# THE RELATIONSHIP BETWEEN POLLUTANT LEVELS IN HOMES AND POTENTIAL SOURCES

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Indoor levels of respirable suspended particulates (RSP), nitrogen dioxide ($NO_2$) and sulphur dioxide ($SO_2$) were measured in homes in two health related studies. The air pollution sampling was conducted using a specially designed system which sampled the pollutants simultaneously.

The potential sources of the air pollution investigated included heating systems, cooking fuel, air conditioners, number of occupants, pets, furniture, floor coverings, tobacco smoke, and fireplaces.

Study I showed that $NO_2$ levels were higher in homes with gas stoves than in homes with electric stoves. The difference averaged 100 ug/$m^3$ with a maximum level detected of 3,000 ug/$m^3$. The levels of RSP in homes was directly related to the number of smokers. Homes with one and two smokers had RSP levels of 14 ug/$m^3$ and 39 ug/$m^3$ respectively higher than homes with no smokers. $SO_2$ levels were very low and there were no obvious indoor sources of this pollutant.

Study II investigated $NO_2$, (suspended particulate matter), and $SO_2$. Homes with gas stoves were excluded from this study. Homes with fireplaces had 18 ug/$m^3$ more $NO_2$ and 6 ug/$m^3$ less RSP than homes without fireplaces; $SO_2$ levels were very low and similar in both types of homes.

Air conditioning usage was found to influence the $NO_2$ and RSP levels to a small extent. The other sources had very little influence. In general, indoor $NO_2$ and RSP levels were higher than outdoor levels.





## INTRODUCTION

It is now recognized that the indoor environment is important in an individual's total exposure to airborne contaminants since in some areas residents spend 70 - 90% of their time indoors [1,2]. The indoor home environment has numerous sources of airborne respiratory irritants. Smoking, cooking, cleaning, heating and fireplace use all contribute to the generation of indoor airborne pollution [2,3,4].

In general, indoor $SO_2$ concentrations are usually less than outdoors unless there are particular indoor sources [5]. Indoor $NO_2$ levels can be higher depending on indoor sources [6]. A significant indoor source of $NO_2$ has been shown to be gas stoves [7,8,9,10]. Tobacco smoke is a major source of indoor airborne particulate matter and to a lesser extent $NO_2$ [11]. Airborne sulphate levels have been shown to be associated with smoking and use of matches [12].

Two studies were conducted to determine the effects of indoor pollution on the respiratory health of residents. In study I, a case/control study was conducted with a group of housewives in which the cases reported chronic cough and phlegm. In study II, another case/control study was conducted in which the cases reported asthma.

In both studies lifestyle factors were evaluated to determine the contribution to airborne $SO_2$, $NO_2$ and RSP, which were measured simultaneously using uniquely designed samplers.

## METHODS

### Study I

The air pollution sampler consisted of a suitcase (50 X 88 X 15cm). A manifold connected to a blower served as the main sampling system from which probes lead to 3 pumps. One of the pumps sampled respirable suspended particulates on to glass fiber filters using a 10mm nylon cyclone assembly. Two other pumps collected $NO_2$ and $SO_2$ by bubbling air into impingers with sodium hydroxide and potassium tetrachloromercurate solutions respectively. The level of $NO_2$ was determined using the Jacobs and Hochheiser method [13] whereas the $SO_2$ was determined by the West and Gaeke method [14]. RSP was determined by the gravimetric method.

The sampler was placed in the area most frequently used by the subject. Samples were collected once in the summer and winter for each subject. The sampling period was 24 hours.

The lifestyle characteristics considered were: air conditioning, cooking fuel, smoking, type of heating system, and carpets on the floor.

Study II

The air pollution sampler was a variation of the one used in Study I. It was made more compact to be used as a personal or indoor sampler. It collected the same gases, but the particulate matter consisted of particles less than 25 um (SPM). Samples were collected everyday for two weeks in the heating and two weeks in the non-heating seasons. The samplers were operated for 6 to 8 hours, primarily during the day time. Details of the sampler design were given elsewhere [15].

