Monitoring Formaldehyde in Indoor Air

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Abstract

There have been many reports over the last several decades of "sick building" syndromes, including some public schools in eastern Idaho. Formaldehyde is known to contribute to poor indoor air quality, and is suspected of being a main cause of such occurrences. Formaldehyde is present in many substances that are commonly found in buildings. It is also used in some personal and clothing care products and is present in human breath. There are serious health effects for people from exposure to formaldehyde in air The initial objective of this study was to have available an instrumentation at Idaho State University that could measure low levels of formaldehyde. Formaldehyde meters from three manufacturers were used to make measurements. As measurements were made in a number of indoor locations involving large numbers of people, a secondary objective became to determine whether the presence of people in an enclosed space was correlated with an increase in the concentration of formaldehyde in the air. Measurements were taken during Sunday services in an unventilated church. Data from one meter showed a linear relationship between the number of people present and the highest sustained measurement of formaldehyde in the air in the church. Due to cross sensitivities, the meter may have been responding to other chemicals in addition to formaldehyde. More work needs to be done to determine what the other chemicals are, and which of them contribute to people's discomfort in poorly ventilated rooms. Two of the three instruments used were deduced to have significant enough sensitivities to other chemicals that the concentration of formaldehyde was often significantly overstated. The third meter appears to have no cross chemical sensitivity (a claim also made by the manufacturer), but requires a longer sampling time, and the cost per sample is about $4.

Key Words: formaldehyde, indoor air, ventilation

Introduction

In Canada and the United States, the average person spends 85% of the time indoors (Leech and others 2002). Therefore, indoor air quality is important. Some substances that cause poor indoor air quality are carbon monoxide, radon, ozone, nitrogen oxides, formaldehyde, mold and dust mites (Environmental Health and Safety Department, 2007). Most of these substances occur in higher concentrations indoors than outdoors.

This study focuses on formaldehyde in indoor air. Formaldehyde, HCHO, has a molecular weight of 30 g/mol (CRC 1965). Some effects from exposure to formaldehyde in air on human beings range from eye irritation at 0.05 ppmV and airway irritation at 0.1 ppmV (WA State Dept of Health 2006) to immediate danger to life at 100 ppmV (OSHA Regulations 2007). In addition, formaldehyde is carcinogenic to human beings (IARC 2004), and recent research has shown that HCHO may be neurotoxic, even at exposures below 0.1 ppmV (Malek and others 2003).

OSHA has set standards for concentrations of HCHO in the air in workplaces. The time weighted average (TWA) for eight hours is 0.75 ppmV. The short term exposure limit (STEL) for fifteen minutes is 2.0 ppmV (OSHA 2006). The World Health Organization has a recommendation that HCHO in indoor air not exceed 0.08 ppmV (WHO 2001).

There are several sources of HCHO in indoor air. It is a combustion product, and is present in smoke from cigarettes, wood-burning stoves and gas appliances (USCPSC 1997). It is used in glues in plywood, oriented strand board, particleboard and insulation. It is also used in paper finishes, permanent press fabrics, cosmetics, disinfectants, preservatives and paints (FETEG 2002).

People use many products on their hair, skin and clothing, including soap, shampoo, deodorants, lotions, detergents, fabric softeners, and fabric finishes, among others. Chemicals from these products evaporate into the air, wherever people go. Some of those products contain formaldehyde (FETEG, 2002). In addition, human breath contains formaldehyde; concentrations of 0.3 to 0.6 ppmV have been reported in breath from healthy women (Ebeler 1997).

In a survey conducted locally on products that could affect air quality (Poulson NJ 2001, unpublished data), respondents identified a mean of 9 different products used personally on hair, skin and clothing. This study included the respondents' perceptions of the air quality in an unventilated church. Eleven of 112 respondents reported physical symptoms which occurred in the church during Sunday services. The symptoms included dizziness, headaches and respiratory problems. Since formaldehyde is known to cause respiratory problems and has been shown to produce neurological symptoms in rats at low exposures (Malek 2002), the question arises as to whether some of the problems with air quality in the unventilated church occur from formaldehyde, and whether the presence of people correlates with formaldehyde in the air.

The term ventilation is used to designate whether or not forced circulation of air in and out of the interior space is provided. Two basic standards are used for public buildings, the ASHRAE Standard 62, which specifies minimum standards for a variety of public buildings, and the Uniform Building Code. The basic requirement is that 7.1 L/s (15 cfm) of air be circulated per person in public buildings (ASHRAE 2004).

Objectives

The objectives of this study were first to evaluate the reliability and nominal accuracy of three different portable meters for measuring HCHO concentrations. A second objective was to evaluate the apparent effect the number of people has on the measured HCHO concentrations in an unventilated indoor meeting room.

Equipment

Three instruments were selected to be used in this study:

Instrument #1 is a pocket-sized electrochemical sensor. The readings appear in a digital display in ppmV. It gives readings every ten seconds for a user-selected time period, up to 90 minutes. There is no fan. The reaction in the sensor is oxidation, $HCHO + 2H2O \rightarrow H2CO3 + 4H+ + 4e-$. The manufacturer lists other chemicals such as other aldehydes, alcohols and carbon monoxide which also produce readings on the meter. An initialization procedure establishes a baseline concentration for gases besides HCHO. The detection range is 0.01 ppmV to 30 ppmV. Instrument #1 was calibrated in an AIHA accredited laboratory in December, 2006.

