IMPACT OF VENTILATION PRACTICES ON LEVELS OF GAS COMBUSTION PRODUCTS

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Introduction

In recent years, the issue of indoor air quality has received considerable attention. Indoor air quality is determined not only by numerous sources of contaminants, including unvented gas appliances, but also by other factors. Some of these factors include the following:

- Chemical and physical characteristics of contaminants
- Type, shape, size, and leakiness of a structure
- Type, capacity, and condition of heating, ventilation, and air conditioning system
- User habits, especially those related to source use and ventilation practices.

The Gas Research Institute has sponsored a research study at GEOMET Technologies, Inc., to quantify these and other factors influencing indoor air quality associated with the use of unvented gas appliances.

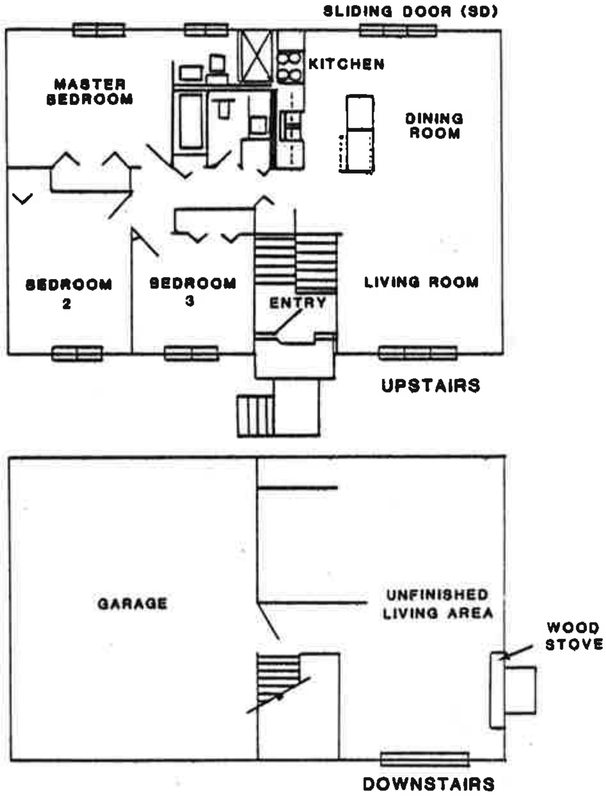
The purpose of this paper is to describe the impact on indoor air quality of one set of factors, namely ventilation practices associated with operation of a kitchen gas range. The following ventilation practices were examined:

- Operation of a range exhaust fan
- Operation of an air-to-air heat exchanger
- Partial opening of a window and sliding door near the kitchen range
- Partial opening of certain windows to allow for cross ventilation.

Study Methods

The study was conducted in a well-characterized, detached house. The house is unoccupied, which permits complete experimental control. The bilevel house has three bedrooms and an integral garage (Fig. 1). This house has been extensively monitored for infiltration, energy use, and indoor air quality over a 1-year period. Thus, baseline data for infiltration and air quality are available (1).

Fig. 1. Floor plan of the experimental house.



The measurement system permits continuous monitoring of carbon monoxide (CO), nitrogen dioxide (NO_2), and tracer gas. The analyzers are located in a mobile laboratory parked near the experimental house (2). Sampling points are located upstairs, downstairs, and outside the house, enabling zone-specific measurements. The tracer gas sulfur hexafluoride is used to measure infiltration rates. Other continuous measurement parameters include temperature, humidity, and on-off status for various appliances. Windspeed and direction and solar radiation are also continuously measured at the site.

Results

Ventilation practices used in a set of 11 experiments are listed in Table 1. During each experiment the gas range was operated for 40 minutes (one burner fully on and oven kept at 175 C). Each experiment was conducted twice: once in the morning and once in the afternoon but on different days. Table 1 also gives the increments in air exchange rates above the natural infiltration rates for each experiment. The natural infiltration rates during the times when the experiments were conducted ranged typically from 0.1 to 0.2 air changes per hour (ACH). The increments in air exchange when operating the range fan and the heat exchanger were reproducible. The addition to the air exchange rate by opening a sliding door and windows was highly variable.

