INDOOR AIR QUALITY INCIDENT RESPONSE

St. Mary of the Annunciation School
Auditorium
14 Otis Street
Danvers, Massachusetts 01923

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health
Indoor Air Quality Program
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Background/Introduction

At the request of Mr. Peter Mirandi, Director of the Danvers Public Health Department (DPHD), the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health (BEH) provided assistance and consultation concerning an incident at St. Mary of the Annunciation School (SMAS), a catholic elementary school located at 14 Otis Street, Danvers, Massachusetts. On February 25, 2009, Mr. Mirandi contacted Suzanne Condon, Associate Commissioner and Director of the Bureau of Environmental Health, regarding an emergency situation reportedly involving acute health impacts among 15 to 20 children. Subsequently, Ms Condon contacted Martha Steele, Deputy Director of the BEH, and Michael Feeney, Director of BEH's Indoor Air Quality (IAQ) Program, to develop a response plan. Mr Feeney then made a visit to the SMAS to observe environmental conditions that may have contributed to symptoms reported among students, all of whom experienced there symptoms during an observance of Ash Wednesday held in the auditorium.

As reported by Mr. Mirandi, a church service was being held in the school auditorium at approximately 11:00AM on February 25, 2009, when a student fainted during the service. In all, fourteen students experienced symptoms following the first child's fainting. Due to these concerns, the Danvers Fire Department (DFD), Emergency Medical Services (EMS), the Massachusetts State HazMat Team and the DPHD responded to the scene. Subsequently, four students were sent to the local hospital for medical evaluation. No reports or complaints of strange odors or other potential pollutants/contaminants (e.g., idling vehicles, chemical usage, fuel odors) were reported.

Methods/Results

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a HNu Photo Ionization Detector (PID). The tests were taken at one half hour intervals between approximately 1:15 PM and 2:45 PM while the auditorium was unoccupied. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that the initial carbon dioxide levels in the auditorium were above the MDPH guideline of 800 parts per million (ppm) for publicly occupied buildings, indicating inadequate air exchange in the auditorium. It is important to note that carbon dioxide decreased 200 ppm over the next 90 minutes of testing. In the experience of BEH staff, these carbon dioxide levels are atypical of an unoccupied area with a functioning heating, ventilating and air-conditioning (HVAC) system. HVAC systems are designed to introduce fresh outdoor air and exhaust stale air from indoor environments (e.g., the auditorium). Occupancy levels of 400+ individuals would likely result in significantly higher levels of carbon dioxide. Under these circumstances, a buildup of common indoor air pollutants can also occur, which can lead to discomfort or health complaints.

Mechanical ventilation for the SMAS is provided by two air-handling units (AHUs) that draw fresh air through intakes and deliver it to the auditorium through ceiling-mounted vents. Exhaust ventilation is provided by a ceiling-mounted vent.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, consult Appendix A.

At the time of the testing, temperature measurements in the auditorium ranged from 66°F to 70°F, which were slightly below the MDPH recommended comfort range (Table 1). It is important to note that the initial measurement was taken two hours after the incident took place. Due to body heat and water vapor produced during respiration, higher occupancy would result both in elevated temperatures and relative humidity. The relationship between temperature and relative humidity is called the heat index. The MDPH recommends that indoor air temperatures be maintained in a range of 70 °F to 78 °F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity measured in the auditorium at the time of the assessment ranged from 18 to 22 percent, which was below the MDPH recommended comfort range (Table 1). The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Other Concerns

Even though symptoms reported (i.e., central nervous system effects e.g., dizziness, headaches, nausea) are consistent with insufficient fresh air in a building, BEH staff performed carbon monoxide testing to ensure that combustion products were not present in the auditorium as the presence of carbon monoxide can result in similar effects. Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health effects.

Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2006). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State

Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2006).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. At the time of the assessment, carbon monoxide concentrations outside the auditorium were non-detect (ND) (Table 1). No detectable levels of carbon monoxide were measured inside the auditorium at the time of the assessment (Table 1).

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the auditorium, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. At the time of the assessment, outdoor TVOC concentrations were ND. TVOC concentrations inside the auditorium were also ND (Table 1).

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2006). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA established a more protective standard for fine airborne particles. This more stringent

PM2.5 standard requires outdoor air particle levels be maintained below 35 μg/m^3 over a 24-hour average (US EPA, 2006). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations the day of the assessment were measured at 6 μg/m^3. PM2.5 levels measured inside the school ranged from 3 to 11 μg/m^3 (Table 1), which were below the NAAQS PM2.5 level of 35 μg/m^3. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Conclusions/Recommendations

At the time of BEH's assessment[1], the auditorium was unoccupied and no measurable levels of carbon monoxide or TVOCs were detected. In addition, no obvious point sources that appeared to be associated with symptoms reported by occupants at the SMAS were identified. Therefore, it is clear that symptoms experienced by students can be attributed to a lack of adequate fresh air coupled with higher temperatures.

In view of the findings at the time of the visit, the following recommendations are made to improve indoor air quality:

[1] Air measurements are only reflective of the indoor air concentrations present at the time of the assessment.

1. Contact an HVAC engineer to examine the HVAC system to determine whether it is capable of providing an adequate amount of fresh air for assemblies in the auditorium.
2. Operate the mechanical ventilation system during occupancy.
3. Use cross-ventilation using openable windows and exterior doors. Consider using stand-up industrial fans to circulate air.
4. Consider reducing size of assemblies to prevent over-occupancy and reduce heat load.
5. Consider adopting a balancing schedule of every 5 years for mechanical ventilation systems, as recommended by ventilation industrial standards (SMACNA, 1994).
6. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website: http://mass.gov/dph/indoor_air.

References

ASHRAE. 1989. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-1989

BOCA. 1993. The BOCA National Mechanical Code-1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL. M-308.1

MDPH. 1997. Requirements to Maintain Air Quality in Indoor Skating Rinks (State Sanitary Code, Chapter XI). 105 CMR 675.000. Massachusetts Department of Public Health, Boston, MA.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R 1910.1000 Table Z-1-A.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0

SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

US EPA. 2006. National Ambient Air Quality Standards (NAAQS). US Environmental Protection Agency, Office of Air Quality Planning and Standards, Washington, DC. http://www.epa.gov/air/criteria.html.

Location: St. Mary of the Annunciation School **Indoor Air Results**

Address: 14 Otis Street, Danvers, MA **Date: February 25, 2009**

Table 1

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	TVOCs (ppm)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background Outdoors	328	ND	35	21	ND	6					
Auditorium Time: 1:15 PM	822	ND	66	22	ND	3	0	N	Y	Y	
Auditorium Time: 1:45 PM	765	ND	69	18	ND	7	0	N	Y	Y	
Auditorium Time: 2:15 PM	700	ND	70	20	ND	11	0	N	Y	Y	
Auditorium Time: 2:45 PM	619	ND	70	18	ND	6	0	N	Y	Y	

ppm = parts per million $\mu g/m^3$ = micrograms per cubic meter ND = non detect

Comfort Guidelines

Carbon Dioxide:	< 600 ppm = preferred	Temperature:	70 - 78 °F
	600 - 800 ppm = acceptable	Relative Humidity:	40 - 60%
	> 800 ppm = indicative of ventilation problems	Particle matter 2.5	< 35 ug/m^3