ESTIMATION OF CANCER RISK BY BENZENE EMITTED FROM VEHICLES

A. Kondo(1) , S. Shi(1) , A.Kaga(1) , Y. Inoue(1) , N.T.P.Thao(2) and P.H.Viet(3)

(1) *Graduate School of Engineering, Osaka University, 2-1 Yamada oka, Suita, Osaka, 565-0871, Japan*
(2) *Institute of Chemistry, National Center for Natural Science and Technology (NCST)*
(3) *Research Center for Environmental Technology and Sustainable Development, Hanoi University of Science T3-Building, 334 Nguyen Trai Road, Hanoi, Vietnam*

ABSTRACT

Benzene is a carcinogen and a chemistry substance with many amounts of emission. The main sources are considered to be automobile exhaust gases. Therefore, it is thought that the benzene concentration level near roads is high and its amount of exposure of the residents is also large. We measured the benzene concentration of Route 43 at Ashiya City in Japan. It was found that benzene concentration exceeded the environmental standard in Japan. From NOx concentration and NOx emission amount, the emission factors of benzene from gasoline car and from diesel car became 12.2mg/km/vehicle and 14.4mg/g/vehicle, respectively. Moreover, the average benzene concentration along Route 43 was calculated by the numerical simulation. Based on this concentration, we evaluated the cancer risk of 1.8×10^{-5} and the number of cancers patients by benzene of 52×10^{-5} / 2023 persons. In Hanoi, in order to evaluate the cancer risk using the same method, benzene concentration was measured in 2003. The obvious conclusion cannot be still obtained.

KEYWORDS

Benzene, nitrogen oxide, cancer risk, emission coefficient, traffic volume

INTRODUCTION

The automobile exhaust gas containing carbon dioxide and toxic substances occupies the social interest, and the benzene is especially attracted attention in recent years. Benzene is one of the hazardous atmospheric pollutants with many amounts of emission, and is the carcinogenic chemical substance. Benzene has been added in order to raise the octane number of gasoline. However, since benzene has the toxicity, the permissible value of the amount of benzene addition in the gasoline in Japan has been regulated to less than 5% in 1996 and to less than 1% in 2000. The environmental standard of benzene in Japan is regulated to 3 μ g/m^3 [1], and the unit risk of the benzene of 2.2 - 7.8$\times 10^{-6}$ m^3/μ g [2] is reported by U.S. EPA. The threshold value for the carcinogenic chemical substance like benzene does not exist. Therefore, the risk management based on the amount of exposure as well as the regulation of the emission amount will be needed.
In this research, we measured benzene concentration near Route 43 at Ashiya City where the benzene concentration is considered to be locally high because of the heavy traffic, and estimated the emission factor of benzene from vehicles. Moreover, we determined the parameter of the building configuration to simply predict the benzene concentration near roads by the numerical simulation, and evaluated the cancer risk based on benzene concentration calculated by the numerical simulation.

Uchide automatic monitoring station

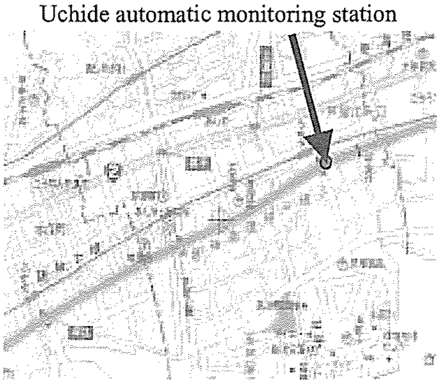

Fig.1 Map around Uchide

Fig.2 Photo of Route 43

The measurement of benzene concentration was performed at Uchide automatic monitoring station for automobile, which is located at the north side of Route 43 shown in Fig.1. Since Hanshin speedway exists above Route 43 shown in Fig.2, the ventilation around Uchide automatic monitoring station becomes worse and the concentration level becomes high, too.The benzene in the air was captured by the absorption tube every 1 hour during 24 hours. The measurements were conducted for 5 days; 18 November,2002, 16 April,2003, 13 May,2003, 15 May,2003, and 21 May,2003. The benzene concentration was analyzed by GC/MS with the thermal desrober. The diurnal variations of benzene concentration are shown in Fig.3. The diurnal variations of NOx concentration measured by the automatic apparatus are shown in Fig.4, too. Benzene concentration has the maximum value at 7p.m. The high level of NOx concentration on a few days continues from noon to 7p.m. Both variations differ from something. The correlation between benzene concentration and NOx concentration is shown in Fig.5. The emission source of NOx is mainly from diesel cars and the emission source of benzene is mainly from gasoline cars. The correlation coefficient R^2 is 0.44 and is not good because of this difference. Therefore, it is difficult to directly estimate benzene concentration from NOx concentration.

