INDOOR AIR QUALITY ASSESSMENT

Boxford Town Library
10 Elm Street
Boxford, Massachusetts

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 Alan Benson, Boxford Town Administrator, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health (BEH) provided assistance and consultation at the Boxford Town Library (BTL), 10 Elm Street, Boxford, Massachusetts. On July 25, 2014, a visit was made to the BTL by Michael Feeney, Director of BEH's Indoor Air Quality (IAQ) Program, and Jason Dustin, Environmental Analyst/Inspector within BEH's IAQ Program. The assessment was prompted by employee concerns, associated with mold, odors, and general indoor air quality. During the assessment, BEH/IAQ staff were accompanied by John Dold, Superintendent of Public Works/Town Engineer, Boxford Department of Public Works, and Ms. Patti Ditullio, Library Director.

The BTL is a two-story wood building constructed in 1843. An addition was built in 1979. The original building has a field stone foundation with a dirt floor. The addition was constructed partially on a cement slab as well as a poured cement foundation/floor. A sump pump is installed in the floor of the addition's basement.

The original portion of the BTL has undergone significant interior renovations, likely when the addition was constructed in 1979. Renovations included replacing the original horse-hair plaster walls with gypsum wallboard (GW). Most recent renovations to the entire building complex consisted of removing portions of water-damaged GW, mold remediation, painting and the installation of new carpet tile. It was reported to BEH/IAQ staff that a new roof was installed approximately 4 years ago.

The second floor contains administrative offices and an employee kitchen/break room. The first floor (main floor) contains the circulation desk, open stack areas, restroom, media room, reference room, children's area and computer stations.

Methods

Air tests for carbon dioxide, carbon monoxide, temperature, and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor 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 a visual inspection of building materials for water damage and/or microbial growth.

Results

The library has 8 full time employees and several volunteers. The BTL typically serves up to 125 visitors on a daily basis. Tests were taken during normal operations. Results appear in Table 1.

Discussion

Ventilation

It can be seen that carbon dioxide levels were below 800 parts per million (ppm) in 10 of 11 areas, indicating adequate air exchange in the majority of areas surveyed at the time of the assessment (Table 1). It should be noted, however, that many areas were sparsely populated at the time of assessment. With increased occupancy, carbon dioxide levels would be expected to be higher.

The BTL does not have mechanical ventilation that introduces fresh/outside air into the building or exhausts stale air from occupied spaces; the system heats and recirculates only. The restroom in the main library has a local exhaust fan that only operates when the light switch is activated. The use of openable windows is the sole means of providing fresh air to the building.

The BTL is heated by two gas-fired forced hot air (FHA) furnace units. It appears that the FHA unit located in the attic (Picture 1) serves the main library (1979 addition), and the FHA unit located in the basement (Picture 2) serves the original 1843 building. As mentioned, these units provide heating but do *not* introduce fresh air. Air from occupant spaces is drawn into return grates (Picture 3) and ducted to the FHA units located in the attic or basement. The air is filtered, heated, and re-circulated back to ducted supply diffusers (Picture 4). The BTL is cooled using window air conditioning (AC) units that are located throughout the building (Table 1).

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, please see Appendix A.

Indoor temperature measurements at the time of the assessment ranged from 74°F to 77°F (Table 1), which were within 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.

Indoor relative humidity measurements at the time of the assessment ranged from 46 to 55 percent (Table 1), which were within the MDPH recommended comfort range. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Humidity levels in the building would be expected to drop during the heating season. 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

In order to become colonized with mold, a material must be exposed to water and remain moist. If sufficiently moistened, porous materials such as GW can support mold growth (US EPA, 2001). In addition, relative humidity in excess of 70 percent for extended periods of time can provide an environment for mold and fungal growth in building materials (ASHRAE, 1989). For storage and handling of paper, parchment, and leather (e.g., books), relative humidity below 55 percent is recommended (Wilson, 1995).

The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend that porous materials (e.g., carpeting, gypsum wallboard) be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If not dried within this time frame, mold growth may occur. Once mold has colonized porous materials, they are difficult to clean and should be removed/discarded.

