INDOOR AIR QUALITY ASSESSMENT

Schofield Elementary School
27 Cedar Street
Wellesley, 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 a parent, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health (BEH) conducted an indoor air quality (IAQ) assessment at the Schofield Elementary School (SES), 27 Cedar Street, Wellesley, Massachusetts. The request was prompted by concerns related to water damage, mold and general IAQ concerns. On October 11, 2011, a visit to conduct a general IAQ assessment was made to the SES by Michael Feeney, Director, and Sharon Lee, Environmental Analyst/Inspector for BEH's IAQ Program. On December 13, 2011, Mr. Feeney returned to the SES while the heating system was activated to conduct additional air testing and temperature measurement of floors, window frames and exterior walls of the 1993 wing. Joseph F. McDonough, Director of Facilities & Grounds, Wellesley Public Schools, Leonard Izzo, Health Director, Wellesley Health Department, and Gerardo J. Martinez, Principal, SES accompanied Mr. Feeney and Ms. Lee during these visits.

The SES is a single-story brick building constructed in 1964. A wing was added in 1993 to the rear of the building, creating space for the music, art and kindergarten classrooms. Additional classrooms were added when a modular building was constructed in 2004. The building is structured around a central courtyard. The school is located at the foot of a forested hill, which has trees that tower over the rear of the school. Windows were openable throughout the building.

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. Surface temperatures of window panes, floors and walls were measured with a ThermoTrace infrared thermometer. BEH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The school houses approximately 345 students in grades K through 5 and has a staff of approximately 35. The tests were taken during normal operations at the school. Test results for October 11, 2011 and December 13, 2011 appear in Tables 1 and 2, respectively. Surface temperature readings of building components measured in the 1993 wing appear in Table 3.

Discussion

Ventilation

It can be seen from Table 1 that on October 11, 2011, carbon dioxide levels were above 800 parts per million of air (ppm) in 10 of 36 areas surveyed. Carbon dioxide levels were above 800 ppm in 12 of 33 areas surveyed on December 13, 2011 (Table 2). These results indicate poor air exchange in approximately one third of areas surveyed during the two site visits. It is also important to note that some areas were empty/sparsely populated, which can greatly reduce carbon dioxide levels. Carbon dioxide levels would be expected to increase with higher room occupancy.

A fresh air source is necessary for the dilution of indoor air pollutants. Fresh air to classrooms in the 1964 and 1993 wings is supplied by unit ventilator (univent) systems. Univents in the 1964 wing draw air from outdoors through a fresh air intake located on the exterior walls of the building and return air through an air intake located at the base of each unit

(Figure 1). Fresh and return air are mixed, filtered, heated and provided to classrooms through an air diffuser located in the top of the unit. The univent configuration observed in the 1964 wing are typical of those observed by BEH staff in other schools.

In contrast, the installation/design of univents in the 1993 wing is unique. The univents in the 1993 wing appear to have been installed in the typical manner, with radiators installed along the windows to temper drafts and provide supplemental heat. However, upon closer examination, the univents seem to be attached to the radiator-like structure. According to Mr. McDonough, the manufacturer of the univents indicates that the return air vents for the univent are the radiator-like structures (Picture 1). The front of the univent where the return air vent is normally located is sealed with a metal strip. As a result of this design, when return air is drawn through these radiator-like structures, air is also drawn from the exterior wall/floor junction (along with moisture and/or odors in the wall cavity). Also of note is the installation of the radiator return structure. The radiator-like structures have exposed fasteners (Picture 2) which would be used to attach them to the wall. The presence of these fasteners may indicate a substitution of equipment for a design originally intended for these classrooms. Please note, this univent configuration has never been encountered by staff within the IAQ Program.

The age of these univents makes service and repairs difficult. According to the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), the service life[1] for a unit heater using 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 from 1964 has been exceeded; the equipment in the 1993 wing will have

[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).

similar issues within two years. 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 the 1964 and 1993 wings is provided by mechanical fans located on the roof. In some rooms, air is drawn into exhaust vents located at the base of closets. Louvers should be repaired to ensure proper function of exhaust ventilation. In other classrooms, mechanical exhaust ventilation is provided by wall- or ceiling-mounted exhaust vents. In many cases, the function of these exhaust vents were hindered by the room design and exhaust vent location. In some classrooms, ceiling-mounted exhaust vents are located above doorways. In such cases, open doors prevent proper functioning of the ceiling-mounted exhaust vents. Rather than exhausting classroom air, these vents draw air from the hallway through open doors, reducing the effectiveness of the exhaust vent to remove common environmental pollutants from classrooms.

Blockages were observed to classroom univents and exhaust vents, inhibiting airflow. Dust/debris from items placed on top of univents can become entrained in the unit, which can result in aerosolization of odors and particulates from these materials. In order to function as designed, both univents and exhaust vents must be activated and allowed to operate free of obstructions.

Dedicated exhaust ventilation was found in the kiln room (Picture 3). It appears that the flexible ductwork for the kiln was installed in a manner that creates a U-bend. This bend can create resistance, limiting the flow of air/movement of materials from the kiln to the outdoors. Measures should be taken to re-attach the flexible ductwork to the dedicated exhaust in a manner that reduces resistance. In addition, a general exhaust vent was observed in the kiln room

(Picture 4). The exhaust vent appears to be connected to the ductwork for a rooftop exhaust fan that services classrooms. If the exhaust fan is not operating, backdrafting can occur, which can force heat, particulates and odors that may escape the kiln into the art room. This general exhaust vent should be disconnected or sealed to ensure the kiln room remains depressurized.

