DEVAL L. PATRICK
GOVERNOR

JOHN W. POLANOWICZ
SECRETARY

CHERYL BARTLETT, RN
COMMISSIONER

The Commonwealth of Massachusetts
Executive Office of Health and Human Services
Department of Public Health
Bureau of Environmental Health
250 Washington Street, Boston, MA 02108-4619
Phone: 617-624-5757 Fax: 617-624-5777
TTY: 617-624-5286
www.mass.gov/dph

April 29, 2014

Kalene Gendron, Health Agent
Nashoba Valley Associate Boards of Health
Two Shaker Road, Suite D225
Shirley, MA 01464

Dear Ms. Gendron:

Enclosed is a copy of the report by the Indoor Air Quality Program on their visit to the Pepperell Police Department to conduct an indoor air quality assessment. Please refer to the recommendations section for advice on how to correct any issues identified by this assessment.

If you have any questions regarding the report or if we can be of further assistance in this matter, please feel free to call us at (617) 624-5757.

Sincerely,

Suzanne K. Condon, Associate Commissioner
Director, Bureau of Environmental Health

cc: Mike Feeney, Director, Indoor Air Quality Program, BEH
Chief David Scott, Pepperell Police Department
The Honorable Representative Sheila C. Harrington
The Honorable Senator Eileen M. Donoghue

Enclosure(s)

INDOOR AIR QUALITY ASSESSMENT

Pepperell Police Department
59 Main Street
Pepperell, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health
Indoor Air Quality Program
April 2014

Background/Introduction

At the request of Kalene Gendron, Health Agent, Nashoba Associated Boards of Health, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health (BEH) provided assistance and consultation regarding indoor air quality (IAQ) concerns at the Pepperell Police Department (PPD) located at 59 Main Street, Pepperell, MA. Concerns about general IAQ and water damage/mold prompted the request. On December 20, 2013, the building was visited by Mike Feeney, Director of BEH's IAQ Program. A letter detailing water damage/mold issues with recommendations for remediation was released on December 31, 2013 (MDPH, 2013). This report details general IAQ conditions that exist at the PPD.

The PPD is a two-story brick and plaster building that was constructed prior to 1900 as the Clara Shattuck School. The building was later converted into a public safety complex. The PPD contains a lock-up, access ramp and car bays in the basement. The first and second floors were reconstructed and sub-divided from their original configuration into office/administrative space. Some portions of the ventilation system date back to the original construction of the building.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 7525. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. BEH/IAQ staff also performed visual inspection of building materials for water damage and/or microbial growth.

Results

The building houses approximately 8 staff. Tests were taken during normal operations at the building and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million (ppm) in 12 of 13 areas, indicating adequate air exchange at the time of assessment. It is important to note that the building does not have a functioning mechanical ventilation system on the first or second floor to provide fresh air. Further, most areas were empty/sparsely populated at the time of assessment, which can greatly reduce carbon dioxide levels. Carbon dioxide levels would be expected to increase with higher occupancy.

The basement lock-up has a mechanical air handling unit (AHU) that provides fresh air to the lockup and adjacent areas by ceiling-mounted supply diffusers. Return air is ducted back to the AHU via ductwork.

First floor offices are equipped with fan coil units (FCUs). FCUs do not introduce outside air and are limited to recirculating air. FCUs are designed to draw from a return air intake vent located at the base of each unit (Figure 1), to provide heat or cooling. FCUs were found in poorly maintained condition with significant corrosion on components.

Function of equipment of this age is difficult to maintain, since compatible replacement parts are often unavailable. According to the American Society of Heating, Refrigeration and

Air-Conditioning Engineers (ASHRAE), the service life[1] for a unit heater, hot water or steam is 20 years, assuming routine maintenance of the equipment (ASHRAE, 1991). Despite attempts to maintain the FCUs, the operational lifespan of the equipment has been exceeded. Maintaining the balance of fresh air to exhaust air will become more difficult as the equipment ages and as replacement parts become increasingly difficult to obtain. Currently, ventilation in the building is controlled by the use of openable windows.

