COMBUSTION-GENERATED INDOOR AIR POLLUTION

I. FIELD MEASUREMENTS 8/75 - 10/75

Craig D. Hollowell, Robert J. Budnitz,
George D. Case, and Gregory W. Traynor

Energy and Environment Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

ABSTRACT

The indoor air quality of six homes with gas and electric cooking and gas heating appliances was characterized to determine the level of gaseous and aerosol air pollutants from typical indoor combustion sources. Field measurements of SO_2, NO/NO_2, O_3, and CO were determined on a continuous basis. Total aerosol samples were collected on filter media for laboratory analysis by X-ray fluorescence and ESCA techniques for the determination of aerosol elemental composition and ionic species such as $SO_4^=$, NO_3^-, and NH_4^+. Results of the study indicate that levels of gaseous and respirable aerosol air pollutants in the indoor environment do frequently exceed those levels commonly found in the outdoor urban air. Such findings may have a large impact on the future design of epidemiological studies, on energy conservation strategies for buildings, and on the need for more stringent control of air pollution from indoor combustion sources.

As mentioned, most people spend a majority of their time indoors, yet the air pollution characterization of the indoor environment is not well understood. Limited information suggests that the indoor environment has a vastly different mix, concentration and temporal distribution of gaseous and particulate air pollutants relative to the outdoor environment. It is thus essential that air pollution characterization of the indoor environment be undertaken in order to assess correctly the human exposures in epidemiological studies and the impact of energy conservation strategies on indoor air quality.

Most studies of indoor air pollution have been concerned with SO_2, CO and/or total suspended particulate matter, and have assumed that the indoor levels arise from and are directly related to the outdoor levels (Refs. 1,2). Surprisingly little work has been done with respect to other potentially important indoor air pollution species, such as NO, NO_2, nitrates, sulfates, metals, organics, and the respirable fraction of the particulate matter. Even more surprisingly, indoor generated air pollution has been neglected in most indoor air pollution studies until quite recently.

A number of indoor sources may contribute appreciably to the total indoor air pollution, notably those associated with combustion (i.e., cooking, heating, and smoking), with aerosol spray can usage, with cleaning, and with food preparation. To date, there are a handful of documented studies which suggest that indoor sources may give rise to levels of pollutants in indoor air which greatly exceed typical levels in the outdoor environment. Among these instances are the airborne build-up of carbon monoxide and suspended particulate matter from cigarette smoking (Ref. 3), nitric oxide and nitrogen dioxide from gas stoves (Refs. 4, 5, 6, 7), formaldehyde from construction materials (Ref. 8), vinyl chloride (Ref. 9) and fluorocarbons (Refs. 10, 11) from the use of aerosol devices containing these substances as propellants, and mercury from interior wall paint and unidentified sources (Refs. 12, 13).

These examples suggest that there may be additional types and sources of air pollutants, for example, those associated with combustion sources such as cooking and heating appliances. Although elevated

EXPERIMENTAL PROGRAM

The principal objective of the field study described here was to obtain quantitative data on the relationship of indoor to outdoor air pollutant concentrations as a function of gas cooking and heating appliance use. Six homes in Berkeley and Albany, California were selected for this study. All homes were fitted with gas heating systems, five with gas stoves, and one with an electric stove. Field measurements reported here were made under conditions simulating typical cooking and heating usage. Only the home with the electric stove was characterized during a cool season when the heating system is normally operated, and is therefore the only home to be evaluated for the effect of gas heating systems on indoor air pollutant levels. Future field work will characterize additional homes to study the effect of heating systems in more detail. The major air pollutants that have been identified with gas combustion sources are carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO_2), and to a lesser degree, sulfur dioxide (SO_2) and particulates. The program also included measurement of ozone (O_3) which is not considered to be an indoor generated pollutant but which may penetrate into the indoor environment and react with the combustion generated pollutants, building materials, or other indoor sinks. Particulate samples were collected on 47 mm filters for laboratory chemical analysis by X-ray fluorescence (XRF) (Refs. 15,16) and electron spectroscopy for chemical analysis (ESCA) (Refs. 17,18,14) techniques. The components of the measurement system are given in Table 1. The instruments were located near the indoor and outdoor sampling locations and measurements were taken sequentially at both locations. The sample intake for the gas and electric stove measurements was placed in the breathing zone approximately 1.5 meters above the floor near the front of the stove. Measurements to study the effect of the heating system were made with the sample intake in the bedroom approximately 1 meter above the floor. Gases were sampled through 4 to 8 meters of 6.4 mm I.D. TFE teflon tubing at a rate of approximately 6 liters per minute (lpm)

