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AN INDOOR AIR STUDY IN URBAN KOREAN HOMES

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Indoor air concentrations of nitrogen dioxide, formaldehyde, carbon monoxide and radon were measured at selected houses, underground shopping stores, and other microenvironments in the Seoul area during June 1988 - February 1989. Outdoor levels for each pollutant were compared with two indoor levels (living room, kitchen) in selected homes. Mean concentrations of each pollutant in the living room exceeded the mean levels outside. Indoor/ outdoor ratios for NO_2, HCHO, CO, and radon were 1.1-4.9 times the outdoor levels. The impact of several important household characteristics (type of heating fuel and cigarette smoking) on the indoor pollutants is evaluated.

INTRODUCTION

The major air pollutants in the Seoul area are sulfur dioxide and total suspended particulates which can have a pronounced effect on human health and well-being. The major sources of air pollution in Seoul are automobile exhaust emissions and the combustion of domestic fuels. Outdoor measurements from air monitoring systems have often been used to represent ambient levels of exposure. However, there has been increased awareness about the importance of indoor air quality in the assessment of the health effects of air pollution, because most individuals spend from 70 to 90 % of their time indoors. Although it is very difficult to measure accurate personal exposure, some epidemiological studies have attempted to investigate the potential effects of outdoor and indoor air pollution. It became apparent that comparison of indoor and outdoor measurements might have important implications of their health effects studies.

Recently limited studies have been reported on the levels of indoor air pollution although little attention has been paid to research on indoor air quality in Korea. This paper attempts to evaluate the indoor and outdoor levels of selected pollutants and the impact of certain household characteristics on the indoor levels in the Seoul area and to examine the adverse health effects of residences from self-reports of respiratory questionnaire.

MATERIALS AND METHODS

A field study was designed to measure indoor pollutant levels in the selected indoor environments during June 1988 - February 1989. The pollutants selected for monitoring during the study were chosen on the basis of their potential exposure levels and probable health effects concern. The pollutants chosen for monitoring were nitrogen dioxide, formaldehyde, carbon monoxide, and radon. Indoor and outdoor measurements of air pollutants were performed at thirty-five homes selected from two Seoul areas, Kuro-dong and Sooyou-dong. Monitoring for each pollutant was performed for proper sampling periods at each house. Indoor air samples of NO_2, HCHO, and CO were collected from two different rooms (living room, kitchen) of the house, whereas indoor air samples of radon were collected from livingroom and basement of the house. Measurements were made of meteorological conditions for subsequent correlation with the indoor air quality. Each pollutant level was monitored during the study using different passive monitors. A summary of study design and procedure is presented in Table 1. In order to investigate adverse health effects of indoor air pollution, each subject was asked to answer respiratory questions selected from the BMRC (British Medical Research Council) questionnaire.

RESULTS AND DISCUSSION

The data collected during the course of this study represents a large amount of information. Only the most important results can be presented here.

Summary results of indoor and outdoor average concentrations of three pollutants are presented in Table 2. In all homes the average concentrations of each pollutant in the livingroom and kitchen (or basement) exceed the corresponding outdoor mean values. The ratio of the mean indoor concentrations (average of two rooms) to the mean outdoor concentrations is greater than 1.0 for each pollutant. The mean outdoor NO_2 concentration was 30.1 ppb for all residences, whereas the mean livingroom levels for NO_2 measurements were 41.8 ppb. On at least one occasion 20% of the homes had a measured concentration of greater than 50 ppb of the Korea ambient NO_2 standard in at least one room.

The mean living room levels for HCHO measurements were 68.2 ppb, whereas the mean outdoor HCHO concentrations were 58.3 ppb. The indoor/outdoor ratio for residences were 1.13. Three homes (10.7%) had averages greater than 100 ppb and less than 200 ppb.

The mean radon concentration in the basements (2.6 pCi/l) were 1.5 times higher than the corresponding levels measured in the living room (1.7 pCi/l). In 3 of 34 (8.8%) living room radon levels are above 4 pCi/l of the EPA's Guideline, while 8 of 34 (26.5 %) basement radon levels are above this level. The mean outdoor radon levels averaged less than 1.0 pCi/l and were less than the indoor levels.

The mean carbon monoxide concentration in bedroom and kitchen were 11.8 and 23.3 ppm, respectively, while the mean indoor/outdoor ratios were 4.9. Approximately 34% of the kitchen and 14% of bedroom exceeded 20 ppm of the Korea ambient carbon monoxide standard (8-hr average) not to be exceeded more than once a year.

The group of residence was classified by use of kerosene heater and by presence or absence of cigarette smokers in homes. The mean concentration of NO_2, CO, HCHO, and in the livingroom with use of kerosene heater was 77.5 and 113.4 ppb, respectively, and were significantly ($p<0.01$) higher than each corresponding level with no use of kerosene heater, while the radon levels were not significantly shown in the differences by use of kerosene heater (Table 3).

The mean concentration of NO_2, HCHO, and radon by presence of smokers in homes are shown in Table 4. The mean concentrations of NO_2 and HCHO with smokers in homes were higher than those corresponding levels with no smokers in homes, respectively, while a significant difference of NO_2 and HCHO levels between smoker and non-smoker homes were shown. On the mean concentrations of radon and CO, there was no significant difference between smoker and non-smoker homes. From these results livingroom concentrations of NO_2 and HCHO varied widely depending on use of kerosene heater and exposure to cigarette smoking.

