INDOOR AIR QUALITY ASSESSMENT

Quinsigamond Community College
Suprenant Building
670 West Boylston Street
Worcester, Massachusetts

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

February 2014

Background/Introduction

At the request Jim Racki, Facilities Manager, Quinsigamond Community College (QCC), the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health (BEH) provided assistance and consultation regarding indoor air quality (IAQ) at the Suprenant Building, located on the QCC campus at 670 West Boylston Street, Worcester, Massachusetts. On December 6, 2013, Michael Feeney, Director of BEH's IAQ Program visited the building to conduct an assessment. Mr. Racki accompanied Mr. Feeney during the assessment.

The building was constructed prior to 1970 as a part of the former Assumption College campus. The heating, ventilating and air-conditioning (HVAC) system in the science classrooms was renovated in approximately 2011.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 7565. 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 is used by several hundred students, faculty and staff daily. Tests were taken during normal operations at the school. Results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in nine of forty-one areas, indicating a lack of air exchange in about a quarter of the areas examined. Fresh air in the majority of classrooms is supplied by unit ventilators (univents) (Picture 1). A univent is designed to draw air from outdoors through a fresh air intake located on the exterior wall of the building (Picture 2). Return air is drawn through an air intake located at the base of each unit where fresh and return air are mixed, filtered, heated or cooled and provided to classrooms through an air diffuser located in the top of the unit (Figure 1). Univents were found deactivated in some classrooms. In order for univents to provide fresh air as designed, intakes/returns must remain free of obstructions. Importantly, these units must remain "on" and be allowed to operate while rooms are occupied.

Exhaust ventilation in most classrooms is provided by wall-mounted vents. In a number of cases exhaust vents were not drawing air. Without adequate supply and exhaust ventilation, excess heat and environmental pollutants can build up and lead to indoor air/comfort complaints.

The science classrooms are ventilated by air handling units (AHUs) located on the roof. AHUs are connected to classrooms via ductwork to ceiling-mounted supply and return vents. The science classroom ventilation system was operating at the time of assessment.

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 heating, ventilating and air conditioning (HVAC) systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of the system outside of classrooms was not available at the time of assessment. Science classroom ventilation systems were reportedly balanced after installation in 2011.

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 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 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, consult Appendix A.

Indoor temperature measurements the day of assessment ranged from 69 °F to 76 °F (Table 1), which were within or very close to the MDPH recommended comfort range. 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 operating the ventilation equipment as designed (e.g., univents/exhaust vents deactivated/obstructed).

The relative humidity measurements the day of assessment ranged from 36 to 50 percent, which were mostly within 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.

Microbial/Moisture Concerns

Plants were noted in some classrooms (Picture 1). Plants can be a source of pollen and mold which can be respiratory irritants to some individuals. Plants should be properly maintained and equipped with drip pans and should be located away from univents to prevent the aerosolization of dirt, pollen and mold. An aquarium was observed in an office. Aquariums should be properly maintained to prevent microbial/algal growth, which can emit unpleasant odors.

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 in the indoor environment, 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 effects. 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).

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, 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, the outdoor carbon monoxide concentration was 3 ppm (Table 1). No measurable levels of carbon monoxide were detected inside the building (Table 1).

Particulate Matter

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter includes airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to PM with a diameter of 10 μm or less (PM10). In 1997, US EPA established a more protective standard for fine airborne particulate matter with a diameter of 2.5 μm or less (PM2.5). 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 PM concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 1 $\mu g/m^3$ (Table 1). PM2.5 levels measured in the school were between non-detectable to 5 $\mu g/m^3$ (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 activities that occur indoors and/or mechanical devices 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, use of stoves and/or microwave ovens in kitchen areas; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Volatile Organic Compounds

Indoor air concentrations can be greatly impacted by the use of products 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 identify materials that can potentially increase indoor VOC concentrations, BEH/IAQ staff examined rooms for products containing these respiratory irritants.

The odor of chemicals related to photography development was noted in the classroom outside the darkroom. A number of photographic chemicals were observed to be stored in the darkroom, which has either non-functional or poorly functioning exhaust ventilation. Photographic chemicals contain VOCs, which can be irritating to the eyes, nose and throat. An area with chemical use such as a darkroom requires adequate exhaust ventilation and make-up air. In addition, local exhaust vents should be located at the level of the wash sink and developing pans to draw chemicals/odors away from users. The current location of the exhaust fan in the exterior wall will tend to draw odors towards users of the wash sink and developing pans.