and measured on a continuous basis. This is equivalent to a retention time in the tubing of 2 to 4 seconds, which is sufficiently short to minimize wall losses and reactivity of the gases. Indoor and outdoor particulate samples were collected on 47 mm filters at a flow rate of approximately 70 lpm. The sampling periods ranged from 30 minutes for aerosols collected on cellulose filter media for XRF analysis to 2 hours for aerosols collected on silver filter media for ESCA measurements.

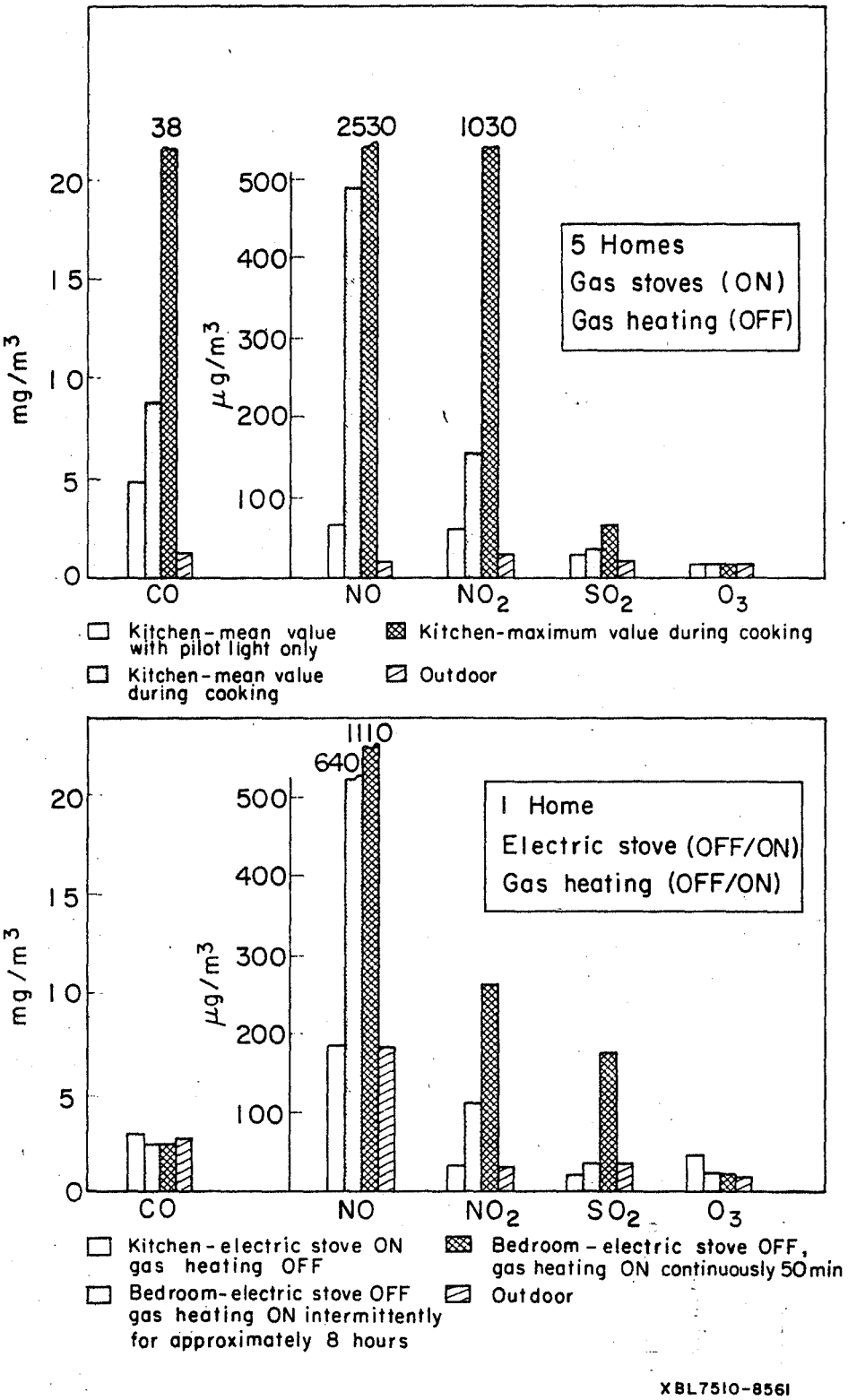

Figure 1. Gaseous indoor and outdoor air pollutant levels observed at homes with varying cooking and heating configurations.

Table 3. Effect of Gas Burner Conditions on Gaseous Emissions*
(Observed Levels ±15%)

Home Identification Number	Pollutant	Kitchen Background	One Burner On No Grate	One Burner On With Grate	One Burner On With Grate and All Stainless Steel Pan
2	CO (mg/m^3)	9	10	9	27
	NO ($\mu g/m^3$)	85	1050	1110	740
	NO_2 ($\mu g/m^3$)	85	380	380	370
	SO_2 ($\mu g/m^3$)	40	65	90	80
3	CO (mg/m^3)	1	2	3	13
	NO ($\mu g/m^3$)	25	165	125	160
	NO_2 ($\mu g/m^3$)	30	115	65	125
	SO_2 ($\mu g/m^3$)	<15	25	<15	<15
4	CO (mg/m^3)	3	4	3	3
	NO ($\mu g/m^3$)	55	1110	1230	680