Each of the modular classrooms is fitted with a rooftop air handing unit (AHU) (Picture 5), which is ducted to a supply diffuser that provides a mix of fresh and returned air to the classroom. Return vents ducted to the AHU return air back to the unit. Please note, return vents in this classroom are fitted with supply diffusers. Supply diffusers that are used for return ventilation can inhibit the draw of air into return ductwork due to their configuration/shape (horizontal fins). Replacing supply diffusers with more appropriate return vents will decrease resistance, increasing the amount of air returned.

Please note, these classrooms have been noted to have slightly elevated (e.g., above 800 ppm) carbon dioxide levels. These elevated levels can be attributed to a lack of exhaust ventilation that would remove air from these classrooms. Without true exhaust ventilation, normally occurring environmental pollutants can build up and become irritating to the eyes, throat and respiratory system. At the time of the assessment, an HVAC technician that services the school suggested that economizers could be installed to provide exhaust ventilation.

In some areas, such as the classroom off the library, the sole source of ventilation is through openable windows. Consideration should be given to installing passive ventilation (e.g., door vent) to aid in dilution/ventilation of the room.

Similarly, the copy room lacks any mechanical means for removing normally occurring pollutants created by the copier. Consideration should be given to installing a switch-activated exhaust fan in the window to aid in removal of these pollutants.

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 ventilation system, the systems must be balanced subsequent to installation to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing was unknown at the time of the assessment.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows (SBBRS, 1997; BOCA, 1993). 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, see Appendix A.

Temperature measurements ranged from 69^{o} F to 74^{o} F on October 11, 2011 and 67^{o} F to 74^{o} F on December 13, 2011 (Tables 1 and 2), which were within or close to the MDPH recommended comfort range at the time of the visits. The MDPH recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} 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.

The relative humidity measured in the building ranged from 45 to 56 percent on October 11, 2011, which was within the MDPH recommended comfort range (Table 1). The relative humidity on December 13, 2011 ranged from 18 to 29 percent, which was below the MDPH recommended comfort range (Table 2). 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

There are on-going concerns at the SES in regards to water damage and mold growth in the 1993 wing. In the past, this area had been a concern, reportedly due to wall-to-wall carpeting. Based on a recommendation from a previous BEH report (MDPH, 2004), wall-to-wall carpeting was removed from this wing. Since no other apparent sources of moisture were present, BEH staff examined and compared the exterior wall systems of the 1964 and 1993 wings. The window system of the 1964 wing rests on cement blocks covered with ceramic tile (Picture 6). The presence and condition of the ceramic covered blocks and the tiled floor adjacent to the window system indicates that water penetration does not readily occur through this material. The exterior wall/window system of the 1993 wing is constructed in a different manner then the original wing.

Visual observations and measurements of the window system in the 1993 wing indicate that the bottom of the window system terminates roughly four inches (4″) above the floor slab. The window frame straddles a short brick exterior wall (Picture 7) and a plastic-covered interior wall. Originally, the design called for the remaining interior portion of the window system to be supported by cement blocks covered with glazed clay (Figure 2), which would prevent water penetration and provide thermal resistance. BEH staff examined the wall cavity and found that a plastic coving-covered wood frame was substituted for the planned cement block. Furthermore, no insulation was observed inside the wall cavity. In essence, a single line of brick separates the indoor environment from the outdoor elements.

In modern construction, brick exterior wall systems are usually designed to prevent moisture penetration into the building interior. An exterior wall system usually consists of an exterior brick curtain wall (Figure 3). Behind the curtain wall is an air space that allows for water to drain downward and for the exterior cladding system to dry. At the base of the curtain wall should be weep holes that allow for water drainage. Opposite the exterior wall and across the air space is a continuous, water-resistant material adhered to the backup wall that forms the drainage plane.

The purpose of the drainage plane is to prevent moisture that crosses the air space from penetrating into interior building systems. The plane also directs moisture downwards toward the weep holes. The drainage plane can consist of a number of water-resistant materials, such as tarpaper or, in newer buildings, plastic wraps. The drainage plane should be continuous. Where breaks exist in the drainage plane (e.g., window systems, door systems and univent fresh air intakes), additional materials (e.g., copper flashing) are installed as transitional surfaces to direct water to weep holes. If the drainage plane is discontinuous, missing flashing or lacking air space, rainwater may accumulate inside the wall cavity and lead to moisture penetration into the building.

In order to allow for water to drain from the exterior brick wall system, a series of weep holes is customarily installed at or near the foundation slab/exterior wall system junction (Figure 3). Weep holes allow for accumulated water to drain from a wall system (Dalzell, 1955). Failure to install weep holes in brickwork or burial of weep holes below grade will allow water to accumulate in the base of walls, resulting in seepage and possible moistening of building components (Figure 4).

The 1993 wing does not have a curtain wall or drainage plane beneath the window system. In this configuration, water penetrating into the wall system below the windows has no means to drain. One method typically employed to prevent water penetration into brick is the installation of flashing beneath the window frame over the outer edge of the brick. No flashing was installed. Without flashing to prevent water from penetrating the brick and weep holes to allow water to drain moisture from the window system, water/condensation can accumulate in the wall cavity.