The lifestyle factors included: heating system, air conditioning, smoking, floor covering, wall covering, fireplace, air tightness of home and crowding.

The data for each individual were averaged and a t-test was conducted to test the differences between the means for those who had or did not have the lifestyle characteristic.

In both studies, comparison measurements were undertaken outside of the homes using similar sampling and analytical methods.

RESULTS

Study I

In order to determine whether there were any indoor sources of the 3 pollutants, indoor levels were compared with outdoor levels. The data show that there were indoor sources of $NO_2$ and RSP but not $SO_2$. In fact the $SO_2$ levels were very low both indoors and outdoors, and no further analysis of the $SO_2$ results are given (Figure 1).

Sources of NO2

Twenty-one percent of the homes had gas stoves, and in these homes the nitrogen dioxide levels (Figure 2) were significantly higher than homes with electric stoves ($P < .001$). This differential between homes with gas and electric stoves was seen in both seasons. The winter $NO_2$ levels were higher than the summer in homes with both gas and electric stoves. Homes with gas stoves and air conditioning had less $NO_2$ than homes without air conditioning, but the numbers in each group were too small for meaningful comparisons (Table I).



Five percent of the homes had gas radiant heaters, but some of these homes also had gas stoves, hence it was not possible to assess the emissions of $NO_2$ from this source. The homes of smokers without gas stoves had more $NO_2$ than homes of non-smokers without gas stoves. Although the differences were significant ($P < .001$ and $P < .02$ respectively), the absolute differences in the geometric means were small (Table II).

The tests conducted to determine the daily variations in domestic $NO_2$ loading showed that in two homes with gas ranges, the $NO_2$ levels were sometimes in excess of 1000 $ug/m^3$ (i.e. 2-hourly values). In one home, thirteen of the sixty 2-hourly values were in excess of 1000 $ug/m^3$ and in the other home, eight of the sixty 2-hourly values were in excess of 1000 $ug/m^3$. In this latter home, peak 2-hourly values in excess of 3000 $ug/m^3$ were observed on two separate occasions. In all cases, these peaks were directly related to extensive use of the gas stoves and ovens.

Sources of RSP

Cigarette smoking contributed significantly to the RSP loading within homes in the winter and summer (Figure 3). The presence of one smoker in the home resulted in significantly more RSP than homes with no smokers ($P < .001$), and homes with 2 or more smokers showed more RSP than homes with one smoker or no smokers ($P < .001$). In homes with air conditioning, the RSP levels were higher in both homes with zero smokers ($P < .01$) and with at least one smoker ($P < .001$) compared with homes without air conditioning (Table III).

Carpeted houses with at least one smoker had more RSP than non-carpeted houses with at least one smoker (Table IV), but houses of non-smokers with carpet had less RSP than houses of non-smokers without carpets.

Homes with hot water heating with no smokers had significantly higher levels of RSP than homes heated by forced air. Homes with one or more smokers and with hot water heating had significantly higher levels of RSP than homes heated by forced air (Table V).

Study II

Indoor $NO_2$ concentrations were higher in homes with at least one fireplace than in homes without any fireplace (Heating Season only) (Table VI). There was no effect of fireplaces on the indoor levels of $SO_2$. The indoor SPM concentrations were higher in homes without fireplaces than in homes with fireplaces.

The presence of smokers in the home had no effect on the concentrations of $SO_2$ and an inconsistent effect on $NO_2$ levels. Indoor SPM levels were higher in homes with smokers.

The use of gas heating on the indoor levels showed that there were higher indoor $NO_2$ levels (Heating Season only) but lower SPM levels (Table VI) compared to homes with other types of heating.

Homes reported as being airtight did not differ in their indoor $SO_2$ levels from homes that were reported as permeable. Any differences observed for indoor concentrations of $NO_2$ and SPM were inconsistent (Table VI).

The indoor concentration of $NO_2$ tended to be higher in homes with more than two adults (Table VI). Very little difference was observed for $SO_2$. The observed differences in the concentration of SPM were small and inconsistent. The indoor concentrations of $NO_2$ were higher in homes with no children (Table IV). No differences were observed for $SO_2$ and any differences observed for SPM were inconsistent.

