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Comparison of Five Pollutant Levels between Inside and Outside Homes†

主要 汚染物質에 대한 家庭에서의 室內外 濃度比較

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國 文 抄 錄

大氣汚染의 疫學的 硏究의 일부로서 미국내 휴스턴시의 家庭을 對象으로 5가지 主要汚染物質(SO_2 NO_2, NO, CO, O_3)에 대한 室內外 濃度를 調査하였다. 室內濃度는 침실, 부엌, 거실에서 調査하였고 室外濃度와 比較하였다. 그 結果 오존을 除外한 각 汚染物質에서 부엌과 거실의 濃度는 室外濃度 보다 높았다. 또한 NO_2와 O_3를 除外한 각 汚染物質의 室內外 濃度比는 1.8 ~ 2.7을 나타냈다. 특히 家庭 內에서 汚染物質의 室內濃度는 家庭의 住宅構造, 居住者의 吸煙狀況 등에 影響을 받는 것으로 시사되었다.

INTRODUCTION

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.[1] Although it is very difficult to measure accurate personal exposure, some epidemiological studies have attempted to investigate the potential health effects of outdoor and indoor air pollution.[2-3] It became apparent to these investigators that comparison of indoor and outdoor measurements might have important implications for their health effects studies.[4] Recently, limited studies have been reported on the subject of the relationships of indoor/outdoor air pollution levels associated with the characteristics of indoor environments.[5-6]

This paper attempts to evaluate the indoor and outdoor levels of five selected gaseous pollutants and the impact of certain household characteristics on the indoor levels in the Houston area.

This work was done while Dr. Kim worked as a faculty staff at the Dept. of Environmental Sciences, School of Public Health, University of Texas at Houston.

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METHODS

As part of an air monitoring system for producing exposure estimates for a health effects study in the Houston area,[7] simultaneous indoor and outdoor measurements of air pollutants were performed at twelve homes selected from two Houston neighborhood, Clear Lake and Sunnyside (Figure 1). The continuously monitored pollutants were sulfur dioxide, nitric oxide, nitrogen dioxide, carbon monoxide, and ozone. Monitoring for each pollutant was performed for at least one week at each house during May-October 1981.

Indoor air samples were collected from three different rooms (living room, bedroom, kitchen) of the house. SO_2 was monitored using a pulsed fluorescence method. NO/NO_2 and O_3 were measured using Bendix chemiluminescence analyzers. CO was measured using a Bendix CO Infrared analyzer. A detailed description of monitoring design, sampling and analytic methods, and data validation procedures is available elsewhere.[8]

RESULTS AND DISCUSSION

Summary results of indoor and outdoor average concentrations of five pollutants are presented in Table I. In all homes the average