The first floor has offices equipped with mechanical exhaust vents connected to fans in the attic. This system was operating during the assessment. In this configuration, offices on the first floor are *depressurized*. Buildings with offices are usually designed to be *pressurized* to prevent the draw of odors from wall cavities or other locations that can contain environmental pollutants. In addition, these vents would remove heated air from offices, making thermal comfort control difficult.

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 balancing the basement HVAC system was not available at the time of this assessment. In their current condition, the existing components of the ventilation system on the first floor cannot be balanced.

Minimum design ventilation rates are mandated by the Massachusetts State Building Code (MSBC). Until 2011, the minimum ventilation rate in Massachusetts was higher for both

[1] The service life is the median time during which a particular system or component of …[an HVAC]… system remains in its original service application and then is replaced. Replacement may occur for any reason, including, but not limited to, failure, general obsolescence, reduced reliability, excessive maintenance cost, and changed system requirements due to such influences as building characteristics or energy prices (ASHRAE, 1991).

occupied office spaces and general classrooms, with similar requirements for other occupied spaces (BOCA, 1993). The current version of the MSBC, promulgated in 2011 by the State Board of Building Regulations and Standards (SBBRS), adopted the 2009 International Mechanical Code (IMC) to set minimum ventilation rates. **Please note that the MSBC is a minimum standard that is not health-based**. At lower rates of cubic feet per minute (cfm) per occupant of fresh air, carbon dioxide levels would be expected to rise significantly. A ventilation rate of 20 cfm per occupant of fresh air provides optimal air exchange resulting in carbon dioxide levels at or below 800 ppm in the indoor environment in each area measured. MDPH recommends that carbon dioxide levels be maintained at 800 ppm or below. This is because most environmental and occupational health scientists involved with research on IAQ and health effects have documented significant increases in indoor air quality complaints and/or health effects when carbon dioxide levels rise above the MDPH guidelines of 800 ppm for schools, office buildings and other occupied spaces (Sundell, J. et al., 2011). 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, please see Appendix A.

Indoor temperature readings at the time of assessment ranged from 67 °F to 75 °F, some of which were below the MDPH recommended comfort guidelines (Table 1). 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. In addition, it is difficult to control temperature and maintain comfort without a modern mechanical ventilation system and/or without operating existing ventilation systems (i.e., FCUs) as designed.

The relative humidity measured in the building at the time of assessment ranged from 19 to 28 percent, which was below the MDPH recommended comfort range in all areas surveyed (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.

Microbial/Moisture Concerns

For information regarding mold/moisture, please consult letter previously released by MDPH on December 31, 2013 (MDPH, 2013).

Other IAQ Evaluations

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present indoor, BEH/IAQ staff obtained measurements for carbon monoxide and PM2.5.

Carbon Monoxide

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 affects. Several air quality standards have been established to address carbon monoxide 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).

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, 2011). 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. On the day of assessment, outdoor carbon monoxide concentrations were non-detect (ND). No levels of carbon monoxide were detected inside the building during the assessment (Table 1). It is important to note that the garage is equipped with a local exhaust ventilation system. BEH/IAQ staff recommends that this system be used to vent vehicle exhaust as warranted.

Particulate Matter (PM2.5)

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 micrograms 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 $\mu g/m^3$ 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 were measured at 13 $\mu g/m^3$ (Table 1). Indoor PM2.5 levels ranged from 12 to 22 $\mu g/m^3$ (Table 1), which were below the NAAQS PM2.5 level of 35 $\mu g/m^3$. 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 buildings can generate particulate matter 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.

Other Conditions

Other conditions that can affect IAQ were observed during the assessment. In several areas, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in areas provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up. In addition, dust and debris can accumulate on flat surfaces (e.g., desktops, shelving and carpets) in occupied areas and subsequently be re-aerosolized causing further irritation.