The indoor levels of $NO_2$ were lower for homes that had pets that would go in and out of doors (Table VI). Pets had no effect on $SO_2$ or SPM.

Homes with air-conditioners (Table VI) had lower $NO_2$ and SPM than homes without air-conditioners. In this sample only asthmatics had air cleaners (Table VI). The indoor concentrations of SPM were higher in home without air cleaners.

Homes with carpets had more SPM than homes without; there were no effects of carpets on $SO_2$ and $NO_2$ levels. Homes with wallpaper had lower SPM than homes without wallpaper; there were no effects of wallpaper on $SO_2$ and $NO_2$ levels. Homes with soft furniture had lower $NO_2$ and higher SPM than homes without soft furniture.

## CONCLUSION

The levels of $SO_2$ were low both inside and outside, and the outdoor levels were generally higher than the indoor levels. With regards to $NO_2$, gas stoves were the major contributors to the high levels measured whereas smoking indoors was a very small contributor to $NO_2$.

Smoking accounted for the high indoor levels of particulates, and carpeted homes seemed to have higher levels of suspended particulates.

Crowding, air tightness and pets had no consistent effects on the indoor pollutant levels.



## REFERENCES


1. A. Szalai. The Use of Time. Mouton, Paris, 1972.

2. R. Binder, C. Mitchell, H.R. Hosein, A. Bouhuys, "Importance of the indoor environment in air pollution exposure," Arch. Environ. Health, 31:277 (1976).

3. J.E. Yocom, W.L. Clink, W.A. Cote, "Indoor--outdoor air quality relationships, "J. Air Pollut. Contr. Assoc., 21(5): 251 (1971).

4. N. Lefcoe, I. Inculet, "Particulates in domestic premises, "Arch. Environ. Health, 30: 565 (1975).

5. K. Biersteker, H. deGraaf,, C. Dimattio, "Indoor air pollution in Rotterdam homes", Int. J. Air Water Pollut. 9:243 (1965).

6. R.J.W. Melia, C du V Florey, S.C. Darby, E.D. Palmes, B.D. Goldstein, "Differences in $NO_2$ levels in kitchens with gas or electric cookers, "Atmos. Environ. 12: 1379 (1978).

7. B.D. Goldstein, R.J.W. Melia, S. Chinn, C du V Florey et al, "Factors affecting $NO_2$ levels in the home, "Int. J. Epid 8: 339 (1979).

8. F.E. Speizer, B. Ferris, Y.M.M. Bishop, J. Spengler, "Respiratory disease rates and pulmonary function in children associated with $NO_2$, "Am-Rev. Resp. Dl3., 121:3 (1980).

9. H. Harke, "The influence of tabacco smoke on indoor atmospheres." Prev. Med., 4: 373 (1976).

10. G. Hoek, R. Meizer, A. Schollen, D. Noij, E. Lebiet, "The relationship between indoor $NO_2$ concentration and personal exposure, "Int. Arch. Occup. Environ. Health, 55: 73 (1984).

11. A. Weber, T. Fischer, "Passive smoking at work", Int. Arch. Occup. Environ. Health, 47:209 (1980).

12. D. Dockery, J.D. Spengler, "Personal exposure to respirable particulates and sulfates, "J. Air Pollut. Contr. Assoc., 31: 153 (1981).

13. M.B. Jacobs and S. Hochheiser, "Continous sampling and ultra-microdetermination of $NO_2$ in air". Anal. Chem. 30:426 (1958).

14. P.W. West and G.C. Gaeke, "Fixation of $SO_2$ as sulfitomercurate III and subsequent colorimetric determination. "Anal. Chem. 28:1816 (1956).

15. S. Mintz, H.R. Hosein, B. Batten, F. Silverman, "A personal sampler for 3 respiratory irritants". J. Air Poll. Contr. Assoc., 32:1068 (1982).

