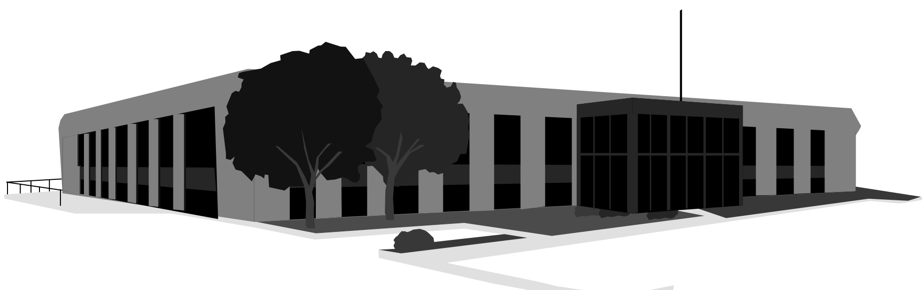
INDOOR AIR QUALITY ASSESSMENT

Federal Street Elementary School
125 Federal Street
Greenfield, Massachusetts



Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
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Background/Introduction

At the request of Lisa Hebert of the Greenfield Board of Health, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality at the Federal Street Elementary School complex, 125 Federal Street, Greenfield, Massachusetts. Reports from building occupants of indoor air quality related symptoms prompted this request. Concerns in this building center around water damage and indoor air quality in the basement of the north wing.

On April 13, 2000, a visit was made to this school by Michael Feeney, Chief of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA, to conduct an indoor air quality assessment. Mr. Feeney was accompanied by Burt White, Greenfield School Department Facilities Manager and Ms. Hebert.

The school complex consists of three distinct sections. Two red brick, two-story buildings constructed between 1900 and 1920 [which are referred to in this report as the north wing (see Picture 1) and south wing (see Picture 2)]. Each of these buildings underwent renovations that replaced the original gravity ventilation system. In the 1980's a gymnasium and cafeteria section (central wing) was constructed connecting each of the red brick buildings (see Picture 1). Elevator shafts were also added during this renovation. The north wing contains general classrooms, the library and an art room in the basement. The south wing contains general classrooms, with office space in the basement. Windows are openable throughout the building.

Methods

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

Results

The school has a student population of 631 and a staff of approximately 40. The tests were taken during normal operations at the school. Test results appear in Tables 1-4. Since general classrooms were not numbered, the results in the tables are identified by the last name of the teacher with the floor and wing identified. The remainder of the areas are identified by activities/function contained therein.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were elevated above 800 parts per million of air (ppm) in twenty-two of thirty-three areas surveyed, indicating a ventilation problem in most areas. It is also noted that several classrooms had open windows and/or were sparsely populated during the assessment, which can greatly reduce carbon dioxide levels. Of note were rooms Latk 1st floor north, the nurse's office, the gymnasium, Pitrat 2nd floor south, and Lebreck 2nd floor south, which had carbon dioxide levels over 800 ppm without occupancy, indicating little or no air movement.

As previously mentioned, the renovations that connected the buildings included the installation of a mechanical supply and exhaust ventilation system that replaced the original gravity system. Fresh air is supplied in many classrooms by a unit ventilator (univent) system (see Figure 1). Univents were deactivated in all classrooms surveyed during the assessment. Obstructions to airflow, such as objects stored on or in front of univents were also observed in a number of classrooms. In order for univents to function as designed, univent fresh air diffusers and return vents must be unblocked and remain free of obstructions. Importantly, these units must be activated and allowed to operate. Without an operational ventilation system, the sole supply of fresh air is from openable windows.

Exhaust ventilation is provided by wall-mounted exhaust vents. As with the univents, exhaust vents were not operating, indicating that the exhaust vent motors are deactivated or broken. Decreasing the efficiency of this system in some classrooms is the location of vents behind wall molding that shields florescent lights (see Picture 3). Without a functional exhaust system, normally occurring environmental pollutants can build-up and lead to indoor air quality complaints.