Another source of moisture relates to the previously mentioned lack of insulation. The purpose of insulating the interior wall cavity is to provide resistance to temperature changes of the outdoors (e.g., air, ground/soil). Without insulation, moisture can accumulate in the 1993 wing wall cavity for the following reasons:

- The slab and brickwork for the lower portion of the exterior wall are buried beneath the ground/soil in places (Picture 8). In this configuration, the slab and brick temperature becomes that of the ground/soil.
- Temperature of the exterior wall system is uneven due to shading. The exterior wall faces a hill covered with trees (Picture 9). The shade reduces the amount of solar heat that would warm exterior walls and windows of the 1993 wing.
- The existing window/wall system configuration (i.e., wood-frame lacking insulation) makes the building highly susceptible to uneven heating.

BEH staff conducted surface temperature sampling of the exterior walls and adjacent floors of each classroom in the 1993 wing. If the exterior walls of the building were properly insulated, the temperature of the interior side of exterior walls and floors would be close to the indoor temperature (Table 1), roughly in a range of 69° F to 73° F. The temperature of the wall/floor junction was measured in a range of 51° F to 64° F (Table 3). The temperature for classroom floors 3-feet from exterior walls ranged from 54° F to 65° F, in contrast to those of floors at the hallway classroom door, which ranged from 65° F to 73° F (Table 3). These temperatures support BEH staff's observations that the exterior wall and floor of the 1993 classrooms have, at best, minimal insulation to prevent heat loss.

The difference in temperature indicates that the window/wall system is not energy efficient and can serve as a thermal bridge[2]. Where a thermal bridge exists, condensation[3] is likely to form on the warm air side of the cold object which can moisten materials, such as floors. Given that the exterior slab and brick were buried in places below soil, both of these building components would have a temperature similar to the ground that it is in contact with. In hot, humid weather, the lowering of temperature of the slab/exterior brickwork would likely lead to the ready accumulation of condensation along the interior side at the base of the exterior wall.

As mentioned, the univents in the 1993 wing are configured in a manner that draws return air from the exterior wall/floor junction. Since this junction is prone to water penetration/ condensation generation, the operation of univents draws water vapor/odors from the exterior wall cavity that then is then distributed into the room. This can result in chronic moistening of water permeable materials such as paper goods, bulletin boards and other porous materials. Under certain conditions, chronically moistened porous materials can be a source of microbial growth.

During the winter, when the heat is operating, concerns of water vapor in the wall cavity are reduced since condensation cannot form. At the time of the December 13, 2011 assessment, all floor temperatures were well above the dew point (37^{o} F to 40^{o} F), preventing condensation formation. If univents with typical return vents located at the bottom/front of the cabinet were installed, the distribution of water vapor into the classrooms would be reduced.

The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with

[2] 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 window temperature is below the dew point.

fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy porous materials is not recommended.

Water-damaged ceiling tiles were observed in a few classrooms (Table 1). Water-damaged ceiling tiles indicate leaks from either the roof or plumbing system and can provide a source for mold growth. These tiles should be replaced after a water leak is discovered and repaired.

The teacher's lounge had a stove and refrigerator directly on carpeting. Carpeting underneath this equipment is vulnerable to water damage or soiling by food preparation, which can lead to mold growth, pests and associated odors.

Some open seams were observed between backsplashes and countertops (Table 1). If not watertight, water can penetrate through the seam, causing water damage. Improper drainage or sink overflow can lead to water penetration into the countertop, cabinet interior and areas behind cabinets. Water penetration and chronic exposure of porous and wood-based materials can cause these materials to swell and show signs of water damage. Many classrooms were also found to have porous materials (e.g., cardboard, paper, cloth) stored beneath sinks, which is a humid environment. Repeated moistening of porous materials can result in mold growth.

Other sources for water damage were also observed. The art room contains a water heater in its sink cabinet, which may be a source of moisture damage to the cabinet's wood. Water penetration and chronic exposure of porous and wood-based materials can cause these

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[3] 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).

materials to swell and show signs of water damage. As discussed above, moistened materials that are not dried within 24 to 48 hours can become potential sources for mold growth.

Plants were observed in a number of areas, including on classroom univents (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 drip pans and located away from univents to prevent the aerosolization of dirt, pollen and mold.

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 staff obtained measurements for carbon monoxide and PM2.5.

Carbon Monoxide

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

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, 1997). 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. Both outdoor and indoor carbon monoxide measurements were non-detectable (ND) during the assessments conducted on October 11, 2011 and December 13, 2011 (Tables 1 and 2).

Particulate Matter (PM2.5)

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2006). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA established a more protective standard for fine airborne particles. This more stringent PM2.5 standard requires outdoor air particle levels be maintained below 35 $\mu g/m^3$ over a 24-hour average (US EPA, 2006). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 10 $\mu g/m^3$ on October 11, 2011 and 14 $\mu g/m^3$ on December 13, 2011 (Tables 1 and 2). PM2.5 levels measured inside the school ranged from 3 to 13 $\mu g/m^3$ on October 11, 2011 and 9 to 18 $\mu g/m^3$ on December 13, 2011 (Tables 1 and 2). On both days, indoor and outdoor PM 2.5 levels were below the NAAQS PM2.5 level of 35 $\mu g/m^3$. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur indoors 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.

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 VOC concentrations, BEH staff examined classrooms for products that may contain these respiratory irritants.

The school reportedly now uses green-seal certified cleaning products, but many rooms had cleaners that were not provided by the school. Household cleaning products, air fresheners and deodorizing materials (e.g., oil/reeds) were found in several areas (Table 1, Picture 10). Cleaning products and 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. Additionally, a Material Safety Data Sheet (MSDS) should be available at a central location for all school chemicals in the event of an emergency such as an adverse chemical interaction between residues left from cleaners used by the facilities staff and those left by cleaners brought in by others.