TABLE I

Nitrogen Dioxide Levels in Homes with Gas and Electric Stoves with and without Air Conditioning

(Summer Levels Only)

| | With Air Conditioning | | Without Air Conditioning | |
|---|---|---|---|---|
| | Electric | Gas | Electric | Gas |
| No. of obs. | 12 | 4 | 29 | 7 |
| Geometric Mean ($ug/m^3$) | 70.9 | 175.1 | 81.8 | 182.1 |
| Geometric Standard Deviation | 2.00 | 1.56 | 1.70 | 1.62 |

TABLE II

Nitrogen Dioxide Levels in Homes without Gas Stoves as a Function of Smoking

| | Winter | | Summer | |
|---|---|---|---|---|
| | Smoker | No Smoker | Smoker | No Smoker |
| No. of obs. | 29 | 12 | 29 | 12 |
| Geometric Mean ($ug/m_3$) | 82.6 | 75.7 | 76.1 | 74.5 |
| Geometric Standard Deviation | 1.75 | 1.23 | 1.74 | 1.93 |
| Unpaired t-test | $P<.001$ | | $P<.02$ | |



TABLE III

Respirable Suspended Particulates Exposure of Smokers and Non Smokers as a Function of Air Conditioning (AC)

(Summer Levels Only)

| | Zero Smokers In Home | | At least one Smoker in Home | |
|---|---|---|---|---|
| | AC | No AC | AC | No AC |
| No. of obs | 4 | 11 | 11 | 25 |
| Geometric Mean ($ug/m^3$) | 34.3 | 32.5 | 80.5 | 70.11 |
| Geometric Standard Deviation | 1.60 | 1.84 | 1.40 | 1.64 |
| Unpaired t-test | | $P<.01$ | | $P<.001$ |

TABLE IV

Respirable Suspended Particulates Exposure of Smokers in Houses with and without Carpets

| | Smoker Home | | Non Smoker Home | |
|---|---|---|---|---|
| | Carpeted | Non-Carpeted | Carpeted | Non-Carpeted |
| No. obs. | 28 | 8 | 9 | 7 |
| Geometric Mean ($ug/m^3$) | 76.6 | 70.2 | 38.7 | 53.7 |
| Geometric Standard Deviation | 1.68 | 2.14 | 1.91 | 1.73 |
| Unpaired t-test | | $P<.001$ | | $P<.001$ |

TABLE V

RSP as a Function of Smoking and Heating

| | Homes | | | |
|---|---|---|---|---|
| | Smoker | | Non Smokers | |
| | Hot Water | Forced Air | Hot Water | Forced Air |
| Geometric Mean ($ug/m^3$) | 84.8 | 57.1 | 66.7 | 37.7 |

TABLE VI

Pollutant Concentration as a Function of Sources

| | | Concentration (ug/m3 | | | | | |
|---|---|---|---|---|---|---|---|
| | | $NO_2$ | | $SO_2$ | | SPM | |
| | POLLUTANT SOURCE | YES | NO | YES | NO | YES | NO |
| * | Fireplace | 24 | 17 | 3 | 3 | 61 | 70 |
| | Smokers in Home | 25 | 27 | 3 | 3 | 83 | 65 |
| * | Gas Heating | 23 | 18 | 2 | 3 | 55 | 77 |
| | Air Tight | 26 | 26 | 6 | 2 | 71 | 70 |
| | At least one child | 23 | 31 | 3 | 3 | 71 | 69 |
| | More than 2 adults | 31 | 24 | 3 | 2 | 71 | 70 |
| | Pets | 25 | 29 | 3 | 3 | 71 | 69 |
| ** | Air Conditioning | 35 | 40 | 2 | 2 | 75 | 79 |
| *** | Air Cleaner | 27 | 26 | 1 | 3 | 65 | 70 |
| | Carpet | 26 | 26 | 3 | 3 | 73 | 66 |
| | Wallpaper | 27 | 26 | 3 | 4 | 66 | 73 |
| | Soft Furniture | 21 | 30 | 4 | 2 | 83 | 65 |

