INDOOR AIR QUALITY REASSESSMENT

Mt. Greylock Regional High School
Mount Greylock Regional School District
1781 Cold Spring Road
Williamstown, Massachusetts

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

At the request of Marti Mellor, Business Manager of the Mount Greylock Regional School District, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality concerns at the Mount Greylock Regional High School (MGRHS), 1781 Cold Spring Road, Williamstown, Massachusetts. Reports of staff developing sarcoidosis and continued concerns related to indoor air quality prompted this request.

On November 15, 2002, a visit was made to this school by Michael Feeney, Director of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA to conduct an indoor air quality reassessment. BEHA staff previously visited the school in March 1997, to conduct a general indoor air quality assessment. A report was issued in April 1997, which described the building and gave recommendations concerning remediation of conditions noted in the building (MDPH, 1997).

The school was constructed in 1960 and renovated with an addition in 1968. The school is a single story multiple wing building. Various shop areas that were in use at the time of the previous indoor air quality assessment are now used for non-shop school activities. Windows are openable throughout the building.

Actions on Recommendations Previously Made by MDPH

BEHA staff had previously visited the building in March 1997 and issued a report that made recommendations to improve indoor air quality (MDPH, 1997). A summary of actions taken on previous recommendations is included as Appendix I of this reported.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for ultrafine particulates were taken with the TSI, P-Trak ™ Ultrafine Particle Counter Model 8525. The tests were taken under normal operating conditions. All tests for carbon monoxide were at or below background.

Results

The MGRHS has a student population of 768 and a staff of approximately 82. The tests were taken under normal operating conditions. Test results appear in Tables 1-2.

Discussion

Ventilation

It can be seen from the Table 1 that the carbon dioxide levels were elevated (i.e. greater than 800 parts per million parts of air [ppm]) in forty-four out of sixty-four areas, indicating an overall ventilation problem within the school. It should be noted that some rooms had open windows during the assessment or minimal population, which greatly contributes to the reduction of carbon dioxide levels indoors.

Fresh air in most classrooms is supplied by a unit ventilator (univent) system (see Picture 1). Univents draw air from outdoors through a fresh air intake located on the exterior walls of a building and return air through an air intake located at the base of each unit. The mixture of fresh and return air is drawn through a filter and a heating coil, and is then expelled from the univent by motorized fans through fresh air diffusers (see Figure 1). Univents were found turned off in classrooms throughout the school. Obstructions to airflow, such as papers and books stored on univents and bookcases, carts and desks in front of univent returns were seen in a number of classrooms (see Picture 2). Some univents also contained accumulated dirt/debris. These univents should be cleaned before operating to prevent aerosolization of this material.

In order for univents to provide fresh air as designed, intakes must remain free of obstructions. Importantly these units must remain "on" and allowed to operate while these rooms are occupied. Turning off the univent system effectively cuts off fresh air supply to the classroom, which could partially be responsible for high carbon dioxide levels in a number of rooms. Several univents were opened and examined. Louver systems appeared to be either altered or disconnected. Univent filters rest in a "pan" that has slots covered with a louver that are designed to control air movement (see Picture 3). The louvers that control intake of fresh air were closed in a number of univents examined. Therefore, univents are recirculating air *only*. This condition can allow the build-up of normally occurring indoor pollutants and lead to IAQ/comfort complaints.

Fresh air in interior classrooms that do not have windows (e.g., 56, 59, 60) is provided by rooftop fresh air intakes that are connected to univents by ductwork (see Figure 2). These vents are designed to use the univent fan to draw fresh air into these intakes and distribute air into ductwork connected to the classroom univent. In general, univents are designed to draw air from fresh air supply vents that are at the same level as and within two feet of the rear of its cabinet. As an example, all classrooms in the MGRHS with windows (perimeter classrooms) are configured in this manner. Interior room supply ductwork is approximately 15 feet in length. In addition, fresh air must make three 90° turns through ductwork prior to reaching the univent fans. As a general rule, each 90° bend in ducting will reduce the draw of air by 50 percent. In this case, the fresh air must make roughly 270° in turns. Assuming that the velocity of the draw of air at the univent fan equals 100 percent, the draw of air at the base of the vent is reduced to roughly 12.5 percent of the draw because of the three 90° bends in the ductwork.

Mechanical exhaust ventilation is supplied by wall-mounted vents powered by rooftop motors. Exhaust vents were found off in a number of rooms. Some exhaust vents were obstructed by filing cabinets (see Picture 4) and other equipment. In several classrooms, the exhaust vent was located behind a closed room divider (see Picture 5) or hallway door. Exhaust vents must remain clear of obstruction in order to remove stale air and pollutants from classrooms.