Open utility holes and wall cracks observed in some rooms. Open utility holes and wall cracks can provide a means of transport for odors, fumes, dusts and vapors between rooms and floors.

Conclusions/Recommendations

The conditions noted at the PPD raise a number of IAQ issues. The general building conditions, maintenance, work hygiene practices and the age/condition of ventilation equipment, if considered individually, present conditions that could degrade indoor air quality. When combined, these conditions can serve to further degrade air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons, a two-phase approach is required for remediation. The first consists of **short-term** measures to improve air quality and the second consists of **long-term** measures that will require planning and resources to adequately address overall IAQ concerns.

Short-Term Recommendations

1. Implement recommendations made in the previously released MDPH letter dated December 31, 2013 (MDPH, 2013).
2. Regulate airflow using windows. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
3. Operate local exhaust ventilation system in garage as needed to vent vehicle emissions.
4. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to

minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

5. Relocate or consider reducing the amount of materials stored to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
6. Seal all open utility holes and wall cracks in the building.
7. 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/iaq.

Long-Term Recommendations

1. Based on the age, physical deterioration and availability of parts, BEH recommends that an HVAC engineering firm evaluate options for providing adequate ventilation building-wide. Since restoration of original FCUs is not a likely option, consideration should be given to replacing them with modern FCUs and installing a mechanical exhaust ventilation system. Determine if existing airshafts, vents, ductwork, etc. can be retrofitted for (modern) mechanical ventilation.

References

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

ASHRAE. 1991. ASHRAE Applications Handbook, Chapter 33 "Owning and Operating Costs". American Society of Heating, Refrigeration and Air Conditioning Engineers, Atlanta, GA.

BOCA. 1993. The BOCA National Mechanical Code/1993. 8th ed. Building Officials and Code Administrators International, Inc., Country Club Hill, IL.

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.

MDPH. 2013. Letter to Kalene Gendron, Health Agent, Nashoba Associated Boards of Health, Regarding Water Damage/Mold Conditions at Pepperell Police Department. Dated December 31, 2013. Massachusetts Department of Public Health, Bureau of Environmental Health Assessment, 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.

