay at distance x for the i th wind speed class

D_z: Building heights (m)

C: Constant to consider building wake effect

2.1.2 Continuous Elevated Release

For elevated release, a plume rise is determined and the effective plume height is calculated for each wind-direction sector k within 16 directional sectors, as a function of distance x which is 1 km from the site in this study.

$$\frac{X}{Q}(x, k) = \frac{2.032}{x} RF(x, k) \sum_{ij} DP_{ij}(x, k)\, DC_i(x)\, f_{ij}(k) [u_i\, \sigma_{zj}(x)]^{-1} exp[-0.5\{\frac{h_e^2}{\sigma_{zj}(x)^2}\}] \quad (3)$$

h_e: Effective plume heights decided by stack heights and plume rise (m)

where $\frac{X}{Q}$, DP_{ij} (x, k) DC_i (x) f_{ij} (k), u_i, σ_{zj} (x), x are given above.

2.2 Atmospheric Dispersion Factor for Purge Release

Those follow equations are appropriate for purge release greater than eight hour period or for a large number of shorter duration release [3]. The atmospheric dispersion factor is determined greater value among (4) and (5) due to the conservative approach.

2.2.1 Purge Ground Release

It is assumed that the plume is uniformly distributed in the horizontal within a 22.5 degree directional sector.

$$\frac{X}{Q} = 2.032\, [x u_i\, (\sigma_{zj}^2(x) + C D_z^2/\pi)^{1/2}]^{-1} \quad (4)$$

and

$$\frac{X}{Q} = 2.032\, [3 u_i \sigma_{zj}^2(x) x]^{-1} \quad (5)$$

where $\frac{X}{Q}$: Atmospheric dispersion factor of purge release ($sec \cdot m^{-3}$)

u_i: Upper limit of the i th wind speed class

σ_{zj} (x): Horizontal standard deviation of material in the plume for stability category j at distance x

x: Down wind distance (m)

2.2.2 Purge Elevated Release

Following equation is used for elevated release [3].

$$\frac{X}{Q}(x, k) = \frac{2.032}{\sigma_{zj}\, u_i(x) x} [\exp\{-1/2(\frac{h_e}{\sigma_{zj}})^2\}] \quad (6)$$

h_e: Effective plume height

where $\frac{X}{Q}$, u_i, σ_{zj} (x), x are given above.

2.2.3 Correction Factor for Elevated Release

If the meteorological data which is not measured at the

Table 1. Joint Frequency Distribution Data at Shin Kori and Wolsong Site

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED DIRECTION										ATMOSPHERIC STABILITY CLASS A							
(M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0.5	0.071	0.062	0.039	0.048	0.043	0.038	0.04	0.04	0.079	0.071	0.057	0.101	0.063	0.042	0.048	0.071	0.913
1	0.121	0.106	0.067	0.082	0.074	0.065	0.068	0.068	0.135	0.121	0.099	0.174	0.108	0.072	0.082	0.122	1.566
1.5	0.156	0.14	0.115	0.146	0.099	0.112	0.123	0.139	0.304	0.182	0.099	0.266	0.155	0.101	0.077	0.108	2.32
2	0.248	0.241	0.171	0.204	0.146	0.135	0.18	0..229	0.398	0.149	0.106	0.299	0.296	0.094	0.073	0.124	3.094
3	0.393	0.389	0.375	0.457	0.398	0.375	0.37	0.565	0.449	0.251	0.244	0.398	0.698	0.283	0.176	0.47	6.29
4	0.113	0.102	0.277	0.508	0.412	0.23	0.184	0.162	0.174	0.142	0.158	0.109	0.367	0.366	0.16	0.343	3.809
5	0.028	0.012	0.158	0.383	0.156	0.083	0.037	0.039	0.058	0.026	0.055	0.03	0.133	0.304	0.133	0.13	1.795
6	0.003	0.002	0.036	0.142	0.019	0.01	0.021	0.01	0.02	0.006	0.013	0.008	0.034	0.179	0.076	0.033	0.613
8	-	0.001	0.004	0.039	0.001	0.001	0.014	0.003	-	0.003	0.004	0.001	0.011	0.077	0.043	0.013	0.214
10	-	-	-	-	-	-	-	-	-	-	0.006	-	-	0.015	-	0.001	0.022
14.56	-	-	-	-	-	-	-	-	-	-	-	-	-	0.002	-	-	0.002
TOTAL	1.13	1.05	1.24	2.01	1.35	1.05	1.04	1.26	1.62	0.95	0.84	1.39	7.87	1.53	0.87	1.44	20.64

