INDOOR AIR QUALITY ASSESSMENT

Silber Early Education Center
99 Hawthorne Street
Chelsea, MA

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

In response to an employee referral, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health (BEH) provided assistance and consultation regarding indoor air quality (IAQ) concerns at the Silber Early Learning Center (SELC) located at 99 Hawthorne Street, Chelsea, MA.

On December 12, 2014, a visit to conduct an assessment was made to this building by Mike Feeney, Director of BEH's IAQ Program. The assessment was prompted by concerns related to roof tar suspected of leaking into the building's interior and the potential to affect indoor environmental conditions.

The SELC is a three-story brick building that was constructed in 1911. The building was renovated in 1997, which added a centralized heating, ventilating and air-conditioning (HVAC) system with air handing units (AHUs) located in a rooftop mechanical room constructed between the two wings of the building. The roof is a rubber membrane and windows are openable throughout the building.

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. Screening for volatile organic compounds was conducted using a MiniRAE 2000 Photo Ionization Detector (PID). BEH/IAQ staff also performed visual inspection of building materials for water damage and/or microbial growth.

Results

The SELC has over 700 students and a staff of over 100. The tests were taken during normal operations. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in all but two areas, indicating inadequate air exchange throughout the building at the time of the assessment. The HVAC system in classrooms consists of ceiling mounted fresh air diffusers (Picture 1) and return vents that are connected to AHUs by ductwork. Offices have supplemental heating/cooling provided by fan coil units (FCUs). The FCUs recirculate air to provide heating/cooling but do not introduce fresh air. Without adequate fresh air supply and exhaust ventilation, normally occurring indoor environmental pollutants can build up indoors, which can lead to irritation of eyes, nose and the respiratory system.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). Information regarding the last date of balancing was not available at the time of the assessment.

Minimum design ventilation rates are mandated by the Massachusetts State Building Code (MSBC). Until 2011, the minimum ventilation rate in Massachusetts was higher for both occupied office spaces and general classrooms, with similar requirements for other occupied spaces (BOCA, 1993). The current version of the MSBC, promulgated in 2011 by the State Board of Building Regulations and Standards (SBBRS), adopted the 2009 International Mechanical Code (IMC) to set minimum ventilation rates. **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.

Temperature readings during the assessment ranged from 70º F to 72º F, which were within the MDPH recommended comfort guidelines. The MDPH recommends that indoor air temperatures be maintained in a range of 70º F to 78º 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 during the assessment ranged from 28 to 42 percent, which was below the MDPH recommended comfort range in the majority of areas surveyed. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Plants were observed in several areas, some placed on porous materials (i.e., paper products). Plants, soil and drip pans can serve as sources of mold/bacterial growth. Plants should be properly maintained, over-watering of plants should be avoided and drip pans should be inspected periodically for mold growth.

Other IAQ Evaluations

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor, and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the indoor environment, BEH/IAQ staff obtained measurements for carbon monoxide and PM2.5.

Carbon Monoxide

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

The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2006). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 2011). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2006).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. On the day of the assessment, outdoor carbon monoxide concentrations were non-detect (ND) (Table 1). No measureable levels of carbon monoxide were detected in the building during the assessment (Table 1).

Particulate Matter

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter includes airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to PM with a diameter of 10 μm or less (PM10). In 1997, US EPA established a more protective standard for fine airborne particulate matter with a diameter of 2.5 μm or less (PM2.5). This more stringent PM2.5 standard requires outdoor air particle levels be maintained below 35 $\mu g/m^3$ over a 24-hour average (US EPA, 2006). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective PM2.5 standard for evaluating airborne PM concentrations in the indoor environment.

Outdoor PM2.5 concentration was measured at 25 μg/m^3 (Table 1). PM2.5 levels measured indoors ranged from 4 to 26 μg/m^3 (Table 1), which were below the NAAQS PM2.5 level of 35 μg/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 indoors can generate particulate matter during normal operations. Sources of indoor airborne particulate matter 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 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.