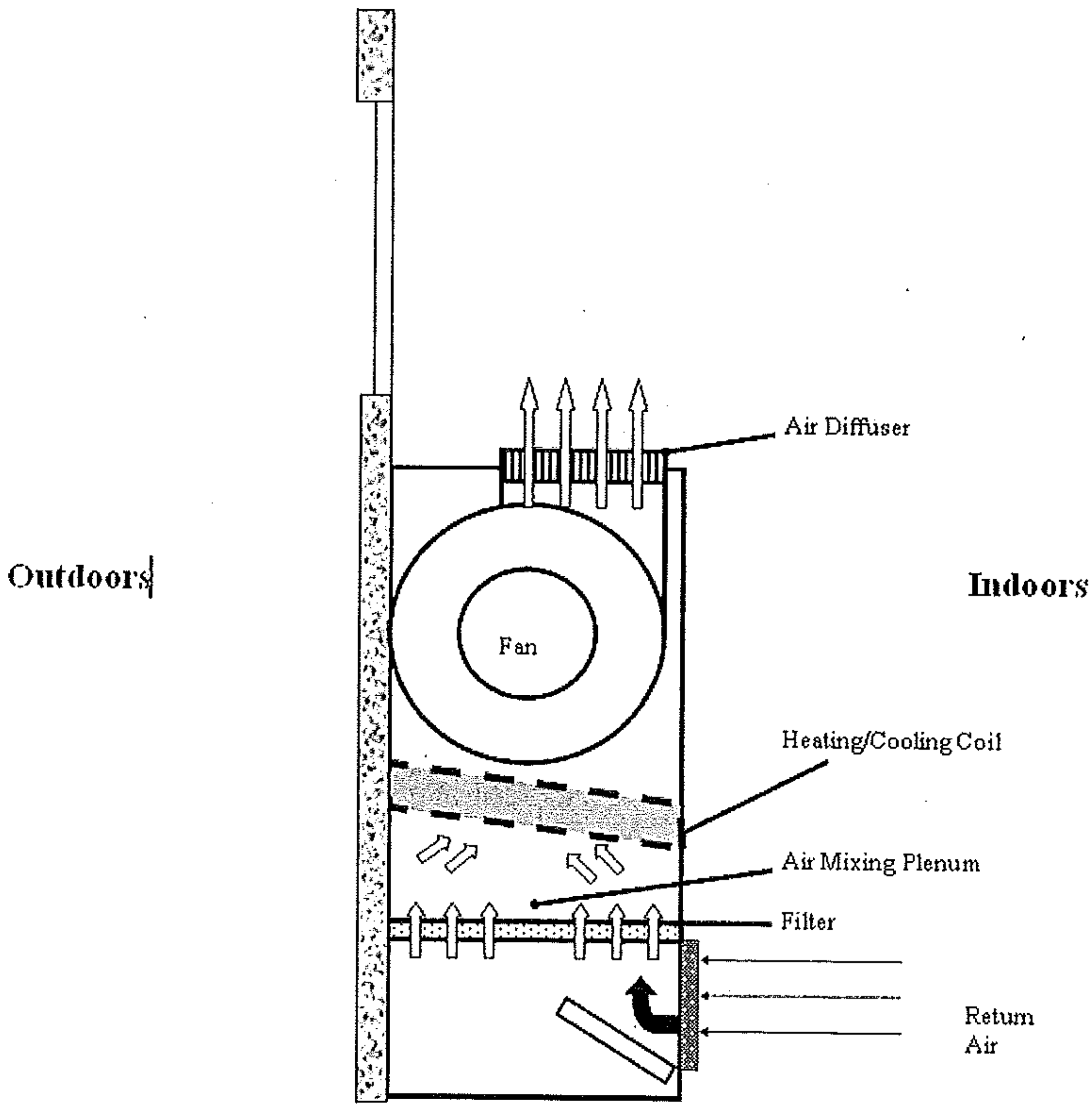
SBBRS. 2011. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations, 8th edition. 780 CMR 1209.0.

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

Sundell, et al. 2011. Sundell, J., H. Levin, W. W. Nazaroff, W. S. Cain, W. J. Fisk, D. T. Grimsrud, F. Gyntelberg, Y. Li, A. K. Persily, A. C. Pickering, J. M. Samet, J. D. Spengler, S. T. Taylor, and C. J. Weschler. Ventilation rates and health: multidisciplinary review of the scientific literature. Indoor Air, Volume 21: pp 191–204.

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.

Figure 1: Fan Coil Unit (FCU)



Location: Pepperell Police Department **Indoor Air Results**

Address: 59 Main Street, Pepperell, MA **Table 1** **Date: 12/20/2013**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Intake	Exhaust	
Background	359	ND	56	57	13					
Library	690	ND	73	27	15	4	Y	N	Y	FCU off, DO
Squad room	681	ND	73	23	14	0	Y	N	Y	FCU off, DO
Sgt. office	611	ND	74	20	14	0	Y	N	Y	FCU off, DO
Chief office	552	ND	73	21	13	0	Y	N	Y	FCU off, DO
Lt. office	541	ND	73	20	18	0	Y	N	Y	FCU off, DO
Main office	597	ND	73	21	14	1	Y	N	Y	FCU off, DO
Inventory	614	ND	73	21	22	0	Y	N	N	
Communications	837	ND	74	25	12	3	Y	N	Y	FCU off, DO, wall-mounted AC
Fire office	593	ND	75	19	16	0	Y	N	Y	FCU off

ppm = parts per million
$\mu g/m^3$ = micrograms per cubic meter
AC = air conditioner
DO = door open
FCU = fan coil unit
GW= gypsum wallboard
ND = non-detect
WD = water-damaged

