Development of Source Profiles and Estimation of Source Contribution for Hazardous Air Pollutants by the Principal Component Analysis in Indoor Air

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Abstract

The purpose of this study is to characterize the indoor-outdoor relationship of airborne pollutants and recognize probable sources in inside and outside individual apartments in Seoul metropolitan. Simultaneous air monitoring in inside and outside of the 16 Korean Apartments classified into 2 groups: less than 1 year old and more than 4 years old from October, 2004 to February, 2005 were sampled for airborne pollutants(volatile organic compounds, formaldehyde, respiratory particles, carbon dioxide and bacteria) using the Korean Indoor Air Quality Official Method. The concentrations of CO_2, TVOCs, HCHO, bacteria and PM10 in the less than 1 year old apartments were determined to be 773.6±422.3ppm, 4,393.8±2,758.2$\mu g/m^3$, 98.0±56.4$\mu g/m^3$, 254.0±186.3CFU/m^3 and 31.7±14.8$\mu g/m^3$, respectively. Also, the concentrations of those in the more than 4 years old apartments were determined to be 798.9±266.5ppm, 792.7±398.3$\mu g/m^3$, 70.0±30.7$\mu g/m^3$, 245.6±122.0CFU/m^3, 49.7±28.7$\mu g/m^3$, respectively. The average ratios of the indoor and outdoor concentrations of CO_2, TVOCs, HCHO, bacteria and PM10 were 2.2, 3.6, 3.1, 3.9 and 1.4, respectively. These results of this analysis is suggested that CO_2, TVOCs, HCHO, bacteria and PM10 in indoor air are both emitted from source within the apartment environment and partly come from outdoor air. With the above considerations in mind, it is suggested that the research for source contribution of indoor air pollutants should be expanded and the detailed interpretation of the results on these needed further study(using principal component analysis(PCA).

Keywords: Apartment, CO_2, TVOCs, HCHO, Bacteria, PM10, I/O ratios, PCA.

Introduction

Because of increasing traffic and industrial emissions, outdoor air quality has become of growing concern during the past 50 years. As a consequence, monitoring of outdoor air pollution has become more and more systematic, either to check that national or international standards on

contaminant emissions are applied, to ensure that outdoor air quality complies with the standards in force, to inform authorities if threshold limit concentrations are exceeded, and to assess health hazard for people. However, evidence has been made that city-dwellers spend most of their time in buildings(Jenkins P.L. et al., 1992; Klepeis N.E. et al., 2001) and are far more exposed to pollution indoors than outdoors. As result, contaminant concentration measurements have been performed in various indoor environments during the past 40 years, providing more accurate information about human exposure.

Issues on indoor environment are of concern to the Korean population in recent years since sick building syndrome indoors has been introduced(Lee H.S. et al., 1996).

In indoor space, the major sources of formaldehyde exposure are construction materials, furniture, household appliances, heating apparatus and cigarette-smoking, Especially, urea-formaldehyde foam adhesives are commonly used as glue in plywood and particle board and also as preservatives in wallpaper. To name a few effects of formaldehyde exposure on human health, formaldehyde irritates eyes, nose, and throat and causes unpleasantness, 'sneezing', coughing;, vomiting' and 'dyspnea'. Besides, the results obtained from animal experiments show that formaldehyde can also cause various cancer(Lee J.Y. et al., 2003; KITC, 2004). Volatile organic compounds are known to be mainly caused by interior construction materials such as plywood, wallpaper, and adhesives and domestic articles such as curtains, carpets and furniture and open-type heating apparatus, insecticides, aromatics, and cigarette-smoking(KACA, 2003). Fine particles emitted from various human activities such as coagulation of smaller particulate emitted from combustion sources, condensation of volatile species and gas-to-particulate conversion(Febo, A., 1991). Fine particulate cause adverse effects like human health problem and visibility degradation(Phillips, J.L. et al., 1993).

For those reasons, on May 31, 2004, the Ministry of Environment executed 「Act of Indoor Air Quality Management in Public facilities」 which was revised and promulgated on May, 2003 and it is to restrict 10 types of indoor air pollutants, including formaldehyde, PM10 and volatile organic compounds, in public facilities and 6 types of volatile organic compounds in newly built apartment(MOE, 2004).

It is the purpose of this study to characterize the indoor-outdoor relationship of airborne pollutants and recognize probable sources inside and outside them of individual apartments in Seoul

Methods

This study was partly carried out by Research Project of the Korea Ministry of Environment. We were surveyed the concentrations of indoor and outdoor airborne pollutants in 16 apartments located in Seoul metropolitan classified into 2 groups : less than 1 year old and more than 4 years old from October, 2004 to February, 2005.

We determined the indoor and outdoor pollutants such as formaldehyde, volatile organic compounds, carbon dioxide, bacteria and respiratory particles. For the determination and analysis of the indoor and outdoor pollutants in apartments, we used the Korean Indoor Air Quality Official Method(MOE, 2004).

Results and Discussion

1. Thermo-circumstance in apartments

Table 1 shows the general characteristics and temperature and humidity conditions of offices investigated by this study. The apartments are classified into 2 groups: less than 1 year old apartments and more than 4 years old apartments.

The mean indoor and outdoor temperature of all apartments are 21.5±2.5℃, 11.6±7.2℃, respectively. The mean indoor and outdoor temperature of less than 1 year old apartments are 23.1±1.6℃, 17.0±4.9℃, respectively. Also the mean indoor and outdoor temperature of more than 4 years old apartment are 20.2±2.4℃, 7.5±6.2℃, respectively. The mean indoor temperature has significant statistical difference among the two age groups of apartments($p<0.05$).