A number of classrooms located in the basement area, originally designed as storage/janitorial/entrances, have been converted into classrooms in the south wing. Some of these spaces do not have mechanical fresh air supply systems, but rely on window mounted air conditioners. These air-conditioners do not appear to have the ability to provide fresh air. No exhaust ventilation exists in these classrooms.

To maximize air exchange, the BEHA 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. The date of the last servicing and balancing was not available at the time of the assessment.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (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.

Temperature readings ranged from 65° F to 77 ° F, which were below the BEHA recommended comfort guidelines in a number of areas. The BEHA 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. Temperature control is difficult in an old building without a functioning ventilation system.

The relative humidity was measured in a range of 7 to 17 percent, which was below the BEHA recommended comfort range in all areas sampled. The BEHA recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. 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

A number of areas, particularly in and around the elevator shaft of the north wing, have water-damaged ceiling tiles and wall plaster which can indicate leaks from the roof, windows or plumbing system. The roof of the north wing had accumulated water against brickwork of the elevator shaft (see Picture 4). It appears that this section of the roof is sloped *towards* the wall *instead of* toward the roof drain. Chronic pooling of this nature can lead to both moisture penetration through exterior brick and damage to the roofing material due to the freezing and thawing of water during winter weather. Water-damaged ceiling tiles and wall plaster can provide a medium for mold and mildew growth especially if wetted repeatedly. These materials should be repaired/replaced after a water leak is discovered. Rheinhold and Harcourt classrooms contained water-stained ceiling tiles with possible mold growth.

The reading recovery room in the south wing, Bull basement north wing, the art room basement north wing and Madder basement north wing all have musty odors. These odors can be attributed to water penetration through either exterior wall brick or interior brickwork of exhaust ventilation shafts. Walls in the basements of both wings show signs of brick deterioration and efflorescence (i.e., mineral deposits), which indicates water penetration. Efflorescence is a characteristic sign of water intrusion. As moisture penetrates and works its way through mortar around brick it leaves behind these characteristic mineral deposits. With moisture entering the basement, porous materials can become wet and serve as growth media for mold. Each of these areas has carpeting that is in contact with exterior brick that is deteriorating (see Picture 5). The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that carpeting be dried with fans and heating within 24 hours of becoming wet (ACGIH, 1989). If carpets are not dried within this time frame, mold growth may occur. Water-damaged carpeting cannot be adequately cleaned to remove mold growth.

Several sources of moisture penetration into the basement were identified. The primary source of moisture penetration into the basement area would appear to be inadequate damage of rainwater runoff from exterior walls. A trough was noted in the ground along the north wall of the north wing in the grass. This condition can lead to water pooling at the base of the wall. Lack of grass and mud discoloring the wall indicated that water pools and splashes on the exterior wall to a height over one foot in this area (see Picture 6). A second source of water penetration along the north wall appears to be from the addition of a wooden roofed structure to the side of the building. Flashing to the wood structure lies flush against the exterior wall (see Picture 7), instead of cut into the brick and sealed. The purpose of roof flashing is to direct rainwater from one flat exterior surface to a generally perpendicular surface (usually a roof) while preventing water penetration at the seam. In general, a seam is ground into brick into which the flashing is inserted and sealed with a waterproof compound (see Figure 2). This configuration prevents water from penetrating into the exterior brickwork or the interior area under the roof. With the existing configuration, rainwater rolling down the exterior wall can penetrate into the building.

The final source of rainwater penetrating into the basement appears to be at the base of brick airshafts that formerly served as part of the exhaust ventilation system. The floor/wall junction of an *interior* wall of the art room also showed signs of efflorescence (see Picture 8) adjacent to carpeting, which indicates water damage to the airshaft. Although these airshafts have chimney caps to prevent water intrusion (see Picture 9), it appears as though they may be failing or are inadequate as evident by the accumulation of brick and mortar debris at the base of the vent shafts.

Since basement areas can become moist with condensation during hot, humid summer months, relative humidity concentrations indoors above 70 percent can foster mold growth in susceptible materials (ASHRAE, 1989). Materials that can foster mold growth include cardboard, paper, books, cloth and other materials in addition to carpeting. These materials if repeatedly exposed to high humidity can serve as mold growth media.