Several classrooms contained dry erase boards and dry erase board markers. One room had cans of paint. Materials such as permanent markers, dry erase markers and dry erase board cleaners and paints 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.

BEH staff observed tennis balls which had been sliced open and placed on chair and/or table legs presumably to reduce noise. Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and cause VOCs to off-gas. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997).

Other Conditions

Other conditions that can affect indoor air quality were observed during the assessment. Window-mounted air conditioners (ACs) were observed in several areas. These units are normally equipped with filters, which should be cleaned or changed as per the manufacturer's instructions to avoid the build-up and re-aerosolization of dirt, dust and particulate matter. Several of the filters were observed with accumulated dust/debris.

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

Conclusions/Recommendations

To remedy building problems, two sets of recommendations are made: **short-term** measures that may be implemented as soon as practicable and **long-term** measures that will require planning and resources to address overall IAQ concerns. In view of the findings at the time of the visits, the following recommendations are provided:

Short Term Recommendations

1. Operate univents in 1993 wing in the heat setting during the non-heating season to prevent water vapor capture until repairs to the exterior wall can be made. Use openable windows and portable fans to provide fresh air in the interim.
2. Examine the feasibility of retrofitting the 1993 wing exterior wall in a manner that reduces condensation generation. Temporary measures can include the use of an appropriate fire-rated insulation foam.
3. Examine the feasibility of reconfiguring the univents in the 1993 wing to a conventional configuration, similar to those in the 1964 wing (Figure 1). At a minimum, seal the openings in the lower section of the radiator-like structures connected to the 1993 wing univents to prevent the draw of air from the base of the exterior wall.
4. Ensure all blockages to univents and exhaust vents are removed to ensure adequate airflow.
5. Ensure all exhaust vents are repaired and are operating. Close classroom doors to maximize exhaust capabilities.
6. Continue with plans to install economizers on the rooftop AHUs to provide exhaust ventilation for modular classrooms.

7. Examine the feasibility of installing mechanical exhaust vents for modular classroom restrooms.
8. Undercut the modular classroom restroom doors by at least two inches for transfer air to aid in removal of odors.
9. Replace supply diffusers with more appropriate return vents in modular classrooms to decrease resistance and increase the amount of return air.
10. Install a passive door vent in the library classroom to provide air exchange.
11. Maximize air exchange in the remainder of the SES. Operate all ventilation equipment (in working order) continuously throughout the building (e.g., gym, auditorium, classrooms) during periods of school occupancy independent of thermostat control.
12. Use openable windows in conjunction with classroom univents and 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.
13. Install the flexible ductwork for the dedicated kiln exhaust in a manner that reduces airflow resistance.
14. Disconnect/seal the general exhaust vent in the kiln room to ensure room remains depressurized.
15. Consider developing training for teachers regarding the functions of HVAC equipment, chemical safety and other issues to promote staff awareness of classroom practices.
16. Consider removing carpeting in the teachers' room and installing a non-porous flooring material (e.g., tile) to prevent water/food damage to carpeting.

17. Ensure any roof/plumbing leaks are repaired and replace water-damaged ceiling tiles. Examine the area above and around these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.
18. Ensure staff are provided with the school-sanctioned cleaning products. Remove/discard any household cleaners and air deodorizing materials.
19. Consider replacing tennis balls with latex-free tennis balls or glides.
20. Clean/change filters for ACs as per the manufacture's instructions or more frequently if needed.
21. Seal breaches between sink countertops and backsplashes to prevent water damage.
22. Ensure 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 diffusers of univents.
23. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning of classrooms. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
24. Consider adopting the US EPA (2000) document, "Tools for Schools", to maintain a good indoor air quality environment in the building. This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.
25. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. Copies of these materials are located on the MDPH's website: http://mass.gov/dph/iaq.

Long Term Recommendations

1. Contact an HVAC engineering firm for a building-wide ventilation systems assessment. Based on historical issues with air exchange/IAQ complaints, age, physical deterioration and availability of parts for ventilation components, such an evaluation is necessary to determine the operability and feasibility of repairing/replacing HVAC equipment (e.g., univents, AHUs, exhaust motors). Strong consideration should be made to replacing univents and exhaust ventilation for classrooms.
2. Consider contacting a building envelope specialist to evaluate measures (e.g., insulation, flashing around window frames) that can be employed to reduce moisture issues along the 1993 wing exterior wall/slab.
3. Install local exhaust ventilation in the copy room to remove VOCs, excess heat and odors. If not feasible, relocate equipment to a well-ventilated area.

References

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

ASHRAE. 1989. ASHRAE Standard: Ventilation for Acceptable Indoor Air Quality. Sections 5.11, 5.12. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. Atlanta, GA.

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

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

Dalzell, J.R. 1955. *Simplified Masonry Planning and Building*. McGraw-Hill Book Company, Inc. New York, NY.

MDPH. 1997. Requirements to Maintain Air Quality in Indoor Skating Rinks (State Sanitary Code, Chapter XI). 105 CMR 675.000. Massachusetts Department of Public Health, Boston, MA.

MDPH. 2004. Indoor Air Quality Assessment for Schofield Elementary School Wellesley, MA. Dated May 2004. Massachusetts Department of Public Health, Bureau of Environmental Health Assessment, Boston, MA.

NIH. 2006. Chemical in Many Air Fresheners May Reduce Lung Function. NIH News. National Institute of Health. July 27, 2006. http://www.nih.gov/news/pr/jul2006/niehs-27.htm

NIOSH. 1997. NIOSH Alert Preventing Allergic Reactions to Natural Rubber latex in the Workplace. National Institute for Occupational Safety and Health, Atlanta, GA.