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED DIRECTION										ATMOSPHERIC STABILITY CLASS B							
(M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0.5	0.018	0.018	0.009	0.011	0.009	0.005	0.006	0.005	0.011	0.011	0.006	0.011	0.011	0.005	0.006	0.009	0.151
1	0.029	0.029	0.016	0.019	0.016	0.008	0.011	0.008	0.019	0.019	0.01	0.019	0.019	0.008	0.011	0.015	0.252
1.5	0.035	0.03	0.025	0.027	0.023	0.014	0.009	0.011	0.026	0.023	0.018	0.023	0.017	0.022	0.018	0.015	0.334
2	0.048	0.045	0.03	0.03	0.035	0.027	0.01	0.015	0.016	0.015	0.027	0.032	0.036	0.015	0.013	0.028	0.421
3	0.092	0.037	0.082	0.085	0.105	0.062	0.04	0.028	0.032	0.032	0.051	0.05	0.059	0.056	0.038	0.088	0.935
4	0.048	0.011	0.06	0.076	0.045	0.048	0.012	0.008	0.018	0.019	0.05	0.012	0.044	0.054	0.033	0.108	0.644
5	0.02	0.007	0.035	0.047	0.016	0.008	0.002	0.004	0.006	0.009	0.017	0.003	0.026	0.06	0.028	0.038	0.324
6	-	0.004	0.008	0.014	-	0.001	0.001	0.001	-	0.003	0.005	0.001	0.006	0.024	0.011	0.01	0.088
8	-	0.001	0.002	0.003	-	-	-	-	-	-	0.002	0.001	0.002	0.003	0.01	-	0.024
10	-	-	-	-	-	-	-	-	-	-	0.003	-	-	-	-	-	0.003
14.56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	0.029	0.18	0.27	0.31	0.25	0.17	0.09	0.08	0.13	0.13	0.19	0.15	0.22	0.24	0.17	0.31	3.18

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED DIRECTION										ATMOSPHERIC STABILITY CLASS A							
(M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0.5	0.013	0.01	0.007	0.005	0.005	0.002	0.002	0.006	0.006	0.012	0.015	0.015	0.013	0.012	0.014	0.018	0.155
1	0.017	0.013	0.009	0.007	0.007	0.002	0.002	0.008	0.008	0.015	0.02	0.02	0.017	0.015	0.019	0.024	0.203
1.5	0.033	0.027	0.015	0.008	0.009	0.004	0.012	0.015	0.022	0.025	0.03	0.027	0.027	0.035	0.052	0.054	0.396
2	0.052	0.04	0.032	0.02	0.008	0.012	0.009	0.025	0.04	0.056	0.055	0.049	0.043	0.061	0.078	0.072	0.65
3	0.11	0.102	0.121	0.085	0.034	0.02	0.031	0.083	0.287	0.214	0.15	0.131	0.121	0.151	0.173	0.137	1.85
4	0.073	0.124	0.29	0.192	0.047	0.019	0.034	0.62	0.148	0.259	0.195	0.152	0.101	0.154	0.134	0.082	2.067
5	0.041	0.127	0.525	0.218	0.02	0.005	0.015	0.015	0.066	0.163	0.132	0.137	0.062	0.1	0.063	0.032	1.721
6	0.01	0.09	0.552	0.144	0.008	0.001	0.008	0.004	0.019	0.056	0.055	0.072	0.025	0.04	0.024	0.01	1.118
8	0.011	0.073	0.456	0.073	0.001	0.001	0.006	0.002	0.004	0.015	0.035	0.031	0.005	0.023	0.006	0.001	0.744
10	-	0.001	0.061	0.002	-	-	0.001	0.001	-	-	0.009	0.002	-	0.001	0.001	-	0.08
13.36	-	-	0.005	-	-	-	-	-	-	-	0.002	-	-	-	-	-	0.007
TOTAL	0.36	0.61	2.07	0.75	0.14	0.07	0.12	0.22	0.5	0.82	0.7	0.64	0.41	0.59	0.56	0.43	8.99