It was reported to BEH/IAQ staff that several areas of the BTL previously identified as having water damage/mold were remediated from November 2013 to February 2014. According to Mr. Dold, water-damaged materials were removed and discarded at that time. Affected areas were treated with an anti-microbial agent and building materials (GW and carpet) were replaced.

The areas were then freshly painted. In addition, air ducts for the FHA units were cleaned due to reported mold within the ducts (Picture 5). It should be noted that the areas remediated for water damage/mold were not confined to a single area. First and second floor areas in both the original building and the 1979 addition were reported to have experienced water damage/mold growth. It is important to note that although it appears that the water damage/mold remediation was completed properly, little has been done to address the sources of water penetration. If the source of water exposure has not been not addressed, water damage and microbial growth will persist.

Due to the repairs/renovations, it was difficult for BEH/IAQ staff to trace specific paths of the water infiltration/damage. However, a number of concerns likely contributing to the moisture problems at the BTL were identified:

- **Lack of roof drainage:** The BTL lacks a gutter system for its roof (Pictures 6 and 7). A gutter system is necessary to collect and shed water *away* from the building. Signs of water pooling and chronic moisture were noted in close proximity to the foundation (Pictures 8 and 9).
- **Breaches in foundation:** Rainwater can infiltrate the foundations through the existing holes/breaches (Picture 10) or by capillary action. The water may then cause microbial growth and odors in basement areas.
- **Breaches to the building envelope:** BEH/IAQ staff observed rotted, damaged, or missing wood siding and trim at the BTL (Pictures 11 through 14). During a driving rainstorm, water can roll down exterior walls and enter through holes/breaches in the siding. This allows water to get behind the siding and enter the wall cavity, where it can be absorbed by insulation and GW. Damage to building materials and microbial growth

can occur when moisture persists. Several windows and door frames were also found to be water-damaged due to improperly flashed/sealed windows and rotted trim (Picture 15).

- **Breaches in other building components:** Water vapor, pollutants, and odors can migrate into occupied spaces through breaches in the basement ceilings or the unsealed seams of the FHA return ductwork in the original building's basement (Picture 16).
- **Groundwater:** The BTL appears to have a high groundwater level as evidenced by the sump pump in the basement of the 1979 addition (Picture 17). Groundwater levels fluctuate seasonally, with highest levels in early spring (Fletcher, 2014). BEH/IAQ staff observed the sump pump in activation at the time of the assessment (late July). It is likely that the 1979 addition basement extends well below the seasonal high groundwater table for the area. This results in a constant exposure to moisture, odors, and elevated humidity. It was also reported to BEH/IAQ staff that during severe storm events, the building has periodically lost power. This results in the deactivation of the sump pump motors. Several floods have occurred as a result of power loss. Town officials have reported that at times over 4 feet of water has accumulated in the basement due to the lack of an operating sump pump. Building materials and stored items were damaged as a result. Due to the repeated flooding of the basement, it is not recommended that porous materials be stored in basement areas. Consideration should be given to providing a back-up power source and a properly sealed cover for the basement sump pump.
- **Condensation:** Condensation is another source of moisture at the BTL. Older single-paned windows are a source for condensation due to the temperature differences on the surface of the glass and interior spaces in relation to the dew point. The condensation collects on windowsills causing further water damage (Picture 18). Also, opening

windows or doors while operating AC units can allow warm, moist air to condense on cooler surfaces.

- **Damp basement:** BEH/IAQ staff noted a strong musty odor in the original building basement during the time of the assessment. This would suggest very damp soil conditions and microbial growth. A window fan has been operating continuously to help alleviate odors/moisture (Picture 19). Warm, moist air moving from the basement to occupied spaces via gaps/crevices in basement ceiling can also condense when the air is in contact with a cool surface.

In order to explain how basement moisture/pollutants may be impacting the first and second floors, the following concepts concerning heated air and the creation of air movement must be understood.

- Heated air will create upward air movement (called the stack effect).
- Cold air moves to hot air, which creates drafts.
- As heated air rises, negative pressure is created, which draws cold air from outdoors through cracks or crevices in foundation walls or passive air vents (PAVs) in the foundation.
- As air rises, airborne pollutants will travel in the created air stream.
- As the range of temperature between hot and cold air increases, the rate of upward airflow increases.

