INDOOR AIR QUALITY REASSESSMENT

Sunderland Elementary School
Old Amherst Road
Sunderland, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program

October 2004

Background/Introduction

At the request of Penelope A. Spearance, School Principal, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation concerning indoor air quality at the Sunderland Elementary School (SES), Old Amherst Road, Sunderland, Massachusetts. The SES is a member of the Union #38 School District that services students in the rural portion of western Massachusetts. The school was previously visited by Mike Feeney, Director of BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program, in October 2003. A report on that investigation was issued by the BEHA and described conditions of the building at that time< as well as recommendations on correcting those problems (MDPH, 2003). On April 16, 2004, a visit to the SES to conduct an indoor air quality reassessment was made by Mr. Feeney.

The SES is a one story, multi-wing structure built in 1988. In February 2003, the middle portion of the roof buckled from the weight of heavy snow. Following the roof collapse, the school was closed and renovation activities commenced. Major alterations were made to improve the building envelope structural problems associated with the roof. Some of these activities included:

- Restructuring of the roof;
- Removal of gypsum wallboard (GW) in the majority of areas in the building;
- Installation of a new ventilation system;
- Reconstruction of the exterior walls; and
- Installation of a vapor barrier to the slab.

At the time of this assessment, renovations were completed and faculty and students had returned to the building.

Actions on Recommendations Previously Made by MDPH

As previously discussed, BEHA staff visited the building in October 2003 and issued a report that made recommendations to improve indoor air quality (MDPH, 2003). A summary of actions taken on previous recommendations is included as Appendix A of this reassessment.

Methods

As part of the current assessment, BEHA staff performed visual inspection of building materials for water damage and/or microbial growth. Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. 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 total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

Results

The school houses approximately 410 students in preschool through sixth grade and has a staff of approximately 40. The tests were taken during normal operations at the school. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million (ppm) in all areas surveyed indicating adequate ventilation at the time of the visit. Ventilation is provided by a heating, ventilating and air-conditioning (HVAC) system. Fresh air in classrooms is supplied by air-handling units (AHUs) located above the ceiling system. Fresh air is provided by ceiling mounted diffusers connected to the AHUs by ductwork. Exhaust ventilation is provided by wall mounted exhaust grilles ducted back to AHUs.

To maximize air exchange, the BEHA 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 balancing of this HVAC system occurred prior to re-occupancy of the school.

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 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. For more information concerning carbon dioxide, see Appendix B.

Temperature measurements ranged from 71 ^{o} F to 79 ^{o} F, which were within the BEHA recommended comfort range with the exception of the computer room. The BEHA 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. Excessive heat was indicated as an issue in the computer room. Computers, monitors and printers all produce waste heat, which can make temperature control difficult. The ceiling-mounted air diffuser and its proximity to the exhaust vent, is not in an ideal location to provide a maximum mixture of fresh air to temper heated air from the computer equipment. In this case, the placement of an exhaust fan in the upper portion of the exterior window would enhance the removal of waste heat and enhance comfort within this room.

The relative humidity measured in the building ranged from 10 to 16 percent, which was below the BEHA recommended comfort range. It is important to note that outdoor relative humidity measured the day of the assessment was 15 percent, which is unusually dry for a mid-spring day in New England. The BEHA 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

As indicated in Appendix A, all mold contaminated GW was removed as part of the extensive renovations to the building. No musty odors or visible mold growth was present in the SES, with the exception of a musty odor in the hallway between rooms 7 and 12. Each room in this area contained freestanding shelves that were made of particleboard covered with veneer (Picture 1). The shelves appeared to be water damaged and were likely the source of the odor detected. If moistened repeatedly, the veneer glue and particleboard can serve as mold growth media. As water is drawn between the veneer/particleboard space, the moisture cannot evaporate since the veneer is water impermeable. In addition, particleboard wood chips are frequently adhered using a urea-formaldehyde resin. With increased heat and moisture exposure, urea-formaldehyde resin breaks down releasing formaldehyde gas. Formaldehyde is an eye, nose, and respiratory system irritant. Since these shelves appear to be the source of the odor detected in the hallway, replacement of the shelves is warranted.