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.

SBAA. 2001. Latex In the Home And Community Updated Spring 2001. Spina Bifida Association of America, Washington, DC.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0.

SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning

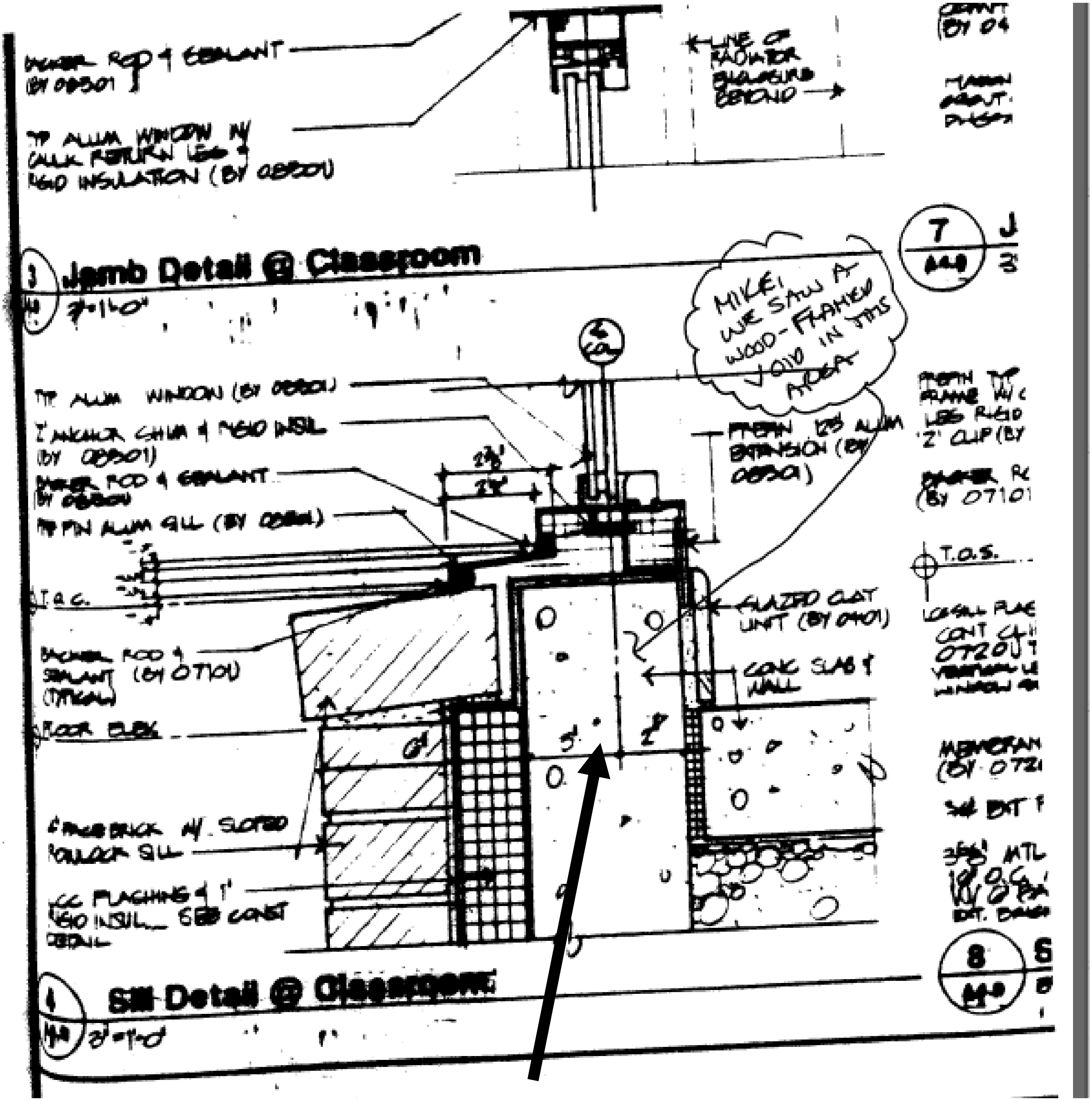
US EPA. 2000. Tools for Schools. Office of Air and Radiation, Office of Radiation and Indoor Air, Indoor Environments Division (6609J). EPA 402-K-95-001, Second Edition. http://www.epa.gov/iaq/schools/tools4s2.html

US EPA. 2001. "Mold Remediation in Schools and Commercial Buildings". Office of Air and Radiation, Indoor Environments Division, Washington, DC. EPA 402-K-01-001. March 2001. Available at: http://www.epa.gov/iaq/molds/mold_remediation.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.