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED DIRECTION										ATMOSPHERIC STABILITY CLASS B							
(M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0.5	0.005	0.004	0.007	0.002	0.001	0.002	0.004	0.002	0.003	0.004	0.004	0.008	0.001	0.006	0.006	0.01	0.066
1	0.006	0.004	0.008	0.008	0.001	0.002	0.004	0.002	0.003	0.004	0.005	0.009	0.001	0.007	0.007	0.012	0.081
1.5	0.018	0.01	0.008	0.004	0.001	0.003	0.008	0.009	0.013	0.017	0.009	0.016	0.01	0.013	0.022	0.035	0.198
2	0.024	0.014	0.012	0.013	0.008	0.009	0.008	0.025	0.037	0.026	0.019	0.026	0.022	0.02	0.033	0.033	0.331
3	0.063	0.062	0.073	0.052	0.036	0.029	0.035	0.05	0.067	0.083	0.076	0.076	0.045	0.063	0.084	0.057	0.952
4	0.036	0.068	0.114	0.078	0.018	0.012	0.014	0.033	0.052	0.073	0.087	0.082	0.061	0.073	0.062	0.034	0.895
5	0.02	0.06	0.149	0.059	0.008	0.002	0.009	0.007	0.024	0.049	0.052	0.063	0.035	0.076	0.031	0.01	0.654
6	0.005	0.028	0.118	0.024	0.001	-	0.007	0.004	0.007	0.013	0.028	0.034	0.014	0.025	0.015	0.004	0.327
8	0.004	0.018	0.087	0.017	-	-	0.003	0.001	0.002	0.002	0.032	0.019	0.009	0.009	0.004	0.002	0.21
10	-	0.004	0.013	0.001	-	0.001	0.001	-	0.001	0.001	0.006	0.004	0.001	0.001	-	-	0.035
13.36	-	-	-	-	-	-	-	-	-	-	-	0.001	-	-	-	-	0.001
TOTAL	0.08	0.27	0.59	0.25	0.08	0.06	0.09	0.13	0.21	0.27	0.32	0.34	0.2	0.29	0.26	0.2	3.75

Table 2. Distribution of Atmospheric Stability Grades

	Unstable Grade			Neutral	Stable Grade		
	A	B	C	D	E	F	G
Kori	20.64	3.18	3.44	22.57	34.28	12.97	2.93
		27.26				50.18	
Wolsong	8.99	3.75	4.16	30.71	35.19	12.67	4.52
		16.9				52.38	

※ Unit: percentage (%)

proper height for elevated release is used and below the correction factor is applied. The wind speed is extrapolated based on the atmospheric stability following the relationship from Smith (1968) [3].

$$\mathrm{COR} = \left(\frac{SL}{PL}\right)^{\mathrm{EX}} \qquad (7)$$

where,

COR: Correction Factor applied to the measure wind speeds

PL: Measured wind height (m)

SL: Desired wind height (m)

EX: 0.25, Constant for unstable or neutral atmospheric conditions and 0.5, for stable conditions

2.3 Meteorological Data Analysis

Meteorological data was measured according to the technical standards of NSSC Notice 2017-26 [5]. These standards are applicable to the safety evaluation of site acceptability for operating license and construction permits of nuclear power plants and relevant facilities sites. The wind direction, wind speed, temperature, atmospheric stability, precipitation, and humidity are observed at the Wolsong and the Shin Kori meteorological tower, which is the representative point of Kori site. IAEA recommends that meteorological data should be collected at least three to five years with over 90 percent of the collection rate for the assessment for safety, if meteorological tower has been operated for a long time. In this study, the three years of data collected from 2008 to 2010 were used in accordance with IAEA recommendations [6].