Plants were observed in a number of classrooms. Plants, soil and drip pans can serve as sources of mold growth, thus should be properly maintained. Over-watering of plants should be avoided and drip pans should be inspected periodically for mold growth. Plants should also be located away from ventilation sources to prevent aerosolization of dirt, pollen or mold.

A pumpkin with visible mold growth on its surface was noted in classroom K1 within a terrarium (Picture 2). The pumpkin should be discarded and the surrounding area should be inspected for mold growth and disinfected with an appropriate antimicrobial as warranted.

Other Concerns

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; however, the pollutant produced is dependent on the material combusted. 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 school environment, BEHA staff obtained measurements for carbon monoxide and PM2.5.

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 airborne pollutants 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).

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 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (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 established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

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. Outdoor carbon monoxide concentrations were non-detectable or ND. Carbon monoxide levels measured in the school were also ND (Table 1).

As previously mentioned, the US EPA also established NAAQS for exposure to particulate matter. 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 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particle levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 28 $\mu g/m^3$. PM2.5 levels measured in the school were below outdoor levels and did not exceed the NAAQS (Table 1). 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 in schools 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, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be negatively influenced by the presence of materials 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 determine whether VOCs were present in the building, air monitoring for TVOCs was conducted during the visit. An outdoor air sample was taken for comparison. An outdoor TVOC concentration of 0.9 ppm was measured. Indoor TVOC concentrations were below background or ND in all areas surveyed (Table 1).

Please note, that the TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. While no TVOC levels measured exceeded background levels, materials containing VOCs were present in the school. Cleaning products were found in classrooms. Cleaning products contain chemicals (such as bleach or ammonia-related compounds), which can be irritating to the eyes, nose and throat. These items should be stored properly and out of the reach of students.

In an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs. 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 off-gas VOCs. 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). A question and answer sheet concerning latex allergy is attached as Appendix C (NIOSH, 1998).

Several other conditions that can affect indoor air quality were noted during the assessment. Of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provide a source for dusts to accumulate. These items, (e.g., papers, folders, boxes) also make it difficult for custodial staff to clean. Dust can be irritating to eyes, nose and respiratory tract. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

Finally, a number of conditions that may attract rodents were observed in classrooms. Stored food containers were seen in some classrooms. In addition, one classroom had student art projects that were made with food. Under current Massachusetts law (effective November 1, 2001) the principles of integrated pest management (IPM) must be used to remove pests in state buildings (Mass Act, 2000). Pesticide use indoors can introduce chemicals into the indoor environment that can be sources of eye, nose and throat irritation. Steps to reduce/eliminate pathways/food sources that can attract pests should be taken.

Conclusions/Recommendations

The Union #38 School District has clearly taken a number of steps to remediate the roof collapse and other water penetration problems at the SES. The majority of these actions have improved conditions in the building. In view of the findings at the time of the reassessment, the following additional recommendations are made:

1. Discard the remaining veneer covered freestanding shelves in classrooms 7 through 12.
2. Discontinue the use of tennis balls on chairs to prevent latex dust generation.
3. Discard pumpkin in classroom K1.
4. Ensure all plants are equipped with drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial where necessary. Consider reducing the number of plants.
5. To prevent pest infestation, use the principles of integrated pest management (IPM) to rid the building of pest. A copy of the IPM recommendations can be obtained from the Massachusetts Department of Food and Agriculture (MDFA) website at the following website: http://www.state.ma.us/dfa/pesticides/publications/IPM_kit_for_bldg_mgrs.pdf. Activities that can be used to eliminate pest infestation may include the following activities.
    a) Avoid using food as components in student artwork.
    b) Rinse out recycled food containers. Seal recycled containers in a tight fitting lid to prevent rodent access.
    c) Remove non-food items that rodents are consuming.