Each of these concepts has influence on the movement of air. Due to the age of the building, it is highly unlikely that a vapor barrier or insulation exists beneath the slab. This lack of barrier/insulation makes the slab prone to temperatures lower than the heated air in the building.

This condition is likely exacerbated during cold, winter weather. A difference in temperature between the slab and the surrounding air likely results in the cement slab serving as a thermal bridge[1] . Where a thermal bridge exists, condensation[2] is likely to form on the warm side of the cold object. Over time, water droplets that form can moisten porous, carbon-containing materials, which can result in mold growth.

Library staff reported strong musty odors and mold growth on books in the northwest corner of the main library. BEH/IAQ staff observed this and noted metal shelving in contact with the uninsulated slab floor. The temperature of the shelving is likely below the dew point, which results in the formation of condensation. Metal shelving showed signs of rusting (Picture 20), indicating prolonged moisture exposure. Condensation can result in chronic moistening of the carpet and books on the lower levels of the shelving.

Library staff also reported that carpeting below the metal shelving had become water-damaged. The carpeting has since been replaced; however, BTL staff indicated that new carpeting was installed around the metal shelving and original water-damaged carpet remnants were left beneath the shelving. This water-damaged carpeting has the potential to be re-colonized by microbial growth if moistened conditions persist.

It was reported that ice dams had caused frequent water damage to the BTL in the past. Ice dams occur in the winter months when warm air escapes from the occupied spaces and rises

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[1] A thermal bridge is an object (usually metallic) in a wall space through which heat is transferred at a greater rate than materials surrounding it. During the heating season, the window comes in contact with heated air from the interior and chilled air from the outdoors, resulting in condensation formation if the windows temperature is below the dew point.

[2] Condensation is the collection of moisture on a surface with a temperature below the dew point. The dew point is a temperature determined by air temperature and relative humidity. For example, at a temperature of 73^{o} F and relative humidity of 57 percent indoors, the dew point for water to collect on a surface is approximately 57^{o} F (IICRC, 2000).

to the attic areas. This warm air causes the roof to melt accumulated snow. The melted snow drains down to lower parts of the roof, where it freezes. Frozen melt creates a dam that restricts any additional snowmelt from draining off the roof. This water can back up into the roof and under shingles. Water penetrating from the exterior into building envelope can cause water damage that may result in microbial growth. Electric heat coils were visible on lower portions of the roof to prevent formation of ice dams (Picture 21). This may help to prevent future ice dams, but it will not address the improper insulation and inadequate ventilation issues that are the root cause. The BTL should be evaluated for loose, missing, and wet insulation as well as interruptions in ridge and soffit ventilation; these are the primary factors contributing to the cycle of ice dams.

Trees, shrubs, plant growth, and mulch were visible in close proximity to the building and foundation (Picture 22). It is important to keep vegetation away from the building, since it may allow moisture, pests, and pollen to enter the building. Bark mulch also absorbs and holds moisture against the foundation. Moisture can penetrate through the foundation into the building through capillary action. Numerous trees have reportedly been cut down prior to this assessment; however, any remaining vegetation within five feet of the building should be trimmed/removed. Consideration should also be given to grading the slope of the surface perimeter down and away from the foundation and installing a water impermeable barrier (clay cap) around the building perimeter (Lstiburek and Brennan, 2001). This should help to reduce soil saturation and storm water infiltration into the basements. Weed blocking fabric and crushed stone can minimize the amount of maintenance required to keep vegetation clear of the perimeter.

The area between the sink counter and the backsplash in the upstairs break room was not properly sealed with caulking (Picture 23). Water can penetrate through backsplash seams if they are not watertight. Water penetration and chronic exposure of porous and wood-based materials can cause these materials to swell and show signs of water damage. Porous materials were found stored under the sink.