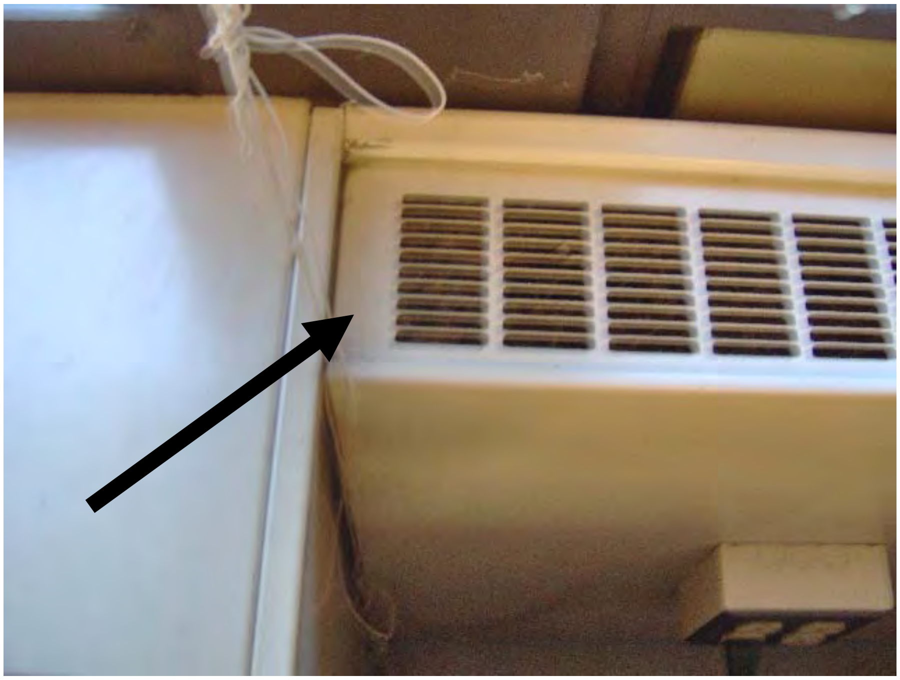
Figure 2

Blueprint of 1993 Wing Exterior Wall and Slab



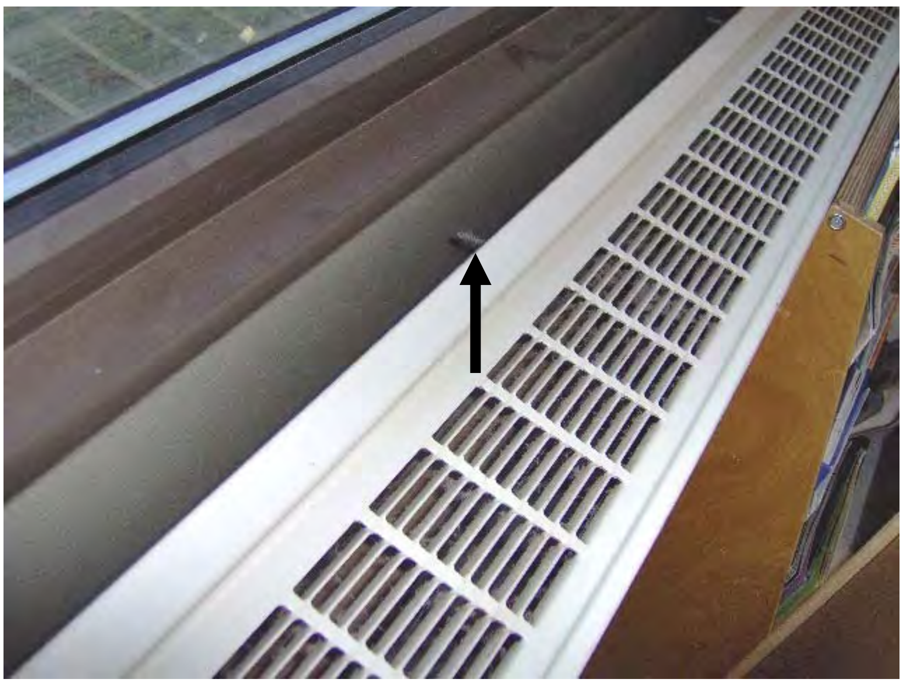
Note: Blueprint calls for a “conc[rete] slab & wall”.
Location indicated by arrow had wood supporting the window system.

Picture 1



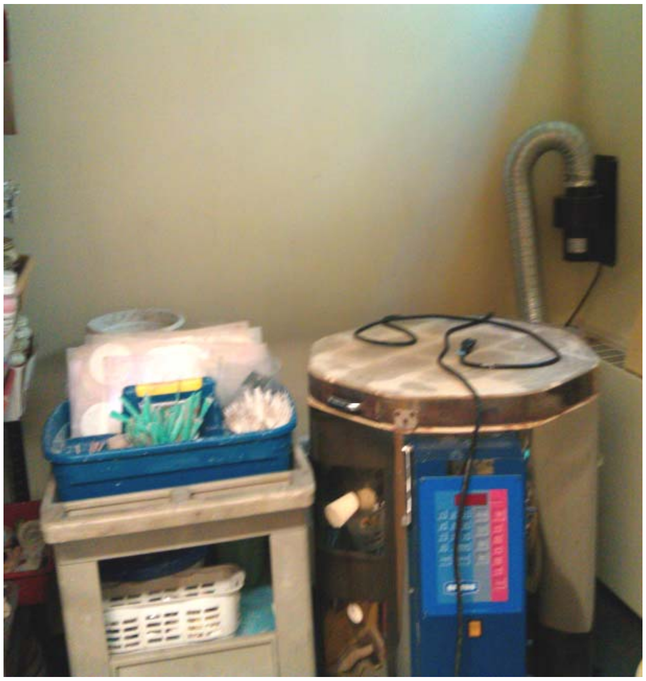
Air Intakes for the univent in 1993 Wing

