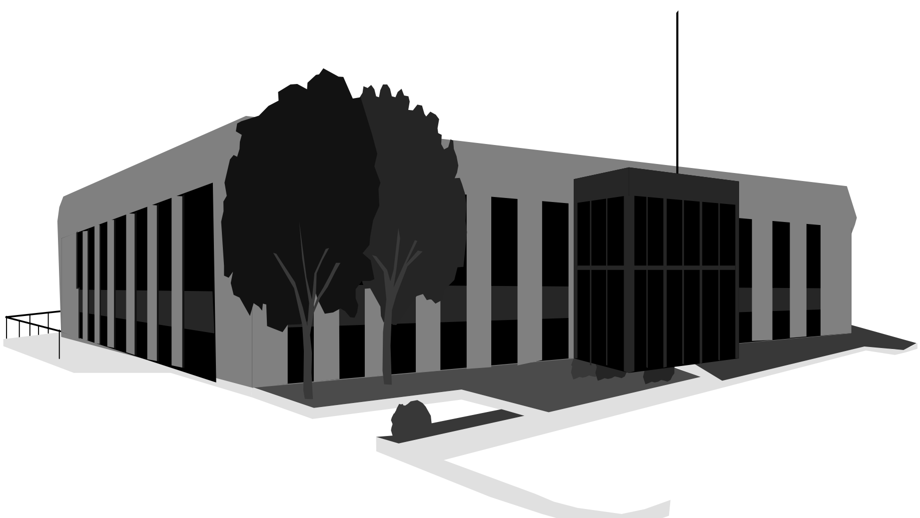
INDOOR AIR QUALITY ASSESSMENT

Upton Town Library
1 Main Street
Upton, Massachusetts



Prepared by:
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Bureau of Environmental Health Assessment
May, 2000

Background/Introduction

At the request of Upton Town Library trustees, an indoor air quality assessment was done at the Upton Town Library, 1 Main Street, Upton, Massachusetts. This assessment was conducted by the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA). Concerns about musty odors in the library area prompted this request.

On March 31, 2000 a visit was made to this building by Michael Feeney, Chief of Emergency Response/Indoor Air Quality (ER/IAQ). Mr. Feeney was accompanied by John Robertson, library trustee and Paul Marchand, of the Upton Department of Public Works.

The Upton Library is a wood frame, two-story building originally constructed as a church in the early 1800's. The building was converted into offices for the Town of Upton in the 1970's by students from a local vocational school. The exterior of the building is clad with aluminum siding. The attic of the building is used for storage. The second floor contains offices for the Upton Historical Society and vacant office space. The first floor contains the library, which has an office and meeting room. The basement has a dirt floor with a gas-fueled furnace. The foundation of the basement consists of stacked flagstone. Several of the original floor joist support pillars are granite (see Picture 1), which indicates that the building may by nearly 200 years old. Windows in the building are openable.

Temperature and relative humidity were previously evaluated by the Massachusetts Board of Library Commissioners (MBLC) (MBLC, 1997). The MBLC recommended lowering the average temperature, lowering the relative humidity in summer months and increasing relative humidity during winter months. No indications were made in this report concerning methods for implementing these recommendations.

Methods

Air tests for carbon dioxide were taken with the Telaire, Carbon Dioxide Monitor and tests for temperature and relative humidity were taken with the Mannix, TH Pen, PTH8708 Hygrometer/Thermometer.

Results

The library has an employee population of 2 and an estimated 50 other individuals who visit the library on a daily basis. The tests were taken under normal operating conditions. Test results appear in Table 1. Air samples are listed in the tables by location that the air sample was taken.

Discussion

Ventilation

It can be seen from the table that carbon dioxide levels were above 800 parts per million parts of air [ppm] in the library meeting room after fifteen minutes of occupancy. This carbon dioxide level is indicative of an inadequate fresh air supply with increased population in the library area.