	NO_2 ($\mu g/m^3$)	60	450	470	380
	SO_2 ($\mu g/m^3$)	<15	40	35	25
5	CO (mg/m^3)	4	8	9	8
	NO ($\mu g/m^3$)	75	1260	990	640
	NO_2 ($\mu g/m^3$)	60	340	320	265
	SO_2 ($\mu g/m^3$)	25	50	30	25

*Measurements in kitchen approximately 60 cm above the stove

Table 4. Gaseous Air Pollutant Levels Observed in Homes With Gas Ovens*

(Observed Levels ±15%)

Home Identification Number	2		3	5
Ventilation Conditions	No Duct Fan Off	No Duct Fan On	Duct No Fan	Duct No Fan
CO (mg/m^3)	23	6	2	7
NO ($\mu g/m^3$)	2000	1000	500	150
NO_2 ($\mu g/m^3$)	850	320	150	95
SO_2 ($\mu g/m^3$)	110	65	<25	<15

* Measurements in center of kitchen, approximately 1.5 meters above the floor, with the gas oven at 550°F for approximately 20 minutes.

Table 5. National Primary Ambient Air Quality Standards*

Pollutant	Averaging Time	Concentration
Carbon Monoxide	1 hr.	40 mg/m^3 (35 ppm)
	8 hr.	10 mg/m^3 (9 ppm)
Nitrogen Dioxide	Annual Arithmetic Mean	100 $\mu g/m^3$ (0.05 ppm)
Sulfur Dioxide	24 hr.	365 $\mu g/m^3$ (0.14 ppm)
	Annual Arithmetic Mean	80 $\mu g/m^3$ (0.03 ppm)

*National standards other than those based on annual arithmetic means or annual geometric means are not to be exceeded more than once per year.

