#1560



Paul J. Hoen^{1,2}, Brian P. Leaderer^{2,3} and Jan A.J. Stolwijk^{2,3}

Leinghoven U. of Tech., Dept. Arch. & Bldg. Tech. The Netherlands John B. Pierce Foundation Laboratory, New Haven, CT. USA Yale U. Sch. of Med. Dept. of Epid. & Public Health, New Haven, CT. USA

Abstract

Continuous monitoring of NO, NO₂, CO, CO₂, SO₂ and O₂ depletion was conducted in 14 residences (13 with Kerosene space heaters and one without) in two locations in the residence (room with the heater and bedroom) and outdoors. The continuous monitoring was conducted concurrently with integrated passive monitoring for NO₂, SO₂ and infiltration rate. Peak concentrations recorded were: SO₂ = 1155.8 $\mu g/m$, NO₂ = 847.4 $\mu g/m$, CO = 21.1 mg/m³ and CO₂ = 0.78%². Average/NO₂ and SO₂ during kerosene heater use for the whole sampling period in each residence calculated from the integrated monitors and continuous monitors agreed well (r² > 0.87) while average NO₂ and SO₂ levels calculated from the/integrated monitors underestimated peak exposures by greater than 30%. Decays of reactive gases (NO₂ and SO₂) were always greater than non-reactive gases (CO₂) but no consistent pattern within or between residences was evident. Integrated infiltration rates (perfluorocarbon tracer technique) agreed well with the average non-reactive gas decay rates.

Introduction

Several controlled chamber studies have been conducted to study the air pollutant emission by-products from unvented kerosene space heaters (7,12). These studies have shown that the use of such heaters may result in human exposures to several air pollutants at concentrations well in excess of existing ambient health standards, and in some cases in excess of occupational health standards. The air contaminants identified in the chamber studies to be of concern include nitrogen dioxide (NO₂), carbon monoxide (CO) and sulfur dioxide (SO₂). Carbon dioxide (CO₂) and oxygen depletion have been studied as well.

We conducted a field study during the heating season of January-April 1983 in the New Haven CT. (USA) area to assess air pollutant exposures and health effects associated with the use of unvented space heaters fueled by kerosene (3,8). The exposure assessment portion of the study employed a staged design of monitoring and estimation. One important component of the staged design was the continuous monitoring for selected air pollutants in a sub-sample of the residences in the study. The continuous monitoring, which was conducted concurrently with the integrated monitoring in the study allowed for an assessment of: a) peak and average concentrations of N0, N0, S0, C0, C0, and 0, depletion during heater use; b) the relationship among peak concentrations, average concentrations during heater use and integrated exposures to N0, and S0; and c) the estimation of removal rates of



Figure 1. Comparison of the gas chromatograph-flame ionization detector chromatograms of (a) the vacuum extract and (b) the charcoal tube air sample of adhesive W-1. 276

277

reactive gases (NO $_2$ and SO $_2$) by surfaces and infilitration rates from the decay of the non-reactive gases.

Methods

A portable instrument rack with recorders and air handling and air sampling equipment was designed, built and tested in our environmental chamber. Air quality parameters continuously measured were: nitrogen oxides (NO, NO and NO₂ = NO - NO) with a Monitor Labs model 8440 chemiluminescence NO analyzer, SO₂ with a Monitor Labs model 8440 chemiluminescence analyzer, SO₂ with a Monitor Labs model 8440 billorrescence analyzer, CO with a Monitor Labs model 8440 chemiluminescence analyzer, SO₂ with a Monitor Labs model 8440 billorrescence analyzer, CO with a General Electric electrochemical SPE CO Detector, CO₂ with a Monitor Labs model 8450 billorescence analyzer. These measurements were made in two locations inside each residence (room with the heater or living room and bedroom) and one location outdoors. Temperature and humidity were recorded at the same time at each location (hydrothermographs). In each residence integrated measurements of NO₂ [using Palmes tubes (9)], and SO₂ [using permeation samplers (10)] were obtained over the total sampling period for the living room, bedroom and outdoors. An integrated measure of the infiltration rate was obtained for a sample of residences using the perfluorocarbon tracer technique (6). Kerosene fuel samples cultur.