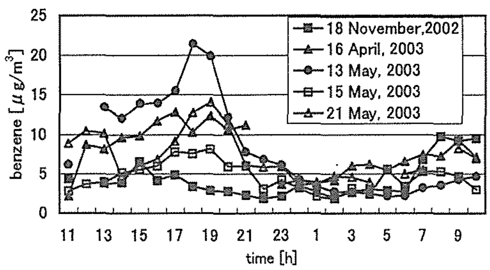

Fig.3 Diurnal variation of benzene concentration

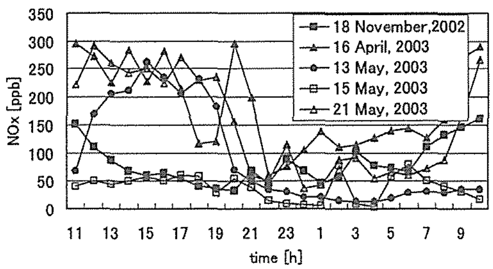

Fig.4 Diurnal variation of NOx concentration

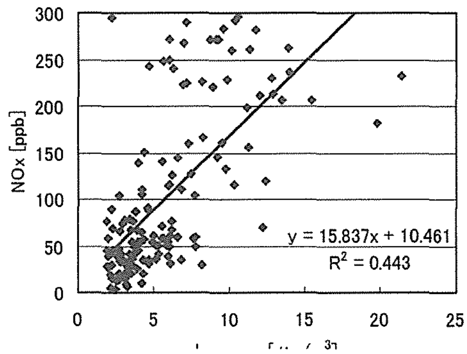

Fig.5 Correlation between NOx concentration and benzene concentration

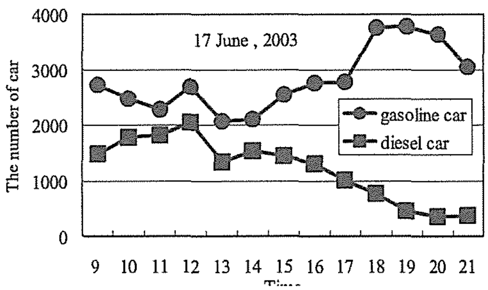

Fig.6 Diurnal variation of traffic volume

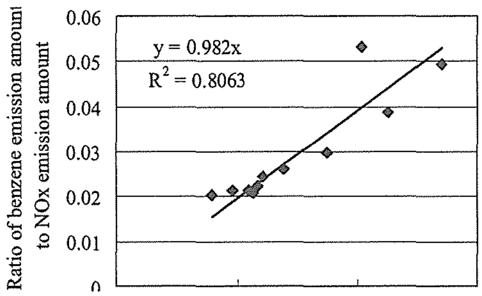

Fig.7 Correlation between benzene/NOx amount ratio and benzene/NOx concentration ratio

to NOx concentration

Table 1 Emission factor of NOx

Car type	Weight	Emission factor
Gasoline car		0.08g/km/vehicle
	< 1.7t	0.28g/km/vehicle
	1.7-2.5t	0.49g/km/vehicle
Diesel car	2.5-3.5t	0.49g/km/vehicle
	3.5t<	0.25g/km/t
	Average	1.42g/km/vehicle