The data observed in the meteorological towers was organized based on Joint Frequency Distribution (JFD). To create the JFD, seven Atmospheric stability classes (A–G) and eleven wind speed classes " < 0.5, 0.5–1.0, 1.1–1.5, 1.6–2.0, 2.1–3.0, 3.1–4.0, 4.1–5.0, 5.1–6.0, 6.1–8.0, 8.1–10.0, 10.0 < $\mathrm{m \cdot sec^{-1}}$" were designated for sixteen directional were designated as per the Table 3 in Regulatory Guide 1.23 [7].

Calm which is defined as its speed is below the threshold of the wind speed class or cannot be detected in the sensor, was proportionally distributed with non-calm wind probability. The effect of recirculation and stagnations was reflected but the building wake was not considered in this study.

3. Results and Discussion

3.1 Results of the Atmospheric Dispersion Factors

To calculate the annual averaged atmospheric dispersion factors of Kori and Wolsong sites, the Joint Frequency Distributions (JFD) of the corresponding sites including wind speed and directions were written for input to the XOQDOQ computer program as shown in Table 1. The JFD of meteorological data was divided into 7 stability classes

Table 3. Results of the atmospheric dispersion factors(X/Q) 1 kilometer away

Time (hr)	Ground (Kori)	Elevated (Kori)	Ground (Wolsong)	Elevated (Wolsong)
100	4.790×10^{-5}	2.402×10^{-6}	8.400×10^{-5}	2.181×10^{-6}
200	4.314×10^{-5}	2.151×10^{-6}	7.724×10^{-5}	1.909×10^{-6}
300	4.058×10^{-5}	2.046×10^{-6}	7.354×10^{-5}	1.806×10^{-6}
400	3.886×10^{-5}	1.977×10^{-6}	7.102×10^{-5}	1.742×10^{-6}
500	3.757×10^{-5}	1.925×10^{-6}	6.913×10^{-5}	1.694×10^{-6}
600	3.655×10^{-5}	1.883×10^{-6}	6.762×10^{-5}	1.656×10^{-6}
700	3.571×10^{-5}	1.849×10^{-6}	6.637×10^{-5}	1.624×10^{-6}
800	3.500×10^{-5}	1.820×10^{-6}	6.530×10^{-5}	1.598×10^{-6}
900	3.438×10^{-5}	1.794×10^{-6}	6.438×10^{-5}	1.574×10^{-6}
1,000	3.384×10^{-5}	1.772×10^{-6}	6.356×10^{-5}	1.553×10^{-6}
1,100	3.336×10^{-5}	1.752×10^{-6}	6.283×10^{-5}	1.535×10^{-6}
1,200	3.292×10^{-5}	1.734×10^{-6}	6.217×10^{-5}	1.518×10^{-6}
