INDOOR AIR QUALITY ASSESSMENT

Lake Street Elementary School
17 Lake Street
Spencer, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health
Indoor Air Quality Program
April 2015

Background/Introduction

At the request of Gary Suda, Spencer Public Schools (SPS) Business Manager, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health (BEH) provided assistance and consultation regarding indoor air quality (IAQ) at the Lake Street Elementary School (LSS) located at 17 Lake Street, Spencer, Massachusetts. On March 27, 2015, Michael Feeney, Director of BEH's IAQ Program visited the school to perform an assessment. This request for assistance was prompted by concerns regarding indoor environmental conditions in the building and whether such conditions posed a health hazard to building occupants.

As reported to IAQ staff, SPS plans to close the LSS at the end of the current school year (June 2015). The purpose of the current assessment was to assess the building's current IAQ and to make recommendations regarding improving IAQ in the building until its scheduled closure in June 2015.

This building was previously visited by BEH/IAQ Program staff in 2014 to assess conditions in the LSS library, however the entire building was assessed at that time. A report with recommendations to improve IAQ was provided to the Spencer school superintendent and school principal at the time of the assessment (March 2014). The 2014 IAQ assessment had provided a number of short and long term recommendations to improve indoor air quality. While conditions that could affect IAQ were noted in the 2014 report, such conditions generally impact comfort parameters versus chronic or long-term health impacts. It is important to note however, that sensitive individuals that encounter specific triggers (e.g., allergens) in any indoor environment may experience irritation to the eyes, nose or respiratory system. For this reason, MDPH urges parents and other building occupants to work with the LSS medical staff to address these issues.

After initially contacting the IAQ Program on March 25, 2015, BEH staff recommended that the LSS be evaluated for carbon monoxide by the Spencer Fire Department (SFD). Mr. Suda and the Spencer Fire Chief reported that SFD found no measureable levels of carbon monoxide in the LSS.

The LSS is a two-story, red, brick and stone building constructed in 1957. An addition was built in 1977. Reportedly there have been no other renovations to the building since that time; therefore, the majority of building materials (e.g., flooring, heating and ventilation components and window systems) appear to be original. The school contains general classrooms, kitchen, a multi-purpose room (cafeteria/auditorium/gymnasium), library, art room, computer rooms, and office space.

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 school houses approximately 340 students in grades 1 through 3 with a staff of approximately 70. 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 21 out of 31 areas, indicating less than adequate air exchange in two thirds of the areas examined. It is also important to note that several areas were empty/sparsely populated, which can greatly reduce carbon dioxide levels. Carbon dioxide levels would be expected to increase with higher occupancy and windows closed.

Fresh air in the majority of classrooms is supplied by unit ventilators (univents). A univent is designed to draw air from outdoors through a fresh air intake located on the exterior wall of the building. 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). At the time of the assessment, univents were found deactivated or obstructed with classroom items in a number of areas (Table 1). SPS staff reported that univents were activated in the morning of the day of the assessment. Despite that, IAQ staff found 18 out of 26 univent deactivated during this assessment. As reported by LSS staff, the univents are controlled by a pneumatic system. As pneumatic control systems age, air leaks may develop rendering control of univent operations difficult.

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.

Please note that the univents are original equipment; units are over 50 years old in the original wing and over 30 years old in the 1977 wing. Optimal 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 univents, 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.

Exhaust ventilation in most classrooms is provided by wall-mounted vents. In some classrooms, exhaust vents are located in coat closets. IAQ examined exhaust motors on the roof and found 10 out of 11 deactivated. Damage to fan belts, motors and electrical connections can frequently occur in extreme snow and cold weather conditions experience in New England during the 2014/2015 winter. Exhaust ventilation must be operating in order to remove indoor air pollutants from the building interior.

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

[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).

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 these systems was not available at the time of assessment.

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. **<u>Please note that the MSBC is a minimum standard that is not health-based</u>**. 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 ranged from 70°F to 76°F (Table 1), which were within the MDPH recommended comfort range on the day of assessment. 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 measured in the building ranged from 25 to 34 percent, below the MDPH recommended comfort range (Table 1). The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. 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

It was reported that an odor existed in the head start office due to a plumbing leak. IAQ staff examined the room and found no odors associated with mold. LSS maintenance staff reported cleaning pooling water in the ceiling plenum above this area. The walls and ceiling of this area showed no signs of water damage.