Two ceiling mounted air-handling units (AHUs) supply fresh air to the library. Each AHU is supplied with fresh air by vents located on the exterior walls of the building. These outdoor fresh air intake vents are connected by flexible ductwork to each AHU. Fresh air is distributed to the occupied space by ceiling-mounted diffusers connected to each AHU via ductwork. During this evaluation, one of the AHUs was deactivated. The deactivation of this AHU decreases the ability of the ventilation system to introduce fresh air. The damper control for both AHUs appeared to be set in the closed position, which limits the draw of fresh air. With dampers closed, the AHU recirculates air, along with other indoor pollutants which may be present, without dilution by the addition of fresh air.

The ventilation system did not appear to have exhaust ventilation. The plastic grates in the suspended ceiling serve as return air vents that direct room air back to each AHU via ductwork. With this system, air in the library continues to recirculate. The second floor did not have a mechanical ventilation system. Openable widows are the only source of ventilation for these offices.

In order to have proper ventilation with a mechanical supply and return system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air. The date of the last servicing and balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (BOCA, 1993, SBBRS, 1997). 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 occurs 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 Department of Public Health 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.

Temperature measurements were in a range of 69° F to 72° F. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide 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. As mentioned previously, fresh air intakes for the AHUs were shut, which can lead to increased temperatures. This results in air being returned to the AHUs to be re-heated. With the fresh air intakes shut, no cold outside air is introduced into the system creating a closed loop, resulting in increased temperatures. It would be expected that with increased occupancy, temperatures would also increase.

The relative humidity in this building ranged from 28 to 31 percent, which is below the BEHA recommended comfort range in all areas sampled. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels 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

A focus of concerns is musty odors noted in storage areas. A distinct musty odor was also noted in the basement. Several conditions exist within the basement that promote mold growth. The basement floor is earthen. This floor does not provide a vapor barrier, which would prevent water from penetrating into the basement. The interior side of the flagstone foundation exhibited large amounts of water staining and efflorescence, which indicates water penetration. A likely source of moisture in the basement is rainwater penetrating through the foundation.

Efflorescence is a characteristic sign of water intrusion. As penetrating moisture works its way through mortar around brick, it leaves behind characteristic mineral deposits. Even though this building has a peaked roof, no gutter system is installed at the edge of the roof on either side of the building, which allows for rainwater from the roof to pool at the base of this wall. The purpose of gutters and downspouts is to direct rainwater away from the base of the building to prevent water penetration into the basement. As water penetrates into the basement, the dirt floor absorbs this moisture and can begin to serve as media for mold growth. Mold grows in cycles, which creates spores, mold fragments and other related problems. These particles can become aerosolized with increased airflow over contaminated materials.

Enhancing the ability of rainwater to penetrate into the basement is the existence of former window casings on the flagstone foundation (see Picture 2). Each window opened into a pit along the exterior of the foundation. Each of these pits was plugged with fiberglass insulation (see Picture 3). The exterior opening for each pit was sealed with a wooden plug (see Picture 4). Since these plugs are not watertight, rainwater impacting along the foundation can readily penetrate into the basement.

Pooling water was noted in the basement (see Picture 5). The source of water appears to be condensation and/or a leak from the water meter (see Picture 6). This active source of water can serve as a constant generator of mold growth in the basement.

In order to explain how mold associated particulates may be impacting the upper floors of the building, the following concepts concerning heated air must be understood.

1. Heated air will create upward air movement (called the stack effect).
2. Cold air moves to hot air, which creates drafts.
3. As the heated air rises, negative pressure is created, which draws cold air to the heat source.
4. Airflow created by the stack effect, drafts or mechanical ventilation can draw airborne particulates into the airstream.

Each of these concepts have an influence on the movement of mold associated particulates into other areas in the library.

If water can penetrate through the flagstone foundation, it is likely that cold air during the winter can also penetrate. The underside of the first floor is uninsulated, which can allow for air penetration into the library through spaces in floorboards or utility holes. If airflow from the basement can penetrate into the first floor, these odors may tend to accumulate in storage areas since they do not have mechanical ventilation and usually have access doors closed. With closed doors, odors will accumulate and be concentrated in areas without mechanical ventilation.