Several classrooms also had a number of plants. Plant soil and drip pans can serve as source of mold growth. In one case, chronic leakage from a hanging plant resulted in water staining of carpeting (see Picture 10). A number of plants did not have drip pans. The lack of drip pans can lead to water pooling and mold growth on windowsills when used indoors. Wooden sills can be colonized by mold growth and serve as a source of mold odor. Plants should also be located away from univents to prevent the aerosolization of dirt, pollen or mold.

One classroom had decaying fruit (see Picture 11). Another classroom contained an aquarium that appeared to be green with algae growth. Aquariums should be maintained to prevent mold/bacterial growth and/or unpleasant odors. Decaying food items can also grow mold and give off unpleasant odors. In addition, decaying fruit can serve as an attraction to pests (insects and rodents). The art room contained a dehumidifier. Dehumidifiers should be emptied and cleaned as per the manufacturer's instructions to prevent bacterial and mold growth.

Other Concerns

A number of other conditions that can potentially affect indoor air quality were also observed. Univents are installed with air filters that provide minimal filtration of particulates. In order to decrease aerosolized particulates, disposable filters with an increased dust spot efficiency can be installed in the univents. The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by ASHRAE to meet its standard for a dust spot efficiency of a minimum of 40 % would be sufficient to reduce airborne particulates (MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced by the univent by increased resistance. Prior to any increase of filtration, each univent should be evaluated by a ventilation engineer to ascertain whether it can maintain function with more efficient filters.

An acrid odor was detected in the library. The odor was traced to an inner tube found in direct sunlight beneath an exterior window (see Picture 12). Rubber materials can emit unpleasant odors, which can be enhanced by heating.

A number of univents had accumulated dirt, dust and debris within sections of the system in contact with airflow. In order to avoid univents serving as a source of aerosolized particulates, the air handling sections of the univents should be regularly cleaned and have filters changed on a regular schedule. Accumulated chalk dust was noted in several classrooms. Chalk dust is a fine particulate, which can become easily aerosolized. Aerosolized chalk dust can provide a source of eye and respiratory irritation to certain individuals.

Many classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain volatile organic compounds (VOCs), (e.g. methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999). These products can also be irritating to the eyes, nose and throat.

The teacher's workroom contained two photocopiers; directly above the photocopiers was an exhaust vent that directs odors into the ceiling plenum. 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, D., 1992). School personnel should ensure that local exhaust ventilation is activated while equipment is in use to help reduce excess heat and odors in this area.

Also of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were seen piled on windowsills, tabletops, counters, bookcases and desks. The large amounts of items stored in classrooms provide a source for dusts to accumulate. These items, (e.g. papers, folders, boxes, etc.) make it difficult for custodial staff to clean around these areas. Household dust can be irritating to eyes, nose and respiratory tract. These items should be relocated and/or should be cleaned periodically to avoid excessive dust build up.

A number of areas contained portable air conditioning units. 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.

Conclusions/Recommendations

Occupant symptoms and complaints are consistent with what might be expected in an environment with a poorly operating or non-existent ventilation system. The conditions noted at Federal Street Elementary School raise a number of complex issues. The combination of the building design, maintenance, work hygiene practices and the condition of stored materials in the building can have an adverse impact on indoor air quality. No exhaust ventilation exists in the basement. Without exhaust ventilation, normally occurring indoor air pollutants can build up and linger in classrooms. The use of odor or dust generating materials can also serve to exacerbate irritation of the eyes, nose and throat of sensitive individuals.

For these reasons a two-phase approach is required, consisting of immediate measures **(short-term)** to improve air quality at Federal Street Elementary School and **long-term** measures that will require planning and resources to adequately address overall indoor air quality concerns.

