Table VII

Comparison of Deposition Velocities for Ions Associated with Fine and Coarse Particles (cm/sec)

	Newark	Wichita[a]	Lubbock[a]	Calculated[b]
Fine Particles				0.002
chloride	<0.01	0.03	<0.01	
sulfate	0.005[c]	0.003[c]	0.005[c]	
sodium	0.05[c]	0.2	0.07	
potassium	0.007	0.004	0.03	
magnesium	0.02	<0.01	0.03	
calcium	0.03	<0.02	0.006	
Coarse Particles				0.6
chloride	0.6	0.8	0.2	
sulfate	0.04[c]	1.8	0.1	
sodium	0.3	0.7	0.2	
potassium	0.2	3.8	0.2	
magnesium	0.3	0.9	0.2	
calcium	0.4[c]	1.0	0.07	

a The Wichita and Lubbock values are based on very sparse data for airborne concentrations.

b Gravitational settling velocity.

c The average annual accumulation and indoor concentration used to compute this number were known with a sufficiently high degree of confidence that the number should be accurate

NO_2 CONCENTRATIONS IN OFFICES WITH KEROSENE SPACE HEATERS AND ELECTRIC HEATERS

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As part of a study to evaluate the impact of combustion source type on indoor air pollution levels, NO_2 concentrations were measured during January-February 1984 in twenty offices in the Seoul area, Korea. Average levels of NO_2 concentrations were compared among offices with either a kerosene heater or electric heaters.

Offices with a kerosene heater had average NO_2 concentrations approximately 85 ppb and 4 times higher than offices with electric heaters. Offices with smokers had slightly higher NO_2 levels than those without smokers.

INTRODUCTION

In Korea, unvented portable kerosene and electric space heaters are commonly used during the cold seasons to supplement conventional heating system.

Several studies suggest that use of the heaters in residential settings may pose significant health hazards by releasing various combustion products such as nitrogen dioxide (NO_2), sulfur dioxide (SO_2), Carbon monoxide (CO), and formaldehyde (HCHO).[1-4] Increased concentrations of NO_2 have shown indoors where kerosene space heaters as gas-burning appliances are used.[5-6]

The objective of this study was the assessment of indoor combustion sources on indoor NO_2 levels. This paper presents the results of a field study conducted to assess the integrated levels of nitrogen dioxide in building offices and their association with the use of kerosene space heaters and electric heaters. The use of two different samplers, diffusion tubes,[7] and filter badges[8] allows the intercomparison of these devices.

METHODS

A pilot study was conducted to measure indoor NO_2 levels in offices in Seoul, Korea during January-February 1984 as part of a more comprehensive indoor NO_2 study.[9] Offices from two selected office buildings were chosen for fixed site monitoring. Most office workers use kerosene space heaters or electric heaters to supplement thye heating system although each building was centrally heated. Office workers willing to participate in this study were given a screening questionnaire on the type and use of indoor combustion sources. In addition, to determine the response between Palmes tube and filter badge measurements, two Palmes tubes and one filter badge were installed in each office.

All offices were monitored for at least a four-day period for integrated NO_2 concentrations. The samples from five offices were collected after five days of monitoring. A filter badge and two Palmes tubes were placed within one foot of each other on a wall approximately 5 feet above the floor and no closer than 10 feet to the heaters.

RESULTS

A total of 20 offices were monitored; seven offices with a kerosene space heater; seven offices with an electric heater; and six offices without supplemental space heaters. All heaters were unvented radiant type. The samples from fifteen offices were monitored on a four-day sampling period, while five offices required a five-day sampling period and anticipated low levels.

Cumulative frequency distribution on mean NO_2 concentrations for total samples by type of devices are presented in Figure 1. Mean NO_2 levels measured by filter badge ranged from 5.3 to 135.3 ppb, while the corresponding NO_2 levels measured by diffusion tube A and diffusion tube B were in the range of 6.0-147.2 ppb and 6.0-156.2 ppb, respectively. The mean NO_2 concentrations for total samples measured by filter badge were about 20% (8 ppb) lower than expected. The difference between diffusion

tubes was less than 5% of the mean value for paired tubes.

Table I presents the mean concentrations of different samplers by selected characteristics. NO_2 concentrations in offices with a central heating system were only 11.0 and 13.0 ppb, depending on the device. Offices with a kerosene heater had average NO_2 concentrations six to seven times higher than offices with central heating and about four times higher than those with electric heaters.

According to categories of selected characteristics, mean NO_2 concentrations were higher where smokers were present in offices. Average concentrations increased with increased heater use. Mean NO_2 concentrations in offices with a kerosene heater exceeded the Korea annual averaged ambient NO_2 standard of 50 ppb,[10] especially during five hours and more of use. The highest NO_2 concentrations, exceeding about twice the Korea ambient NO_2 standard, occurred in an office of less than 5 m^2.

Figure 2 presents the cumulative percent distributions of NO_2 concentrations by heating source and samplers. Higher NO_2 levels in offices with a kerosene heater is clearly demonstrated. Mean NO_2 levels above 50 ppb were exceeded in approximately 71% of the offices with kerosene space heaters based on diffusion tube results.