The plumbing under the sink also appears to be leaking, since BEH/IAQ staff observed water damage and moist conditions directly below the sink drain (Picture 24). Materials stored under sinks may make leaks harder to detect and repeated moistening of porous materials can result in mold growth. As discussed, moistened materials that are not dried within 24 to 48 hours can become potential sources for mold growth.

Plants were noted in some areas (Table 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 non-porous drip pans. Plants should also be located away from ventilation sources to prevent the entrainment and/or aerosolization of dirt, pollen or mold.

A water cooler and water bottles were observed in carpeted areas (Picture 25). Spills or leaks from this equipment can moisten carpet and lead to microbial growth and degradation of the carpet. MDPH recommends placing rubber or plastic trays beneath this equipment to protect the carpet from any leaks.

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 and 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 the 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, which can result in eye and respiratory irritation if exposure occurs. 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 was measured at 13 $\mu g/m^3$ (Table 1). PM2.5 levels measured indoors ranged from 18 to 21 $\mu g/m^3$ (Table 1), which were below the NAAQS PM2.5 level of 35 $\mu g/m^3$. Frequently, indoor air levels of particulate matter (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, 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.

A variety of copying and printing devices were noted in occupied areas of the building. Of particular note is the lack of dedicated local exhaust vents for the copy machines in the main library as well as the copy area on the second level. Also, equipment used in areas where food is stored and heated or prepared, including coffee pots, microwaves and ovens, may all produce particulates. Such equipment with a high potential to cause particulate emissions or odors should be located close to exhaust ventilation (or windows) and away from sensitive individuals when possible. BEH/IAQ staff did not observe any local exhaust vents in the kitchen/break room area.

Volatile Organic Compounds (VOCs)

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. Total volatile organic compounds (TVOCs) can result in eye and respiratory irritation if exposure occurs. 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.

Hand sanitizers were found in some offices and common areas (Table 1). Hand sanitizer products may contain ethyl alcohol and/or isopropyl alcohol, which are highly volatile and may be irritating to the eyes and nose and may contain fragrances to which some people may be sensitive.

Air deodorizers and cleaning products were observed in several areas (Picture 26). Air deodorizers contain chemicals that can be irritating to the eyes, nose and throat of sensitive individuals. Many air fresheners contain 1,4-dichlorobenzene, a VOC which may cause reductions in lung function (NIH, 2006). Furthermore, deodorizing agents do not remove materials causing odors, but rather mask odors that may be present in the area. Cleaning products contain chemicals that can be irritating to the eyes, nose and throat of sensitive individuals. These products should be properly labeled. Consideration should be given to working with building management to provide staff with cleaning products and supplies to prevent any potential for adverse chemical interactions.

Other Conditions

The FHA unit in the attic space above the main library has a humidifier ducted to the return vent. Beneath the attached humidifier unit is a condensate drain that catches any water generated when the humidifier is in use (Picture 27). This drain line leads to a water trap that is attached to a sewer drain/vent stack (Picture 28). It was reported to BEH/IAQ staff that the humidifier is no longer in use. Water traps are designed to be filled with water to create a seal to prevent sewer gases from entering occupied areas. Since this humidifier is no longer in use, no water is present in the trap to prevent sewer gases and odors from being drawn into the FHA unit. Odors entrained in the heating unit can be dispersed throughout occupied areas. This unit should be disconnected and the drain line and trap properly capped and sealed.

BEH/IAQ staff also discovered a make-up air supply duct in the attic over the main library that traversed the roof. This duct did not appear to have any screen to prevent birds and rodents/squirrels from accessing the attic. A plastic container was modified and placed under the duct to catch rainwater (Picture 29). BEH/IAQ staff observed water staining as well as bird waste and gnawed walnut shells on the plywood floor below the duct/plastic container, confirming the presence of pests.

Mr. Dold reported that filters for the FHA unit are changed twice per year. The filters were not readily accessible to BEH/IAQ staff to examine. Pleated filters with a dust spot efficiency of 40 percent is typically recommended. The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by ASHRAE to meet its standard for a dust spot efficiency of a minimum of 40 percent would be sufficient to reduce many airborne particulates (Thornburg, 2000; MEHRC, 1997; ASHRAE, 1992). Pleated filters with a Minimum Efficiency Reporting Value dust-spot efficiency of 9 or higher are recommended. Note that increasing filtration can reduce airflow (called pressure drop), which can subsequently reduce the efficiency of the unit due to increased resistance. Prior to any increase of filtration, each FHA unit should be evaluated by a ventilation engineer to ascertain whether it can maintain function with more efficient filters.