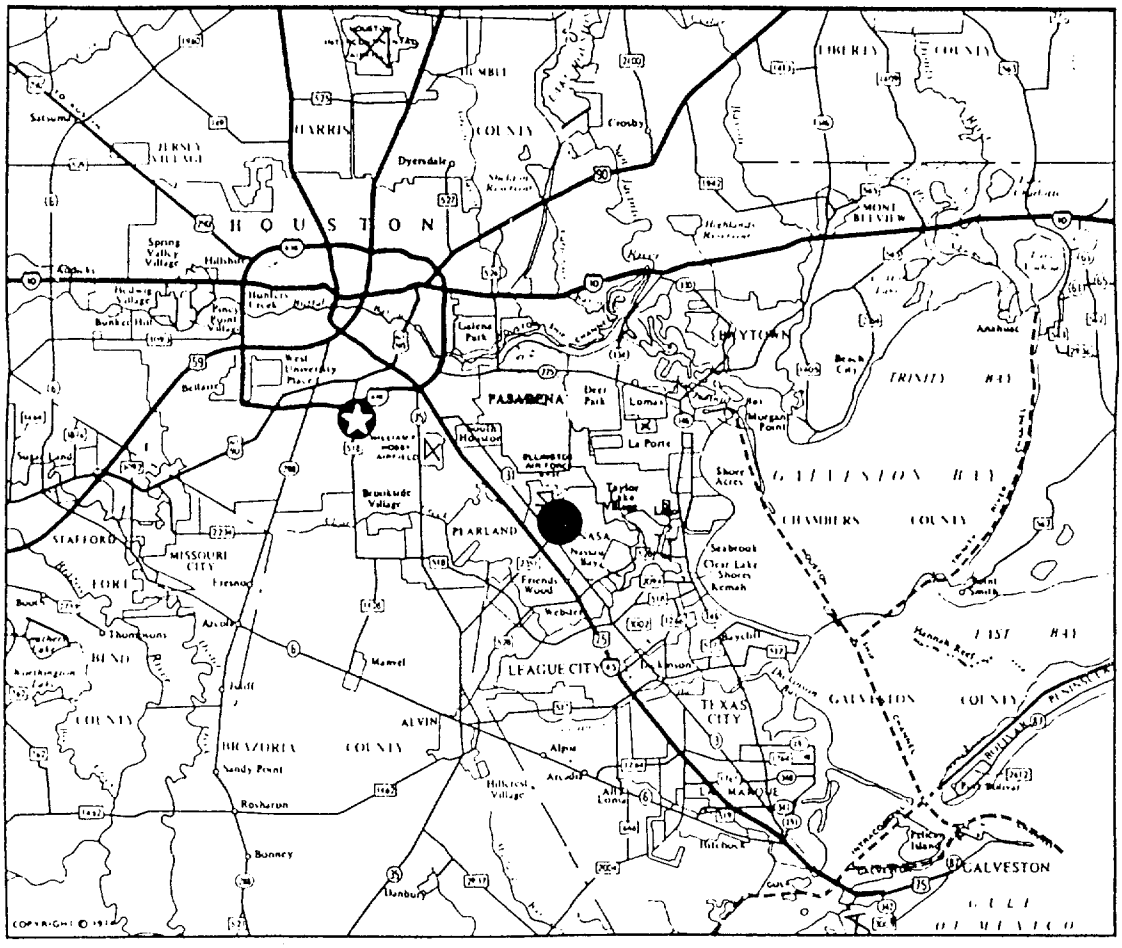

Figure 1. Map of Houston area study sites (● Clear Lake, ✪ Sunnyside)

concentrations of each pollutant in the kitchen and living room exceed the corresponding outdoor mean values except for O_3, while mean bedroom levels for all gases except for O_3 and NO_2 are higher than the corresponding outdoor levels.

The ratio of the mean indoor concentrations (average of three rooms) to the mean outdoor concentrations is $\geqslant 1.0$ for NO_2, SO_2, CO, and NO, but is only 0.06 for O_3. It appears that indoor mean concentrations do not vary much from room to room.

It is interesting to examine the data from the individual homes to see the effects of relevant household characteristics. The houses monitored in this study consist of a mix of homes with obvious potential sources of combustion-generated indoor pollutants (smokers and gas stoves) and homes with no obvious indoor combustion sources. Thus, eight of the homes may be classified into two groups: a "Source" group consisting of homes with both gas stoves and at least one resident smoker who routinely smokes indoors (Houses 6,7,8,9), and a "Nonsource" group containing homes with electric stoves and no resident smoker (Houses 4,5,10,11). The remaining four homes have gas stoves (Houses 3 and 12) or smokers (Houses 1 and 2), but not both.

House-specific mean concentrations of each pollutant and indoor/outdoor (I/O) ratios of the means are presented in Table II. In this table the indoor data are concentrations measured in the living room.

Table I. Summary of indoor and outdoor average concentrations (ppb) for five pollutants.