The houses monitored in this study consist of a mix of homes with obvious potential sources of combustion-generated indoor pollutants (smokers and kerosene heaters) and homes with no obvious indoor combustion sources. Thus, nine of the homes may be classified into two groups: four homes for a "Source" group consisting of homes with both kerosene heaters and at least one resident smoker who routinely smokes indoors, and five homes for a "Nonsource" group containing homes with no use of kerosene heaters and no resident smoker. The remaining homes have kerosene heaters or smokers, but not both.

The probabilities associated with the t-tests for the differences in each pollutant concentrations between Source and Nonsource homes is presented in Table 5. Indoor and outdoor mean concentrations of each pollutant for the Source homes are higher than the corresponding levels for the Nonsource homes. Indoor/outdoor ratios of mean concentrations for each pollutant in the Source homes exceed the corresponding levels in the Nonsource homes except for radon. The differences in indoor mean concentrations of each pollutant between Source and Nonsource homes are highly statistically significant except for radon. In summary, it seems that indoor measured levels of indoor pollutants may be influenced by housing characteristics and environmental variables.

CONCLUSIONS

These results show that indoor concentration of NO_2, HCHO, radon and CO are in general higher than the corresponding outdoor levels. The data indicate that average room-to-room differences in each pollutant concentrations are not large except for CO.

It is shown that indoor concentrations of NO_2, HCHO, and CO in the Source homes are significantly higher than the corresponding levels in the Nonsource homes. This suggests that increased indoor levels of NO_2, HCHO, and CO are likely related to the use of kerosene heaters and/or the presence of a resident smoker.

Additional information concerning more detailed housing characteristics, daily activity patterns, and seasonal factors should provide important information on exposure for epidemiological studies of indoor air pollution.

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Table 1. Summary of study design and procedure

Parameters measured	Sampling location	Sampling device & methods	Sampling period
NO2	Kuro, Sooyou-dong kitchen, living room . 35 homes,	Filter badge sampler 24 hr. exposure	Winter 1989
	Underground environments		Summer 1988
HCHO	Kuro-dong, 35 homes (kitchen, living room)	HCHO passive monitor (PF-1) 7 day exposure	Winter 1989
	25 underground shopping stores 15 fabric stores		Summer 1988
Radon	Kuro, Sooyou-dong (living room, basement) 34 homes	Ttack Etch Radon Monitor 3 month exposure	Winter 1989
	Underground environments		Summer 1989
CO	Kuro, Sooyu-dong (kitchen, living room) 35 homes	CO passive monitor 24 hr. exposure	Winter 1989

Table 2. Summary of indoor and outdoor average concentrations for from pollutants

Pollutant (unit)	Sampling location	Number of samples	Mean	S.D.	I/O ratio
NO2 (ppb)	Indoor, living room	35	41.8	12.6	1.29
	Indoor, kitchen	35	35.7	15.1	
	Outdoor	35	30.1	9.8	
HCHO (ppb)	Indoor, living room	28	68.2	14.7	1.13
	Indoor, kitchen	28	63.7	18.6	
	Outdoor	28	58.3	16.3	
Radon (pCi/l)	Indoor, living room	34	1.7	0.5	2.69
	Indoor, basement	34	2.6	1.9	
	Outdoor	34	0.8	0.7	
CO (ppm)	Indoor, Bedroom	33	11.8	7.2	4.88
	Kitchen	33	23.3	26.2	
	Outdoor	33	3.6	5.9	

S.D.: Standard Deviation
I/O ratio: Ratios of overal means of indoor average concentrations of two rooms/outdoor concentrations

Table 3. Mean indoor pollutant concentrations in living room by use of kerosene heater

Pollutant (unit)	Kerosene heater Use	No Use	P-value
NO2 (ppb)	77.5 (n=9)	38.5 (n=26)	<0.01
HCHO (ppb)	113.4 (n=8)	50.6 (n=20)	<0.01
Radon (pCi/l)	1.9 (n=8)	1.8 (n=26)	>0.05
CO (ppm)	27.5 (n=9)	18.6 (n=24)	<0.01

Table 4. Mean indoor pollutant concentrations in living room by presence of smokers in homes

Pollutant (unit)	Smokers in homes Presence	Absence	P-value
NO2 (ppb)	49.5 (n=26)	30.1 (n=9)	<0.01
HCHO (ppb)	77.6 (n=21)	55.1 (n=7)	<0.05
Radon (pCi/l)	2.3 (n=25)	1.5 (n=9)	NS
CO (ppm)	13.1 (n=24)	10.3 (n=9)	NS

Table 5. Results of t-tests of differences of concentrations between "Source" and "Nonsource" homes

Pollutant (unit)	Homes	Concentration Indoor	Outdoor	I/O	Significance Indoor	Outdoor
NO2 (ppb)	Source	81.4	35.7	2.3	<0.01	NS
	Nonsource	37.2	29.8	1.2		
HCHO (ppb)	Source	143.6	60.1	2.4	<0.01	<0.05
	Nonsource	60.3	47.9	1.3		
Radon (pCi/l)	Source	2.0	1.1	1.8	NS	NS
	Nonsource	1.7	0.9	1.9		
CO (ppm)	Source	28.3	4.6	6.2	<0.01	NS
	Nonsource	15.1	3.2	4.7		

NS-Not significant;
Indoor - Living room concentration; I/O - Indoor/Outdoor