Picture 2



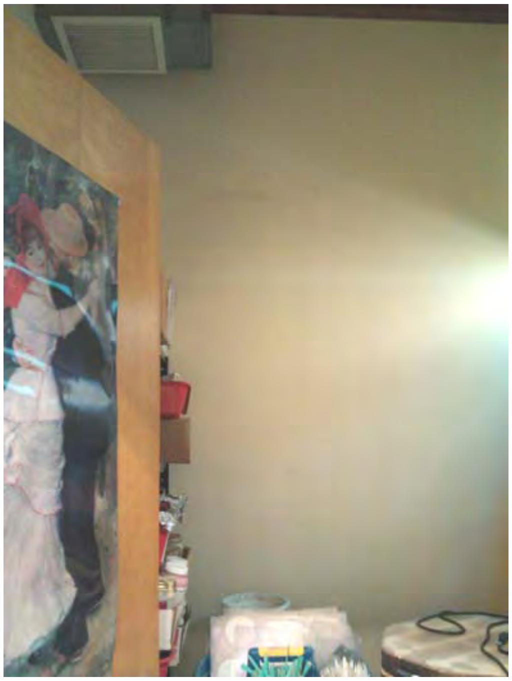
Exposed Fasteners in Wall Cavity (Arrow)

Picture 3



Flexible Ductwork for Dedicated Kiln Exhaust, Note U-bend at the Top

Picture 4



General Exhaust Vent (Top Left Corner) in Kiln Room

Picture 5

Modular Classroom AHUs

Picture 6

Window System in the Older Section of SES, Note Windows System Rests on Solid Stone Blocks, Which Would Resist Water Penetration

Picture 7

1993 Wing Window System Resting Partially on Brick Wall

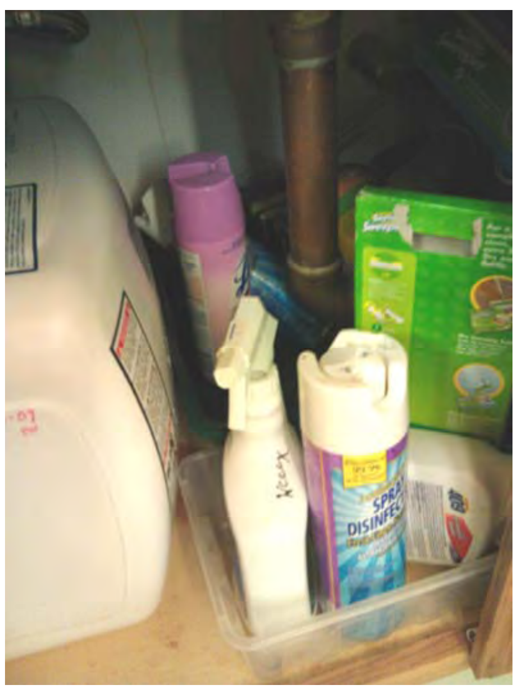
Picture 8

1993 Wing Exterior Wall and Slab Buried beneath Soil
(Arrow Indicates Depth of Slab below Grade of Soil)

Picture 9

1993 Wing Shaded by Dense Stand of Trees

Picture 10



Cleaning Products and Air Deodorizers under Sink Cabinet

Location: Schofield Elementary School **Indoor Air Results**

Address: 27 Cedar St. Wellesley, MA **Table 1** **Date: 10/11/2011**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Background	320	ND	65	49	10					Sunny, slight breeze
Modular bathroom									N	
Girls		ND	70	48	12				Y	
Teachers	479	ND	72	45	12	0	N	Y	N	DO, water dispenser on carpeted floor
Main office	387	ND	71	45	7	1	N	Y		DO
nurse	375	ND	71	47	6	71	Y	N	N	AC-filter occluded
Principal	347	ND	71	47	6	0	Y	N	N	DO, AC
Copy room	403	ND	71	48	6	0	Y	N	N	DO, recommend installing exhaust fan in window
Gym-128	382	ND	69	49	6	18	N	Y Blocked Gym mats	Y	
Gym office-128A	413	ND	69	49	6	0	N	N	N	DO

ppm = parts per million
$\mu g/m^3$ = micrograms per cubic meter
ND = non-detect
AC = air conditioner
AD = air deodorizer
CPs = cleaning products
CT = ceiling tile
DEM = dry erase materials
DO = door open
ND = non detect
PF = personal fan
TB = tennis balls
UF = upholstered furniture
WD = water-damaged

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%

Location: Schofield Elementary School | **Indoor Air Results**

Address: 27 Cedar St, Wellesley, MA | **Table 1 (continued)** | **Date: 10/11/2011**

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	
101	563	ND	72	47	7	5	Y	Y	Y	DEM
102	386	ND	73	42	7	5	Y	Y	Y	DO
102A	533	ND	74	47	6	2	Y 1/2 open	N	N	Recommend passive vent in door
103	780	ND	72	47	8	23	Y	Y	Y	PF, TB
104	908	ND	73	50	8	20	Y	Y Items	Y	TB
105	847	ND	71	50	13	21	Y	Y	Y Off	PF, TB
106	602	ND	72	47	9	0	Y	N		AD
107	1010	ND	73	50	9	21	Y	Y	Y	TB, DEM
108	1124	ND	73	52	9	22	Y	Y Items, weak	Y	Plants, TB
109	613	ND	73	48	8	1	N	Passive	Y	

ppm = parts per million
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AD = air deodorizer
CPs = cleaning products
CT = ceiling tile
DEM = dry erase materials
DO = door open
ND = non detect
PF = personal fan
TB = tennis balls
UF = upholstered furniture
WD = water-damaged