Building occupants reported irritant symptoms that they believed are associated with exposure to asphalt leaking into the ceiling plenum and classrooms on the topmost floor of the building. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Please note, that the TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. No measureable levels of TVOCs were detected on the fourth floor of the building during the assessment (Table 1).

Classrooms on the first, second and third floors had measurable VOC levels slightly above background levels (a range of 0.1 to 2.5 ppm; Table 1). Classrooms with measurable VOC levels were found to have plug-in air fresheners and a distinctive fragrance odor upon entry. Plug-in air fresheners and other 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.

Hand sanitizer was found in many locations. 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 also contain fragrances to which some people may be sensitive (GOJO, 2007). Other cleaning products were also noted in some areas. Cleaning products should be properly labeled and stored. In addition, a Material Safety Data Sheet (MSDS) should be available at a central location for each product in the event of an emergency.

There were significant amounts of electronics, including standard desktop computers and adaptive devices in offices. Computers and electronics contain plastics, resins and metal components which may give off fumes and odors, particularly when they are new or when they are heated (Maddalena, *et al,* 2011). The number and placement of exhaust vents may not be sufficient for the amount of equipment currently present.

Several areas contained photocopiers (Table 1), which were not outfitted with local exhaust ventilation or near an exhaust vent. VOCs and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, 1992). A laminator was observed in A145. Laminators can be a source of pollutants and odors caused by the melting of plastic, laminators should also be located in areas with exhaust ventilation.

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

Asphalt Drippings

It was reported to BEH/IAQ staff that the SELC experiences issues regarding roofing material dripping into top floor classrooms through the suspended ceiling. Chelsea Public Schools (CPS) officials reported that when the building was initially built it had an asphalt roof. When the building was renovated, a decision was made to install a rubber membrane roof over the existing asphalt roof. As sunlight heats the roof, the asphalt temperature is increased and the heat is retained by the rubber membrane roof. This heating is particularly acute around metal penetrations for plumbing/ductwork through the roof, which are likely reaching a temperature at which the asphalt melts, going from a solid into a liquid. The liquid then passes between spaces around exhaust fans and other roof penetrations and drips into the space above the suspended ceiling (the ceiling plenum). Roofing material has reportedly dripped through the suspended ceiling at times.

Asphalt is a heavy hydrocarbon mixture, which may be naturally occurring but is typically produced as the heaviest fraction when crude oil is separated during the refining process (called cracking). It is commonly used for paving, caulking and waterproofing. It is a solid at room temperature and becomes a viscous liquid when heated. Because it is composed of very long chain, heavy, hydrocarbons, asphalt contains a very low/negligible percentage of

VOCs (Tesoro, 2010). Asphalt fumes, which are generated when the product is very hot, have been associated with irritation of the eyes, nose and throat.

As mentioned, asphalt is a solid at room temperature. Depending on the type of asphalt, it can begin to soften and start to liquefy/flow at a temperature between 150º F to 200º F. These temperatures may be achieved when roof materials are in direct sunlight during warm weather. Increasing this likelihood is the rubber membrane roof material that was installed over the asphalt, which acts as a cover to prevent the asphalt from dissipating heat. Building occupants reported that asphalt is seen between ceiling tiles during warm weather at the beginning and the end of the school year. CPS staff report dripping asphalt with the appearance of black stalactite-like structures, similar to conditions seen in other buildings (Pictures 2 and 3). It is important to note that it is unlikely that asphalt will form a fume (heated particulate matter) as the asphalt transitions from a liquid to a solid. Asphalt fume occurs when asphalt is heated for applications such as road paving and roofing, which is an inhalation exposure/hazard. The temperature of asphalt when applied during roof project is $\geq$500º F. It is during the heating of the asphalt in the roof kettle that asphalt fume would be created. It is also unlikely that asphalt is a continuous source of VOC exposure in fourth floor classrooms immediately below roof decking, as reflective in the VOC sampling conducted in these areas (e.g., ND). However, asphalt/coal tar has a distinctive odor that may be irritating.