1,300	3.253×10^{-5}	1.717×10^{-6}	6.157×10^{-5}	1.503×10^{-6}
1,400	3.216×10^{-5}	1.702×10^{-6}	6.102×10^{-5}	1.489×10^{-6}
1,500	3.183×10^{-5}	1.688×10^{-6}	6.052×10^{-5}	1.476×10^{-6}
1,600	3.152×10^{-5}	1.675×10^{-6}	6.005×10^{-5}	1.465×10^{-6}
1,700	3.124×10^{-5}	1.663×10^{-6}	5.961×10^{-5}	1.453×10^{-6}
1,800	3.097×10^{-5}	1.651×10^{-6}	5.920×10^{-5}	1.443×10^{-6}
1,900	3.072×10^{-5}	1.641×10^{-6}	5.881×10^{-5}	1.433×10^{-6}
2,000	3.048×10^{-5}	1.631×10^{-6}	5.845×10^{-5}	1.424×10^{-6}
2,100	3.026×10^{-5}	1.621×10^{-6}	5.810×10^{-5}	1.416×10^{-6}
2,200	3.004×10^{-5}	1.612×10^{-6}	5.777×10^{-5}	1.407×10^{-6}
2,300	2.984×10^{-5}	1.604×10^{-6}	5.746×10^{-5}	1.399×10^{-6}
2,400	2.965×10^{-5}	1.596×10^{-6}	5.717×10^{-5}	1.392×10^{-6}
2,500	2.947×10^{-5}	1.588×10^{-6}	5.689×10^{-5}	1.385×10^{-6}
2,600	2.930×10^{-5}	1.580×10^{-6}	5.662×10^{-5}	1.378×10^{-6}
2,700	2.913×10^{-5}	1.573×10^{-6}	5.636×10^{-5}	1.372×10^{-6}
2,800	2.897×10^{-5}	1.566×10^{-6}	5.611×10^{-5}	1.365×10^{-6}
2,900	2.882×10^{-5}	1.560×10^{-6}	5.587×10^{-5}	1.359×10^{-6}
3,000	2.867×10^{-5}	1.554×10^{-6}	5.565×10^{-5}	1.354×10^{-6}
3,100	2.853×10^{-5}	1.547×10^{-6}	5.542×10^{-5}	1.348×10^{-6}
3,200	2.839×10^{-5}	1.542×10^{-6}	5.521×10^{-5}	1.343×10^{-6}
3,300	2.826×10^{-5}	1.536×10^{-6}	5.501×10^{-5}	1.338×10^{-6}
3,400	2.813×10^{-5}	1.530×10^{-6}	5.481×10^{-5}	1.333×10^{-6}
3,500	2.801×10^{-5}	1.525×10^{-6}	5.462×10^{-5}	1.328×10^{-6}
3,600	2.789×10^{-5}	1.520×10^{-6}	5.443×10^{-5}	1.323×10^{-6}
3,700	2.778×10^{-5}	1.515×10^{-6}	5.425×10^{-5}	1.319×10^{-6}
3,800	2.767×10^{-5}	1.510×10^{-6}	5.407×10^{-5}	1.314×10^{-6}
3,900	2.756×10^{-5}	1.506×10^{-6}	5.391×10^{-5}	1.310×10^{-6}
4,000	2.745×10^{-5}	1.501×10^{-6}	5.374×10^{-5}	1.306×10^{-6}
4,100	2.735×10^{-5}	1.497×10^{-6}	5.358×10^{-5}	1.302×10^{-6}
4,200	2.725×10^{-5}	1.492×10^{-6}	5.342×10^{-5}	1.298×10^{-6}
4,300	2.715×10^{-5}	1.488×10^{-6}	5.327×10^{-5}	1.294×10^{-6}
4,400	2.706×10^{-5}	1.484×10^{-6}	5.312×10^{-5}	1.290×10^{-6}