As previously mentioned, window-mounted ACs were observed in several areas. These units are normally equipped with filters, which should be cleaned or changed as per manufacturer's instructions to avoid the build-up and re-aerosolization of dirt, dust and particulate matter. Care should also be taken to ensure that the condensate from the units is draining outside the building and that there is a weather-tight seal between the unit and the window frame.

BEH/IAQ staff observed holes/breaches in the wall and around ductwork under a sink cabinet in the second floor break room (Picture 30). Odors, pollutants, moisture, and pests can enter occupied areas through theses breaches. These breaches should be sealed properly to prevent these issues.

Signs of rodent infestation were observed throughout the BTL. Mouse droppings were visible under the sink in the second floor break room and traps and bait boxes were noted in basement areas (Pictures 24 and 31). There were many rodent holes observed along the perimeter of the foundation as well as holes/gaps around doors and in between fieldstone, which allow for easy access for rodents to enter the building. It was reported to BEH/IAQ staff that a pest control company makes a visit once per month. MDPH typically recommends adopting a more comprehensive integrated pest management plan (IPM) to more effectively control rodents and other pests.

In some areas, a large number of items were on flat surfaces (e.g., floors, windowsills, tabletops), which provide a source for dusts to accumulate. These items (e.g., papers, folders, boxes, books) make it difficult for areas to be cleaned. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up. Dust and rusting was observed collected on supply diffusers and return grates in a few areas (Picture 32). Dust that has collected on diffusers can be re-aerosolized when HVAC equipment is reactivated. Dust can be irritating to the eyes, nose and respiratory tract.

Upholstered furniture and plush toys were observed in several areas (Picture 33; Table 1). These items are covered with fabrics that may be exposed to human skin. This type of contact can leave oils, perspiration, hair and skin cells. Dust mites feed upon human skin cells and excrete waste products that contain allergens. In addition, if relative humidity levels increase above 60 percent, dust mites tend to proliferate (US EPA, 1992). In order to remove dust mites and other pollutants, frequent vacuuming of upholstered furniture and plush toys is recommended (Berry, 1994). It is also recommended that upholstered furniture be professionally cleaned on an annual basis. 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).

Most areas in the BTL are carpeted. The Institute of Inspection, Cleaning and Restoration Certification (IICRC) recommends that carpeting be cleaned annually (or semi-annually in soiled high traffic areas) (IICRC, 2012). Regular cleaning with a high efficiency particulate air (HEPA) filtered vacuum in combination with an annual cleaning will help to reduce accumulation and potential aerosolization of materials from carpeting.

The BTL has an outbuilding on the premise that is currently being used to store books and other porous materials. Storing porous materials in unconditioned areas can result in damage to the materials due to moisture, microbial growth, and rodents (Pictures 34 and 35).

Conclusions/Recommendations

The conditions found within the BTL raise a number of indoor air quality issues. The penetration of storm/rainwater into the building envelope combined with the chronically moist conditions in basement spaces due to infiltration and high groundwater create conditions that likely allow moist basement air, odors and other pollutants into occupied areas of the BTL. While some problems can be addressed immediately, others will require planning and resources. In view of the findings at the time of the visit, the following recommendations are made:

1. Consult with a building engineer/contractor to evaluate strategies to stop water/moisture from penetrating the building envelope. Failure to address the sources of water

penetration will result in repeated water damage of building materials and chronic microbial growth.

2. Disconnect the abandoned humidifier attached to the FHA unit in the attic space from the drain line. Properly cap and seal the drain line to prevent entrainment of sewer gases into occupied spaces.

