INDOOR AIR QUALITY ASSESSMENT

Farmington River Regional Elementary School
555 North Main Street
Otis, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
October 2005

Background/Introduction

At the request of Donna Leep, Superintendent of the Farmington River Regional School District, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH), provided assistance and consultation regarding indoor air quality concerns at the Farmington River Regional Elementary School (FRRES), 555 North Main Street, Otis, Massachusetts. The request was prompted by concerns of potential mold growth as a result of chronic roof leaks.

On June 1, 2005, a visit to conduct an assessment of the FRRES was made by Michael Feeney, Director of CEH’s Emergency Response/Indoor Air Quality (ER/IAQ) Program. The FRRES is a two-story, red brick building constructed in 1998. The school is built at the top of a hill on a concrete slab. Windows throughout the building are openable.

Methods

Air tests for carbon dioxide, carbon monoxide, 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). MDPH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

This school houses approximately 190 pre-kindergarten through sixth grade students, and approximately 25 staff members. Tests were taken during normal operations at the school. 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 air exchange. Fresh air in classrooms is supplied by unit ventilator (univent) systems. A univent draws air from outdoors through a fresh air intake located on the exterior wall of the building and returns air through an air intake located at the base of the unit (Figure 1). Fresh and return air are mixed, filtered, heated and/or cooled and provided to classrooms through a diffuser located on the top of the unit. Mechanical exhaust ventilation in classrooms is provided by wall-mounted exhaust vents ducted to rooftop exhaust fans.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of school 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). 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 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 A.

Temperature measurements ranged from 70° F to 78° F, which were within the MDPH recommended comfort range (Table 1). The MDPH recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants.

In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity measurements ranged from 39 to 55 percent, which were within or very close to the lower end of the MDPH recommended comfort range. 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

The central section of the building contains a large atrium. The atrium ceiling is installed along the contours of the roof, forming a large, vaulted ceiling (Picture 1). One section of the ceiling is parallel to the floor (Picture 2). Ms. Leep reported that this general area of the ceiling had significant repair work, which removed water damaged insulation and gypsum wallboard. The water damaged area roughly corresponds to a section where the roof joins in a seam that covers the main entrance lobby (Picture 3). The eave of the lobby roof appears to penetrate through the plane of the cafeteria atrium roof. At the time of this assessment the section of the ceiling was under repair. There was no evidence of mold growth or water damaged materials in any other area during this evaluation.

In the experience of CEH staff, roof areas that are most likely to experience leaks are ones where: 1) seams exists in a single roof plane (a roof plane is the surface of a single, continuous, flat roof section); 2) penetrations through the roof plane exist (e.g., skylights, chimneys, etc.); 3) the seam where two separate roof planes are joined; or 4) sections of the roof that abut the exterior wall. In this case, two of these conditions exist above the water damaged ceiling in the atrium. Where two separate roof planes are joined, a trough is created where rainwater will likely concentrate (Picture 4). This situation is addressed through a number of different methods. Older, slate shingled roofs usually have metal sheeting (e.g., copper/lead/ aluminum) installed over the seam and under shingles, to create a tough. With modern construction, it is customary to place asphalt shingles over seams, to create a cascade effect of water transferring from one shingle on to another. This type of installation was actually done on several other roof seams (Picture 5). Above the problem area, the singles are *not* overlapping the seam, allowing for rainwater to concentrate and likely penetrate beneath shingles.

Another possible source for moisture penetration is missing flashing. It appears that part of the roof eaves penetrate the plane of the roof without the installation of flashing (Picture 6). In general where two dissimilar materials meet on the exterior of a building, the seam between these materials is likely to be a point source for water penetration. The installation of flashing allows for water to transition from one surface to the next. Without flashing, water can penetrate through the seam resulting in water damage and potential mold growth.

Lastly, the design of the roof directs a large amount of rainwater on this small section of roof (Picture 7). Not only does the lower section drain the largest portion of the roof, water from a large section of the roof over the lobby entrance is directed onto this roof as well. This design concentrates rainwater onto the lower roof, more so than any other section of the building, which can lead to water accumulation along the base of the building. Since the cafeteria is below the level of the soil, water can accumulate against the exterior wall and may eventually penetrate into the cafeteria.