Classrooms contained dry erase boards and related materials. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat. Accumulated debris was also observed in dry erase board trays (Table 1).

Other Conditions

Other conditions that can affect IAQ were observed during the assessment. In many classrooms, a large number of items were on floors, windowsills, tabletops, counters, bookcases and desks, which provide 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.

The basement of the building contains a room with a computer mainframe. This type of equipment produces a number of pollutants, including waste heat, heated plastic odors and ozone. It is recommended that an exhaust vent be installed in this room near the mainframe.

Broken/dislodged ceiling tiles were seen in a few classrooms. Damage or movement of ceiling tiles may create pathways for dust/debris in the ceiling plenum to enter into occupied areas, which may serve as an eye and/or respiratory irritant.

A stand of several pine trees, which could be a source of pollen, was observed to be growing in close proximity to the building. The tops of these trees are above the roofline. Under the right wind conditions, it is possible that pollen from these trees could enter the building through open windows or into fresh air intakes of the rooftop AHU. It is important to note that no accumulation or discoloration of dust associated with pollen was noted within the building or window sills.

Floors in some offices and other areas are covered by wall-to-wall carpeting. The Institute of Inspection, Cleaning and Restoration Certification (IICRC), recommends that carpeting be cleaned annually (or semi-annually in soiled high traffic areas) (IICRC, 2005).

Where an excessively dusty environment exists due to outdoor conditions or indoor activities (e.g., renovations), cleaning frequency should be increased (every six months) (IICRC, 2000).

Conclusions/Recommendations

In view of the findings at the time of assessment, the following recommendations are made to improve IAQ:

1. Operate univents and AHUs continuously during periods of occupancy to maximize air exchange.
2. Remove all blockages/items from the surface of univent air diffusers and return vents (along front/bottom) to ensure adequate airflow.
3. Ensure classroom exhaust vents are unobstructed and operating during occupancy; make repairs as needed.
4. Consider adopting a balancing schedule of every 5 years for all mechanical ventilation systems, as recommended by ventilation industrial standards (SMACNA, 1994).
5. Use openable windows in conjunction with classroom exhaust vents to facilitate air exchange in classrooms only. Care should be taken to ensure windows are properly closed at night and on weekends to avoid the freezing of pipes and potential flooding.
6. Windows should not be opened in sections of the building provided with air conditioning during summer months. Opening of windows allows for outdoor pollutants (e.g., pollen and mold) to enter the building, as well as uncontrolled hot humid air. Hot, humid air drawn into a building during hot, humid weather can result in conditions that can moisten building materials, which in turn can result in mold growth.

7. 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 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).
8. Ensure indoor plants are equipped with drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial, as needed. Move plants away from the air stream of mechanical ventilation equipment.
9. Clean and maintain aquariums and terrariums to prevent bacterial/microbial growth and associated odors.
10. Explore the feasibility of improving exhaust ventilation in the darkroom.
11. Relocate or consider reducing the amount of materials stored in classrooms and offices to allow for more thorough cleaning of classrooms. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
12. Clean dry erase board trays regularly to avoid the build-up of particulates.
13. Consider installing exhaust ventilation for the equipment in the mainframe training room.
14. Repair/replace broken and dislodged ceiling tiles.
15. Clean carpeting annually or semi-annually in soiled high traffic areas as per the recommendations of the Institute of Inspection, Cleaning and Restoration Certification (IICRC). Copies of the IICRC fact sheet can be downloaded at: http://1.cleancareseminars.net/?page_id=185 (IICRC, 2005).

16. Consider adopting the US EPA (2000) document, "Tools for Schools", as an instrument for maintaining a good indoor air quality environment in the building. This document is available at: http://www.epa.gov/iaq/schools/index.html.

17. Refer to resource manual and other related indoor air quality documents located on the MDPH's website for further building-wide evaluations and advice on maintaining public buildings. These documents are available at: http://mass.gov/dph/iaq.

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 and Code Administrators International, Inc., Country Club Hill, IL.

IICRC. 2000. IICRC S001. Reference Guideline for Professional On-Location Cleaning of Textile Floor Covering Materials. Institute of Inspection, Cleaning and Restoration Certification. Institute of Inspection Cleaning and Restoration, Vancouver, WA.