Instrument #2 uses a similar electrochemical detection method. This meter uses a fan to draw an air sample into the meter.

Instrument #3 uses a colorimetric detection method. A paper tab impregnated with hydroxylamine sulfate and Methyl Yellow is inserted into the instrument immediately prior to making a measurement. If HCHO is present, the following reaction occurs: $2HCHO + (NH2OH2) H2SO4 \rightarrow 2H2C{=}NOH + H2SO4 + 2H2O$. The Methyl Yellow reacts with the sulfuric acid and changes color (Nakano and Nagashima 1999). A light is reflected off of the tab; the light intensity is compared to a standard exposure curve and the result is displayed in ppmV. The user can select an exposure time of 15 minutes, with a range of 0.01 to 1.0 ppmV, or 30 minutes, with a range of 0.01 to 0.06 ppmV.

Procedure

Permission to measure formaldehyde concentrations was obtained from an owner or manager for all buildings tested.

To establish the validity of the measurements, comparisons between all three instruments were made in outdoor air and in an unventilated church sanctuary. There was no time when all three instruments were available. In outdoor air, meters #1 and #3 were run simultaneously for 15 minutes. Several data points were recorded for instrument #1, and the average given by #3 was recorded. At other times measurements were taken with meter #2 in outdoor air; it samples air for one minute for each reading. In the model houses, #1 was used to find an area in each house with significant levels of HCHO. Then the two meters #1 and #3 were run side-by side, and the data was recorded as above. The church used in the survey mentioned above was selected to test for formaldehyde in air correlated to the presence of people. All measurements made during Sunday service were taken in a balcony at the rear of the church. On days when services were held, instrument #1 was initialized, usually before the beginning of the service. Measurements were recorded until the people left the room after the service. Instrument #3 was run for 15 minutes, usually once during the service. On one Tuesday morning, when there were no people present, the candles were lit, and measurements were recorded for one hour. Measurements were recorded in the same room on other occasions for shorter times. During services, the people present were counted by church officials.

Results and Discussion

The data from the comparison of meters #1 and #3 is shown in Figure 1, with a regression line fit to the data. R^2 for the regression line is >0.99. The slope of the line is 0.887. Because the meters each use different techniques and reactions for measuring HCHO in air, it appears that the both meters are working properly and are obtaining reliable results, with #1 giving about 12% higher readings than #1. In other situations, instrument #2 gave results 10 to 25% higher than #1.

Instrument #3 reads “over” for all values over 1.0 ppmV. The most conservative value of 1.0 was used for the plot in Figure 1. For instrument #3, values below 0.01 ppmV are shown as “<0.01” and were plotted as 0.

In the unventilated church, there is a high peaked ceiling with fans to circulate air. The air volume is about 1600 m^3. Figure 2 shows a plot of the HCHO concentration as measured by instruments #1 and #3 on a Sunday morning, with an attendance of 114. This is a typical plot, with the concentration starting low and rising to a plateau before the end of the service. On this Sunday, communion, using wine, was started at 52.8 minutes. A peak in the plot occurs between that time and the end of the service, at 67.5 minutes. The manufacturer indicates that meter #1 responds to ethanol; several of the measurements occurred during the time the sacrament, using wine, was served to parishioners. The measurements from meter #1 include substances that the meter responds to other than HCHO, if they are introduced into the air after the instrument is initialized. Instrument #3 was run two times, for 15 minutes each time, with a measurement reported at the end of each run. The readings were both < 0.01.

Figure 3 shows a plot of the plateau concentrations of air HCHO, measured with meter #1, in the unventilated church against the attendance. Data for the point at (1, 0) was collected on a Tuesday morning. The point at (305, 0.3) was from a service when doors were opened for ventilation. Disregarding those two points, R^2 for the data fit to the line is 0.96. One reason the line doesn’t go through the origin may be that the plaster and furnishings in the room adsorb or absorb some of the emissions (Matthews, Hawthorne, and Thompson 1987).

Figure 4 shows a plot of HCHO concentrations on another Sunday, when Instrument #1 was purged with clean air from a tank during the service, then reinitialized. If the readings were all due to HCHO, and if all residual HCHO were removed from the meter by purging then the curve would drop to zero during purging and immediately rise to the previous concentration after reinitialization. The measurements do not rise to the previous level. Therefore, it is concluded that some or all of the responses on this occasion are from other gases. Instrument #3 was used successfully during 4 services. Four of the measurements (On one Sunday two measurements were made.) from #3 for a fifteen minute exposure were < 0.01 ppmV. The one measurement, 0.02 ppmV, occurred on a Sunday when the gym floor in another part of the building had recently been refinished.