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Table 1 (continued)

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 (μg/m³)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Intake	Exhaust	
Crime lab	482	ND	68	27	12	0	Y	Y	Y	WD GW
Booking	455	ND	67	28	12	0	Y	Y	Y	DO
Garage	451	ND	68	27	14	0	Y	N	Y	
Interview	457	ND	68	27	12	0	Y	Y	Y	DO

ppm = parts per million
μg/m³ = micrograms per cubic meter
AC = air conditioner
DO = door open
FCU = fan coil unit
GW= gypsum wallboard
ND = non-detect
WD = water-damaged

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Appendix A

Carbon Dioxide and its Use in Evaluating Adequacy of Ventilation in Buildings

The Bureau of Environmental Health's (BEH) Indoor Air Quality (IAQ) Program examines indoor air quality conditions that may have an effect on building occupants. The status of the ventilation system, potential moisture problems/microbial growth and identification of respiratory irritants are examined in detail, which are described in the attached report. In order to examine the function of the ventilation system, measurements for carbon dioxide, temperature and relative humidity are taken. Carbon dioxide measurements are commonly used to assess the adequacy of ventilation within an indoor environment.

Carbon dioxide is an odorless, colorless gas. It is found naturally in the environment and is produced in the respiration process of living beings. Another source of carbon dioxide is the burning of fossil fuels. Carbon dioxide concentration in the atmosphere is approximately 250-600 ppm (Beard, 1982; NIOSH, 1987).

Carbon dioxide measurements within an occupied building are a standard method used to gauge the adequacy of ventilation systems. Carbon dioxide is used in this process for a number of reasons. Any occupied building will have normally occurring environmental pollutants in its interior. Human beings produce waste heat, moisture and carbon dioxide as by-products of the respiration process. Equipment, plants, cleaning products or supplies normally found in any building can produce gases, vapors, fumes or dusts when in use. If a building has an adequately operating mechanical ventilation system, these normally occurring environmental pollutants will be diluted and removed from the interior of the building. The introduction of fresh air both increases the comfort of the occupants and serves to dilute normally occurring environmental pollutants.

Appendix A

An operating exhaust ventilation system physically removes air from a room and thereby removes environmental pollutants. The operation of supply in conjunction with the exhaust ventilation system creates airflow through a room, which increases the comfort of the occupants. If all or part of the ventilation system becomes non-functional, a build up of normally occurring environmental pollutants may occur, resulting in an increase in the discomfort of occupants.

The MDPH approach to resolving indoor air quality problems in schools and public buildings is generally two-fold: 1) improving ventilation to dilute and remove environmental pollutants and 2) reducing or eliminating exposure opportunities from materials that may be adversely affecting indoor air quality. In the case of an odor complaint of unknown origin, it is common for BEH staff to receive several descriptions from building occupants. A description of odor is subjective, based on the individual's life experiences and perception. Rather than test for a potential series of thousands of chemicals to identify the unknown material, carbon dioxide is used to judge the adequacy of airflow as it both dilutes and removes indoor air environmental pollutants.

As previously mentioned, carbon dioxide is used as a diagnostic tool to evaluate air exchange by building ventilation systems. The presence of increased levels of carbon dioxide in indoor air of buildings is attributed to occupancy. As individuals breathe, carbon dioxide is exhaled. The greater the number of occupants, the greater the amount of carbon dioxide produced. Carbon dioxide concentration build up in indoor environments is attributed to inefficient or non-functioning ventilation systems. 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).

Appendix A

Carbon dioxide can be a hazard within enclosed areas with **no air supply**. These types of enclosed areas are known as confined spaces. Manholes, mines and sewer systems are examples of confined spaces. An ordinary building is not considered a confined space. Carbon dioxide air exposure limits for employees and the general public have been established by a number of governmental health and industrial safety groups. Each of these standards of air concentrations is expressed in parts per million (ppm). *Table 1* is a listing of carbon dioxide air concentrations and related health effects and standards.