The melting of roof asphalt is likely tied to warm weather, sunlight conditions and would be highly unlikely to occur during cold weather. Based on these observations, solidified asphalt drippings would not be expected to pose a health hazard in the current circumstances, aside from the odor irritation that sensitive individuals may experience.

Or more importance is the safety hazard posed by dripping asphalt. As noted previously, the temperature of liquid asphalt is at least 150º F, which can cause serious burns if liquid asphalt comes into contact with skin. Measures must be taken to prevent the leakage of liquid asphalt into occupied space.

Other Conditions

Other conditions that can affect indoor air quality were observed during the assessment. BEH/IAQ staff noted the presence of debris adhered to the ceiling of classrooms throughout the building (Pictures 1 and 4). This type of dust pattern is typically associated with a lack of routine cleaning around air diffusers as well as a lack of sufficient filtration of outdoor air drawn into the building by the HVAC system. The SELC is located in an area that has a number of pollutant sources in close proximity, including housing with chimneys at the level of the SELC's roof line on all sides; the Tobin Bridge with highway traffic to the west; the Chelsea Creek fuel depot with oil tankers to the east; and Logan International Airport to the southeast (Figure 1).

CPS officials reported that filters in the building were MERV 9 rated filters. The feasibility of installing disposable filters with an increased dust spot efficiency for the environment around the SELC should be examined. The dust spot efficiency is the ability of a filter to remove particulate matter 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 (MERV) dust-spot efficiency of 9 would normally be recommended, since this type of filter would remove common air particles such as pollen. Since products of combustion are a smaller diameter, installation of a filter with a MERV rating of 11 or higher in fresh air intakes of the HVAC system may be necessary. 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 AHU should be evaluated by a ventilation engineer to ascertain whether it can maintain function with more efficient filters.

Upholstered furniture was seen in several classrooms. Upholstered furniture, pillows and cushions are covered with fabric that comes in contact with 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 is recommended (Berry, M.A., 1994). It is also recommended that upholstered furniture (if present in schools), be professionally cleaned on an annual basis. If outdoor conditions or indoor activities (e.g., renovations) create an excessively dusty environment, cleaning frequency should be increased (every six months) (IICRC, 2000).

Conclusions/Recommendations

Due to the SELC's location, the surrounding building stock and point sources of air pollution, it appears that the HVAC system should be upgraded to enhance filtration capabilities in order to remove respirable particles. In addition, in its current state, the HVAC system is not providing an adequate amount of fresh air, as demonstrated by elevated carbon dioxide measurements. The staining noted around fresh air diffusers throughout the building would be attributable to a lack of filtration and/or a lack of cleaning around fresh air diffusers and is not related to the issue of asphalt entering the fourth floor ceiling plenum. However, dripping asphalt can be a significant safety/burn hazard; therefore steps must be taken to prevent asphalt leakage from entering occupied space.

It is important to note that it is routine to install a rubber membrane roof *in place* of an asphalt roof. The asphalt roof is normally stripped away prior to membrane installation. In this condition, it is expected that the asphalt will continue to melt and drip into the ceiling plenum until the roof is replaced and/or the asphalt removed. With this deterioration, it would also be possible that rainwater penetration will occur as these materials continue to deteriorate.

Correcting some of the issues may take significant amounts of planning and capital resources. In view of these findings, 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:

Short-Term Recommendations

1. Install materials to serve as a barrier/catch basin beneath areas with leaking asphalt. Work with faculty to determine locations of asphalt drips and install barriers as needed.
2. Institute a reporting system for faculty to report signs of dripping asphalt.
3. Remove all asphalt-covered ceiling tiles if not already done. Ensure that all 4^{th} floor classrooms have a complete set of ceiling tiles installed.
4. In order to dilute and remove normally occurring environmental pollutants, it is recommended to increase fresh air supply by the HVAC system in conjunction with recommendation number 5.
5. Ensure AHU filters are changed as per the manufacturers' instructions or more frequently if needed. Consider upgrading to pleated MERV 11 (or higher) dust-spot efficiency filters. Prior to any increase of filtration, HVAC system components should be evaluated

by a ventilation engineer as to whether they can maintain function with more efficient filters.