Plants were noted in several areas. Plants, soil and drip pans can serve as sources of mold growth and thus should be properly maintained. Plants should have drip pans to prevent wetting and subsequent mold colonization of window frames. Plants should also be located away from univents and ventilation sources to prevent aerosolization of dirt, pollen or mold.

Other IAQ Evaluations

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion products 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, MDPH 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 carbon monoxide pollution 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-detect or ND (Table 1). Carbon monoxide levels measured in the school were also ND.

As previously mentioned, the US EPA also established NAAQS for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. 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, 2000a). This standard was 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 particulate 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, 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 41 μg/m^3 (Table 1). PM2.5 levels measured indoors ranged from 10 to 69 μg/m^3, which were below the NAAQS PM2.5 level of 65 μg/m^3 in all areas, with the exception of the cafeteria. 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 (as was the case in the cafeteria).

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are 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. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were ND (Table 1). Indoor TVOC measurements throughout the building were also ND.

Please note, 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 measurable TVOC levels were detected in the indoor environment, VOC-containing materials were noted. Several classrooms contained dry erase boards and dry erase board markers. 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.

Conclusions/Recommendations

The main lobby ceiling appears to be damaged from chronic roof leaks detailed in this assessment. The materials moistened appear to be limited to a small section of the ceiling, which was under repair. Until rainwater drainage of the roof is addressed as described in the following recommendations, the water damage noted in the main lobby is likely to be a recurring problem. In view of the findings at the time of the assessment, the following recommendations are made:

1) Consider consulting a building engineer on the appropriate manner by which water drains from the roof above the area of chronic water damage. Possible areas of remediation may include:
    a) Examining the flashing and installing in a manner to prevent water penetration.
    b) Considering reinstalling shingles along roof trough to overlap the seam between the roof joint in a manner similar to other sections of the roof.
    c) Exploring the feasibility of installing a gutter/downspout system along the roof edge of the front lobby and the roof shown in Picture 7. Please note that the gutter must be designed and configured with the appropriate capacity to drain water from this roof while preventing overspill onto the ground outside the cafeteria.
    d) Improving drainage outside the cafeteria window wall. Repair of any cracks and crevices in the exterior wall and foundation in this area is advised.

2) Continue to work with concerned individuals to identify and address IAQ/mold concerns. Should mold issues recur, remove mold-contaminated materials in a manner consistent with recommendations found in "Mold Remediation in Schools and Commercial Buildings" published by the US EPA (2001). Copies of this document can be downloaded from the US EPA website at: http://www.epa.gov/iaq/molds/mold_remediation.html.
3) To maximize air exchange, operate both supply and exhaust ventilation continuously during periods of school occupancy.
4) 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. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
5) Keep plants away from univents in classrooms. Ensure all plants are equipped with drip pans. Examine drip pans for mold growth and disinfect areas of water leaks with an appropriate antimicrobial where necessary.
6) Consider adopting the US EPA (2000b) 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.
7) Refer to resource manuals and other related indoor air quality documents for additional building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website: http://www.state.ma.us/dph/MDPH/iaq/iaqhome.htm.

References

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Picture 1

Large, Vaulted Ceiling

Picture 2

Section of Ceiling That is Chronically Water Damaged

Picture 3

Section of Roof That Corresponds to Water Damage in Atrium (Arrow)

Picture 4

Trough Created by Roof Seam, Note Distinct Seam Created by Shingles Joining at Trough

Picture 5

Asphalt Shingled Over Seams, to Create A Cascade Effect of Water Transferring From One Shingle on to Another, Note Lack of Distinct Seam at Roof Tough

Picture 6

Joint Missing Flashing

Picture 7

Cafeteria windows with brick cracks

White Arrows Indicate Likely Water Flow from Three Roof Sections onto the Roof Section above the Cafeteria Window