The door to the basement is not airtight, which can allow for basement air to penetrate through the doorframe. The return air vents of the library AHUs tend to draw air from the back hallway, where the door to the basement is located. This draw of air can create air currents that can enhance the movement of particulates into occupied areas. In addition, increased air movement into the interior of the building can also enhance the draw of water vapor from the dirt floor and foundation walls. This condition can add to the wetting of soil, which in turn can accelerate mold growth.

In order to control mold growth, water penetration into the basement area must be minimized. Control of water penetration through the foundation can be limited by installing gutters and permanently rendering watertight the former window frames in the basement. A second method would be to control the relative humidity within these areas by the application of heat. The basement has two heater/fan combination units installed to direct heated air into the dirt floor area of the basement (see Picture 7). It appears that a previous method used to control moisture in these areas was to provide heat from these units to reduce relative humidity. As air is heated, its volume expands and the relative humidity will decrease. With these units operating on a regular basis, relative humidity would be decreased and mold growth controlled or at least minimized. None of these units were operating during the assessment.

The use of these fans to reduce relative humidity in the basement may not be advisable at this time. Since musty odors already exist in the basement, the operation of these fans may create positive pressure in the basement. Positive pressure may serve to force mold spores into the occupied areas of the building through spaces in walls or ceiling tiles. Until water penetration is controlled, these fans should not be operated.

Water damaged ceiling plaster was noted in the rear stairwell near the exterior door of the building, which indicates water leaks through the roof. This leak is most likely though the seam where a small roof meets the exterior wall of the building (see Picture 8).

The AHUs have the capacity to provide air-conditioning during warm weather. The provision of air-conditioning produces condensation from the operation of cooling coils in each AHU, which requires each unit to have a drain. PVC pipe is connected to each unit and serves as a drain, which empties at the base of the building outdoors. A pipe joint with an open length of PVC pipe exists above the suspended ceiling (see Picture 9). This open pipe can serve as a source for moisture to penetrate into the occupied areas of the library.

Other Concerns

During the early part of this assessment, strong restroom odors/deodorizer were noted beneath the return air vents in the library. This odor was traced to the library restrooms located in the rear of the first floor. It appears that restrooms in this building were not equipped with mechanical exhaust ventilation. Without mechanical exhaust ventilation, restroom odors and water vapor can accumulate and be drawn into occupied space by the ventilation system.

According to town officials, it is unknown when the last time filters were replaced in the AHUs. AHUs are equipped with filters that strain particulates from airflow. In order to decrease aerosolized particulates, disposable filters with increased dust spot efficiency can be installed. 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 % would be sufficient to reduce airborne particulates (ASHRAE, 1992). Note that increased filtration can reduce airflow produced by the AHU by increased resistance. Prior to any increase of filtration, each AHU should be evaluated by a ventilation engineer to ascertain whether the ventilation system can maintain function with more efficient filters.

Regular replacement of filters is necessary to prevent the distribution of particulates by the AHUs. As the media becomes saturated with debris, filters will not remove particulates from the air stream and can in and of themselves become a source of pollutants.

Conclusions/Recommendations

The conditions observed in the library create a somewhat complicated environment. The renovations that converted this former church into a library/office space rendered the occupied areas of the building airtight. Sources of natural ventilation (such as air infiltration and exfiltration) through window frames and doors were limited by the installation of modern airtight portal frames. The installation of aluminum siding and fiberglass insulation also serves to minimize air movement along exterior walls that previously existed in the original wood siding/frame. With air exchange limited, normally occurring pollutants can build up, unless an operating ventilation system exists to dilute these materials by supplying fresh air while removing pollutants through exhaust ventilation. Since this building does not have mechanical exhaust ventilation, odors, particulates and other materials can build up in the indoor environment.