6. 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 for 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).
7. Ensure plants are equipped with drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial as needed.
8. Clean fresh air diffusers, exhaust vents, surrounding ceiling tiles and personal fans on a regular basis. If ceiling tiles cannot be cleaned, replace.
9. Discontinue the use of plug-in air fresheners.
10. Clean upholstered furniture on a regular schedule. If not possible/practical, consider removing from classrooms.
11. Consider installing local exhaust ventilation in areas where photocopiers and lamination machines are used. If not feasible, relocate to well-ventilated areas (e.g., open windows).
12. Increase ventilation in areas of heavy electronic use. If not feasible consider reducing use/devices.
13. Ensure cleaning products are kept out of reach of children and maintain MSDSs for all school-issued materials at a central location.

14. 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. Consideration should be given to replacing the existing roof.
2. Given the age and lack of routine maintenance of HVAC system equipment, have a ventilation engineer check the entire HVAC system for function and to make recommendations for repair or replacement of system components.

References

ASHRAE. 1989. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-1989.

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.

Berry, M.A. 1994. Protecting the Built Environment: Cleaning for Health, Michael A. Berry, Chapel Hill, NC.

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

GOJO. 2007. Material Safety Data Sheet for Purell® Instant Hand Sanitizer. GOJO Industries, Akron, OH. October 15, 2007.

IMC. 2009. 2009 International Mechanical Code. International Code Council Inc., Country Club Hills, IL. Administrators International, Inc., Country Club Hill, IL.

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

Maddalena. 2011. Maddalena, R., T. McKone, H. Destaillats, M. Rusell, A. Hodgson, and C. Perino. Quantifying Pollutant Emissions from Office Equipment: A Concern in Energy-Efficient Buildings. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2011-046.

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.

MEHRC. 1997. Indoor Air Quality for HVAC Operators & Contractors Workbook. MidAtlantic Environmental Hygiene Resource Center, Philadelphia, PA.

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

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

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

SBBRS. 2011. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations, 8th edition. 780 CMR 1209.0.

Schmidt Etkin, D. 1992. Office Furnishings/Equipment & IAQ Health Impacts, Prevention & Mitigation. Cutter Information Corporation, Indoor Air Quality Update, Arlington, MA.

SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

Sundell. 2011. Sundell, J., H. Levin, W. W. Nazaroff, W. S. Cain, W. J. Fisk, D. T. Grimsrud, F. Gyntelberg, Y. Li, A. K. Persily, A. C. Pickering, J. M. Samet, J. D. Spengler, S. T. Taylor, and C. J. Weschler. Ventilation rates and health: multidisciplinary review of the scientific literature. Indoor Air, Volume 21: pp 191–204.