ESTIMATION OF EMISSION FACTOR OF VEHICLES

The traffic volume was counted in front of Uchide automatic monitoring station from 9a.m to 8p.m. on 17 June 2003. Though the day counted the traffic volume was different from the day measured benzene concentration, the traffic volume of weekdays is assumed to be almost same. The variation of traffic volume is shown in Fig.6. The emission factors of benzene from gasoline cars and from diesel cars were estimated by the assumption that the ratio of benzene concentration to NOx concentration is equivalent with the ratio of benzene emission amount to NOx emission amount. NOx emission amount was estimated from the emission factors shown in Table 1. Consequently, the emission factors of benzene from gasoline car and from diesel car became 12.2mg/km/vehicle and 14.4mg/g/vehicle, respectively. The correlation between the ratio of benzene concentration to NOx concentration and the ratio of benzene emission amount to NOx emission amount is shown in Fig.7. The correlation coefficient R^2 is 0.81. The research of Ministry of Environment in Japan reported that the emission factor from gasoline cars was 0.6 mg/km/vehicle. Fushime[3] estimated the emission factor based on the analysis of the observation data and reported that the actual emission factor became some dozens times. The emission factor in California[4], in England[5], and in Denmark[6] was reported to be 75.6mg/km, 90 150mg/km, and 150 mg/km, respectively. The emission factor strongly depends on the traveling condition. The detail research will be needed about the emission factors.

PARAMETER OF BUILDING CONFIGURATION NEAR ROADS

In order to evaluate cancer risk of residents along the roads, it is necessary to presume benzene concentration along the roads. Although it is one method to measure benzene concentration in many places, it is not realistic in order to require many time and labors. In this research, the prediction method of benzene concentration along the roads by

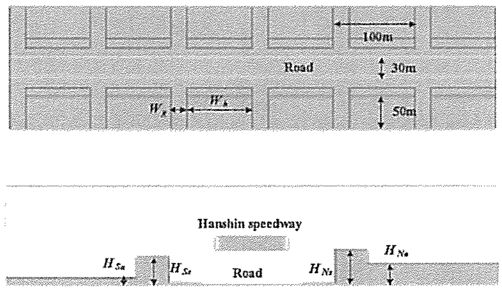

Fig.8 The calculated domain

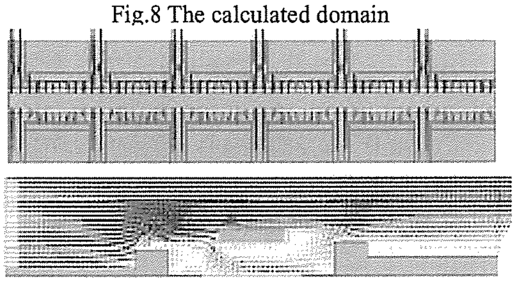

Fig.9 The wind distribution

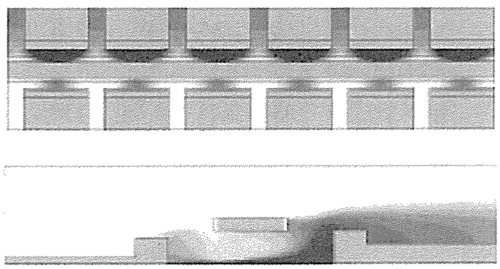

Fig.10 The concentration distribution

Table 2 Building configurations for each block

Parameter	Block				
	1	2	3	4	5
H_{Ns}[m]	3.8	4.0	3.1	4.5	4.1
H_{Na}[m]	1.8	1.3	2.0	1.5	2.6
H_{Ss}[m]	4.8	5.2	6.4	7.2	12.7
H_{Sa}[m]	1.9	3.3	1.7	2.7	2.4

Table3 The frequency of wind speed

Wind direction	Wind speed	Frequency
North	-3.5m/s	0.001
	-2.5 m/s	0.007
	-1.5 m/s	0.089
	-0.5 m/s	0.487
South	0.5 m/s	0.218
	1.5 m/s	0.171
	2.5 m/s	0.026
	3.5 m/s	0.001