3. Install a gutter and downspout system to capture water and direct it away from the foundation.

4. Repair/replace damaged siding, flashing, trim, and window/door frames.

5. Consider replacing older, single pane windows with newer insulating models.

6. Consult with a basement water intrusion contractor to take necessary actions to prevent storm water, groundwater, and associated moisture from entering basements. This may include:

    a. sealing gaps in foundations;

    b. installing perimeter drains;

    c. providing vapor barriers;

    d. installing a sloped, water impermeable surface barrier (clay cap);

    e. sealing the cover for sump pump; and

    f. sealing gaps/crevices in basement ceilings.

7. Examine the building envelope for proper insulation and ventilation, and remedy conditions leading to condensation, ice dams, water damage, and microbial growth.

8. Ensure that any carpet remnants under the metal shelving in the main library were properly dried within 48 hours of becoming wet. If not dried properly, water-damaged carpet should be removed discarded. Treat the area with an antimicrobial agent.

9. Remove vegetation within 5-feet of the building, and consider using weed blocking fabric and crushed stone over proposed clay perimeter barrier to avoid excess maintenance involved with keeping vegetation away from foundation.

10. Consult "Mold Remediation in Schools and Commercial Buildings" published by the US Environmental Protection Agency (US EPA, 2001) for more information on mold. This document can be downloaded from the US EPA website at: http://www.epa.gov/mold/mold_remediation.html.

11. Consider providing a back-up power source for the sump pump to avoid continued flooding events during severe storms/power loss.

12. Seal the joints of the return ductwork in the original basement to avoid entrainment of basement moisture, odors, and pollutants.

13. Continue to use exhaust fans and dehumidifiers in basement areas to reduce risk of moisture and odors from entering occupied areas.

14. Seal gaps, cracks, and crevices in basement ceiling/first floor flooring, and seal door gaskets to help prevent the migration of moisture, odors, and pollutants from entering occupied spaces.

15. Examine the make-up air duct for the FHA unit in the attic for proper rain water and pest protection.

16. Use the principles of integrated pest management (IPM) to rid this building of pests. Activities that can be used to eliminate pest infestation may include the following:

    a. Keep list/inventory of location of all rodent bait/sticky traps, monitor on a regular basis and replace as needed to prevent odors from rodent die off. Do not place rodent traps in the airstream of ventilation equipment;

b. Do not use recycled food containers for other purposes. Seal containers to be recycled in a container with a tight fitting lid to prevent rodent access;

c. Remove non-food items that rodents are consuming or using as bedding;

d. Store foods in tight-fitting containers;

e. Avoid eating at workstations. In areas were food is consumed, vacuum periodically to remove crumbs;

f. Regularly clean crumbs and other food residues from toasters, toaster ovens, microwave ovens coffee pots and other food preparation equipment;

g. Examine each room and the exterior walls of the building for means of rodent egress and seal appropriately. Holes as small as ¼" is enough space for rodents to enter an area. If doors do not seal at the bottom, install a weather strip as a barrier to rodents;

h. Reduce harborages (cardboard boxes, paper) where rodents may reside; and

i. Refer to the IPM Guide, which can be obtained at the following Internet address: http://www.mass.gov/eea/docs/agr/pesticides/publications/ipm-kit-for-bldg-mgrs.pdf.

17. Continue to change the filters for the FHA units a minimum of twice per year. Ensure that the filters have the recommended minimum 40% dust spot efficiency accounting for manufacturer limitations with pressure drop.

18. Clean AC filters as per the manufacturer's recommendations or more frequently if needed.

19. Seal the space between the break room/kitchen sink and backsplash with waterproof, mildew resistant caulking and repair any leaks in the plumbing to avoid further water damage. Also, refrain from storing porous materials under the kitchen sink.

20. Seal holes/breaches in wall under sink cabinet in break room to prevent entry of pests, moisture and odors into occupied areas.

21. Refrain from storing porous materials (e.g. books, papers) in the basement area due to the continued moisture concerns such as groundwater, high humidity, and flooding.

22. Refrain from leaving windows and doors open during operation of AC units.

23. Storage of porous materials (e.g., books) in the unconditioned outbuilding is not recommended. These materials are subject to moisture, microbial growth, and rodent damage. Due to site limitations, off-site storage of these materials may be preferred.

24. 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, 2012).