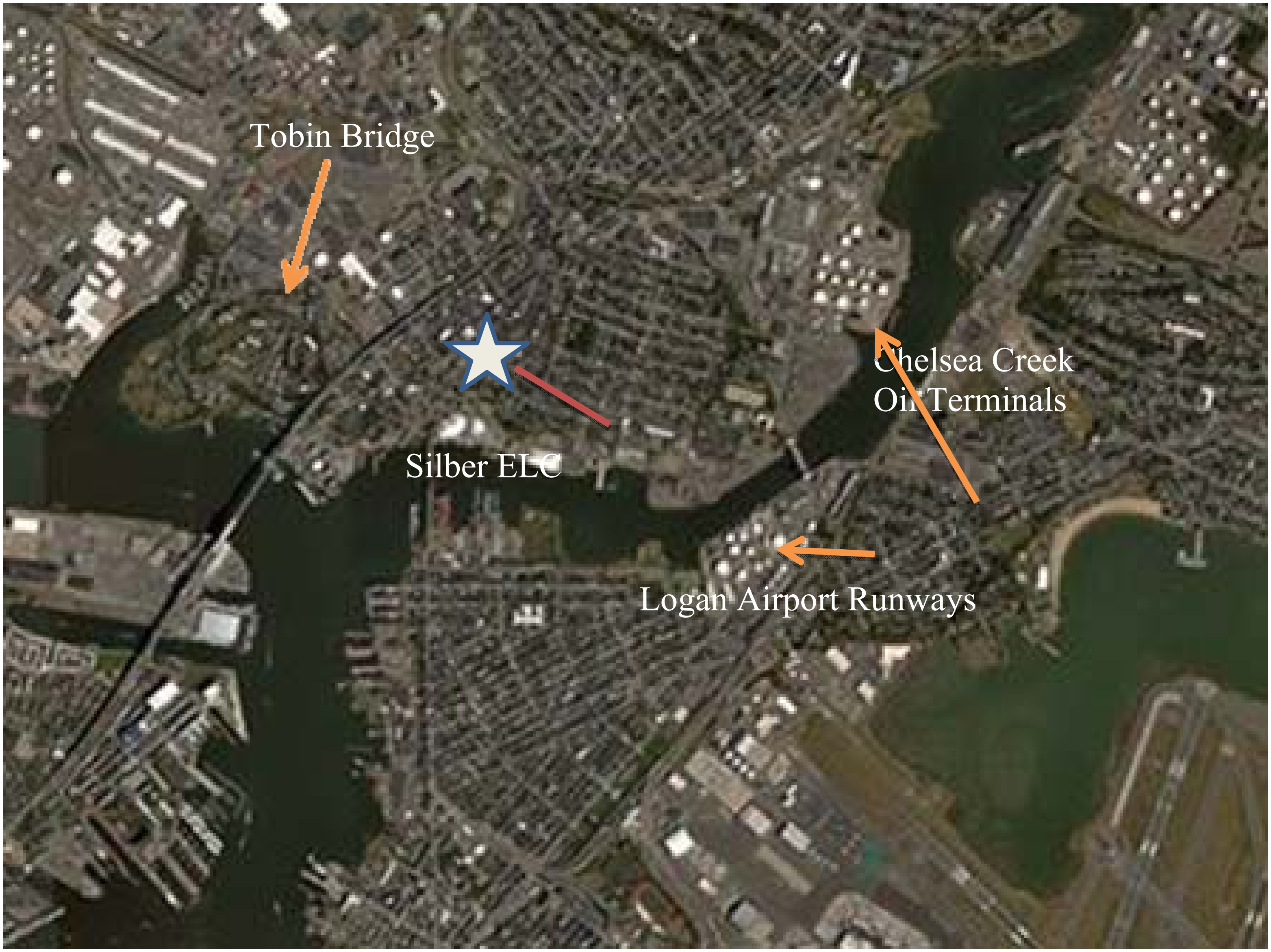
Tesoro. 2010. Material Safety Data Sheet (MSDS Document No: 888100004477). Asphalt. Tesoro Refining & Marketing Co., San Antonio, TX. Accessed January 2015. http://www.montmech.com/hasp/MISC/MSDS/MSDS%20files%5C12007%20Asphalt.pdf

Thornburg, D. 2000. Filter Selection: a Standard Solution. *Engineering Systems* 17:6 pp. 74-80.

US EPA. 1992. Indoor Biological Pollutants. US Environmental Protection Agency, Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, research Triangle Park, NC. EPA 600/8-91/202. January 1992.

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 1
Approximate Location of the Silber ELC (star) to Likely PM2.5 Sources



Picture 1

Example of fresh air diffuser (Note darkened areas around diffuser)

Picture 2

Example of solidified asphalt drippings observed by IAQ staff in a school,
(Photograph taken in 1999)

Picture 3

Example of solidified asphalt drippings observed by IAQ staff in a school (Photograph taken in 1999)