d) Store foods in tight fitting containers.

e) Avoid eating at workstations. In areas where food is consumed, periodic vacuuming to remove crumbs is recommended.

f) Clean crumbs and other food residues from ovens, toasters, toaster ovens, microwave ovens, coffee pots and other food preparation equipment on a regular basis;

g) Examine each room and the exterior walls of the building for means of rodent egress and seal. Holes as small as ¼" are enough space for rodents to enter an area. If doors do not seal at the bottom, install a weather strip as a barrier to rodents. Reduce harborages (cardboard boxes) where rodents may reside (MDFA, 1996).

6. Consult "Mold Remediation in Schools and Commercial Buildings" published by the US EPA (2001) for further information on mold. Copies of this document can be downloaded from the US EPA website at: http://www.epa.gov/iaq/molds/mold_remediation.html.

7. Consider adopting the US EPA (2000b) document, "Tools for Schools" in order to maintain a good indoor air quality environment on the building. This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.

8. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

References

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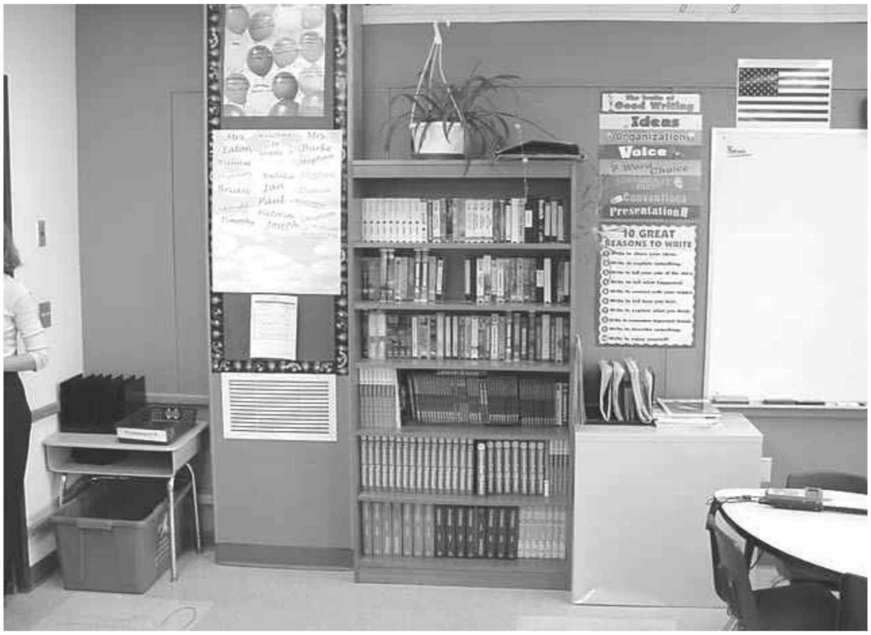
Picture 1



Free Standing Veneer-Clad Bookshelf

Picture 2

Pumpkin in Terrarium

Sunderland Elementary School

Old Amherst Road, Sunderland MA 01375

Table 1

Indoor Air Results

April 16, 2004

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background (Outdoors)	62	15	381	ND	0.9	28	-	-	-	-	
11	74	15	656	ND	0.3	19	16	Y			Plants, UF, clutter
01	72	15	454	ND	ND	8	1	Y	Y Off Wall	Y Off Wall	Plants, food storage/use/ aqua. Guinea pig cage-not clean; exterior door open
07	71	14	459	ND	ND	7	3		Y	Y	TB, hallway door open
05	73	16	505	ND	ND	4	4		Y Off Wall	Y Off Wall	Plants, UF, clutter, aqua.; hallway door open
03	72	15	434	ND	ND	9	0		Y Off	Y Off	Plants, clutter, cleaner; guinea pig; hallway and exterior doors open
06	74	12	596	ND	0.4	12	15	Y	Y Ceiling	Y Wall	DEM, hallway door open; exhause blocked by furniture