Farmington River Regional Elementary School
555 North Main Street, Otis, MA 01253-0679

Table 1

Indoor Air Results
Date: 06/01/2005

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
background		69	53	352	ND	ND	41	N # open: 0 # total: 0			
gym	0	72	46	392	ND	ND	37	N # open: 0 # total: 0	Y	Y	
main office	1	71	50	592	ND	ND	48	Y # open: 0 # total: 0	Y ceiling	Y ceiling	PC.
8	16	78	45	725	ND	ND	46	Y # open: 0 # total: 0	Y wall	Y wall	DEM.
4	16	78	45	751	ND	ND	51	Y # open: 2 # total: 2	Y wall	Y wall	Hallway DO, DEM, plants.
6	8	77	45	683	ND	ND	42	Y # open: 2 # total: 2	Y wall	Y ceiling	Hallway DO, PF, plants.
5	16	77	45	744	ND	ND	40	Y # open: 1 # total: 2	Y wall	Y ceiling	Hallway DO, DEM, PF, plants.

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
VL = vent location
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%

Farmington River Regional Elementary School
555 North Main Street, Otis, MA 01253-0679

Table 1

Indoor Air Results
Date: 06/01/2005

									Ventilation		
Location/ Room	**Occupants in Room**	**Temp (°F)**	**Relative Humidity (%)**	**Carbon Dioxide (ppm)**	**Carbon Monoxide (ppm)**	**TVOCs (ppm)**	**PM2.5 (µg/m3)**	**Windows Openable**	**Supply**	**Exhaust**	**Remarks**
EC 1	0	73	46	466	ND	ND	40	Y # open: 2 # total: 4	Y wall	Y wall	Hallway DO,
EC 2	2	74	47	528	ND	ND	45	Y # open: 0 # total: 0	Y wall	Y wall	Hallway DO, DEM.
library	4	76	39	420	ND	ND	36	Y # open: 0 # total: 0	Y wall	Y wall	Hallway DO, PC.
resource	2	75	45	493	ND	ND	43	Y # open: 2 # total: 2	Y wall	Y wall	Hallway DO,
3	17	74	49	618	ND	ND	48	Y # open: 1 # total: 2	Y wall	Y wall	Hallway DO,
conference	2	73	51	561	ND	ND	48	Y # open: 0 # total: 0	Y ceiling	Y ceiling	Hallway DO, DEM.
health	2	73	52	615	ND	ND	51	N # open: 0 # total: 0	Y ceiling	Y ceiling	

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									Supply	Exhaust	
cafeteria	50	74	55	549	ND	ND	69	Y # open: 1 # total: 10	Y ceiling	Y ceiling	WD-ceiling, #WD-CT : 2, plants.
art	0	72	52	597	ND	ND	49	Y # open: 0 # total: 0	Y ceiling	Y ceiling	Hallway DO, DEM.
music	14	73	51	600	ND	ND	51	Y # open: 0 # total: 0	Y ceiling	Y ceiling	Hallway DO, WD-ceiling, #WD-CT : 2, plant(s) on carpet.
tutorial 3	3	75	46	658	ND	ND	47	Y # open: 0 # total: 0	Y ceiling	Y ceiling	Hallway DO, DEM.
7	18	76	47	721	ND	ND	43	Y # open: 4 # total: 4	Y wall	Y ceiling	Hallway DO, DEM.
2	18	75	47	600	ND	ND	50	Y # open: 2 # total: 2	Y wall	Y wall	Hallway DO, CP, DEM.
1	17	75	48	606	ND	ND	43	Y # open: 2 # total: 2	Y wall (off)	Y wall	Hallway DO, DEM, plants.

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									Supply	Exhaust	
boiler room	0	70	39	586	ND	ND	10	N # open: 0 # total: 0	N	N	Comments : return air vent.
tutorial 2	2	75	47	654	ND	ND	56	Y # open: 0 # total: 0	Y wall	Y wall	Hallway DO, DEM.
EC 3	9	74	50	644	ND	ND	44	Y # open: 1 # total: 4			Hallway DO, DEM.

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