25. Vacuum/clean upholstered furniture and plush toys frequently to remove dust mites and other pollutants. Upholstered furniture should be professionally cleaned on an annual basis.

26. Reduce, relocate, and/or clean accumulated items on flat surfaces periodically to avoid excessive dust build up.

27. Periodically clean supply diffusers and return grates to avoid re-aerosolizing particulates.

28. Place rubber or plastic trays beneath water coolers to protect the carpet from any leaks.

29. Maintain plants and place drip pans underneath pots. Locate plants away from air supplies to prevent the aerosolization of dirt, pollen and mold.

30. Refrain from using air fresheners and deodorizers to prevent exposure to VOCs.

31. 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).

32. 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.

33. Consider installing a new HVAC system that incorporates both exhaust ventilation and fresh air intake to remove common indoor pollutants and alleviate health complaints. Consideration should be taken during design to account for the location of local exhaust vents for point source pollutants such as copy areas, kitchen, and restrooms.

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Picture 1

Forced Hot Air (FHA) furnace unit in attic

Picture 2

FHA furnace unit in basement of original 1843 building

Picture 3

Return air grate

Picture 4

Supply air diffuser

Picture 5

Access hole with cover used for mold remediation in ducts

Picture 6

Boxford library (north side); note lack of gutter system

Picture 7

Boxford library (south side); note lack of gutter system

Picture 8

Evidence of water pooling in close proximity to foundation

Picture 9

Signs of chronic moisture near foundation

Picture 10

Holes/gaps in original foundation

Picture 11

Water-damaged wood siding; note large hole

Picture 12

Water-damaged trim

Picture 13

Water-damaged siding & trim

Picture 14

Missing siding

Picture 15

Water-damaged window frame, note pencil inserted by BEH/IAQ staff

Picture 16

Return ductwork showing unsealed joints/gaps (arrow)