Results and Discussion

A total of 14 residences were continuously monitored during the course of the field study. Thirteen of the residences used unvented kerosene space heaters and one residence had no kerosene heater but did have a gas cooking stove. The number of hours of continuous sampling in the residences ranged from 43 hours to 209 hours. The hours of kerosene heater use recorded ranged from 9.5 hours to 67.5 hours. A wide range of types and volymes of homes were monitored from a relatively small apartment (178 m³) to larger homes such as a raised ranch (890 m³). Four of the residences had gas cooking stoves, five used radiant kerosene heaters and eight used convective kerosene heaters. The sulfur content of the fuel ranged from 0.021% to 0.083%. All the kerosene

Peak Concentration The range of concentrations (background levels subtracted) of gases in howes with kerosene heaters was; S_0 , 107 $\mu g/m^3$ to 1155.8 μgm^3 ; S_0 , 0 $\mu g/m^2$ to 0.155.8 μgm^3 ; S_0 , 0 $\mu g/m^2$ to 0.21.1 $\mu g/m^3$; C_0 , 0-21.1 $\mu g/m^3$; C_0^2 , 0.1% to 0.78%; and 0_2 dépletion 0.12% to 0.75%. Concentrations of S_0^2 in the one home with a gas stove and no heafer vere 0 while the peak level of NO was 222.5 $\mu g/m^3$, NO_2^2 211.9 $\mu g/m^3$, C_0^2 , S_0^2 in the one home with a gas stove and no heafer vere 0 while the peak level of NO was 222.5 $\mu g/m^3$, NO_2^2 211.9 $\mu g/m^3$, C_0^2 , S_0^2 and NO_2^3) were generally higher in the rooms with the kerosene heaters, while fevels of the non-reactive gases (C_0 , NO_1 C_0^2 and Z_0^2 depletion) while fevels of the morts in the homes. This suggests rapid mixing of the emissions throughout the homes. This suggests concentrational differential of the more reactive gases attributable to sinks. Peak levels of NO_2 typically exceeded 100 $\mu g/m^3$ [USA EPA annual average ambient health standard (4)] in both locations in the

residences, while one residence consistently had NO₂ levels in excess of 480 $\rm ug/m^3$ [1 hr. California ambient health standard²(11)]. Homes with convective heaters had higher NO₂ levels than homes₃with radiant kerosene heaters. Peak SO₂ levels exceeded 80 $\rm ug/m^3$ [USA EPA annual average ambient health standard (4)] in₃all residences with kerosene space heaters. Co levels above 10 $\rm mg/m^3$ [USA EPA 8 hr. ambient health standard (4)] were exceeded 10 $\rm ug/m^3$ [USA EPA 8 hr. ambient health average ambient health standard (4)] $\rm un_3$ [USA EPA 8 hr. ambient health standard (4)] were exceeded in only one residence. Peak CO₂ levels of 0.25% (the ANSI/ASHRAE guidelines (2)] were exceeded in almost all homes while peak CO₂ levels exceeded 0.50% [the USA OSHA 8-hr time weighted 0.50% in two others.

Peak vs Average Exposures Passive integrated measurements of NO₂ and SO₂ made concurrently with the continuous monitoring in each residence allows for an evaluation of the relationship between integrated concentrations and average or peak exposures. The <u>average</u> NO₂ and SO₂ concentrations during heater use calculated from the integrated monitor, were obtained by correcting the integrated measurements for outdoor levels of pollutants and adjusting for the total hours of use (8). This <u>average</u> concentration was then compared to the average and peak concentrations of NO₂ and SO₂ during heater use determined from the records of the continuous monitoring results were not weighted by hours per use event even though a short use of the heater (1 or 2 hours). Figures 1 and 2 show this comparison and the standard deviations associated with average NO₂ and SO₂ levels continuous monitors. The average NO₂ and to results the use event even though a short use of the heater (1 or 2 hours). Figures 1 and 2 show this comparison and the standard deviations associated with average NO₂ and SO₂ values calculated from the continuous monitors. These standard deviations probably reflect the differences in infiltration rates, in the rates of removal by surfaces, and in hours of heater use. There is however, good agreement between the average concentrations calculated by the two different methods.