Several areas (e.g., the auditorium and library) have fresh air supplied by rooftop air handing units (AHUs). Of note is a classroom that was created by erecting a wall over a former library area. This room is serviced by an oversized ceiling mounted fresh air diffuser (see Picture 6) that is connected to the library HVAC system. This classroom does not have an exhaust vent, which would result in difficulty in controlling temperature as well as result in the build-up of normally occurring indoor pollutants.

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 balancing of these systems was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

This recommendation should take into account the practicality of restoring the existing univents. An examination of the interior of univents revealed significant alterations to the louver mechanisms. These alterations either reduce or eliminate the ability of univents to draw fresh outdoor air. In addition, the manufacturer of the univents [Schemennen (see Picture 7)] appears to have ceased operations. No internet web site could be identified for this company, which indicates there may not be a source to obtain replacement parts to restore univent fresh air intakes to their original function. Without replacement parts to restore the univents, balancing of the HVAC system may not be possible.

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. For more information concerning carbon dioxide, please see Appendix II.

Temperature readings ranged from 71 ^{0}F to 74 ^{0}F, which were within BEHA's recommended comfort guidelines in all areas sampled. The BEHA recommends that indoor air temperatures be maintained in a range of 70 ^{0}F to 78 ^{0}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. It is also difficult to control temperature and maintain comfort without the air handling equipment operating as designed (e.g. univents deactivated, non-operable/obstructed exhaust vents).

The relative humidity measurements in the building ranged from 30 to 44 percent, which was below the BEHA recommended comfort range in most of the areas surveyed. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. It is important to note however, that relative humidity measured indoors exceeded outdoor measurements (range +1-10 percent). The increase in relative humidity can indicate that the exhaust system alone is not operating sufficiently to remove normal indoor air pollutants (e.g., water vapor from respiration). Moisture removal is important since the sensation of heat conditions increases as relative humidity increases (the relationship between temperature and relative humidity is called the heat index). As indoor temperatures rise, the addition of more relative humidity will make occupants feel hotter. If moisture is removed, the comfort of the individuals is increased. Removal of moisture from the air, however, can have some negative effects. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

The school has a ceiling tile system that is glued directly to the ceiling in some classrooms. A number of hallways and classrooms have ceiling tiles that appear to be water-damaged by either water penetration through window frames or by leaks around ductwork that penetrate the roof (see Picture 8). Replacement of these ceiling tiles is difficult, since their removal appears to necessitate the destruction of the tile, which can result in the aerosolization of particulates. Water-damaged ceiling tiles may provide a medium for microbial growth and should be replaced after a water leak is discovered.

Various forms of debris [leaves (see Picture 9)] were noted in direct contact with the rubber membrane roof. In one instance, plants had taken root in the debris and were growing on the roof membrane. Debris can hold water in contact with the roof, which may cause damage resulting in leaks from freezing and thawing during cold weather.

A number of several classrooms have cabinets that are water damaged from spaces between sink countertops and splashboards (see Picture 10). Water penetration and chronic wetting of wood can cause these materials to swell and serve as a growth medium for mold.

Several areas also had a number of plants. The library had a plant located on top of wall-to-wall carpeting. The planter can be a source of moisture that can chronically moisten carpet. Plant soil and drip pans can serve as source of mold growth. A number of these plants did not have drip pans. Plants should be properly maintained and be equipped with drip pans. Plants should also be located away from the air stream of mechanical ventilation to prevent aerosolization of dirt, pollen or mold.

Several other areas had a musty odor, the source of which appeared to be from carpeting (see Table 1). In addition, some classrooms experienced unidentified (skunk-like) odors that school officials believe to come from building materials. Some classrooms divided by walls made of a material identified by school officials as Homasote, also experienced odors. Homasote is a board material made of recycled paper (Homasote Company, unknown). It is possible that exposure to excessive water vapor during summer months caused these odors. During the summer of 2002, several periods of excessively humid weather occurred in Massachusetts, producing an outdoor relative humidity at various times from 73 percent to 100 percent without precipitation from July 4, 2002 through July 12, 2002 (The Weather Underground, 2002). According the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE), if relative humidity exceeds 70 percent, mold growth may occur due to wetting of building materials (ASHRAE, 1989). As relative humidity levels increase indoors, porous building materials, such carpeting and board materials can absorb moisture. The moisture content in these materials can fluctuate with increases/decreases in indoor relative humidity and temperature. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 hours of becoming wet (ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Once mold growth has occurred, disinfection of some materials may be possible, however since carpeting and board material is a porous surface, disinfection is likely to be ineffective.