Pollutant	Sampling Location	No. of Hours	Mean	SD	I/O* Ratio
SO_2	Indoor, Living room	2430	5.10	5.17	1.83
	Indoor, Bedroom	2427	4.97	5.03	
	Indoor, Kitchen	2425	5.10	5.12	
	Outdoor	2565	2.76	4.97	
NO	Indoor, Living room	2423	52.68	64.80	2.72
	Indoor, Bedroom	2425	51.98	66.38	
	Indoor, Kitchen	2415	53.67	66.94	
	Outdoor	2472	19.40	44.60	
NO_2	Indoor, Living room	2400	16.56	22.11	0.99
	Indoor, Bedroom	2402	13.73	16.31	
	Indoor, Kitchen	2391	18.79	28.06	
	Outdoor				
CO	Indoor, Living room	2382	1398.83	2237.98	2.02
	Indoor, Bedroom	23	1272.44	1921.89	
	Indoor, Kitchen	2378	1489.87	2597.31	
	Outdoor	2649	702.68	1161.35	
O_3	Indoor, Living room	2332	1.25	5.88	0.06
	Indoor, Bedroom	2342	1.24	3.42	
	Indoor, Kitchen	2335	1.29	4.23	
	Outdoor	2505	22.29	25.43	

* I/O – Ratios of overall means of Indoor average conc. of three rooms/Outdoor conc.

Table II. House-specific mean concentrations (ppb) for each pollutant

House #	I/O	SO_2 N	SO_2 X (SD)	I/O	NO N	NO X (SD)	I/O	NO_2 N	NO_2 X (SD)	I/O	CO N	CO X (SD)	I/O	O_3 N	O_3 X (SD)	I/O
1	I	142	7.3 (5.7)	5.5	156	24.2 (10.0)	10.0	156	17.4 (10.1)	2.7	165	519.4 (766.8)	1.2	157	0.6 (1.8)	.04
	O	156	1.3 (1.6)		157	2.4 (3.5)		157	6.4 (4.9)		175	431.4 (361.0)		164	15.6 (10.7)	
2	I	173	1.5 (1.4)	0.6	171	22.2 (18.9)	5.9	151	31.5 (16.0)	2.9	177	475.7 (334.8)	1.8	168	1.1 (1.2)	.04
	O	172	2.4 (3.4)		173	3.8 (8.6)		173	10.7 (9.2)		177	270.1 (314.0)		168	24.5 (20.4)	
3	I	170	3.7 (3.6)	1.2	170	57.6 (35.2)	7.6	170	25.0 (23.6)	1.6	174	779.3 (963.0)	1.9	168	1.8 (0.9)	.06
	O	199	3.0 (3.2)		198	7.5 (9.1)		198	15.6 (10.2)		201	407.9 (428.3)		197	27.3 (27.5)	
4	I	175	8.4 (6.3)	3.9	180	14.2 (12.2)	1.4	180	4.9 (5.6)	0.7	180	236.7 (264.7)	0.8	175	1.2 (0.9)	.06
	O	174	2.2 (2.5)		176	9.9 (12.7)		176	6.9 (7.8)		182	307.3 (335.2)		180	20.7 (21.7)	