Time (hr)	Ground (Kori)	Elevated (Kori)	Ground (Wolsong)	Elevated (Wolsong)
4,500	2.697×10^{-5}	1.480×10^{-6}	5.298×10^{-5}	1.287×10^{-6}
4,600	2.688×10^{-5}	1.476×10^{-6}	5.284×10^{-5}	1.283×10^{-6}
4,700	2.679×10^{-5}	1.472×10^{-6}	5.270×10^{-5}	1.280×10^{-6}
4,800	2.671×10^{-5}	1.469×10^{-6}	5.257×10^{-5}	1.276×10^{-6}
4,900	2.662×10^{-5}	1.465×10^{-6}	5.244×10^{-5}	1.273×10^{-6}
5,000	2.654×10^{-5}	1.461×10^{-6}	5.231×10^{-5}	1.270×10^{-6}
5,100	2.646×10^{-5}	1.458×10^{-6}	5.218×10^{-5}	1.267×10^{-6}
5,200	2.639×10^{-5}	1.455×10^{-6}	5.206×10^{-5}	1.263×10^{-6}
5,300	2.631×10^{-5}	1.451×10^{-6}	5.194×10^{-5}	1.260×10^{-6}
5,400	2.624×10^{-5}	1.448×10^{-6}	5.182×10^{-5}	1.257×10^{-6}
5,500	2.616×10^{-5}	1.445×10^{-6}	5.171×10^{-5}	1.255×10^{-6}
5,600	2.609×10^{-5}	1.442×10^{-6}	5.159×10^{-5}	1.252×10^{-6}
5,700	2.602×10^{-5}	1.439×10^{-6}	5.148×10^{-5}	1.249×10^{-6}
5,800	2.596×10^{-5}	1.436×10^{-6}	5.138×10^{-5}	1.246×10^{-6}
5,900	2.589×10^{-5}	1.433×10^{-6}	5.127×10^{-5}	1.244×10^{-6}
6,000	2.582×10^{-5}	1.430×10^{-6}	5.117×10^{-5}	1.241×10^{-6}
6,100	2.576×10^{-5}	1.427×10^{-6}	5.106×10^{-5}	1.238×10^{-6}
6,200	2.570×10^{-5}	1.424×10^{-6}	5.096×10^{-5}	1.236×10^{-6}
6,300	2.563×10^{-5}	1.422×10^{-6}	5.086×10^{-5}	1.233×10^{-6}
6,400	2.557×10^{-5}	1.419×10^{-6}	5.077×10^{-5}	1.231×10^{-6}
6,500	2.551×10^{-5}	1.416×10^{-6}	5.067×10^{-5}	1.229×10^{-6}
6,600	2.545×10^{-5}	1.414×10^{-6}	5.058×10^{-5}	1.226×10^{-6}
6,700	2.540×10^{-5}	1.411×10^{-6}	5.049×10^{-5}	1.224×10^{-6}
6,800	2.534×10^{-5}	1.409×10^{-6}	5.040×10^{-5}	1.222×10^{-6}
6,900	2.528×10^{-5}	1.406×10^{-6}	5.031×10^{-5}	1.219×10^{-6}
7,000	2.523×10^{-5}	1.404×10^{-6}	5.022×10^{-5}	1.217×10^{-6}
7,100	2.518×10^{-5}	1.401×10^{-6}	5.013×10^{-5}	1.215×10^{-6}
7,200	2.512×10^{-5}	1.399×10^{-6}	5.005×10^{-5}	1.213×10^{-6}
7,300	2.507×10^{-5}	1.397×10^{-6}	4.996×10^{-5}	1.211×10^{-6}
7,400	2.502×10^{-5}	1.394×10^{-6}	4.988×10^{-5}	1.209×10^{-6}
7,500	2.497×10^{-5}	1.392×10^{-6}	4.980×10^{-5}	1.207×10^{-6}
7,600	2.492×10^{-5}	1.390×10^{-6}	4.972×10^{-5}	1.205×10^{-6}
7,700	2.487×10^{-5}	1.388×10^{-6}	4.964×10^{-5}	1.203×10^{-6}
7,800	2.482×10^{-5}	1.386×10^{-6}	4.957×10^{-5}	1.201×10^{-6}
7,900	2.477×10^{-5}	1.384×10^{-6}	4.949×10^{-5}	1.199×10^{-6}
8,000	2.473×10^{-5}	1.382×10^{-6}	4.941×10^{-5}	1.197×10^{-6}
8,100	2.468×10^{-5}	1.379×10^{-6}	4.934×10^{-5}	1.195×10^{-6}
8,200	2.463×10^{-5}	1.377×10^{-6}	4.927×10^{-5}	1.193×10^{-6}
8,300	2.459×10^{-5}	1.375×10^{-6}	4.919×10^{-5}	1.192×10^{-6}
8,400	2.454×10^{-5}	1.374×10^{-6}	4.912×10^{-5}	1.190×10^{-6}
8,500	2.450×10^{-5}	1.372×10^{-6}	4.905×10^{-5}	1.188×10^{-6}
8,600	2.446×10^{-5}	1.370×10^{-6}	4.898×10^{-5}	1.186×10^{-6}
8,760	2.439×10^{-5}	1.367×10^{-6}	4.887×10^{-5}	1.184×10^{-6}
Continuous	2.439×10^{-5}	1.367×10^{-6}	4.887×10^{-5}	1.184×10^{-6}