Picture 17

Sump pump in flood remediated 1979 addition basement; note makeshift cover

Picture 18

Water-damaged window sill

Picture 19

Window fan used as exhaust ventilation for original dirt floor basement

Picture 20

Metal shelving showing rust due to condensation

Picture 21

Electric heat coils to prevent further ice dams

Picture 22

Shrubbery in close proximity to building

Picture 23

Gap between sink counter and backsplash

Picture 24

Water-damaged sink cabinet; note mouse droppings

Picture 25

Water cooler on carpeted surface

Picture 26

Plug-in air deodorizer

Picture 27

Attached FHA humidifier; note condensate catch/drain line apparatus

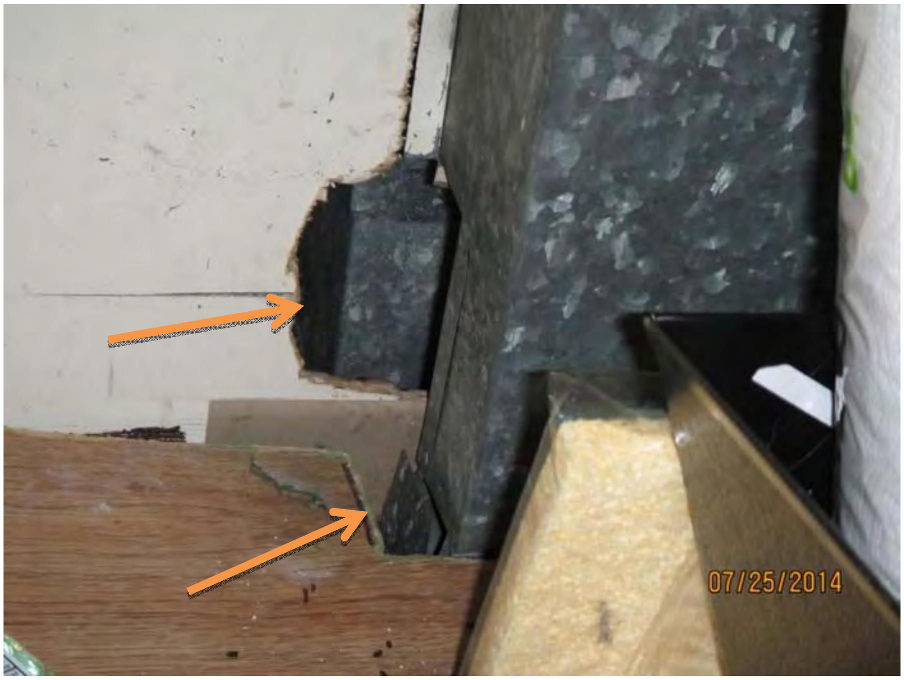
Picture 28

Humidifier drain line entering water trap attached to sewer drain/vent line

Picture 29

Make-up air duct for FHA unit; note container used to catch storm water

Picture 30



Holes/breaches in wall and around ductwork under sink cabinet

Picture 31

Mouse trap in basement of 1979 addition

Picture 32

Supply diffuser showing rusting and dust particles

Picture 33

Upholstered furniture

Picture 34

Storage of books and other porous materials in outbuilding

Picture 35

Evidence of rodent activity in outbuilding with stored books

Location: Boxford Public Library | **Indoor Air Results**

Address: 10 Elm Street, Boxford, MA | **Table 1** | **Date: 7/25/2014**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 (μg/m³)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Background	298	ND	73	57	13					Sunny, light wind
Second Floor										
Break Room	1041	ND	77	49	20	2	Y	Y	N	WC on new carpet tiles, window AC on, WD under sink, breaches, mouse droppings under sink, sink missing caulking, MF
Copy Area	665	ND	77	48	19	0	Y	N	N	PC, new carpet tile
Rear Office	614	ND	77	46	20	0	Y	Y	N	Window AC on, multiple computers, new carpet tile, HS, AI
Director's Office	582	ND	77	49	19	0	Y	Y	N	New carpet tile, new GW, mold remediation
First Floor										

ppm = parts per million
μg/m³ = micrograms per cubic meter
ND = non detect
AI = accumulated items
WD = water damage
UF = upholstered furniture
WC = water cooler
HS = hand sanitizer
AD = air deodorizer
MF = mini fridge
GW = gypsum wallboard
AC = air conditioner
PC = photocopier
DO = door open
FHA = forced hot air

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: Boxford Town Library **Indoor Air Results**

Address: 10 Elm Street, Boxford, MA **Table 1 (continued)** **Date: 7/25/2014**

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	
Media Room	641	ND	76	53	19	3	Y	Y	Y	Newspapers, DVDs, shelving
Reference Room	597	ND	75	54	18	0	Y	Y	Y	
Main Library- Reception	591	ND	74	54	19	3	Y	Y	Y	New carpet tile, south side windows/mold remediation, PC, printers, HS, plant
Main Library- NW Corner	585	ND	74	54	19	0	Y	Y	Y	WD window frame/paint, rusted metal book shelves, mold complaints/odors
Main Library- Children's Area	559	ND	74	55	21	2	Y	Y	Y	Plush dolls
Main Library- SE Corner	565	ND	74	54	20	1	Y	Y	Y	UF, window AC on
ML- North Central	655	ND	74	55	21	1	Y	Y	Y	Window AC on
Bathroom									Y	Exhaust fan switched to light

ppm = parts per million
$\mu g/m^3$ = micrograms per cubic meter
ND = non detect
AI = accumulated items
WD = water damage
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Location: Boxford Town Library **Indoor Air Results**

Address: 10 Elm Street, Boxford, MA **Table 1 (continued)** **Date: 7/25/2014**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 (μg/m³)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Original basement										Dirt floor, strong musty odor, gas FHA furnace, unsealed return ducts, rodent traps/bait boxes, exhaust fan in window on, gaps in ceiling, large number of holes in foundation
1979 Addition Basement										Sump pump, rodent traps, reports of flooding, mold/flood remediation, new paint, AD, exhaust fan, dehumidifier
Attic/Mechanical										Gas FHA furnace, abandoned attached humidifier, condensate drain w/possible dry water trap, make-up duct (possible pest entry/moisture), evidence of rodents/birds

ppm = parts per million
μg/m³ = micrograms per cubic meter
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AI = accumulated items
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