As indicated in Table II, offices with a kerosene heater had significantly higher NO_2 concentrations than those with an electric heater, with values not significantly effected by the presence of smokers. Even controlling for heater types, office cigarette smoking does not appear to be an important contributor to indoor NO_2 concentration (see Table III). Other studies have indicated that cigarette smoking at home increases NO_2 concentrations 1-2 ug/m^3 on the average.[11-12]
To examine the effects of environmental sources on NO_2 concentrations, multiple regression analysis was performed with NO_2 concentrations as the independent variable and sampling period, heater use time and office size as the dependent variables.

Since the sampling was not performed at the same time in all offices, the effect of time as a variable, in terms of ventilation or some other non-measured parameter, had to be examined. This examination indicated that there is no systematic variation in the data because of the sampling period. Direct room or building ventilation rates were not measured. We do not expect a systematic relationship among these variables and ventilation rates.

The analysis indicated that heater use and office volume are important determinants of concentration. Table IV presents the summary of regression analysis results of mean NO_2 concentrations in offices. Heater use time (hour per day) had a positive and significant regression coefficient, while office size had a negative regression coefficient.

CONCLUSIONS

Even though this study may have been limited with respect to the number of buildings and length of sampling period, it is clear that elevated indoor concentration of NO_2 are associated with routine use of kerosene space heaters. Averaged NO_2 concentrations were four times higher in the offices with kerosene heaters versus those with electric heaters. These concentrations often exceeded the Korea ambient air quality standard. While other contaminants were not simultaneously measured, we would expect particles, CO and HCHO concentrations to be elevated in association with kerosene heater use. SO_2 may be elevated depending on sulfur content of fuel. These findings raise concern about the possible health consequences of indoor exposures. Follow-up studies to assess other contaminants, carboxyhemoglobin levels in workers, respiratory and pulmonary function surveys are recommended.

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Table I. Mean NO_2 concentrations (ppb) for different samplers by selected characteristics

Characteristics	Category	N	Badge x	Badge s	Tube A x	Tube A s	Tube B x	Tube B s
Heating source	Central	6	11.0	3.8	13.0	4.3	13.0	4.7
	Electric	7	17.0	2.4	19.9	4.7	21.0	5.4
	Kerosene	7	66.7	43.4	85.9	47.0	82.9	53.7
Smokers in Office	No	9	24.0	25.2	31.1	34.3	31.3	34.3
	Yes	11	39.6	42.1	49.0	49.3	47.6	51.7
Sampling periods (days)	4	15	27.1	25.1	36.3	35.6	35.1	37.3
	5	5	49.0	57.9	55.0	63.8	55.8	63.7
Length of heater use (hrs./day) 1-2	Electric	1	11.9	-	15.8	-	13.5	-
	Kerosene	2	28.6	5.7	35.4	11.7	26.1	0.6
3-4	Electric	3	17.6	0.8	21.0	3.3	22.7	5.7
	Kerosene	1	33.6	-	57.4	-	48.4	-
5+	Electric	3	18.2	1.4	20.2	6.8	21.8	4.7
	Kerosene	4	94.1	37.7	118.2	31.7	120.0	37.1
Office size (m_2)	-5	3	97.8	45.2	125.3	34.1	125.7	43.3
	6-8	6	35.0	24.3	44.3	9.7	40.2	30.6
	9+	11	13.5	4.3	16.1	5.8	17.0	6.9

Note: N = number of samplers, x = mean, s = standard deviation

Table II. Mean NO_2 concentrations (ppb) for different samplers by type of heaters and presence of smokers in offices.

		Heater Electric (n=7)	Heater Kerosene (n=7)	p-value	Smoker No (n=9)	Smoker Yes (n=11)	p-value
Badge	x	17.0	66.7	.011	24.0	39.6	.343
	s	2.4	43.4		25.2	42.1	
Tube A	x	19.9	85.9	.003	31.1	49.0	.370
		4.7	47.0		34.3	49.3	
Tube B	x	21.0	82.9	.010	31.3	47.6	.427
	s	5.4	51.7		34.2	51.7	

Note: x = mean, s = standard deviation, p-value based on two tailed t-test

Table III. Mean NO_2 concentrations (ppb) for different samplers by environmental smoke and type of heater

		Smoker Electric (n=5)	Smoker Kerosene (n=5)	P	Nonsmoker Electric (n=2)	Nonsmoker Kerosene (n=2)	P
Badge	x	16.6	67.3	.000	18.0	65.2	.115
	s	2.9	51.6		0.5	24.8	
Tube A	x	20.1	83.8	.001	19.5	91.2	.008
	s	5.6	57.2		2.8	8.4	
Tube B	x	20.7	80.3	.000	21.8	89.5	.042
	s	5.3	64.8		7.8	18.8	

Note: x = mean, s = standard deviation, p = value based on two tailed t-test

Table IV. Multiple regression analysis of NO_2 concentrations (ppb) measured by Palmes tube (A) sample

	B	S.E. of B	t-value
Sampling period	0.204	0.252	0.809
Heater use time	6.341	2.477	2.560*
Office size	-9.698	2.798	-3.467*
(Constant)	78.060	24.241	1.764

Note: B = regression coefficient, S.E. = standard error, *$p < .05$
Adjusted R square = 0.630
Overall F-statistics = 11.798 ($p < .0001$)