Effects of the ventilation practices on peak and 8-hour average CO concentrations are presented in Table 2. Reductions of 40 to 50% in peak concentrations occurred in experiments for which the range exhaust fan was used during all 40 minutes of gas range operation. Most other practices had only a small effect on peak concentrations. In one experiment, where the range fan was not used, an air exchange increment of 1.2 ACH resulted in a 30% reduction in the peak. The practices having the greatest impact on the 8-hour average, i.e., reductions of 40 to 65%, were those discussed above and the case where the air-to-air heat exchanger was used. The heat exchanger was operated continuously whereas the other ventilation practices were used for only 1 hour at most.

Similar data for NO_2 are presented in Table 3. Only the use of the range fan for all 40 minutes during range operation affected peak NO_2 concentrations. Using the range fan in the last 20 minutes during range operation and beyond or opening the sliding door and windows did not decrease peak concentrations. This lack of effect is consistent with the observation that most of the NO_2 emissions occurred during the first 10 to 20 minutes of range operation. NO_2 undergoes chemical decay indoors (3) and thus the concentrations in the second hour following range operation are quite low, irrespective of the ventilation practice used. Outdoor NO_2 concentrations, due again to indoor chemical reactivity, do not affect indoor concentrations.

Conclusions

Use of a range exhaust fan is an effective practice for reducing peak and 8-hour CO concentrations and peak NO_2 concentrations. In particular, NO_2 concentrations can be reduced only if the range fan is operated at least during the early part of range operation. Opening windows/doors has a variable impact on CO concentrations, which is consistent with that reported for kerosene space heaters (4). Opening windows has no discernible impact on reducing NO_2 concentrations.

Table 1. Ventilation experiments and increment in air exchange rates.

Number	Type of ventilation	Minutes used with range	Minutes used after range turned off	Air exchange increment, ACH
1	None	N/A	N/A	0
2	Air-to-air heat exchanger (AAHX)	40	Continuous	0.33
3	Range fan (RF)	20	0	0.13
4	RF	40	0	0.29
5	RF	20	20	0.31
6	RF	40	20	0.41
7	RF and sliding door (SD)*	20	0	0.20
8	RF and SD	20	20	0.53
9	RF and SD	40	20	0.84
10	SD and bedroom 2 (BR2) window*	40	0	0.63
11	Multiple windows--all three bedrooms, living room, and SD (All)*	40	0	1.24

* Sliding door and windows were opened 15 cm.

Table 2. Effect of ventilation practices on CO concentrations.

Number	Type of ventilation/ minutes used with range/ minutes used after range turned off	Average CO concentration, ppm		
		15-minute peak	8-hour average	8-hour outdoors
1	None	6.3	3.8	0.7
2	AAHX/40/Continuous	5.9	2.2	1.0
3	RF/20/0	5.2	3.0	1.0
4	RF/40/0	3.7	2.0	0.8
5	RF/20/20	6.0	3.1	0.9
6	RF/40/20	3.2	1.7	0.8
7	RF & SD/20/0	5.8	3.4	1.1
8	RF & SD/20/20	6.3	2.9	1.4
9	RF & SD/40/20	3.1	1.3	1.0
10	SD & BR2/40/0	5.9	4.0	1.3
11	SD & ALL/40/0	4.4	1.8	0.7

Table 3. Effect of ventilation practices on NO_2 concentrations.

Number	Type of ventilation/ minutes used with range/ minutes used after range turned off	NO_2, ppb		
		15-minute peak	Next hour[a]	Outdoor concentration
1	None	69	26	19
2	AAHX/40/Continuous	62	23	10
3	RF/20/0	61	15	31
4	RF/40/0	37	15	9
5	RF/20/20	69	14	26
6	RF/40/20	41	13	24
7	RF & SD/20/0	68	14	26
8	RF & SD/20/20	68	24	31
9	RF & SD/40/20	36	18	16
10	SD & BR2/40/0	96	27	30
11	SD & ALL/40/0	65	17	27

[a] One hour after range ignition.