A significant amount of moistened outdoor debris (cut grass) was found between louvers of univent fresh air intakes (see Picture 11). This material can be drawn into the air stream of univents and provide a source of allergenic material as well as a mold growth medium. Shrubbery in close proximity to univent fresh air intakes (see Picture 12) or in direct contact with the exterior wall brick was noted in several areas around the building, including pine trees in a courtyard located between the library and rooms 55 through 59. Shrubbery growing directly against the building can serve as a possible source of water impingement on the exterior curtain wall. In addition, the growth of roots against exterior walls can bring moisture in contact with wall brick and eventually lead to cracks and/or fissures in the slab. Over time, this process can undermine the integrity of the building envelope and provide a means of water entry into the building through capillary action through foundation concrete and masonry (Lstiburek, J. & Brennan, T.; 2001).

Other Concerns

Several other conditions were noted during the assessment, which can affect indoor air quality. Air filters in univents and rooftop AHUs consisted of ill-fitting metal screens that provide minimal filtration of respirable dust (see Picture 13). Univent filters are designed to strain particulates from airflow. In order to decrease aerosolized particulates, disposable filters with an increased dust spot efficiency can be installed. 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 percent would be sufficient to reduce airborne particulates (Thornburg, D., 2000; MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced by increased resistance (called pressure drop). Prior to any increase of filtration, each piece of air handling equipment should be evaluated by a ventilation engineer to ascertain whether it can maintain function with filters that are more efficient.

A number of classrooms contained upholstered furniture. Upholstered furniture is 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 or every six months if dusty conditions exist outdoors (IICR, 2000).

Stored food containers were noted in some classrooms. Art projects that were made from food were also seen in classrooms. Each of these circumstances can attract pests. 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 a source of eye, nose and throat irritation. The reduction/elimination of pathways/food sources that are attracting these insects should be the first step taken to prevent or eliminate infestation.

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 can be a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and off-gas volatile organic compounds (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, 1998). A question and answer sheet concerning latex allergy is attached as Appendix III (NIOSH, 1997).

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

An exhaust vent fan was found with its hinged louvers frozen open (see Picture 14). These exhaust vent louvers are designed to close when the fan is deactivated. With the louvers open, an uncontrolled amount of outdoor air can enter the building, making temperature control difficult in this area. This vent can also lead to moisture penetration and water damage to building fixtures. This vent also can serve as a means of access for animals and insects to gain entry into the building. All of these examples can have an adverse effect on indoor air quality.

Sarcoidosis

Two individuals working at the MGRHS were reported to have developed pulmonary sarcoidosis. Both individuals shared a general use classroom without windows (hereinafter, the "subject room") during the school year 2000-2001. One individual was diagnosed with sarcoidosis in June 2001. The second individual moved to another classroom the following school year (school year 2001-2002) and was in the same classroom in school year 2002-2003. This second individual was diagnosed with sarcoidosis in September 2002 (during school year 2002-2003). The diagnoses of cases were separated by 15 months. Limited case specific information did not indicate that a bacterial or viral infection existed prior to the development of sarcoidosis in these individuals. Concerns were expressed that their diagnoses might be related to the subject room in which both individuals worked during the school year 2000-2001.

Sarcoidosis is a disease that causes inflammation of various organs of the body. This disease is the most common type of fibrotic lung disease diagnosed by physicians. The disease can begin as an inflammation of the lungs. The disease can appear swiftly and rapidly resolve. Some individuals may experience symptoms that repeat over their lifetime. Symptoms of the disease can ease without treatment, in most cases in 24 to 36 months after the presentation of symptoms.

The causes of sarcoidosis are at this time unknown. Infectious agents such as bacteria, viruses and fungi are one set of possible agents that can cause this disease. These infectious agents can include *Mycobacterium tuberculosis*, *Mycoplasma*, *Corynebacteria*, *Spirochetes*, atypical *Mycobacteria*, *Propionibacterium acnes*, *Borrelia burgdorferi*, Herpes simplex virus, Epstein-Barr virus, cytomegalovirus, coxsackie virus, rubella virus, *Histoplasma*, *Cryptococcus*, Coccidioidomycosis, and Sporotrichosis (Gould and Callen, 2001). *Histoplasma* and *Cryptococcus* are associated with bird waste, which can be encountered in building ventilation systems and attic/crawlspaces. Several environmental/ occupational sources of exposure to hazardous materials or allergens have been implicated in playing a role in the development of sarcoidosis. These include exposure opportunities to metal dusts such as zirconium, aluminum, and beryllium (Gould and Callen, 2001). Organic and inorganic non-metal dusts such as pine pollen, clay, soil, and talc are the third possible group of agents. (Gould and Callen, 2001). According to the American Lung Association, none of these agents has been definitively linked to an individual developing sarcoidosis after exposure (ALA, 2002).

