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APPLICABILITY EVALUATION OF GAUSSIAN PLUME MODEL (XOQDOQ) FOR ASSESSING RADIOLOGICAL IMPACT ASSESSMENT OF RADIOACTIVE MATERIALS AROUND THE NUCLEAR POWER PLANT SITE WITH THE COMPLENX TARRAIN IN KOREA

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Abstract: XOQDOQ which is one of the Gaussian plume model has been applied to assess the public dose during the normal operation of the nuclear power plant in Korea. XOQDOQ was originally designed in the flat terrain and constant wind conditions. IAEA performed the peer review SALTO mission for the license renewal of Wolsong Unit 1. And IAEA recommended that the applicability of XOQDOQ model should be taken into account according to the IAEA guideline to assess the public dose around Wolsong nuclear power site with the complex terrain and variable weather conditions. The model applicability has been evaluated in two ways. For the first, the results of XOQDOQ model were compared with the observed tritium concentrations in air moisture. And secondly, the XOQDOQ model results were compared with the CALPUFF model results which reflect the complex terrain effects and the temporal /spatial variation of weather conditions. The results of XOQDOQ model analysis were generally more conservative than CALPUFF model results and observed concentration of airborne tritium. The Spearman correlation showed that the XOQDOQ model is statistically significant with the CALPUFF model results and the observed concentration of airborne tritium, except for few locations. Therefore, it is concluded that XOQDOQ model is suitable for assessment of the public dose by securing the radiation safety margin and consistency of time series with the observed tritium concentration in Wolsong nuclear power site.

Key words:.

INTRODUCTION

The public dose has been assessed to assure the radiation safety of a member of the public around the nuclear power plant site in Korea. XOQDOQ (US NRC, 1982) which is a Gaussian plume model based on US NRC regulatory guide 1.109 (US NRC, 1977) has been applied to assess the public dose during the normal operation. XOQDOQ was originally designed for the flat terrain and constant wind conditions. However, as most NPP sites in Korea are located near the coast with lots of hills and mountains, the atmospheric dispersion of radioactive materials might be affected by terrain effects.

IAEA recommended, during the peer review SALTO mission for the license renewal of Wolsong Unit 1, that the applicability of XOQDOQ model should be taken into account according to the IAEA guideline (IAEA, 2002) to assess the public dose around Wolsong nuclear power site which has complex terrain and variable weather conditions.

The model applicability has been evaluated in two ways. The first method was that XOQDOQ model results were compared with the observed concentration of airborne tritium. And the second way was that XOQDOQ model results were compared with the CALPUFF model results which reflect the complex terrain effects and the temporal/spatial variation of weather conditions. The period of model calculation and observation of tritium concentration was three years, from 1 January 2010 to 31 December 2012 and 10 locations around the Wolsong site were selected as the target points.

In this study, the radiation safety margin of XOQDOQ was reviewed, and the correlation between model results and observed tritium concentrations was analyzed.

METHODOLOGY

The concentarations of airborne tritium were measured by KHNP (Korea Hydro & Nuclear Power Co., LTD) twice a month at the 10 points around Wolsong nuclear power plant site (Table 1). The values lower than MDA (Minimum Detectable Activity) were excluded for statistical significance. The airborne tritium concentrations were calculated by XOQDOQ and CALPUFF codes for the 10 location points.

The comparison between XOQDOQ and CALPUFF model results was carried out for all the 10 points. However, the comparison between XOQDOQ model results and the measured data was performed for only 5 points where data has been measured continuosly. Some of the evaluation points were exclued because they had changed for improvement of radiological environmental monitoring plan (REMP) in 2012. The average monthly tritum concentrations were analyzed for 3 year preriod from 1 January 2010to 31 December 2012. And the tritium released from Wolsong unit 1 ~ 4 were used as the source terms.