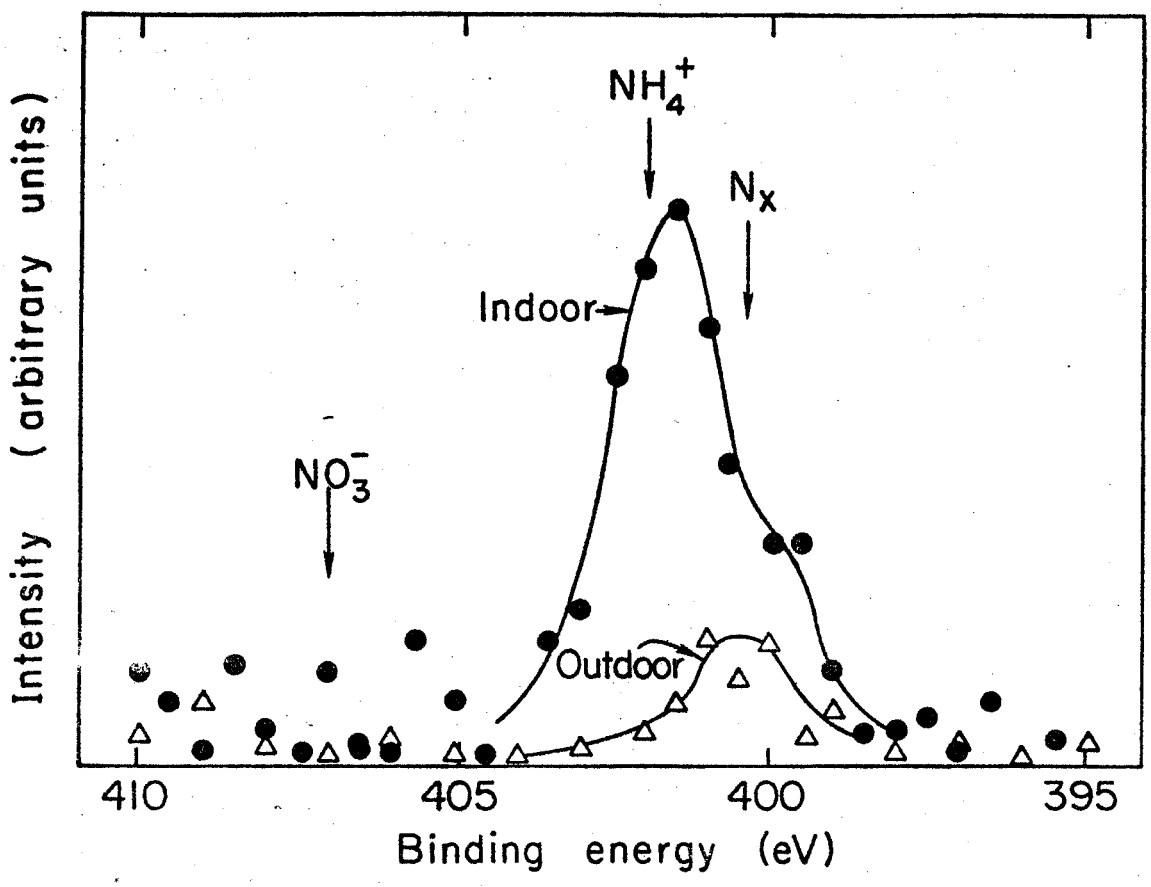

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Figure 3. Nitrogen (1s) photoelectron (ESCA) spectra of indoor and outdoor particulate samples taken at home with the gas furnace on. Individual peaks corresponding to NO_3^-, NH_4^+, and N_x (organic nitrogen species) are indicated.

CONCLUSIONS AND FUTURE WORK

It is obvious from this study that elevated levels of gaseous air pollutants and particulate sulfur and nitrogen compounds are present in indoor environments with gas cooking and heating appliances. High levels of CO, NO, and NO_2 approach or exceed promulgated and proposed ambient air quality standards. Such findings may have a large impact on the future design of epidemiological studies, on energy conservation strategies for buildings, and on the need for more stringent control of air pollution from indoor combustion sources.

Future work at LBL will entail field and laboratory studies to characterize the air pollution from indoor combustion sources, namely gas/electric stoves, gas/oil heating systems, gas hot water heaters, gas clothes dryers and other appropriate combustion sources in homes, schools, and office buildings. The goals of this characterization study will be to examine in detail the sources, rates of emissions, and fates of gaseous and aerosol air pollutants. Laboratory studies will identify various parameters (e.g., flame temperature and geometry, venting conditions, air infiltration rate, etc.), which affect rates of emissions from cooking and heating combustion appliances and air pollution levels in the indoor environment. Field and laboratory measurements will be made with the LBL Mobile Atmospheric Research Laboratory capable of multi-point sampling, for such pollutants as SO_2, NO/NO_2, CO, O_3, aerosol size and aerosol chemistry. Measurements on field-collected aerosol samples will be performed by laboratory-based X-ray fluorescence, ESCA, combustion, and wet-chemistry techniques.

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