The following **short-term** measures should be considered for immediate implementation:

1. Remove water damaged carpeting from the basement classrooms. Disinfect non-porous surfaces with an appropriate antimicrobial compound. After disinfection, clean non-porous surfaces with a soap and water.
2. Examine porous materials (other than carpeting) for mold growth and musty odors. If present, discard these materials.
3. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room and make univent repairs as needed. Check fresh air intakes for repair and increase the percentage of fresh air intake if necessary. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers school-wide.
4. To maximize air exchange, the BEHA recommends that mechanical ventilation operate continuously during periods of school occupancy independent of classroom thermostat control.
5. Consider cutting spaces into wood molding blocking exhaust vents in classrooms.

6. In order to decrease aerosolized particulates, disposable filters with an increased dust spot efficiency can be installed in the univents.
7. Remove all blockages from univents to ensure adequate airflow.
8. Remove carpeting beneath hanging plant in Picture 10. Disinfect non-porous surfaces with an appropriate antimicrobial compound. After disinfection, clean non-porous surfaces with a soap and water.
9. 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).
10. Move plants away from univents in classrooms. Ensure plants have drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial where necessary.
11. Ensure aquariums are properly cleaned to prevent odors and/or algae growth.
12. Clean and maintain dehumidifiers as per the manufacturer’s instructions to prevent bacterial and mold growth.
13. Store food items properly to avoid spoilage and associated odors.
14. Change filters for univents and window-mounted air conditioners as per the manufacturer’s instructions, or more frequently if needed. Clean and vacuum

interior of univents and window-mounted air conditioners prior to operation to avoid the re-aerosolization of accumulated dirt, dust and debris.

15. Clean chalkboards and trays regularly to prevent the build-up of excessive chalk dust.

16. 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.

17. Remove the tire inner tube from the library and store in a cool place.

The following **long-term measures** should be considered:

1. Examine the feasibility of providing mechanical exhaust ventilation for all basement classrooms. For those basement classrooms with univents, examine the feasibility of converting the existing airshafts of the original ventilation system into mechanical systems. Contact an HVAC engineering firm to determine if existing vents, ductwork, etc. can be retrofitted for mechanical ventilation.

2. Re-grade the ground around the north wall of the north wing to direct water away from the building. Examine the feasibility of installing drainage to eliminate water pooling along this wall.

3. Reinstall the flashing on the wooden structure of the north wall to prevent water penetration into its interior.

4. Repair the pitch of the roof above the elevator shaft shown in Picture 4 to direct water towards the roof drain and away from the exterior brick.

5. Repair roof and replace/repair any water-stained ceiling tiles and wall plaster. Examine the area above and around these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial if necessary.
6. Examine the feasibility of installing local exhaust ventilation in teacher's room to vent pollutants from photocopying and other activities out of the building.