Table 1. Points for the comparison

Locations	**XOQDOQ vs measured data**	**XOQDOQ vs CALPUFF**
Waste storage facility (NNW, 0.5km)	O	O
Company dormitory (SSW, 2km)	O	O
Site boundary (South) (N, 1.1km)	O	O
Sangbong (NNE, 2km)	O	O
Gyeongju (NW, 22.3km)	O	O
Eucheon (SSW, 2.5km)	X	O
Gilcheon (NNW, 4km)	X	O
Pohang (NNW, 30km)	X	O
Busan (SW, 80km)	X	O
Nasan (W, 10km)	X	O

OriginPro program was used to calculate the correlation coefficient. The correlation coefficient is a value between -1 and 1. The closer coefficient to -1 or 1, the more relevant the two variables are linearly. If the correlation coefficient is a positive value, it means the two variables have the same trend. If the coefficient value is a negative, it means two variables have the opposite trend. The correlation coefficient of Spearman's rank was applied for the analysis of environmental data which has a non-parametric characteristics. The trend of two values was compared at the range of significant level $P < 0.05$.

RESULT AND DISSCUSION

Comparisons of the calculation results by XOQDOQ and CALPUFF and the measured concentration at the waste storage facility, site boundary (south), and Gyeongju are shown in Figure 1~3. The scatter diagrams between XOQDOQ results and the measured data at the 5 points are illustrated in Figure 4.

A comparison XOQDOQ model with the measured data

The estimated value of tritium concentrations is several times higher than the measured concentrations. This indicats that the XOQDOQ results are sufficiently conservative. The largest gap between XOQDOQ and measurement (Figure 1) is shown at the point of ‘Waste storage facility’, which is the closest point from the center of site. However, the gap is gradually reduced by distance. It could be due to the ground release assumption in XOQDOQ .

The correlation coefficients with the measured tritium concentration are positive for all evaluation points. It means that the estimated and the measured values have the same trend. It can be confirmed by the scatter diagram in Figure 4. For the fixed significance level of 0.05, the two values have a correlation at four evaluation points except ’Company dormitory’. Therefore, the result shows that the estimated value of XOQDOQ code properly reflects the measured value with a qualitative trend (Table 2).

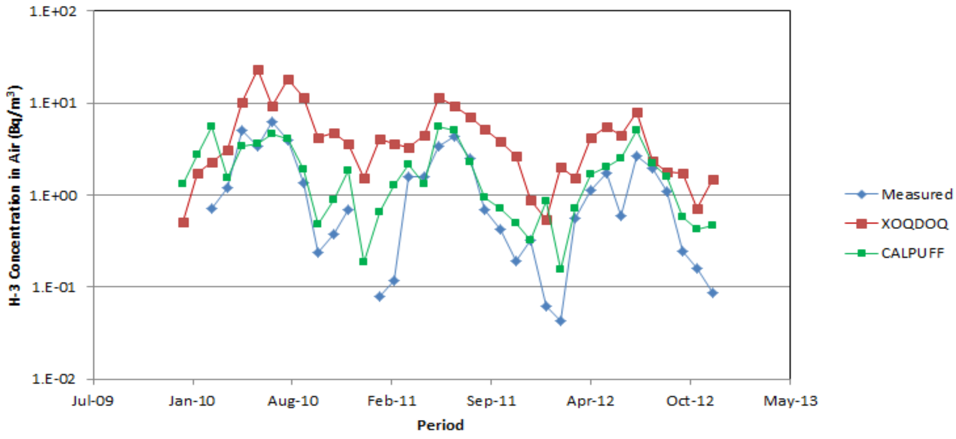


Figure 1. Airborne tritium concentration from XOQDOQ vs CALPUFF vs Measured data (Waste storage facility)