5	I	197	5.6 (4.4)	4.0	199	13.6 (9.5)	1.3	199	2.9 (1.9)	0.3	201	278.1 (231.3)	07	199	0.9 (0.8)	.06
	O	198	1.4 (1.5)		198	10.2 (11.2)		98	9.1 (4.9)		200	394.5 (307.4)		200	16.0 (19.9)	
6	I	181	6.9 (6.7)	2.1	181	65.5 (43.2)	4.3	181	31.6 (46.7)	1.5	183	7471.6 (3581.2)	9.7	175	0.9 (1.4)	.05
	O	215	3.3 (7.9)		192	15.4 (20.0)		191	21.1 (18.9)		209	771.8 (766.0)		206	18.7 (19.9)	
7	I	179	2.9 (3.4)	0.6	176	135.3 (94.6)	4.5	174	19.9 (26.9)	1.3	181	1632.0 (945.6)	1.8	174	1.2 9 0.7)	.07
	O	174	5.3 (6.3)		165	30.0 (35.3)		165	15.0 (10.4)		196	890.8 (1059.6)		173	17.3 (33.9)	
8	I	195	3.2 (4.3)	1.4	197	43.2 (24.9)	5.9	197	18.9 (8.8)	1.0	200	1140.0 (459.8)	2.2	175	0.7 (0.9)	.02
	O	211	2.2 (3.3)		210	7.3 (12.3)		209	19.5 (13.3)		212	526.9 (505.6)		190	31.9 (313)	
9	I	181	3.7 (3.8)	1.9	181	105.6 (74.4)	3.3	180	27.8 (21.2)	1.2	183	2582.0 (1180.1)	2.4	180	0.4 (0.8)	.01
	O	175	2.0 (4.3)		194	32.2 (56.5)		194	22.8 (21.5)		196	1073.0 (1565.3)		192	32.0 (32.7)	
10	I	194	8.7 (7.5)	10.9	198	113.2 (9.3)	1.0	198	1.6 (2.1	0.1	199	415.1 (307.1)	1.4	177	1.1 (0.4)	.07
	O	194	0.8 (0.9)		196	13.5 (16.6)		195	14.0 (8.9)		199	299.5 (349.5)		173	15.6 (14.1)	
11	I	196	4.9 (4.3)	2.6	197	19.3 (17.5)	1.4	197	2.8 (4.2)	0.2	201	447.8 (588.9)	0.8	175	1.3 (1.5)	.06
	O	180	1.9 (2.3)		195	14.2 (26.9)		192	11.3 (10.0)		195	565.6 (756.1)		179	22.6 (16.8)	
12	I	283	5.9 (3.7)	1.3	252	130.1 (85.3)	1.9	252	24.3 (21.6)	0.7	176	1570.5 (1512.6)	0.9	249	2.8 (17.5)	.1
	O	318	4.6 (7.0)		281	69.3 (98.70		281	35.9 (30.8)		316	1777.8 (23940		277	24.5 (30.9)	
All	I	2430	5.1 (5.2)	1.8	2423	52.7 (64.8)	2.7	2400	16.6 (22.1)	1.0	2382	1398.8 (2238.0)	2.0	2332	1.3 (5.9)	.06
	O	2565	2.8 (5.0)		2472	19.4 (44.6)		2466	16.6 (17.6)		2649	702.7 (1161.4)		2505	22.3 (25.4)	