Comparison of average NO₂ and SO₂ levels during heater use with peak levels obtained by continuous monitor indicates: a) these values are highly correlated (r = 0.94 for NO₂ and r = 0.92 for SO₂); b) the peak NO₂ level was an average 84% higher than the average concentration during heater use; and, c) the peak SO₂ level was 30% greater (determined from the slopes). $\rm NO_2$ and SO_2 Removal Processes Two of the most important parameters controlling the air contaminant levels observed indoors are the infiltration rate and sink terms. The decay rates of non-reactive gases (CO_ and NO) were not significantly different (p > 0.05). These were calculated from the point at which the kerosene heater was shut off to the baseline concentration in the room. They are indicative of the tastes calculated from the decays of the non-reactive gases infiltration rate (air changes per hour) of the residence. Infiltration rates calculated from the decays of the non-reactive gases indicated that infiltration rates between homes can vary greatly (0.18 ach to over 1 ach). Within houses infiltration rates varied by as much as a factor of 2. A comparison of the integrated infiltration rate for the whole sampling period for the continuously monitored homes (perfluorocarbon technique) with the average infiltration rates determined from the decay of non-reactive gases produced a correlation coefficient of 0.78 ach to over the integrated infiltration rates determined from the decay of non-reactive gases produced a correlation coefficient of 0.78 achted active gases produced a correlation coefficient of 0.78 achted active gases produced active coefficient of 0.78 active decay the decay of non-reactive gases produced active coefficient of 0.78 active decay of non-reactive gases produced active gases produced active coefficient of 0.78 active decay of non-reactive gases produced active coefficient of 0.78 active decay of non-reactive gases produced active coefficient of 0.78 active decay of non-reactive gases produced active coefficient of 0.78 active decay of non-reactive gases produced active coefficient of 0.78 active decay of non-reactive gases produced active coefficient of 0.78 active decay of non-reactive gases produced active coefficient of 0.78 active decay decay decay of non-reactive gases produced active