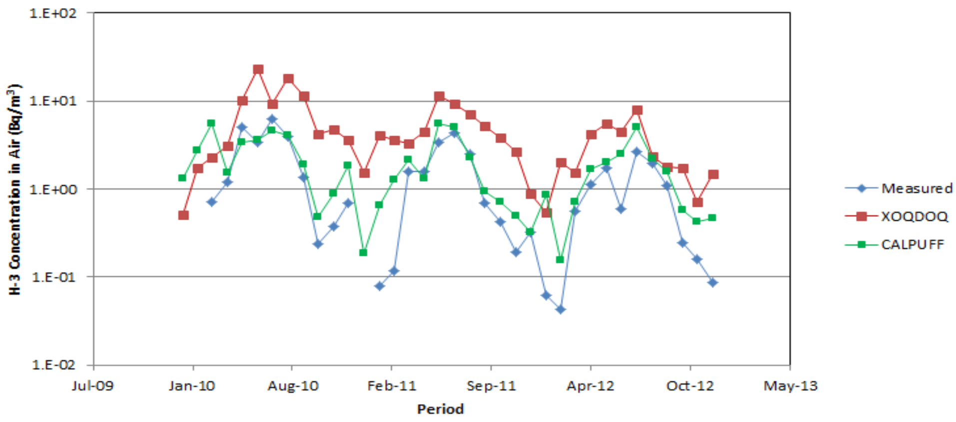


Figure 2. XOQDOQ vs. Measured data vs CALPUFF (Site boundary(South))

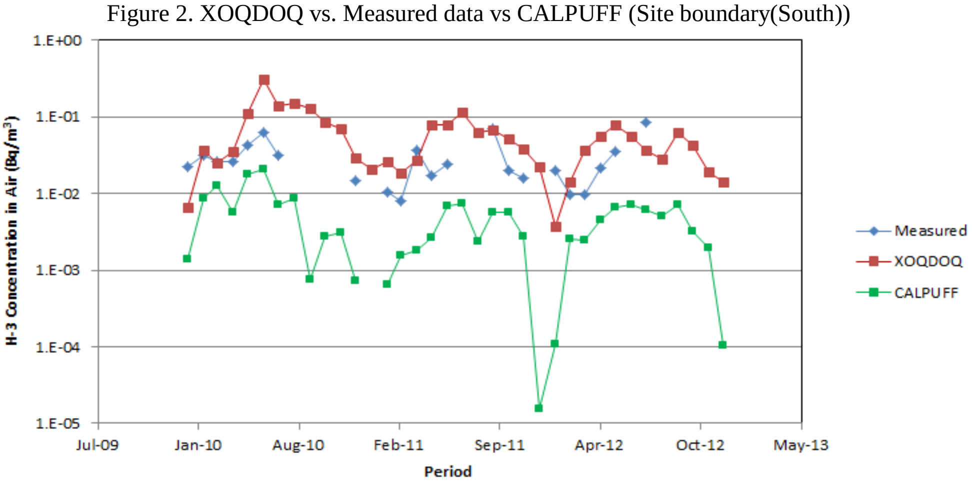
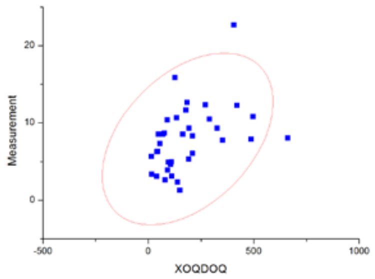


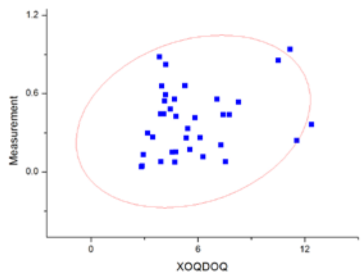
Figure 3. XOQDOQ vs. Measured data vs CALPUFF (Gyeongju)