Conclusions

Instruments #1 and #2 were reasonably convenient and easy to use. Instrument #3 indicated that in an unventilated church sanctuary, with an air volume of 1600 m^3, with an occupancy between one and two hundred over a time of approximately one hour, formaldehyde did not accumulate to a concentration > 0.01 ppmV. However, other chemicals did build up in the air, with a linear relationship between the number of people present and the concentration at the end of an hour. More work could be done to determine which of the chemicals which produce a response on meter #1 accumulate, and whether those are harmful to humans in the concentrations found. The combination of instruments #1 and #2 worked very well to distinguish between HCHO and other chemicals. Instrument #1 gives a result every 10 seconds, and can quickly give an indication of places where there may be a problem. Instrument #2 has similar usefulness, and has a fan to force air into and out of the instrument. Instrument #3, with its cost of about $4 per sample, need only be used in those areas where a problem is indicated. If #1 and #3 both indicate a problem involving HCOH, further study or remedial action may be indicated. One low cost remedy is to increase the ventilation rate.

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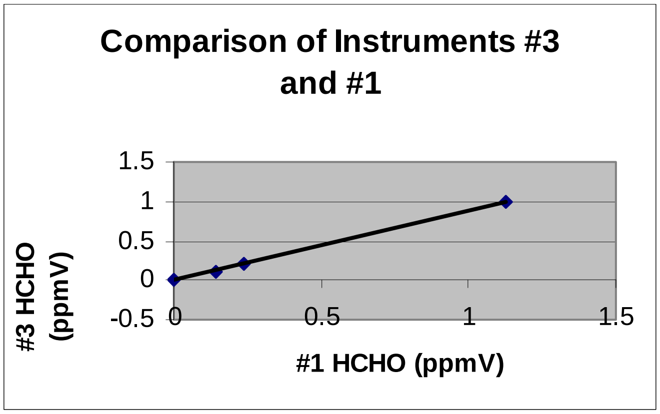


Figure 1: A comparison of measurements using instruments #1 and #2 under stable conditions in four locations.

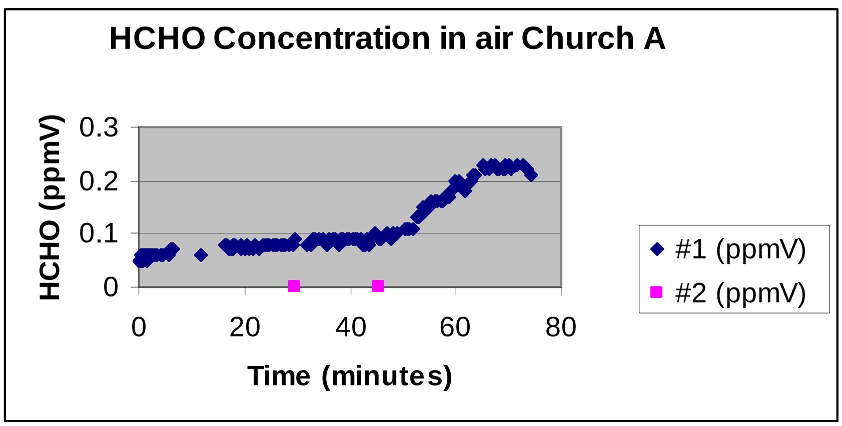


Figure 2: HCHO concentration in an unventilated church during a Sunday service, as measured by Instrument #1 and Instrument #2.

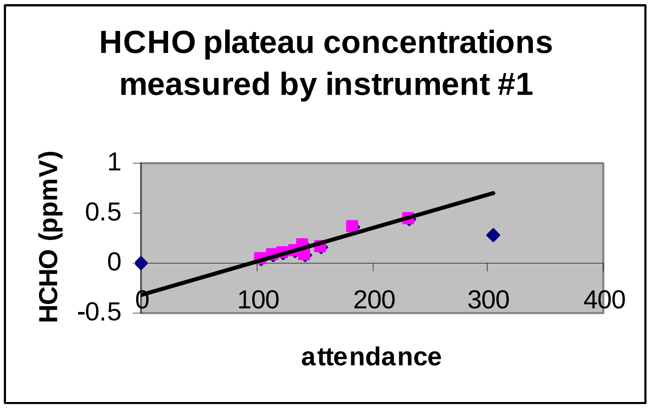
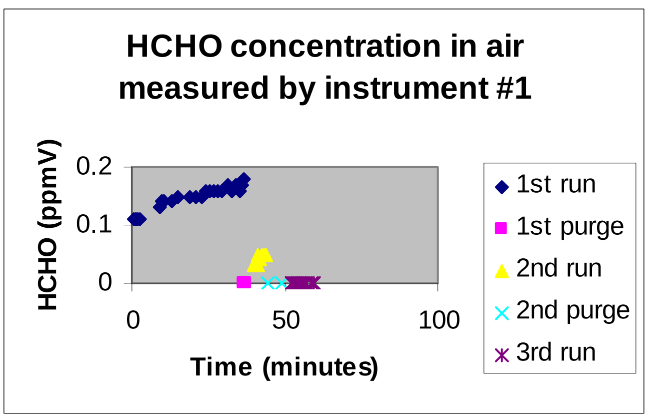


Figure 3: Highest sustained concentration of HCHO and interfering gases in unventilated church on a given day as a function of attendance on that day.



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