While no definitive cause of sarcoidosis is known, BEHA staff examined the interior and exterior of the subject room and those areas in close proximity (including the roof) for signs of any of the agents or exposures discussed previously. In addition, BEHA staff conducted air monitoring to determine if any unusual concentrations of airborne particles in a number of rooms were present. Different activities such as a combustion of fossil fuels, welding, metal cutting, grinding of materials and other such activities can produce particulate matter that is of a small diameter (<10 μm) (UFPs), which can penetrate into the lungs and subsequently cause irritation. For this reason a device that can measure particles 10 μm or less in diameter was used to identify the presence and possible pollutant pathways into occupied areas.

The instrument used by BEHA staff to conduct air monitoring for UFPs counts the number of particles that are suspended in a cubic centimeter (cm^3) of air. This type of air monitoring is useful in that it can track and identify the source of airborne pollutants by counting the actual number of airborne particles. The source of particle production can be identified by moving the UFP counter through a building towards the highest measured concentration of airborne particles. Measured levels of particles/cm^3 of air increase as the UFP counter is moved closer to the source of particle production. The primary purpose of these tests at the school was *to identify any particulates in the indoor air and/or exposure pathways.*

This equipment cannot be used to quantify whether the national ambient air quality standard for particulate matter were exceeded.

Air monitoring for UFPs was conducted in classrooms, hallways and other areas. For comparison, indoor and outdoor measurements were taken in areas away from the subject room and those in close proximity. No increased levels of UFPs were identified in air monitoring in rooms of primary interest compared to other rooms as well as outdoors (see Table 2).

An assessment of possible sources of environmental pollutants was conducted throughout the building. A greenhouse exists down the hall from the classroom. However no visible signs of soil were present anywhere outside the greenhouse. The building did not house activities that aerosolize metals or generate metal dusts (e.g., cutting, welding, grinding, polishing), and hence no potential means for exposure to inorganic dusts were identified during the assessment.

The building was also examined for the presence of bird wastes. No evidence of bird wastes were found in the subject room or its ventilation system, which would rule out exposure to fungi associated with bird waste (*Histoplasma* and *Cryptococcus*) or soil (Sporotrichosis) (Gillespie, 1994).

Possible sources of organic dust (e.g., pollen) were also evaluated. A stand of several pine trees, which could be a source of pollen, grow within the courtyard of the building. The tops of these trees are above the roofline. The fresh air intakes for rooms of interest are located on the roof (see Picture 15). The courtyard is thirty feet to the east of this fresh air intake (see Picture 16). Under the right wind conditions, it is possible that pollen from these trees could pass over the univent fresh air intakes. However, no accumulation or discoloration of dust associated with pollen was noted within the univent fresh air intake or univent cabinet. It is also important to note that draw of fresh air through the room's univent is minimal at best, as outlined in the ventilation section of this report.

Conclusions/Recommendations

While the cause of sarcoidosis is not well established in the medical literature, BEHA staff attempted to identify possible environmental sources that have suggested to play a role in the development of this disease. No evidence of direct sources of a variety of agents that may be associated with the disease was identified as possible containments in the subject room. While the location of the pine trees in the courtyard provide(s) a possible source of pollen, the condition of the ventilation system in the subject room would tend to limit the introduction of airborne outdoor materials in the subject room.

While conditions in the building do not suggest that air quality factors at the MGRHS are likely to have played a role, access to personal medical information may be helpful in order for MDPH consulting physicians to further evaluate concerns. (Note: Informed consent forms will be provided to the school and local health officials to *facilitate this follow up activity should the teachers impacted be interested in this service.)*

Other conditions that influence indoor air quality were identified in this assessment. In order to address the conditions listed in this assessment, the recommendations made to improve indoor air quality are divided into **short-term** and **long-term** corrective measures. The short-term recommendations can be implemented as soon as practicable. Long-term solution measures are more complex and will require planning and resources to adequately address overall indoor air quality concerns.