References

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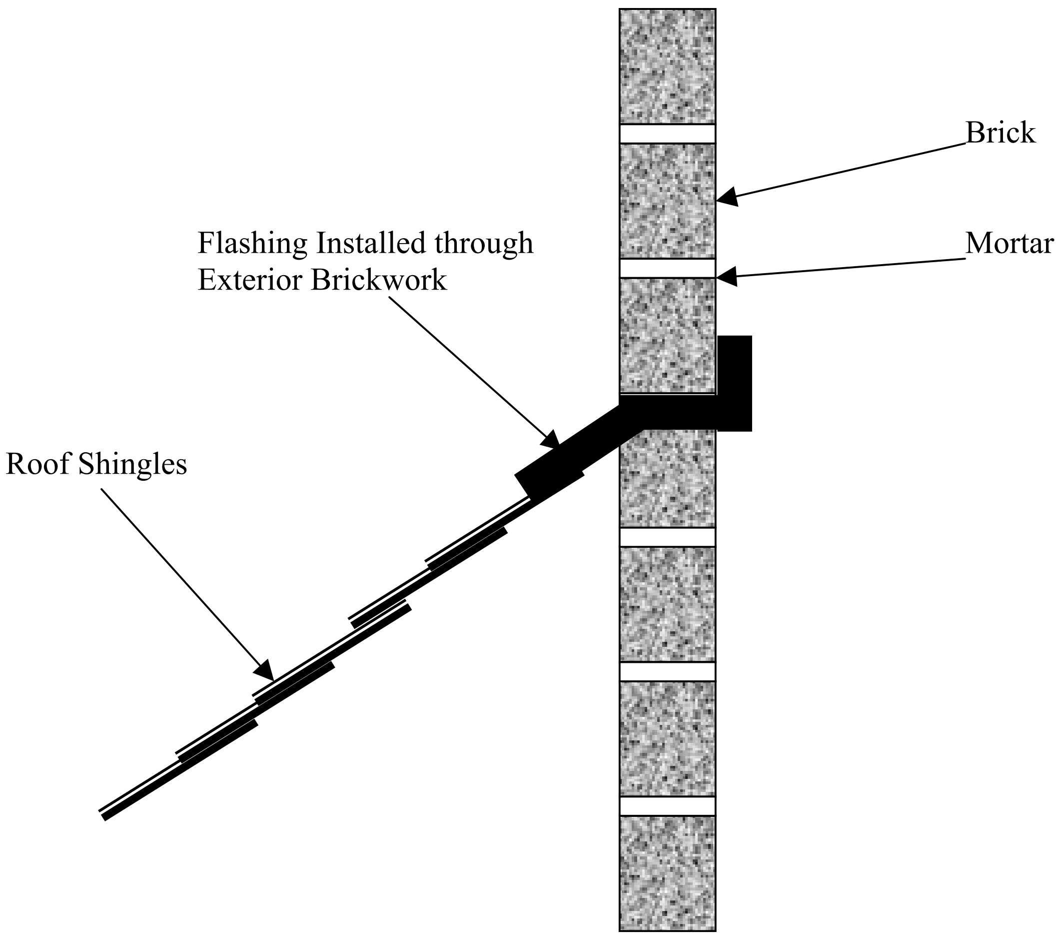
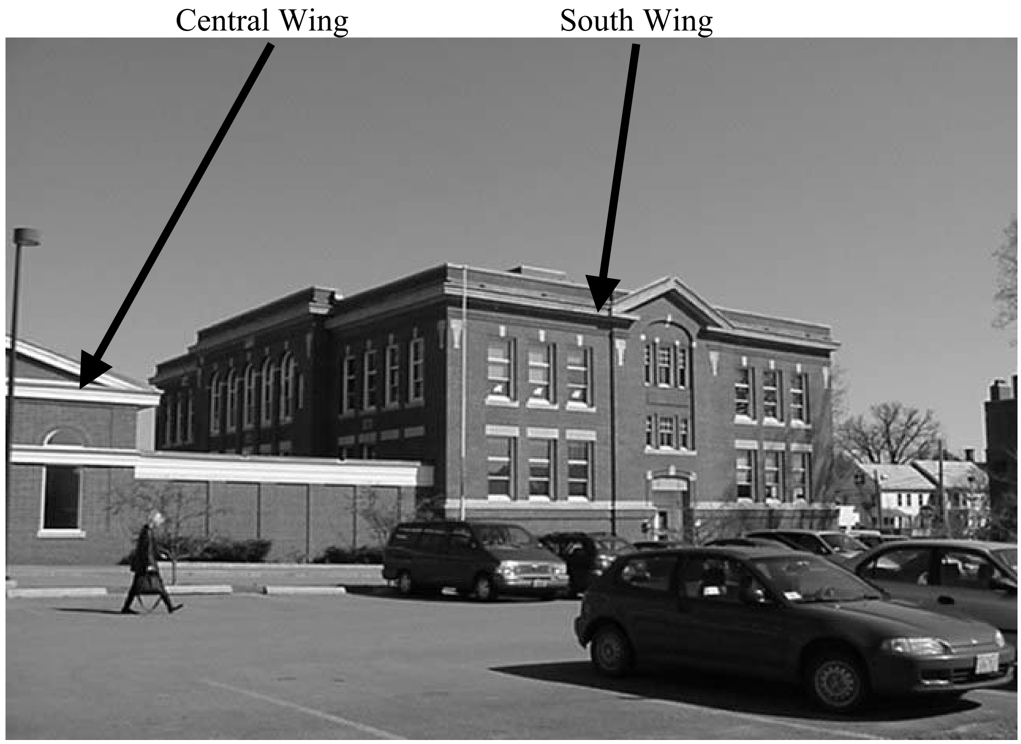
Figure 2 **Installation of Flashing that Prevents Water Penetration**