The mean indoor and outdoor relative humidity of all apartments are 45.0±10.3%, 43.0±17.8%, respectively. The mean indoor and outdoor relative humidity of less than 1 year old apartments are 48.9±10.4%, 53.1±20.9%, respectively. And more than 4 years old apartments are 41.9±8.5%, 35.4±7.8%, respectively. The mean indoor relative humidity has no significant statistical difference among the two age groups($p>0.05$).

Table 1. Summary of thermo-circumstance measurement in apartments.

	< 1 year old		> 4 years old		Total	
	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor
Number of apartment	7	6	9	8	16	14
Temperature(℃)	23.1±1.6	17.0±4.9	20.2±2.4	7.5±6.2	21.5±2.5	11.6±7.2
Relative humidity(%)	48.9±10.4	53.1±20.9	41.9±8.5	35.4±7.8	45.0±10.3	43.0±17.8

2. Indoor air quality in apartments

The concentration of carbon dioxide in the less than 1 year old apartments and more than 4 years old apartments were determined to be 773.6±422.3ppm and 798.9±266.5ppm, respectively, and the concentration of carbon dioxide in the indoor air appeared to have no significant statistical difference among the two age groups of apartments($p>0.05$). The concentration of total volatile organic compounds in the less than 1 year old apartments and more than 4 years apartments were determined to be 4,393.8±2,758.2$\mu g/m^3$, 792.7±398.3$\mu g/m^3$, respectively, and there was significant statistical difference between them($p<0.05$). The concentration of formaldehyde in the less than 1 year old apartments and more than 4 years old apartments were measured to be 98.0±56.4$\mu g/m^3$, 70.0±30.7$\mu g/m^3$, respectively. There were significant statistical difference between them($p<0.05$). The concentration of bacteria in the indoor air of the less than 1 year old apartments and more than 4 years old apartments were measured to be 254.0±186.3CFU/ m^3, 245.6±122.0CFU/ m^3, respectively, and there were no significant statistical difference between them($p>0.05$). The concentration of PM10 in the indoor air of the less than 1 year old apartments and more than 4 years old apartments were determined to be 31.7±14.8$\mu g/m^3$, 49.7±28.7$\mu g/m^3$, respectively. There were no significant statistical difference between

them($p><0.05$). It is shown that indoor concentration of volatile organic compounds included formaldehyde in less than 1 year apartments higher than in more than 4 years apartments.
The average ratios of the indoor and outdoor concentrations of CO_2, TVOCs, HCHO, bacteria and PM10 were 2.2, 3.6, 3.1, 3.9 and 1.4, respectively. For all of the apartments, indoor pollutants(CO_2, TVOCs, HCHO, bacteria and PM10) concentrations were greater than outdoor concentrations. These results of this analysis suggest that CO_2, TVOCs, HCHO, bacteria and PM10 in indoor air are both emitted from source within the apartment environment and partly penetrate from outdoor air.

Table 2. The concentration level of indoor and outdoor air pollutants in the surveyed apartments.

	< 1 year old			> 4 years old			Total		
	Indoor	Outdoor	I/O	Indoor	Outdoor	I/O	Indoor	Outdoor	I/O
CO_2 (ppm)	773.6 ±422.3 (N=7)	353.0 ±201.2 (N=6)	2.2	798.9 ±266.5 (N=9)	276.3 ±38.1 (N=8)	2.9	349.8 ±462.4 (N=16)	155.6 ±210.5 (N=14)	2.2
TVOCs ($\mu g/m^3$)	4,393.8 ±2,758.2 (N=21)	1,114.4 ±933.4 (N=7)	3.9	792.7 ±398.3 (N=27)	304.6 ±122.5 (N=9)	2.6	2,368.2 ±2,566.0 (N=48)	658.9 ±727.1 (N=16)	3.6
HCHO ($\mu g/m^3$)	98.0 ±56.4 (N=21)	32.5 ±32.1 (N=7)	3.0	70.0 ±30.7 (N=27)	21.3 ±19.4 (N=9)	3.3	82.2 ±45.6 (N=48)	26.2 ±23.5 (N=16)	3.1
Bacteria (CFU/m^3)	254.0 ±186.3 (N=12)	95.5 ±114.3 (N=6)	2.7	245.6 ±122.0 (N=14)	39.1 ±23.7 (N=8)	6.3	248.5 ±170.4 (N=26)	63.3 ±78.5 (N=14)	3.9
PM10 ($\mu g/m^3$)	31.7 ±14.8 (N=7)	13.8 ±15.2 (N=6)	2.3	49.7 ±28.7 (N=9)	42.0 ±38.8 (N=8)	1.2	41.8 ±24.6 (N=16)	29.9 ±33.3 (N=14)	1.4

Conclusions

Indoor and outdoor concentrations of CO_2, TVOCs, HCHO, bacteria and PM10 were measured in apartments to identify the source contribution of them in apartments. For all of the apartments, indoor pollutants(CO_2, TVOCs, HCHO, bacteria and PM10) concentrations were greater than outdoor concentrations. I/O ratios of CO_2, TVOCs, HCHO, bacteria and PM10 were found to be greater than unity. These results suggest that CO_2, TVOCs, HCHO, bacteria and PM10 in indoor air are both emitted from source within the apartment environment and partly penetrate from outdoor air. With the above considerations in mind, it is suggested that the research for source contribution of indoor air pollutants should be expanded and the detailed interpretation of the results on these were needed further study(using principal component analysis(PCA), in order to identify emission sources.

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