In order to address the conditions listed in this assessment, the recommendations to be made to improve indoor air quality in this building are divided into **short-term** and **long-term** corrective measures. The short-term recommendations can be implemented as soon as possible. Long-term solution measures are more complex and will require planning and resources to adequately address the overall indoor air quality concerns within this library. In view of the findings at the time of this visit, the following recommendations are made:

Short Term Recommendations:

1. Consider consulting a ventilation engineer to evaluate the library AHUs. Open fresh air dampers to increase the quantity of air circulated by the AHUs.
2. Replace AHU filters regularly as per the manufacture's instructions.
3. Render the former basement windows watertight.
4. Seal the condensation pipe in Picture 9.
5. Repair the leaking water pipe in the basement.
6. Consider insulating water utility pipes to reduce the potential for condensation.
7. Examine the feasibility of installing mechanical exhaust ventilation in restrooms.
8. Examine the junction between the lower roof and exterior wall for water penetration and reseal if necessary. Repair water damaged wall materials in the rear stairwell.
9. Install weather stripping along the edges of the basement door to limit air movement through the doorframe.

Long Term Recommendations:

The key issue to address on-going indoor air quality problems in this building is to limit the amount of water vapor within the basement area. This can be done in three ways: installing a barrier to prevent water penetration; limiting the amount of groundwater in contact with the dirt floor and foundation wall; and lowering the relative humidity in the basement. The following long-term recommendations should be considered:

1. Eliminate pooling water by installing/restoring the roof gutter/down spout system to direct rainwater way from the base of the building.
2. Consider installing insulation beneath the first floor floorboards to create a vapor barrier to limit air movement from the basement into the library. Render all utility pipes holes in the first floor airtight.
3. Consider reactivating fan heaters in the basement. Operate these systems continuously to reduce relative humidity in the basement. If this option is chosen, the installation of mechanical exhaust fans in the basement to equalize air pressure in the basement while exhausting odors should be considered. This system may be installed using the abandoned foundation widows to provide exhaust ventilation.
4. Examine the feasibility of installing a mechanical ventilation system for second floor office space.

References

ACGIH. 1989. Guidelines for the Assessment of Bioaerosols in the Indoor Environment. American Conference of Governmental Industrial Hygienists, Cincinnati, OH.

ASHRAE. 1992. Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 52.1-1992.

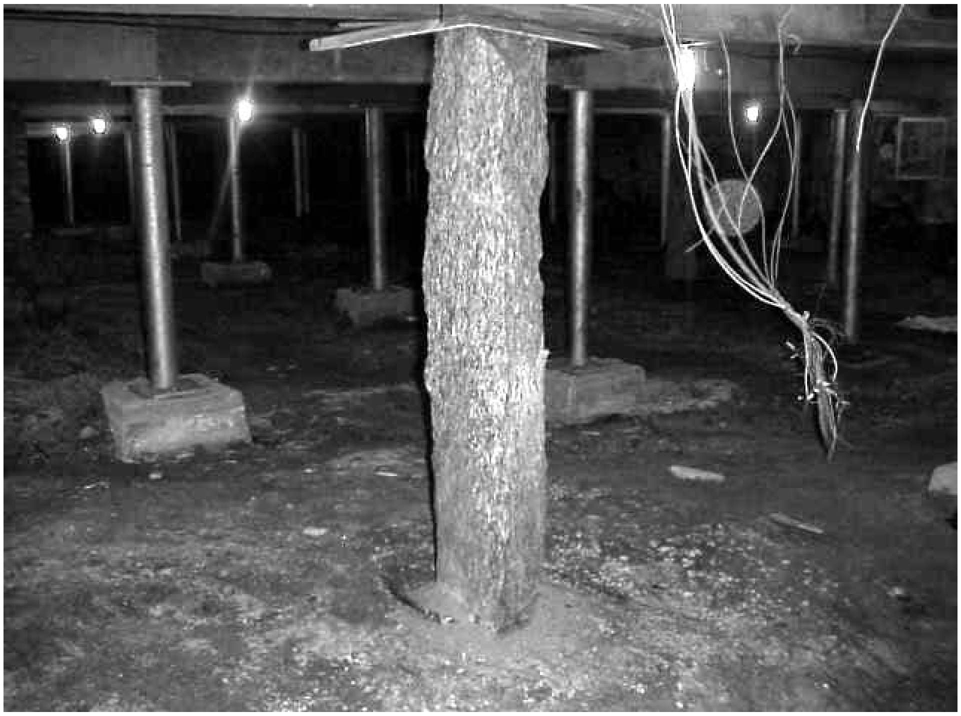
BOCA. 1993. The BOCA National Mechanical Code-1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL. M-308.1

MBLC. 1997. Upton Town Library, Upton, Massachusetts Report. Massachusetts Board of Library Commissions, Boston, MA. August 1996-January 1997.