* Heating Season data only
** Non-heating season data
*** Asthmatic only



FIGURE 1

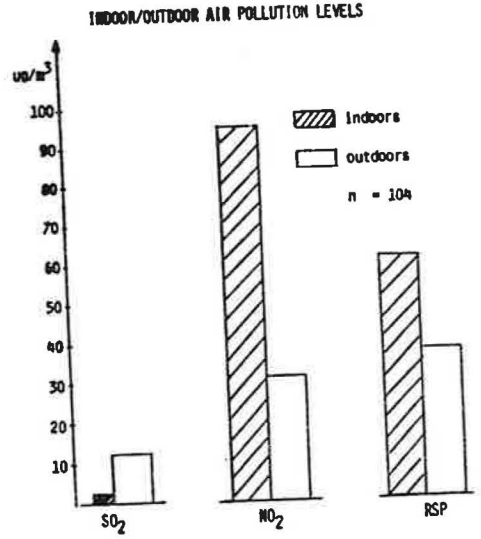



FIGURE 2

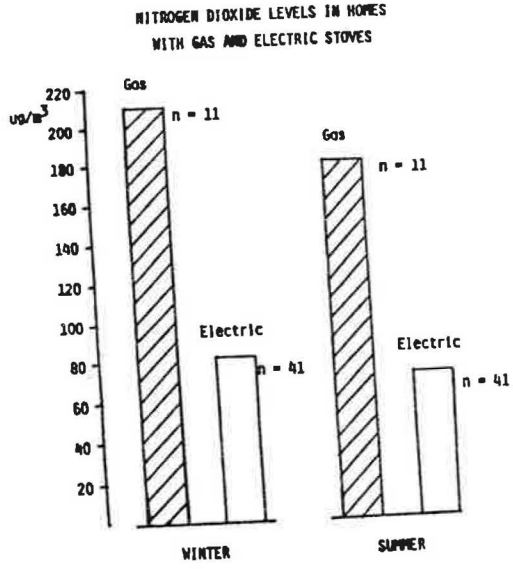
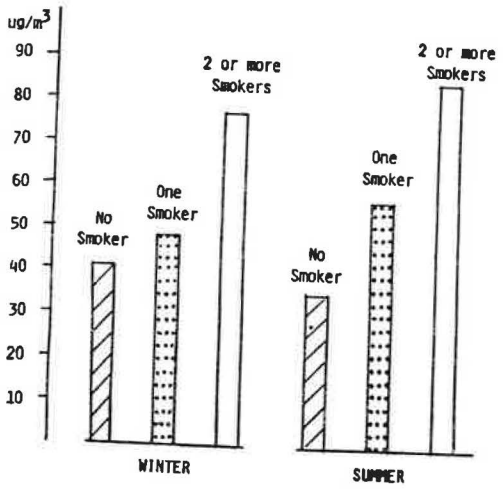


FIGURE 3

RESPIRABLE SUSPENDED PARTICULATE LEVELS
AS A FUNCTION OF SMOKING






# NITROGEN DIOXIDE LEVELS IN RESIDENCES - EFFECTS OF SOURCE TYPES

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This study was conducted to determine $NO_2$ contamination characteristics of residences which utilize a variety of combustion and noncombustion space heating systems, as well as those which use gas cooking. Residences were classified as gas cooking, gas furnace/electric cooking, wood-burning stoves/electric cooking, kerosene heat/electric cooking, noncooking steam heat, and all electric. Sampling was conducted by collecting $NO_2$ on Palmes diffusion tubes during several heating seasons. Highest $NO_2$ levels were measured in residences which used gas for cooking or kerosene heaters for supplemental space heating. Significantly lower $NO_2$ concentrations were measured in residences heated by gas furnaces/electric cooking, wood-burning stoves/electric cooking, steam-heated dormitory rooms, and all-electric residences. $NO_2$ levels in each of these four residence types were similar. In residences with wood-burning stoves, $NO_2$ could not be related to heating degree days, a measure of the 24 hr. average outdoor temperature. Multiple concurrent measurements in the upstairs and basement levels of a gas-heated residence indicated significantly higher levels upstairs even though the gas furnace was located in the basement. These results suggest that the source of $NO_2$ contamination in such residences, and possibly in those heated by wood, steam or electricity, is primarily external to the residences.