Picture 4

Example of blackened material around fresh air supply on cloth panel in gym

Location: Silber Early Learning Center **Indoor Air Results**

Address: 99 Hawthorn Street, Chelsea, MA **Date: 12/12/2014**

Table 1

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	TVOCs (ppm)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Intake	Exhaust	
Outdoors (Background)	368	ND	38	65	ND	25					
M403 Music	1463	ND	71	37	ND	6	25	Y	Y	Y	Dust around fresh air diffuser
M405	1804	ND	71	39	ND	4	24	Y	Y	Y	Dust around fresh air diffuser, DO
M407 Art	699	ND	70	29	ND	7	22	Y	Y	Y	Window open, dust around fresh air diffuser
M410 Gym	1030	ND	71	32	ND	10	40+	Y	Y	Y	Dust around fresh air diffuser
M411	1187	ND	71	33	ND	10	1	Y	Y	Y	Dust around fresh air diffuser, Fan coil unit
M412	1828	ND	70	42	ND	12	15	Y	Y	Y	Dust around fresh air diffuser
M413	1195	ND	70	35	ND	12	26	Y	Y	Y	Dust around fresh air diffuser
M415	1642	ND	70	37	ND	13	25	Y	Y	Y	Dust around fresh air diffuser
M417	986	ND	70	33	ND	10	0	Y	Y	Y	Dust around fresh air diffuser
M304	810	ND	71	30	ND	10	2	Y	Y	Y	Dust around fresh air diffuser

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

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: Silber Early Learning Center **Indoor Air Results**

Address: 99 Hawthorn Street, Chelsea, MA **Table 1 (continued)** **Date: 12/12/2014**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	TVOCs (ppm)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Intake	Exhaust	
M305	978	ND	70	31	ND	12	16	Y	Y	Y	Dust around fresh air diffuser
M307	1031	ND	71	33	ND	11	10	Y	Y	Y	Dust around fresh air diffuser, DO
M313	1129	ND	71	32	ND	13	10	Y	Y	Y	Dust around fresh air diffuser
M315	1060	ND	71	30	ND	12	20	Y	Y	Y	
M316	1001	ND	71	31	ND	11	3	Y	Y	Y	Fan coil unit
M318	1132	ND	72	33	ND	11	16	Y	Y	Y	Dust around fresh air diffuser, upholstery, plants
M320	1209	ND	71	33	ND	12	14	Y	Y	Y	Dust around fresh air diffuser
M322	1034	ND	72	32	ND	12	0	Y	Y	Y	
M326	1250	ND	71	36	ND	6	6	Y	Y	Y	Dust around fresh air diffuser
M328	815	ND	70	28	ND	13	12	Y	Y	Y	Dust around fresh air diffuser
Multi-purpose room 3rd floor	920	ND	71	29	ND	12	0	Y	Y	Y	5 water-damaged ceiling tiles

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Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	TVOCs (ppm)	PM2.5 (µg/m³)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Intake	Exhaust	
A331	1674	ND	72	41	ND	11	14	Y	Y	Y	Dust around fresh air diffuser
A336	854	ND	72	40	0.9	17	20	Y	Y	Y	Dust around fresh air diffuser
A337	1338	ND	72	37	0.5	12	10	Y	Y	Y	Dust around fresh air diffuser, DO
A339	2259	ND	72	42	ND	13	29	Y	Y	Y	Dust around fresh air diffuser
A341	2153	ND	71	42	1	14	20	Y	Y	Y	
A345	1842	ND	71	37	0.5	14	18	Y	Y	Y	Dust around fresh air diffuser
A347	2429	ND	72	42	ND	15	24	Y	Y	Y	Dust around fresh air diffuser
Teacher’s room	1223	ND	71	34	ND	13	4	Y	Y	Y	Dust around fresh air diffuser, DO
M204	1537	ND	71	35	ND	12	16	Y	Y	Y	Dust around fresh air diffuser
M207	1458	ND	71	36	ND	11	10	Y	Y	Y	Dust around fresh air diffuser
M208	1213	ND	71	32	ND	13	1	Y	Y	Y	Fan coil unit, DO

ppm = parts per million µg/m³ = micrograms per cubic meter ND = non detect DO = door open

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: Silber Early Learning Center **Indoor Air Results**

Address: 99 Hawthorn Street, Chelsea, MA **Date: 12/12/2014**

Table 1 (continued)