using the numerical model was adopted. Building configuration along the roads has infinite variety. Although this configuration can be included in the numerical model as it is, many labors are required for the creation of the configuration, and the calculation meshes become immense. Then, the configuration along the route was approximated with five parameters. The validity of the parameters was examined as compared with the measured concentration and calculated concentration. Five parameters are building height faced the north road side H_{Ns}, average building height of the north road side H_{Na}, building height faced the south road side H_{Ss}, average building height of the south road side H_{Sa}, and the ratio of building width W_b to open space width W_g. Four parameters except the ratio of W_b and W_g were determined from the field survey. Since it was difficult to appropriately set up the ratio of W_b and W_g from the field survey, the most appropriate value of the ratio of W_b and W_g was determined by the numerical simulation. The calculated domain is shown in Fig.8. For an example, the wind field and concentration field of the case where the ratio of W_b and W_g is 5:5 are shown in Fig.9 and Fig.10, respectively. The 11 times calculations from 10a.m to 20:00p.m were carried out for four cases where the ratio of W_b and W_g is 5:5, 6:4, 7:3, and 8:2.The amount of benzene emission of each time was computed from the benzene emission factor and traffic volume. The north-south wind component was given as the boundary condition of the numerical model. The calculated concentrations at the height of 2m near north building were compared with the average measured concentration of each time, and these results are shown in Fig.11. Fig.11 shows that the case where the ratio of W_b and W_g is set to 8:2 is close to the measured concentration. However, if W_b / W_g exceeds 1, the extreme change of the calculated concentration cannot be found. Although it is immediate to draw a conclusion here, it is thought that the case where the ratio of W_b and W_g is set to 8:2 is valid.Moreover, since the benzene concentration value calculated by numerical simulation is mostly in agreement with the order of measured value, it is suggested that the values of the emission factor are also almost appropriate.

ESTIMATION OF CANCERS RISK BY BENZENE

The region of 3000m (length)× 600m(width) along Route 43 at Ashiya City is the target region of the cancer risk. This region was divided into five blocks with the interval of 600m and the parameter of the building configuration shown in Table 2 was determined from the field survey. In order to calculate the annual average benzene concentration for each block, the wind data at Koshien automatic monitoring station near Uchide automatic monitoring station was used. The north-south wind speed frequency for one year is shown in Table 3. The calculations were carried out for each block and for each wind speed. The average benzene concentration for each block was given by the weighted average of the frequency. The cancer risk and the number of cancers patients by benzene were given by

$$R_{isk} = U \times B_i ,$$

$$R = \sum R_{isk} \times P_i / L ,$$

where R_{isk} is the cancer risk, R is the number of cancers patients of the target region, U (= 5×10^{-6} m^3/ μ g) is the unit risk, B_i is benzene concentration at the location i, P_i is the population at location i, and L (=70 years) is the average life. Table 4 shows the population, the cancer risk, and the number of cancers patients. The average cancer risk was 1.8×10^{-5}, and this value was almost same as other researches. The number of cancers patients of the target population of 2023 persons become 52×10^{-5}. If 100 million persons live along roads, the number of cancers patients will become about 26 persons.

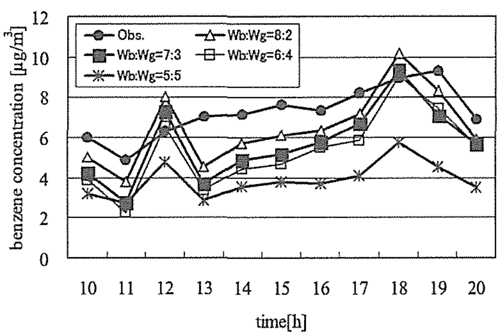

Fig.11 The comparison of measured and calculated benzene concentration

Table 4 The cancer risk for each block

	Block				
	1	2	3	4	5
Population	323	536	477	353	334
Concentration	3.76	3.55	3.26	3.66	4.11
$R_{isk} \times 10^{-5}$	1.63	1.78	1.63	1.83	2.05
$R \times 10^{-5}$	8.67	13.59	11.11	9.23	9.81

BENZENE CONCENTRATION IN HANOI

We measured benzene concentration at Institute of Chemistry, NCST faced to road on 2nd and 3rd December 2003. At the same time, nitrogen dioxide and traffic volume, wind speed and wind direction were also measured. The method to measure benzene concentration is same as the method at Uchide. The situation of the measurement is shown in Fig.12. The diurnal variations of benzene concentration, nitrogen dioxide concentration, traffic volume and wind speed are shown in Fig.13. Nitrogen dioxide concentration has two peaks at 8a.m. and 5p.m. Its level is 60ppb. These peaks correspond to commuter time and to traffic volume. In Hanoi, almost vehicles are bike. The number of its traffic volume exceeds 5,000/h. Benzene concentration level becomes high during daytime (from 9a.m. to 5p.m). But its level is less than 1ug/m3 during nighttime. This variation is not similar to the variation of nitrogen dioxide concentration and of traffic volume. We cannot obtain the obvious conclusion about why the diurnal variation of benzene concentration indicates such behavior. We will measure benzene concentration again to elucidate this cause.