Note) X/Q ($sec\cdot m^{-3}$): Atmospheric dispersion factor which is not considered decay and depletion which can be categorized stable, unstable, and neutral as shown in Table 2. The percentages of stable atmosphere were greater than the unstable condition for both sites.

The Exclusion Area Boundary (EAB) is basically determined as per the requirements of 10 CFR 100.11 for each unit, 700 meters radius from Kori Units, 560 meters from Shin Kori Units, and 914 meters from Wolsong Units. Considering the EAB of two sites, the receptor location was selected to 1 kilometer along. Within 16 directions, the highest value was selected to evaluate the atmospheric dispersion factors for the comparison of results.

Using the 10 m meteorological data, the annual atmospheric dispersion factors (X/Q) were calculated for ground release and elevated release at 60 m height.

The ground release is generally applied to gain X/Q values for both sites (as stated in 2.1.1) but the values for the elevated release were also calculated based on the purge time to verify the declining status. The inputted purge time means that the number of purge release hour per year since the program evaluates purge release in terms of total purge hours of release, the results for two times the purge release of 10 hours is the same as 1 time purge release of 20 hours, in case of emission height and rate are the same.

As the results of Section 2, both release type of the atmospheric dispersion factors for two sites were calculated based on the purge release duration time from 100 to 8,760 (24 hours × 365 days) hours in a year as shown in Table 3.

Depending on radionuclides which can be release in atmosphere, for instance, ^{39}Ar, ^{81}Kr, and ^{85}Kr defined in NUREG/CR-3474, X/Q factor could be changed. In this study, decay and depletion of them were ignored.

The values in Table 3 represented the maximum value among in the 16 directions. Although Kori site had the highest number of X/Q value direction ENE in ground release, but the highest value of elevated release was shown in direction S. In case of Wolsong site, direction SE and SSE.

As the annual purge time went up from 100 hours to 8,760 hours, the X/Q values in ordinate were rapidly decreased down and finally convergence to the value of continuous release in every four types of release as shown in Fig. 1. When the annual purge time reduced by almost half of 8,760 hours (4,600/8,760 to 4,900/8,760), the X/Q factor was decreased only ten percent as shown in Table 3. While the annual purge time was reduced under the eight percent of 8,760 hours (600/8,760 to 700/8,760), the X/Q factor was decreased 50 percent down.

It means that it can be expected to 50 percent of the quantitative effect of full time continuous release with less