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

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
WP = wall plaster

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%

Sunderland Elementary School | **Indoor Air Results**

Old Amherst Road, Sunderland MA 01375 | **April 16, 2004**

Table 1

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
13	74	14	681	ND	0.4	15	13	Y	Y Ceiling	Y Wall	Clutter
04	76	16	482	ND	0.6	9	3	Y	Y Ceiling	Y Wall	DEM, plants, clutter; hallway door open
09	71	15	434	ND	0.3	9					DEM
07	77	13	688	ND	0.4	14	10	Y	Y Ceiling	Y Wall	DEM, plants; stale odor
15	77	15	759	ND	0.4	14	15	Y	Y Ceiling	Y Wall	Plants, cleaners
12	76	14	722	ND	0.4	9	17		Y Ceiling	Y Wall	Musty & stale odors, DEM
10	76	13	725	ND	0.3	9	13				DEM, plants, food storage/use

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14	75	13	532	ND	0.3	12	0	Y	Y Ceiling	Y Wall	PF, plants; hallway door open
19	79	14	789	ND	0.3	15	17	Y	Y Ceiling	Y Wall	DEM, clutter, 19 computers,
18	75	14	720	ND	ND	25	18	Y	Y Ceiling	Y Wall	DEM, clutter, hallway door open;
16	75	14	703	ND	ND	20	20	Y	Y Ceiling	Y Wall	Plants, clutter
23	74	10	655	ND	ND	17	19	Y	Y Ceiling	Y Wall	DEM, cleaners, bean bag chairs
21	77	16	623	ND	ND	10	15	Y			DEM, UF, clutter, cleaners
Atrium	78	12	561	ND	0.3	12	2		Y Ceiling		Plants
Library	78	10	423	ND	0.3	7	1				

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									Supply	Exhaust	
Copy Room	75	16	591	ND	ND	16	1		Y Ceiling	Y Wall	2 photocopiers, 1 laminator, odors; hallway door open
04	72	16	581	ND	ND	14	2		Y Ceiling	Y Wall	DEM, plants; hallway door open
Cafeteria	71	14	523	ND	ND	15	40+		Y Wall	Y Wall	Plants
Gym	71	15	466	ND	ND		0		Y Wall	Y Wall	
Main Office	72	14	519	ND	0.4	10	2				

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Appendix A

Actions on MDPH Recommendations, Sunderland Elementary School, Sunderland, MA

The following is a status report of action(s) taken on MDPH recommendations (**in bold**) based on reports from town officials, school maintenance staff, documents, photographs and MDPH, BEHA staff observations.

1. **Replace all gypsum wallboard (GW) that has visible microbial growth.**
   Action: All GW with visible mold growth was replaced.
2. **Examine the GW behind cabinets in the art room and kindergarten classrooms. If mold colonized, remove and replace GW at least one foot above the floor level.**
   Action: GW in this area was removed and replaced.
3. **Examine the GW behind tiled walls of the kindergarten restrooms. If mold colonized, remove and replace GW at least one foot above the floor level.**
   Action: GW in this area was removed and replaced.
4. **Remove water saturated GW from the library window (Picture 4).**
   Action: GW in this area was removed and replaced.
5. **Discard couch in cafeteria.**
   Action: The couch was discarded.
6. **Clean upholstered furniture in the building according to the schedule recommended. If not possible/practical, remove upholstered furniture from classrooms.**
   Action: Upholstered furniture and carpeting was professionally cleaned prior to reoccupancy (SES, 2004).

Reference

SES. 2004. Letter to Michael Feeney, Dir. ER/IAQ Program from Penelope Spearance, Principal, Sunderland Elementary School, concerning remedial action in response to BEHA recommendations, dated March 23, 2004. Sunderland Elementary School, Sunderland, MA.