279

280 281	<pre>nours of nours of number of hours the hours the hours the hours the hours the hours the more for the 3rd International Conference on Indoor Air Quality and Climate, Stockholm 1984.</pre>	ements (n = 10) (4) Code of Federal Regulations, Title 40 (Government Printing Office, endard deviation Washington, D.C., 1980), parts 50.4, 50.8, and 50.11.	(5) Code of Federal Regulations, Title 29 (Government Printing Office, Washington, D.C., 1979), 1910: 1000.	rate and the (6) Dietz, R.N. and Cote, E.A. Air infiltration measurements in a home m for NO ₂ and using a convenient perfluorocarbon tracer technique. Env. International (1982) 8, 419-433.	ve gases either (1) Leaderer, B.P. Air Pollutant Emissions from Kerosene Space The sink terms Heaters. Science, 1982, 218, 1113-1115.	(8) Leaderer, B.P., Zagraniski, R.T., Berwick, M., Stolwijk, J.A.J. and Ma. Q.S. Residential Exposure to NO ₂ , SO ₂ and HCHO Associated with	Unvented Kerosene Space Heater, Gas Äppliänces and Sidestream Tobacco Smoke. Proceeding of the 3rd International Conference on Indoor Air Quality and Climate, Stockholm 1984.	ces using (9) Palmes, E.D., Gunnison, A.F., Dimattio, J. and Tomczyk, C. Personal Sampler for Nitrogen Dioxide, Am. Ind. Hyg. Assoc. J., 1976, 37, 570-577.	passive (10) Reiszner, K.D. and West, P.W. Collection and Determination of d hours of Sulfur Dioxide Incorporating Permeation and West Gaeke Procedure, Env. Sci. Technol., 1973, 7, 526-532.	(11) State of California, California Administrative Code, Title 17, mportant in Subchapter 1.5, Section 70100, 1977. ter	 (12) Traynor, G.W., Allen, J.R., Apte, M.G., Girman, J.R. and Hollowell, C.D. Pollutant Emissions from Portable Kerosene Fired Space Heaters, Env. Sci. Technol., 1983, 17, 369-371. 	the U.S. by Contract No. mission.		ey, California	Society of
	uding one outlier residence). The relatively few hours able decays for each residence when compared to the num ntegrated sample was taken (in one case only 4% of the apped) and the large variations in filtration rates on served to prevent a hetter correlation hetween the two	rements. The integrated infiltration rates measurement ced a median air exchange rate of 0.5 ach with a standa 3 ach.	Figure 3 shows the observed relationship between the de of non-reactive was and NO and SO in the home contra	ored. The difference between the NO, and SO, decay rate active decay rate is an indication of the sink term fo While, the decay of NO2 and SO2 is always greater than	eactive gases, no consistent pattern for the reactive g n or between residences is evident. A weak correlation al concentration and decay rate was found for NO2. The 0, and SO, need better characterization.	conclusions	The continuous monitoring portion of this field study in	 peak levels of NO₂, SO₂, CO and CO₂ in residences t kerosene space heaters² can exceed concentrations si ambient health standards.) integrated levels of NO ₂ and SO ₂ recorded with pase monitors, when corrected for oufdoor levels and hou kerosene heater use, can represent average exposure heater use in residences but underestimate peak exit) sink terms for NO ₂ and SO ₂ in residences are import controlling indoor concenfrations and need better	characterization. <u>Acknowledgements</u>	his work was supported by Grant No. ES-00354 from the U al Institute of Environmental Health Sciences and by Co -83-1196 from the U.S. Consumer Product Safety Commissi	References	ir Quality Research Inc. 901 Grayson Street Berkeley, C 4710.	berican National Standards Institute and American Socie Matine, Refrigerating and Ait-Conditioning Tandards

Comparison, of average NO, concentrations in CM houses between integrated monitoring

erage NO₂ Concentration (µg/m³) from Integrated Monitor

500 540 580 350

an intercept of 1.33 µg/m and a correlation coefficient of 0.96. use. The calculated slope is 0.90 with data corrected for hours of use and continuous monitoring data during heater

Figure L.

OPI

Average NO₂ Concentration (µg/m³) from Continuous Monitor

200

540 982

320

260

001

0++

08+

H - Heater

also shown.

360



data contected for hours of use and continuous data corrected for hours of use and continuous SO, monitoring data during heater use. The calculated sigpe is 0.99 with an intercept of -0.79 µg/m and correlation coefficient

Comparison of average SO, concentration in CM houses between integrated monitoring

Figure 2.

Average SO_2 Concentration ($_{\mu}g \sqrt{m^3}$) from integrated Monitor

81

HZ

ни

811

801 82

100 200 300 400 200 600 700 800

and correlation coefficient

The reference decay rate was mither NO Comparison of the NO₂, SO₂ and reference decay rates calculated from the decays measured in the continuously calculated slope. Each point represents a single decay event for the residences. The 1 to 1 slope which would be expected if there were no NO_2 or SO_2 sink terms is or CO, and chosen on the basis of which one had the smallést confidence intervals associated with the Figure 3. monitored homes.

.£0.0 ło

°0

500

200 00\$

009 Trom

001

008

006

0001

BE HOI HE 001

88

HR

HE

moorbs8 = 8 H=Heater Room Average SO₂

Concentration

(µg/m³) 009

Continuous Monitor

283

282