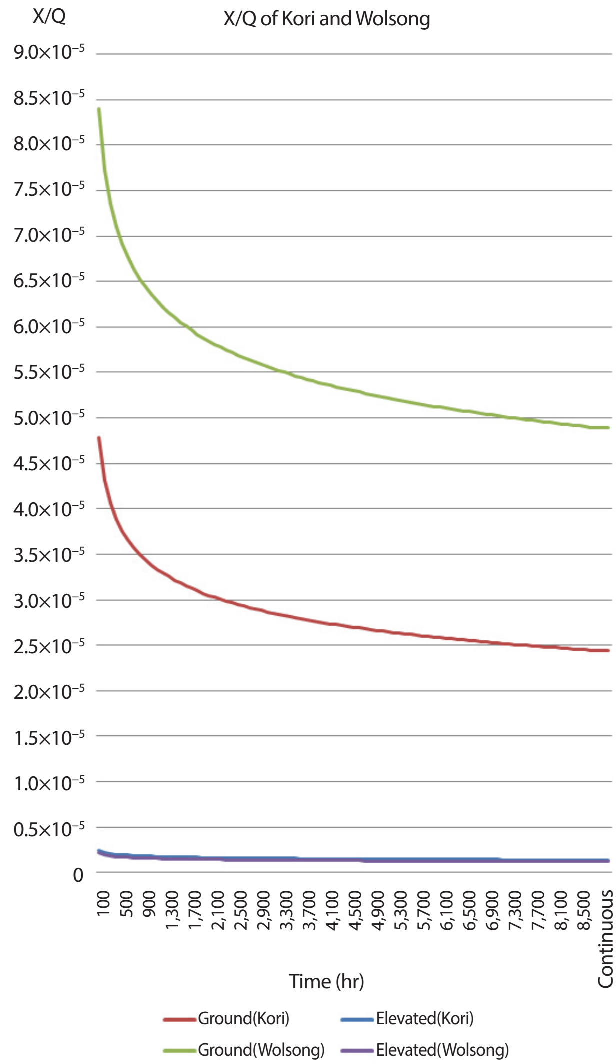

Fig. 1. Results of atmospheric dispersion factors using meteorological data of Kori and Wolsong.

than two hours (600 hours/365 days) purge release in everyday for a year. The value range of X/Q factor will not be significantly changed depending on the purge time with exceeding 2 hours in a day.

3.2 Comparison

In this study, four kinds of the X/Q values were calculated for the ground and elevated release at Kori and Wolsong. Calculation of the atmospheric dispersion factor of nuclear power plants in Korea has been applied ground release as per the NSSC Notice. [1] Although both nuclear power plants are corresponded to ground release, the X/Q values were calculated by assuming elevated release to review the change of X/Q values with purge time. Approximately, it can be identified that the X/Q value line of ground release for Wolsong was above than Kori line as shown in Fig. 1. From this point of meteorological view, Kori site may be more favorable than Wolsong site since there are more nuclear power plants in Kori and Shin Kori site than Wolsong has.

3.2.1 Purge and Continuous Releases

To compare the X/Q values in the aspect of the purge and continuous release, the maximum is at 100 hours and minimum at 8,760 hours respectively because of heights of adjacent structure following NSSC Notice 2017-26. Each continuous release values were not over the X/Q values of 100 hours purge release which correspond to minimum values for both ground and elevated cases in Kori and Wolsong. As shown below (8), the maximum values divided by the minimum were not greater than 2. Therefore, it was verified that the purge release values were less than two times of the continuous release values.

$$\frac{\textit{Maximum value } (\frac{X}{Q} \textit{ factor of 100 hour purge release})}{\textit{Minimum value } (\frac{X}{Q} \textit{ factor of Continuous release})} < 2 \quad (8)$$

4. Conclusions

In general, it has been assumed that releases from nuclear power plants were continuous when calculating the atmospheric dispersion factor in Korea as it stated in 1.2 in this study. The reason is that consideration of purge releases is acceptable if the releases were randomly established in unspecified meteorological condition.

Therefore in this study, the annual atmospheric dispersion factors of purge release were calculated according to the purge time and compared with those of continuous release.

As the results, it was found that the value of only purge release were not greater than two times of continuous release one even though in the worst meteorological case. Moreover, by the fact that the mean value of them was applicable around 600 hours purge release time, it can be satisfactory to release more than that time, typically continuous release of nuclear power plants. Since Gaussian plume model has high reliability in flat geography it could be expected conservative approach when applying it to Korea geography which has lots of mountainous area.

This study may be helpful for the understanding for aspect of the atmospheric dispersion factors decline and for uncertainty of predictive atmospheric dispersion factor for the purpose of reviewing current regulation in routine release of gaseous radioactive effluents from nuclear facilities including nuclear power plants.

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