Comfort Guidelines

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

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

Location: Schofield Elementary School **Indoor Air Results**

Address: 27 Cedar St, Wellesley, MA **Table 1 (continued)** **Date: 10/11/2011**

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	
110	651	ND	73	50	5	2	Y	Y	Y	TB
111	681	ND	73	48	6	2	Y	Y weak	Y	PF
112	821	ND	73	53	8	10	Y	Y	Y	CPs, TB
113	540	ND	72	48	5	1	Y	Y	Y	TB, PF
114	1148	ND	74	56	8	14	Y	Y items	Y	TB, PF, solar gain, DEM, plants
115	914	ND	74	50	10	19	Y	Y items	Y	Plants, DEM, CPs, TB
116	859	ND	73	49	4	22	Y	Y	Y	
117	737	ND	71	54	3	18	Y	Y	Y	Items. 6 WD-CTs
118	1008	ND	74	49	4	21	Y	Y	Y	2 WD-CT
119	759	ND	73	50	4	17	Y	Y	Y	
120	510	ND	71	48	6	1	Y	Y	Y	

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ND = non-detect
AC = air conditioner
AD = air deodorizer
CPs = cleaning products
CT = ceiling tile
DEM = dry erase materials
DO = door open
ND = non detect
PF = personal fan
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Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
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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 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
121	880	ND	71	50	10	0	Y	Y	Y	Dehumidifier, paint, clay, AD, items
122	527	ND	71	48	6	4	Y	Y	Y	DEM, CPs, TB
123	448	ND	70	47	8	19	Y	Y	Y	TB, DO, dehumidifier, breach/sink backsplash, mini fridge
124	515	ND	72	45	6	28	Y 4/10 open	Y Blocked by sand pit	Y	PF, AD, dehumidifier, CPs, DEM, DO, UF/pillows
125	683	ND	70	52	12	20	Y	Y Items	Y	Pine needle odor, breach/sink backsplash, dehumidifier
126	449	ND	72	46	8	20	Y	Y Items	Y	TB, solar gain, food containers (soda)
126	546	ND	73	45	7	11	Y	Y	Y	CPs, TB, PF
127	465	ND	72	47	8	12	Y	Y	Y	TB, items, DO, PF

ppm = parts per million
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AC = air conditioner
AD = air deodorizer
CPs = cleaning products
CT = ceiling tile
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DO = door open
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Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
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Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Location: Schofield Elementary School **Indoor Air Results**

Address: 27 Cedar Street, Wellesley, MA **Table 2** **Date: 12/13/2012**

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 (Outdoors)	346	ND	52	17	14					
Gym	424	ND	71	18	15	16	Y	Y	Y	
Gym office	382	ND	71	18	12	0	Y	Y	Y	
Staff work room	416	ND	72	19	15	0	Y	N	N	
Library	426	ND	72	19	15	6	Y	Y	Y	
Teacher room	445	ND	73	19	14	0	Y	Y	Y	
Main office	471	ND	69	21	14	2	N	Y	Y	
101	487	ND	72	18	14	7	Y	Y	Y	
102A	435	ND	73	19	12	0	Y	Y	Y	
103	717	ND	72	20	12	24	Y	Y	Y	
104	654	ND	73	19	13	19	Y	Y	Y	

ppm = parts per million μg/m³ = micrograms per cubic meter 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%

Location: Schofield Elementary School **Indoor Air Results**

Address: 27 Cedar Street, Wellesley, MA **Table 2 (continued)** **Date: 12/13/2012**

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	
105	830	ND	72	21	14	23	Y	Y	Y	
106	611	ND	67	26	14	0	Y	Y	Y	
107	874	ND	74	21	15	22	Y	Y	Y	
108	909	ND	73	21	18	25	Y	Y	Y	
109	908	ND	73	23	13	2	Y	N	Y	Transfer air vent
110	882	ND	74	23	10	5	Y	Y	Y	
111	594	ND	73	19	14	18	Y	Y	Y	
112	884	ND	73	24	11	9	Y	Y	Y	
113	585	ND	73	20	11	18	Y	Y	Y	
114	1434	ND	74	29	10	12	Y	Y	Y	
115	983	ND	71	26	13	0	Y	Y	Y	
116	879	ND	69	24	11	23	Y	Y	Y	

Comfort Guidelines

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

Location: Schofield Elementary School **Indoor Air Results**

Address: 27 Cedar Street, Wellesley, MA **Table 2 (continued)** **Date: 12/13/2012**

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	
117	976	ND	73	25	9	21	Y	Y	Y	
118	1362	ND	73	27	13	18	Y	Y	Y	
119	922	ND	69	25	13	19	Y	Y	Y	
120 Music	592	ND	72	19	16	21	Y	Y	Y	
121 Art	672	ND	71	23	13	19	Y	Y	Y	Mouse droppings in sink cabinet Water damaged cabinet
122	428	ND	72	18	13	0	Y	Y	Y	
123	728	ND	73	20	14	19	Y	Y	Y	Air cleaner
124	636	ND	70	21	13	26	Y	Y	Y	Supply blocked by bookcase Dehumidifier operating
125	541	ND	69	29	15	12	Y	Y	Y	
126	494	ND	70	21	15	11	Y	Y	Y	
127	500	ND	70	21	13	12	Y	Y	Y	

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%

Location: Schofield Elementary School **Indoor Air Results**

Address: 27 Cedar Street, Wellesley, MA **Table 3** **Date: 12/13/2012**

Room	Exterior Wall/Floor Junction	Floor 3′ from Exterior Wall	Floor at Classroom Hallway Door	Air Temperature in Classroom	Temperature of Exterior Wall/Floor Junction to Air Temperature in Classroom
120	58	61-63	67-67	72	-14
121	54	54-59	65-66	71	-17
122	64	65-67	69	72	-8
123	61	61-65	71-73	73	-12
124	58	59-63	66-68	70	-12
125	51-58	58-64	66	69	-11 to 18

Surface Temperatures in F^{o}