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, outdoor carbon monoxide concentrations were non-detect (ND) (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 5 $\mu g/m^3$ (Table 1). PM2.5 levels measured in the school were between 1 to 8 $\mu g/m^3$ (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 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.

Other Conditions

An open testing hole was observed in flue of the main boiler located in the furnace room. This hole should be sealed to prevent the escape of exhaust gases to the indoor environment.

Conclusions/Recommendations

Based on conditions assessed at the time of the visit, the BEH /IAQ program has determined that the LSS does not pose any chronic/long term health impacts associated with use of the school through the end of the 2014/2015 school year. In light of the planned closure of this school at the end of the school year, the following short-term recommendation are made to improve and maintain indoor air quality for the remainder of the time the school is open.

1. Implement the recommendations made in 2014 IAQ assessment (Appendix B) to reduce/eliminate sources of indoor air pollutants.
2. Given the lack of control of the univents by the pneumatic control system and the age of the HVAC equipment, use openable windows in conjunction with classroom exhaust vents to facilitate air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
3. Exhaust vents on the roof should be repaired and operating during school hours. Focus should be given to repairing restroom associated rooftop exhaust fans and motors.
4. Repair/seal holes where pipes enter univent cabinets using appropriate fire-rated sealant in classrooms above the furnace room if not already sealed.
5. Repair the hole in the flue.
6. Operate all ventilation systems throughout the building (e.g., gym, cafeteria, classrooms) continuously during periods of occupancy to maximize air exchange. If increased airflow is desired, operate univents in fan "high" mode.
7. Remove blockages/items from the surface of univent air diffusers and return vents (along front/bottom).
8. Remove blockages/items from wall and coat closet exhausts to ensure adequate airflow.
9. Ensure classroom doors are closed for proper operation of mechanical ventilation system/air exchange.

10. 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

ACGIH. 1989. Guidelines for the Assessment of Bioaerosols in the Indoor Environment. 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. 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

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. 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. 2011. 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.

Location: Lake Street School **Indoor Air Results**

Address: 17 Lake Street, Spencer, MA **Table 1** **Date:3/27/2015**

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	
Background	432	ND	46	48	5					Rain
13	970	ND	74	33	4	22	Y	Y	Y	DO
12	1011	ND	73	31	6	24	Y	Y	Y	DO
10	881	ND	72	30	6	0	Y	Y	Y	
11	871	ND	72	31	3	18	Y o	Y	N	DO
Teachers	1034	ND	72	34	3	3	Y o	N	Y	
9	1265	ND	72	33	6	0	Y	Y	Y	
8	1007	ND	74	32	5	0	Y	Y	Y	
7	509	ND	76	25	4	0	Y	Y	Y	
6	641	ND	77	26	3	1	Y	Y	Y	DO
5	1141	ND	77	31	5	24	Y	Y off	Y	
3	994	ND	76	29	1	0	Y	Y off	Y	DO

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: Lake Street School | **Indoor Air Results**

Address: 17 Lake Street, Spencer, MA | **Table 1 (continued)** | **Date:3/27/2015**

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	
4	851	ND	76	25	2	2	Y	Y off	Y	DO
2	1145	ND	75	30	5	21	Y	Y off	Y	DO
1	1416	ND	75	32	5	18	Y	Y off	Y	
17	488	ND	74	37	2	0	Y	Y off	Y	
18	571	ND	74	25	4	0	Y	Y off	Y	DO
19	682	ND	72	26	5	2	Y	Y	Y	DO
Teacher's lounge	1022	ND	71	33	4	4	Y	Y	Y	DO
20	1211	ND	72	34	4	0	Y	Y	Y	DO
27	1167	ND	73	28	5	0	Y	Y off	Y	
21?	947	ND	72	30	5	2	Y	Y off	Y	DO
26	845	ND	72	29	5	4	Y	Y off	Y	
25	1087	ND	72	33	6	14	Y	Y off	Y	DO

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

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 (μg/m³)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
22	1271	ND	72	32	8	8	Y	Y off	Y	DO
24	1207	ND	72	31	5	11	Y	Y off	Y	DO
23	1391	ND	72	32	5	0	Y	Y off	N	DO
Family Advocate	599	ND	74	27	6	0	Y	N	N	DO
Meeting room	563	ND	74	25	6	1	Y	N	N	
Medical office	577	ND	76	25	5	0	Y	N	Y off	
PE	544	ND	72	25	6	0	N	N	N	DO
Art	518	ND	70	26	5	0	N	Y off	N	DO
Library	578	ND	70	26	6	0	n	Y off	N	

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