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

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.

Picture 1



Granite Floor Support Pillar, Note Steel Tube Floor Supports in Background That Indicate Renovations

Picture 2

Fiberglass

Former Basement Window Casing in Basement, Sealed with Fiberglass Insulation

Picture 3

Exterior Shot of Window Casing Sealed with Fiberglass Insulation

Picture 4

Wood Plug

Wooden Plug Sealing Window Casing of Picture 3

Picture 5

Standing Water in Basement

Picture 6

Condensation on Water Pipes

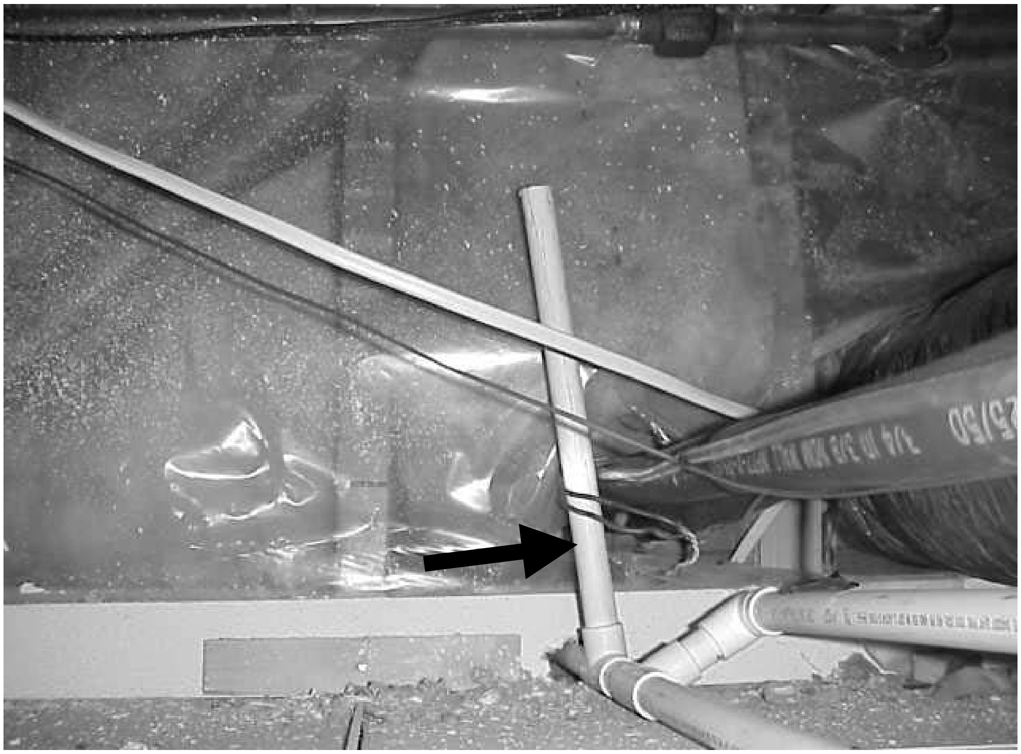
Picture 7

Fan Heating Unit in Basement

Picture 8

Wall/Roof Junction above Stairwell Water Damaged Plaster

Picture 9



Open PVC pipe of AHU Condensation Drain

TABLE 1

Indoor Air Test Results –Upton Town Library, Upton, MA – March 30, 2000

Remarks	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	438	55	25					
2nd Floor Foyer	677	69	28	0	yes	no	no	
Director's Office	616	69	30	1	yes	yes	no	
Library	630	72	29	3	yes	yes	no	
Library Meeting Room	906	71	30	3	yes	yes		

*** ppm = parts per million parts of air**
CT = water-damaged ceiling tiles

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%