I – Indoor (living room); O – Outdoor; N – Number of hours;

X – Mean; SD – Standard Deviation

Indoor mean concentrations of SO_2 across the homes range from 1.5 to 8.7 ppb, while I/O mean ratios range from 0.6 to 10.9. The indoor concentrations in each home are higher than the corresponding outdoor levels except for Homes 2 and 7; however all concentrations are relatively low.

Across all homes indoor NO concentrations are generally higher than the corresponding outdoor concentrations. The range of I/O mean ratios is 1.0 to 10.0. The four lowest indoor mean concentrations are associated with homes (# 4,5,10,11) with electric stove and no resident smoker, while the four highest indoor mean concentrations are found in three "Source" homes (# 6,7,9) and one home (# 12) with gas stove and no resident smoker.

Indoor NO_2 mean concentrations across homes range from 1.6 to 31.6 ppb, while I/O mean ratios do not vary as greatly from home to home and range from 0.1 to 2.9. The four lowest indoor mean concentrations are associated with "Nonsource" homes (# 4,5,10,11), and outdoor concentrations at these homes are higher than the corresponding indoor levels.

Indoor average concentrations of CO across homes range from 0.2 to 7.5 ppm. The house I/O ratios range from 0.8 to 9.7. There appear to be real differences between "Source" and "Nonsource" homes; the Nonsource homes have the four lowest indoor concentrations, while the Source homes have the three highest

Table III. Results of t-tests of differences of concentrations (ppb) between "Source" and "Non-source.. homes

Pollutant	Homes	Concentration		I/O	Significance	
		Indoor	Outdoor	Radio	Indoor	Outdoor
SO_2	Source	4.2	3.1	1.4	*	**
	Nonsource	6.8	1.5	4.5		
NO	Source	86.1	20.6	4.2	**	*
	Nonsource	15.1	12.0	1.3		
NO_2	Source	24.4	19.8	1.2	**	*
	Nonsource	3.0	10.4	0.3		
CO	Source	3164.6	809.2	3.9	**	**
	Nonsource	347.1	393.2	0.9		
O_3	Source	0.8	25.0	0.03	NS	*
	Nonsource	1.1	18.7	0.06		

* $P < 0.05$; ** $P < 0.01$; NS – Not Significant;
Indoor – Living room concentration; I/O – Indoor/Outdoor

indoor concentrations (Homes 6,7,9).

In all homes indoor O_3 concentrations are much lower than the corresponding outdoor concentrations. House indoor means range from 0.4 to 2.8 ppb. House I/O ratios range from 0.01 to 0.1.

The probabilities associated with the t-tests for the differences in each pollutant concentration between Source and Nonsource homes are presented in Table III. Indoor mean concentrations of each pollutant for the Source homes are higher than the corresponding levels for the Nonsource homes except for SO_2 and O_3, while outdoor levels of all pollutants for the Source homes are higher than the corresponding levels for the Nonsource homes. The differences in outdoor concentrations are due to the fact that all of the Nonsource homes are in one area (Clear Lake), while 3 of the 4 Source homes are in the other, generally more polluted area (Sunnyside).

I/O ratios of mean concentrations for NO, NO_2, and CO in the Source homes exceed the corresponding values in the Nonsource homes. The differences in indoor mean concentrations of NO, NO_2, and CO between Source and Nonsource homes are highly statistically significant ($p < 0.01$).

CONCLUSIONS

These results show that indoor concentrations (average of all rooms monitored) of SO_2, NO, and CO are in general higher than the corresponding outdoor levels. Indoor-outdoor ratios of mean concentrations for NO_2 and O_3 are 0.99 and 0.06, respectively. The data indicate that average room-to-room differences in pollution concentrations are not large.

It is shown that average indoor concentrations of NO, NO_2 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, NO_2, and CO are likely related to the use of gas stoves and/or the presence of a resident smoker. Examination of diural variations of indoor pollution concentrations in the homes could be effective in understanding the potential indoor sources affecting indoor levels. For O_3 and SO_2, indoor levels are very low, and appear not to be greatly influenced by the presence of gas stoves or smokers.

Additional information concerning more detailed housing characteristics, daily activity patterns, and seasonal factors which may influence both indoor and outdoor measured levels of pollutants levels of pollutants should provide important information on exposure for epidemiological studies of air pollution.

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ABSTRACT

As part of an air pollution epidemiological study of asthmatics residing in the Houston area, an air monitoring system provided data on the indoor and outdoor measurements of major pollutant gases sampled at selected residences during May ~ October 1981. Continuously monitored pollutant gases included sulfur dioxide (SO_2), nitrogen dioxide (NO_2), nitric oxide (NO), carbon monoxide (CO), and ozone (O_3). Outdoor levels for each pollutant were compared with their indoor levels (bedroom, kitchen, living room). Mean concentrations of each pollutant in the kitchen, and living room exceeded the mean levels outside except for ozone, while average bedroom levels for all gases except for O_3 and NO_2 were found higher than the corresponding outside levels. Indoor/outdoor ratios for SO_2, NO, and CO were 1.8 ~ 2.7 times the outdoor levels, but indoor/outdoor ratios for NO_2 and O_3 were 0.99 and 0.06, respectively. The impact of several important household characteristics (type of cooking fuel and cigarette smoking) on the indoor levels of these gases is evaluated.

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