Fig.12 Photo of measurement in Hanoi

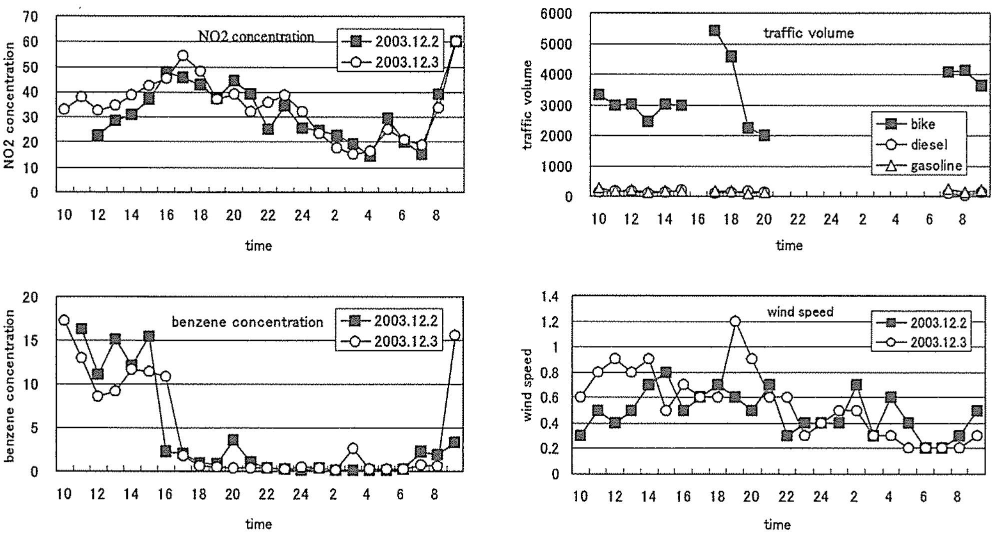

Fig13. The diurnal variations of benzene concentration, nitrogen dioxide concentration, traffic volume and wind speed

CONCLUSIONS

We measured the benzene concentration of Route 43 at Ashiya City in Japan. It was found that benzene concentration exceeded the environmental standard in Japan. From NOx concentration and NOx emission amount, the emission factors of benzene from gasoline car and from diesel car became 12.2mg/km/vehicle and 14.4mg/g/vehicle, respectively. Moreover, the average benzene concentration along Route 43 was calculated by the numerical simulation with the simple parameter of building configuration. Based on this concentration, we evaluated the cancer risk of 1.8×10^{-5} and the number of cancers patients by benzene of 52×10^{-5} / 2023 persons. There are a few problems on the parameterization of the building configuration. Its modification is one of the subjects. The part of this research was supported by Nippon Life Insurance Foundation.

In Hanoi, in order to evaluate the cancer risk using the same method, benzene concentration was measured in 2003. Its diurnal variation is not similar to the variation of nitrogen dioxide concentration and of traffic volume. We cannot obtain the obvious conclusion about why the diurnal variation of benzene concentration indicates such behavior. In 2004, benzene concentration will be measured again to elucidate this cause.

REFERENCES

1. Ministry of Economy, Trade and Industry, Technology and Law of Protection of Air pollution (1998) (in Japanese).
2. U.S.EPA, Carcinogenic of Benzene: An Update EPA/600/P-97/001F (1998)
3. A. Fushimi, H.Kajihara and et.al., Estimation of Atmospheric Concentrations and Evaluation of the PRTR Data Using a Dispersion Model: A Case Study of Benzene., Journal of Environmental Science, 15, 35-47 (2002)
4. R.T.Paul, and S. A. Pezda Mobile source contributions to U.S. Air Toxics. For presentation at the Air & Waste Management Association's 90th Annual Meeting & Exhibition, June 8-13 (1997)
5. R G.Derwent, D. R Middleton, R. A. Field, M. E.Goldstone, J. N. Lester and a Perry, Analysis and interpretation of air quality data from an urban roadside location in central London over the period from July 1991 to July1992. Atmospheric Environment, 29, 923-946. (1995)
6. F.R.Palmgren, Berkowicz, A. Ziv and O. Hertel, Actual car meet emissions estimated from urban air quality measurements and street pollution models. The Science of the Total Environment, 235, 101-109 (1999).