In view of the findings at the time of this assessment, the following **short-term** recommendations are made:

1. Remove all blockages from univents and exhaust vents.
2. Examine each univent for function. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers.
3. Repair frozen exhaust vent louvers in Picture 14.
4. To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy independent of classroom thermostat control. Please note that this recommendation is contingent on examination and repair of univents system made under long-term recommendations made in this report.

5. Examine the feasibility of increasing HVAC filter efficiency. Ensure that installed filters are of a proper size and installed in a manner to eliminate particle bypass of the filter. Note that prior to any increase of filtration, each unit should be evaluated by a ventilation engineer as to whether they can maintain function with more efficient filters. Please note that this recommendation is contingent on examination and repair of univents system made under long-term recommendations made in this report.
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. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
7. Move plants away from univents in classrooms. Avoid over-watering and examine drip pans periodically for mold growth. Disinfect with an appropriate antimicrobial where necessary.
8. Remove plant from carpet in library.
9. Remove and replace Homasote walls dividing classrooms.
10. Remove and replace water damaged sink cabinet materials. Seal areas around sinks to prevent water-damage to the interior of cabinets. Disinfect areas of microbial growth with an appropriate antimicrobial as needed.
11. Clean roof and catch basins periodically of debris to enhance rainwater drainage. Consider instituting roof inspections on a regular basis for proper drainage and accumulated debris.
12. Remove trees and/or plant growing against the exterior wall/foundation of the building to prevent water penetration. Consider relocating/removal of pine trees in courtyard.

13. Cut grass in a manner as to not introduce clippings into univent air intakes. If not possible, temporarily cover intakes prior to or clean out intakes after lawn cutting.
14. Discontinue the use of tennis balls on chairs to prevent latex dust generation.
15. Do not store food projects in classrooms.
16. It is highly recommended that the principles of integrated pest management (IPM) be used to rid this building of pests (MDFA, 1996). A copy of the IPM guide can be obtained at the flowing Internet web site address: http://www.state.ma.us/dfa/pesticides/publications/IPM_kit_for_bldg_mgrs.pdf
17. Clean upholstered furniture on the schedule recommended in this report. If not possible/practical, remove upholstered furniture from classrooms.
18. In order to maintain a good indoor air quality environment on the building, consideration should be give to adopting the US EPA document, "Tools for Schools" as recommended by the Athol Board of Health. This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.
19. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.
20. *Upon receipt of signed medical consent forms, the BEHA's environmental/occupational physician will review medical records and further evaluate health concerns.*

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

1. Based on the age, physical deterioration and availability of parts for ventilation components, the BEHA strongly recommends that an HVAC engineering firm fully evaluate the ventilation system. It is possible that restoration of the current univents in this building is not feasible from a technical standpoint or may be cost prohibitive since the manufacturer appears to be out of business. If repair is technically not feasible or is cost prohibitive, consideration should be give to replacing the ventilation system.
2. Examine the feasibility of introducing more fresh air into air shafts of interior room univents to increase distribution of fresh air.
3. Replace water stained ceiling tiles adhered to ceilings. Examine the area above these tiles for continuing water leaks and repair. Remove mold contaminated materials in a manner consistent with recommendations found in "Mold Remediation in Schools and Commercial Buildings" published by the US Environmental Protection Agency, Office of Air and Radiation, Indoor Environments Division, Washington, DC. EPA 402-K-01-001. March 2001. Copies of this document can be downloaded from the US EPA website at: http://www.epa.gov/iaq/molds/mold_remediation.html.
4. In order to provide self assessment and maintain a good indoor air quality environment on your building, consideration should be give to adopting the US EPA document, "Tools for Schools", which can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.

References

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

ALAW. 2002. Facts about Sarcoidosis. American Lung Association® of Washington, Seattle, WA. http://www.alaw.org/lung_disease/information_and_referral/sarcoidosis/sarcoidosis.html

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.

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

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. Section M-308.1.1.

Gillespie, S. 1994. Medical Microbiology Illustrated. Butterworth-Heinemann, Ltd., Oxford, UK.

Gould, K.P. and Callen, J.P. 2001. Sarcoidosis. eMedicine Clinical Knowledge Base, eMedicine.com, Inc., San Francisco, CA. **Last Updated:** December 3, 2001 http://www.emedicine.com/DERM/topic381.htm

Homasote Company. Unknown. About Homasote web page. Homasote Company, Trenton, NJ. http://www.homasote.com/about.html.

IICR. 2000. IICR 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.