IICRC. 2005. Carpet Cleaning FAQ 4 Institute of Inspection, Cleaning and Restoration Certification. Institute of Inspection Cleaning and Restoration, Vancouver, WA.

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.

Sanford. 1999. Material Safety Data Sheet (MSDS No: 198-17). Expo® Dry Erase Markers Bullet, Chisel, and Ultra Fine Tip. Sanford Corporation. Bellwood, IL.

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. 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. 2000. Tools for Schools. Office of Air and Radiation, Office of Radiation and Indoor Air, Indoor Environments Division (6609J). EPA 402-K-95-001, Second Edition. http://www.epa.gov/iaq/schools/actionkit.html.

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.

Picture 1

Univent, note plants on sill on top of towel

Picture 2

Univent fresh air intake

Location: Quinsigamond Community College, Suprenant Building **Indoor Air Results**

Address: 670 West Boylston Street, Worcester, MA **Table 1** **Date: 12/6/2013**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 (µg/m^3)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Background (outdoors)	381	3	55	45	1					
Lobby	591	ND	74	37	1	16	Y	Y	Y	
Auditorium	437	ND	71	37	ND	0	N	Y	Y	Main frame training, electrical odor
Dark room	755	ND	74	41	1	0	N	N	N	
Balance room	483	ND	71	37	ND	0	N	Y	Y	
003	1011	ND	73	43	3	15	Y	Y	Y	
005	1078	ND	73	42	1	5	Y	Y	Y	
007	780	ND	73	41	ND	1	Y	Y	Y	Door open
009	639	ND	73	40	ND	0	Y	Y	Y	Cleaner, DO
010	834	ND	74	44	ND	2	N	Y	Y	
123	630	ND	74	36	1	4	Y	Y	Y	

ppm = parts per million µg/m^3 = micrograms per cubic meter DO = door open ND = non detect

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

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

Location: Quinsigamond Community College, Suprenant Building **Indoor Air Results**

Address: 670 West Boylston Street, Worcester, MA **Table 1 (continued)** **Date: 12/6/2013**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
134	617	ND	75	40	1	2	Y	Y	Y	DO
203	688	ND	73	40	1	6	Y	Y	Y	8 computers, DO
207	748	ND	76	39	1	17	Y	Y	Y	
208	712	ND	76	38	2	3	Y	Y	Y	
211	813	ND	76	39	2	0	Y	Y	Y	
212	869	ND	75	39	2	19	Y	Y	Y	
213	682	ND	75	38	ND	1	Y	Y	Y	
214	696	ND	74	39	1	1	Y	Y	Y	
217	662	ND	72	40	1	12	Y	Y	Y	Plants
301	501	ND	72	36	2	0	Y	Y	Y	DO
301 office	580	ND	72	38	1	0	Y	N	N	

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

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%

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 (μg/m^3)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
307	831	ND	72	42	1	13	Y	Y	Y	DO
308	675	ND	73	41	ND	1	Y	Y	Y	DO
309	802	ND	72	46	2	0	Y	Y	Y	DO
310	795	ND	69	47	2	8	Y	Y	Y	DO
312	1245	ND	73	50	3	1	Y	Y	Y	DO
313	470	ND	73	39	ND	0	Y	Y	Y	DO
314	642	ND	73	42	2	0	Y	Y	Y	DO
317	590	ND	71	39	1	19	Y	Y	Y	DO
318	578	ND	71	37	1	2	Y	Y	Y	DO
319	463	ND	71	37	2	0	Y			DO
403	653	ND	72	43	1	2	Y	Y	Y	Fish tank, water bin on sill

ppm = parts per million μg/m^3 = micrograms per cubic meter DO = door open ND = non detect

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%

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
407	661	ND	74	40	1	4	Y	Y	Y	
410	824	ND	75	40	3	4	Y	Y	Y	DO
412	706	ND	76	39	2	3	Y	Y	Y	DO
413	542	ND	74	39	3	0	Y	Y	Y	DO
414	741	ND	73	43	4	7	Y	Y	Y	DO
417	540	ND	72	42	1	0	Y	Y	Y	Plants
417 science storeroom	617	ND	70	43	5	1	Y	Y	Y	Chemical storage
417 prep room	528	ND	69	44	1	0	Y	Y	Y	Plants on window sill
418	418	ND	73	37	ND	0	Y	Y	Y	

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

Comfort Guidelines

Carbon Dioxide:	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems	Temperature: Relative Humidity:	70 - 78 °F 40 - 60%