Picture 1

North and Central Wings of the Federal Street Elementary School

Picture 2

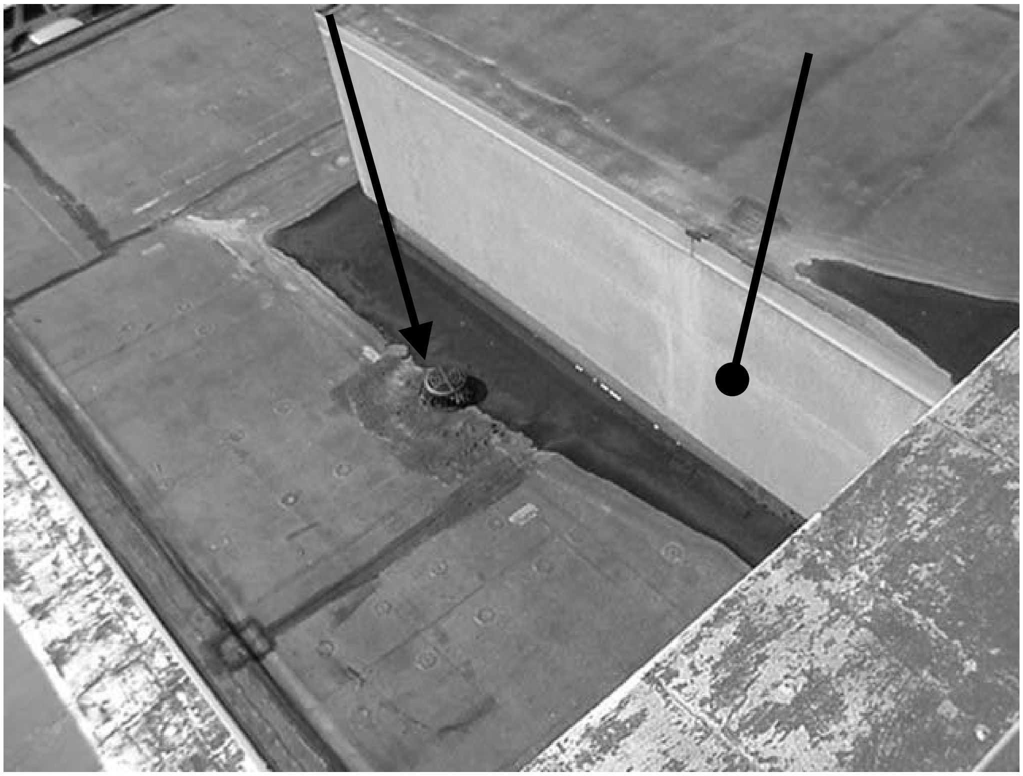


South and Central Wings of the Federal Street Elementary School

Picture 3

Exhaust Vent behind Wood Molding

Picture 4



Water Pooling on Roof Several Days after Rain, Note Roof Drain

Picture 5

Water Intrusion and Powdered Brick on Carpeting, Note the Proximity of Carpet to Wall

Picture 6

North Wall of North Wing with Mud Spattering and Discoloration, Note the Trough in Soil against the Wall

Picture 7

Roof Flashing Laying Flush on Exterior Brick of North Wall

Picture 8

Carpet in Close Proxity to Interior Wall with Signs of Water Intrusion in Art Room