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	TVOCs (ppm)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Intake	Exhaust	
M213	1286	ND	71	32	ND	13	22	Y	Y	Y	Dust around fresh air diffuser
M215	1612	ND	71	32	0.9	17	23	Y	Y	Y	Dust around fresh air diffuser, DO
M216	1100	ND	71	32	1	11	1	Y	Y	Y	Fan coil unit, DO
M217	1357	ND	71	36	ND	13	23	Y	Y	Y	Dust around fresh air diffuser, DO
M218	1132	ND	71	34	ND	10	8	Y	Y	Y	Dust around fresh air diffuser
M220	1439	ND	70	37	ND	14	11	Y	Y	Y	Dust around fresh air diffuser
M222	1149	ND	71	32	ND	13	12	Y	Y	Y	Fan coil unit, DO
M226	1422	ND	71	38	ND	19	22	Y	Y	Y	DO
M228	2070	ND	71	38	ND	12	22	Y	Y	Y	Dust around fresh air diffuser, DO
Multipurpose room 2nd floor	1376	ND	70	37	0.6	13	8	Y	Y	Y	
A230	1284	ND	71	38	0.6	13	7	Y	Y	Y	

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Table 1 (continued)

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	TVOCs (ppm)	PM2.5 (μg/m³)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Intake	Exhaust	
A231	1687	ND	70	38	0.8	12	19	Y	Y	Y	Dust around fresh air diffuser
A236	1691	ND	70	38	0.8	14	25	Y	Y	Y	Dust around fresh air diffuser
A237	2034	ND	70	42	1.5	18	14	Y	Y	Y	Dust around fresh air diffuser
A239	2258	ND	70	42	2.5	26	1	Y	Y	Y	Dust around fresh air diffuser, DO
A241	1702	ND	70	39	0.7	12	13	Y	Y	Y	DO
A245	1790	ND	71	39	0.8	14	1	Y	Y	Y	Dust around fresh air diffuser
A247	1822	ND	71	42	ND	15	20	Y	Y	Y	Dust around fresh air diffuser
N112	807	ND	70	29	ND	11	0	Y	Y	Y	
M114	882	ND	72	28	ND	13	3	Y	Y	Y	Photocopier
M116	1024	ND	71	31	ND	12	2	Y	Y	Y	
M117	978	ND	71	31	ND	13	2	Y	Y	Y	

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Location: Silber Early Learning Center **Indoor Air Results**

Address: 99 Hawthorn Street, Chelsea, MA **Date: 12/12/2014**

Table 1 (continued)

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	TVOCs (ppm)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Intake	Exhaust	
M119	872	ND	71	32	ND	12	0	Y	Y	Y	
M125	834	ND	71	29	ND	12	0	Y	Y	Y	Dust around fresh air diffuser
M127	848	ND	71	28	ND	13	0	Y	Y	Y	Dust around fresh air diffuser
A130	1431	ND	70	39	ND	24	13	Y	Y	Y	
A131	1272	ND	70	33	ND	15	15	Y	Y	Y	Dust around fresh air diffuser
A135	1533	ND	70	40	ND	13	15	Y	Y	Y	Dust around fresh air diffuser
A137	1332	ND	70	36	ND	11	15	Y	Y	Y	Dust around fresh air diffuser, DO
A139	1768	ND	71	41	1.1	13	20	Y	Y	Y	
A141	2241	ND	70	42	1.3	19	21	Y	Y	Y	DO
A145	968	ND	70	31	ND	13	0	Y	Y	Y	Laminator, photocopier
A147	921	ND	70	30	ND	13	0	Y	Y	Y	

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Comfort Guidelines

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	600 - 800 ppm = acceptable	Relative Humidity:	40 - 60%
	> 800 ppm = indicative of ventilation problems		

Location: Silber Early Learning Center

Address: 99 Hawthorn Street, Chelsea, MA

Table 1 (continued)

Indoor Air Results

Date: 12/12/2014

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	TVOCs (ppm)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Intake	Exhaust	
Main hall	949	ND	70	29	ND	12	8	Y	Y	Y	
Main office	772	ND	71	28	ND	13	2	Y	Y	Y	

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

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%