Table 2. Statistical significance of XOQDOQ vs. Measured concentration in air

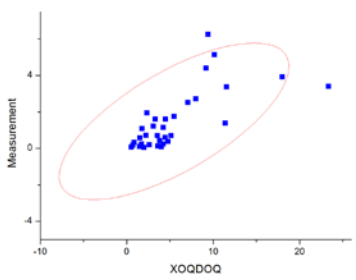
point	Spearman Corr.	Sig.	Correlation
Waste storage facility	0.46502	0.00427	O
Company dormitory	0.1533	0.37205	X
Site boundary (South)	0.73897	9.06E-07	O
Sangbong	0.83243	3.09E-10	O
Gyeongju	0.48052	0.0236	O



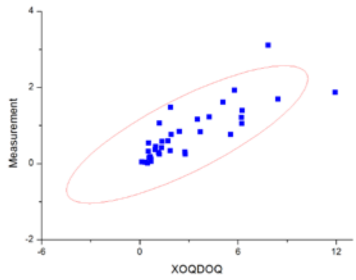
Waste storage facility



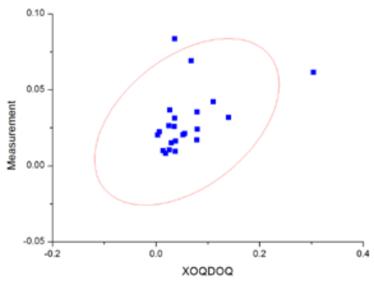
Company dormitory



Site boundary(South)



Sangbong



Gyeongju

Figure 4. Scatter diagram between XOQDOQ results and Measured concentration

A comparison XOQDOQ model with CALPUFF model

XOQDOQ code shows more conservative tendency comparing to the CALPUFF, in other words, XOQDOQ result is about ten times higher than those of CALPUFF averagely. This indicates that XOQDOQ code is more conservatively applicable than CALPUFF with higher safety margin for the public dose. Especially, all the results from ‘Gyeongju’ point which is far from the source (about 20km) shows that XOQDOQ code is perfectly conservative (Figure 3).

Correlation between XOQDOQ and CALPUFF model results were analyzed at all 10 points which have measurement data of the airbone tritium concentration around Wolsong nuclear power plant site. Mostly the evaluation points show positive correlation coefficients with corresponding trend. Moreover, 7 points show the correlation with a significance level of 0.05. Thus, the result indicates that the estimated value of XOQDOQ code can properly reflect the qualitative trend with the CALPUFF value although the results of two points do not show quantitative coincidence. The trend matches up to the points far from the source more than 3 km. Even though XOQDOQ code could not consider terrain effects, this model could analyze perfectly a long-range atmospheric dispersion with conservative evaluation (Table 3).

Table 3. Statistical Significance of XOQDOQ vs. CALPUFF

Point	Spearman Corr.	Sig.	Correlation
Waste storage facility	0.05097	0.76785	X
Company dormitory	0.15495	0.36685	X
Site boundary (South)	0.64659	2.04E-05	O
Sangbong	0.58739	1.66E-04	O
Gyeongju	0.6242	4.74E-05	O
Eucheon	0.12381	0.47188	X
Gilcheon	0.46203	0.00456	O
Pohang	0.47156	0.00369	O
Busan	0.426	0.00958	O
Nasan	0.69807	2.21E-06	O

CONCLUSION

Based on the IAEA peer review recommendation, the applicability of XOQDOQ code for the assessment of the public dose around Wolsong nuclear power plant site was reviewed.

Through the comparison between XOQDOQ and CALPUFF model results and mesured airborne tritium concentrations, it is confirmed that XOQDOQ model results are more conservative than the others. And it also shows a similar trend with those of CALPUFF and the measured data. But for the ’Gyeongju’ point which is about 20 km away from the source, the XOQDOQ code is much more coservative than CALPUFF evaluation. In conclusion, XOQDOQ code performs qualitatively excellent evaluation even though the result of XOQDOQ code(without considering the complex terrain) is not coincident with the measured value quantitatively. The applicability and sufficient safety margin of XOQDOQ were confirmed based on the conservative result and qualitative excellence of XOQDOQ code.

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