Picture 9

Capped Air Shaft on North Wing Roof

Picture 10

Plant in Classroom, Note Water Stain on Carpet beneath Plant

Picture 11

Decaying Fruit in Classroom

Picture 12

Rubber Inner Tube in Sunlight in the Library

TABLE 1

Indoor Air Test Results –Federal Street School, Greenfield, MA – April 13, 2000

Remarks	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	455	54	11					
Fields-3rd floor N	925	69	7	22	yes	yes	yes	univent and exhaust off, window and door open, cleaning product, chalk dust
Morris-3rd floor N	1049	71	9	24	yes	yes	yes	univent and exhaust off, cleaning product, wasp nests, door open
Teachers' Lounge-3rd floor N	997	73	11	5	yes	yes	yes	univent and exhaust off, window and door open
Rheinhold-3rd floor N	1021	76	10	0	yes	yes	yes	window open, plants, desk near univent
Ward – 3rd floor N	1180	76	11	23	yes	yes	yes	univent and exhaust off, window and door open, floor fan-on, chalk dust
Anderson Speech – 2nd floor N	612	71	11	0	yes	no	yes	1 CT, 1 ceiling tile-possible mold growth, door open
Mahr – 2N	717	71	7	18	yes	yes	yes	univent and exhaust off, exhaust blocked by wood, window and door open, chalk dust
Poliot-2N	873	72	10	19	yes	yes	yes	univent and exhaust off, exhaust blocked by wood, window and door open, chalk dust, fish tank algae

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

Comfort Guidelines

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

TABLE 2

Indoor Air Test Results –Federal Street School, Greenfield, MA – April 13, 2000

Remarks	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Slowinsky-2N	977	74	11	18	yes	yes	yes	6 CT, hamster, door open
Harcourt	955	73	13	18	yes	yes	yes	exhaust off, 1 ceiling tile-possible mold growth, planter, door open
Fuller-2S	1290	73	12	19	yes	yes	no	univent off, chalk dust
Pietrat-2S	1049	73	13	0	yes	yes	yes	univent off
Lebreck-2S	1136	74	13	0	yes	yes	yes	univent off
Abramson-2S	1064	75	10	18	yes	yes	yes	univent off, window and door open, 1 CT
Teachers' Room	901	75	8	1	yes	no	yes	exhaust off, refrigerator
Bell-1S	1231	77	13	19	yes	yes (2)	no	restroom-exhaust vent, univents off
Weber-1S	979	75	11	20	yes	yes	no	univent off, restroom-exhaust vent, door open
Conant-1S	1111	76	11	20	yes	yes	no	univent off, door open
Engel-1S	1096	75	9	19	no	no	no	window mounted air conditioner (a/c), door open

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TABLE 3

Indoor Air Test Results –Federal Street School, Greenfield, MA – April 13, 2000

Remarks	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Reading Recovery Room	536	70	17	0	yes	no	no	musty odor, carpet
Bull-BN	1011	69	12	7	yes	no	no	door open,
Ostrowski-2N	941	72	10	16	yes	yes	yes	univent and exhaust off, univent blocked by bench, chalk dust, door open
Upton-2N	1018	72	11	18	yes	yes	yes	univent and exhaust off, plant-water damaged paper
1st Floor Elevator						no	no	6 CT-active roof leak
Library – 1N	1113	73	13	22	yes	yes	yes	
Rubenstein-1N	707	72	12	0	yes	yes	yes	univent and exhaust off, door open,
Latk-1N	932	72	11	0	yes	yes	yes	univent and exhaust off, birds
Allord-1N	688	72	9	0	yes	yes	yes	univent and exhaust off, chalk dust
Nurse's Office-1N	907	71	10	2	yes	no	no	latex glove

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Relative Humidity -	40 - 60%

TABLE 4

Indoor Air Test Results –Federal Street School, Greenfield, MA – April 13, 2000

Remarks	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Gym	919	72	16	0	yes	yes	yes	
Cafeteria	771	74	11	0	yes	yes	yes	
Photocopier Room						no	yes	exhaust into ceiling plenum-no duct
Madder-BN	588	70	15	7	yes	no	yes	exhaust off, musty odor, brick dust, door open
Art Room-BN	500	65	9	0	yes	yes (2)	yes	univents off, dehumidifier

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CT = water-damaged ceiling tiles

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