The MDPH uses a guideline of 800 ppm for publicly occupied buildings (Burge et al., 1990; Gold, 1992; Norback, 1990; OSHA, 1994; Redlich, 1997; Rosenstock, 1996; SMACNA, 1998). 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. Several sources indicate that indoor air problems *are significantly reduced* at 600 ppm or less of carbon dioxide (ACGIH, 1998; Bright et al., 1992; Hill, 1992; NIOSH, 1987). Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches.

Air levels for carbon dioxide that indicate that indoor air quality may be a problem have been established by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE). Above 1,000 ppm of carbon dioxide, ASHRAE recommends adjustment of the building's ventilation system (ASHRAE, 1989). In 2001, ASHRAE modified their standard to indicate that no more than 700 ppm above the outdoor air concentration; however 800 ppm is the level where further investigation will occur.

Carbon dioxide itself has no acute (short-term) health effects associated with low level exposure (below 5,000 ppm). The main effect of carbon dioxide involves its ability to displace oxygen for the air in a confined space. As oxygen is inhaled, carbon dioxide levels build up in the confined space, with a decrease in oxygen content in the available air. This displacement of oxygen makes carbon dioxide a simple asphyxiant. At carbon dioxide levels of 30,000 ppm, severe headaches, diffuse sweating, and labored breathing have been reported. No **chronic** health effects are reported at air levels below 5,000 ppm.

Air testing is one method used to determine whether carbon dioxide levels exceed the comfort levels recommended. If carbon dioxide levels are over 800-1,000 ppm, the MDPH recommends adjustment of the building's ventilation system. The MDPH recommends that corrective measures be taken at levels above 800 ppm of carbon dioxide in office buildings or schools. (Please note that carbon dioxide levels measured below 800 ppm may not decrease indoor air quality complaints). Sources of environmental pollutants indoors can often induce symptoms in exposed individuals regardless of the adequacy of the ventilation system. As an example, an idling bus outside a building may have minimal effect on carbon dioxide levels, but can be a source of carbon monoxide, particulates and odors via the ventilation system.

Therefore, the MDPH strategy of adequate ventilation coupled with pollutant source reduction/removal serves to improve indoor air quality in a building. Please note that each table included in the IAQ assessment lists BEH comfort levels for carbon dioxide levels at the bottom (i.e. carbon dioxide levels between 600 ppm to 800 ppm are acceptable and <600 ppm is preferable). While carbon dioxide levels are important, focusing on these air measurements in isolation to all other recommendations is a misinterpretation of the recommendations made in these assessments.

Appendix A

Table 1: Carbon Dioxide Air Level Standards

Carbon Dioxide Level	Health Effects	Standards or Use of Concentration	Reference
250-600 ppm	None	Concentrations in ambient air	Beard, R.R., 1982 NIOSH, 1987
600 ppm	None	Few indoor air complaints, used as reference for air exchange for protection of children	ACGIH, 1998; Bright et al., 1992; Hill, 1992; NIOSH 1987
800 ppm	None	Used as an indicator of ventilation adequacy in schools and public buildings, used as reference for air exchange for protection of children	Mendler, 2003 Bell, A. A., 2000; NCOSP, 1998; SMACNA, 1998; EA, 1997; Redlich, 1997; Rosenstock, 1996; OSHA, 1994; Gold, 1992; Burge et al., 1990; Norback, 1990 ; IDPH, Unknown
1000 ppm	None	Used as an indicator of ventilation inadequacy concerning removal of odors from the interior of building.	ASHRAE, 1989
950-1300 ppm*	None	Used as an indicator of ventilation inadequacy concerning removal of odors from the interior of building.	ASHRAE, 1999
700 ppm (over background)	None	Used as an indicator of ventilation inadequacy concerning removal of odors from the interior of building.	ASHRAE, 2001
5000 ppm	No acute (short term) or chronic (long-term) health effects	Permissible Exposure Limit/Threshold Limit Value	ACGIH, 1999 OSHA, 1997
30,000 ppm	Severe headaches, diffuse sweating, and labored breathing	Short-term Exposure Limit	ACGIH, 1999 ACGIH. 1986

* outdoor carbon dioxide measurement +700 ppm

Appendix A

References

ACGIH. 1986. Documentation of the Threshold Limit Values. American Conference of Governmental Industrial Hygienists. Cincinnati, OH.