References

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SUMMARY

N.L. Nagda, M.D. Koontz, and I.H. Billick: Impact of Ventilation Practices on Levels of Gas Combustion Products. The effects of different ventilation practices on levels of carbon monoxide (CO) and nitrogen dioxide (NO_2) from an unvented gas range were studied under controlled conditions at an experimental house near Washington, DC. The ventilation practices included operation of kitchen exhaust fan, air-to-air heat exchanger, and opening of windows. Air infiltration rates, pollutant concentrations, temperature, and relative humidity were continuously monitored inside and outside the experimental house. In addition, an onsite meteorological measurement system provided a continuous record of windspeed, wind direction, relative humidity, and temperature. Results indicated that the most effective ventilation practice for CO and NO_2 was using the range exhaust fan concurrent with range operation. The partial opening of several windows and a sliding glass door was not effective for reducing peak NO_2 concentrations and had a limited impact on reducing CO concentrations.

INHALTSANGABE

N.L. Nagda, M.D. Koontz, und I.H. Billick: Einfluss der Ventilations-Methoden auf Niveaux von Gas Verbrennungs Produkten. Der Einfluss der verschiedenen Ventilationsmethoden auf Niveaux von Kohlen Oxid (CO) und Stickstoff Oxid (NO_2) von einem Gas Kochherd wurden unter kontrollierten Bedingungen in einem für Experimente bestimmten Haus in der Nähe von Washington, D.C. versuchshalber studiert. Die Ventilationsmethoden schlossen Küchen Auspuffsventil, Luft-zu-Luft Wärmeaustausch Gerat und Öffnung von Fenstern, ein. Das Verhältnis der eindringenden Luft, Konzentration der Beschmutzung, Temperatur, und relativer Feuchtigkeit wurden bestandig im Innern und Äussern des Hauses gemessen. Zusätzlich wurden von einem an der Stelle vorhandenen meteorologischen Messungsapparat fortdauernd Messungen von Windgeschwindigkeit, Windrichtung, relativer Feuchtigkeit und Temperatur, wiedergegeben. Die Resultate ergaben, dass die wirksamste Ventilationsmethode fur CO und NO_2 der Auspuffsventilator ist, welcher nach Gebrauchsanweisung des Kochherdes benutzt wird. Das teilweise Eroffnen von Fenstern und einer Glasschiebetüre war nicht wirksam zum reduzieren des höchsten Grades von NO_2, und hatte nur einen beschränkten Einfluss zur Herabsetzung von CO.

RESUME

N.L. Nagda, M.D. Koontz, et I.H. Billick: Effet des Systemes de Ventilation sur le Niveau des Emanations des Gaz de Combustion. Les résultats des différentes méthodes d'aération sur les niveaux d'oxide de carbone (CO) et de péroxide d'azote (NO_2) provenant de fourneaux à gaz ont été étudiés sous contrôle dans une maison expérimentale près de Washington, D.C. Les systèmes de ventilation comprenaient le fonctionnement d'un ventilateur d'échappement de la cuisine, d'échangeurs de chaleur d'air à air, ainsi que l'ouverture de fenêtres. Les taux d'infiltration, les concentrations d'agents de pollution et l'humidité relative furent constamment contrôlés à l'intérieur et à l'extérieur de la maison expérimentale. En outre, un système de mesure meteorologique fournit un enregistrement suivi de vitesse et orientation du vent, d'humidité relative et température. Les résultats démontrèrent que la méthode la plus efficace de ventilation pour le CO et le NO_2 consistait à utiliser le ventilateur d'échappement du fourneau pendant la chauffe de celui-ci. L'ouverture partielle de plusieurs fenetres ainsi que celle d'une porte vitrée coulissante ne fut pas efficace pour diminuer les concentrations maximales de NO_2 et produit seulement un effet limité sur les concentrations de CO.