ACGIH. 1998. Industrial Ventilation A Manual of Recommended Practice. 23rd Edition. American Conference of Governmental Industrial Hygienists. Cincinnati, OH.

ACGIH. 1999. Guide to Occupational Exposures-1999. American Conference of Governmental Industrial Hygienists, Cincinnati, OH.

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

ASHRAE. 1999. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-1999.

ASHRAE. 2001. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-2001.

Beard, R.R. 1982. Chapter Fifty-two, Inorganic Compounds of Oxygen, Nitrogen, and Carbon. *Patty's Industrial Hygiene and Toxicology, Vol. IIc. 3rd ed.* Clayton, G. D. & Clayton, F. E., eds. John Wiley & Sons, New York, NY.

Bright, P.; Mader, M.; Carpenter, D.; and Hermon-Cruz, I.Z. 1992. Guideline for Indoor Air Surveys. Brooks Air Force Base, TX. Armstrong Laboratory, Occupational and Environmental Health Directorate. NTIS AL-TR-1992-0016.

Burge, H. and Hoyer, M. 1990. Focus On ... Indoor Air Quality. Appl. Occup. Environ. Hyg. 5(2):88.

EA. 1997. Indoor Air Quality. Environment Australia, Department of the Environment, Sport and Territories, Canberra, Australia.
www.environment.gov.au/soe/1996/publications/technical/pubs/12indora.pdf

Gold, D. 1992. Indoor Air Pollution. Clinics in Chest Medicine. 13(2):224-225.

Hill, B.; Craft, B.; and Burkart, J. 1992. Carbon Dioxide, Particulates and Subjective Human Responses in Office Buildings without Histories of Indoor Air Quality Problems. Appl. Occup. Environ. Hyg. 7(2): 101-111.

IDPH. Unknown. Illinois Department of Public Health Guidelines for Indoor Air Quality. Illinois Department of Public Health, Springfield, Il.
http://www.idph.state.il.us/envhealth/factsheets/indoorairqualityguide_fs.htm

Mendler, S. and Odell, W. 2003. Indoor Air Quality for the EPA. *ArchitectureWeek*. April 16, 2003. http://www.architectureweek.com/2003/0416/environment_1-2.html

Appendix A

NCOSP. 1998. Workplace Requirements for Safety & Health, Indoor Air Quality 3.3.3. NC Office of State Personnel, Raleigh, NC. www.osp.state.nc.us/emprsk/safety/handbook/5-9.pdf

NIOSH. 1987. Guidance for Indoor Air Quality Investigations. Cincinnati, OH. National Institute for Occupational Safety and Health, Hazards Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluation and Field Studies.

Norback, D.; Torgen, M.; and Edling, C. 1990. Volatile Organic Compounds, Respirable Dust, and Personal Factors Related to Prevalence and Incidence of Sick Building Syndrome in Primary Schools. British Journal of Industrial Medicine. 47:740.

OSHA. 1994. Occupational Safety and Health Administration. Indoor Air Quality (Proposed Regulation), Federal Register 59:15968-16039, (1994) Appendix A.

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.

Redlich, C.; Sparer, J.; and Cullen, M. 1997. Sick-building Syndrome. Lancet. 349:1016.

Rosenstock, L. 1996. NIOSH Testimony to the U.S. Department of Labor on Air Quality, Appl. Occup. Environ. Hyg. 11(12):1368.

SMACNA. 1998. Indoor Air Quality: A Systems Approach. 3rd ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc, Chantilly, VA. National Association, Inc.