Lstiburek, J. & Brennan, T. 2001. Read This Before You Design, Build or Renovate. Building Science Corporation, Westford, MA. U.S. Department of Housing and Urban Development, Region I, Boston, MA

Mass. Act. 2000. An Act Protecting Children and families from Harmful Pesticides. 2000 Mass Acts c. 85 sec. 6E.

MDFA. 1996. Integrated Pest Management Kit for Building Managers. Massachusetts Department of Food and Agriculture, Pesticide Bureau, Boston, MA.

MDPH. 1997. Indoor Air Quality Assessment. Mount Greylock Regional High School, Williamstown, MA. Massachusetts Department of Public Health, Bureau of Environmental Health Assessment, Boston, MA.

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

NIOSH. 1998. Latex Allergy-A Prevention. National Institute for Occupational Safety and Health, Atlanta, GA.

NIOSH. 1997. Latex Allergy. National Institute for Occupational Safety and Health, Atlanta, GA. June 1997. Document #705006.
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.

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

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

SBAA. 2001. Latex In the Home And Community Updated Spring 2001. Spina Bifida Association of America, Washington, DC.
Http://www.sbaa.org/html/sbaa_mlatex.html

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

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

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

US EPA. 2001. Mold Remediation in Schools and Commercial Buildings. US Environmental Protection Agency, Office of Air and Radiation, Indoor Environments Division, Washington, D.C. EPA 402-K-01-001. March 2001. http://www.epa.gov/iaq/molds/mold_remediation.html

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. ECAO-R-0315. January 1992.

The Weather Underground. 2002. Weather History for Westfield, Massachusetts, July 4, 2002 through July 12, 2002.
http://www.wunderground.com/history/airport/KBAF/2002/7/4/DailyHistory.html
http://www.wunderground.com/history/airport/KBAF/2002/7/5/DailyHistory.html
http://www.wunderground.com/history/airport/KBAF/2002/7/6/DailyHistory.html
http://www.wunderground.com/history/airport/KBAF/2002/7/7/DailyHistory.html
http://www.wunderground.com/history/airport/KBAF/2002/7/8/DailyHistory.html
http://www.wunderground.com/history/airport/KBAF/2002/7/9/DailyHistory.html
http://www.wunderground.com/history/airport/KBAF/2002/7/10/DailyHistory.html
http://www.wunderground.com/history/airport/KBAF/2002/7/11/DailyHistory.html
http://www.wunderground.com/history/airport/KBAF/2002/7/12/DailyHistory.html

TABLE 1

Indoor Air Test Results –Williamstown, MA – Mt. Greylock Regional High School - November 15, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
(Outside) Background	346	58	34					Weather cold, clear, wind 15-20, easterly, freezing temperatures
N 41	869	72	37	10	Y	Y	Y	Door open
N 40	738	72	37	2	Y	Y	Y	Exhaust off Door open
N 39	68	72	35	1	Y	Y	Y	Exhaust off
N 37B	573	72	35	0	Y	Y	Y	Exhaust off Door open
N 30	603	72	34	1	Y	Y	Y	Supply blocked by bookcase Exhaust off - door open
N 37A	511	71	32	0	Y	Y	Y	Window and door open Supply and exhaust off
N 35	1421	71	42	15	Y	Y	Y	
N 36	573	71	34	1	Y	Y	Y	Exhaust off Door open
N 34B	401	71	30	0	Y	Y	Y	Door open

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

Comfort Guidelines

(1 Story – Red Brick)

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

TABLE 1

Indoor Air Test Results –Williamstown, MA – Mt. Greylock Regional High School - November 15, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
N34A	869	72	35	5	Y	Y	Y	Exhaust off Door open
N 33	1055	72	37	7	Y	Y	Y	Exhaust off
Room 53	1868	73	42	27	Y	Y	Y	Supply/exhaust off Window board - plant
Room 54	1284	74	37	19	Y	Y	Y	Window open Shelf blocking exhaust
C-2	2350	74	44	25	N	Y	Y	CT 7, univent blocked with plastic
C-1	1000	74	37	11	N	Y	Y	Supply off, carpet, upholstered furniture, food cartons
Cafeteria	1311	74	39	8	Y	Y	Y	25 CT ⅔ supply, door open
Band Room	1304	73	38	0	N	Y	Y	½ supply, door open Mold odor – carpet
Chorus	1060	73	37	13	Y	Y	Y	Window/door open Exhaust off
Teachers Lounge	1203	73	39	8	Y	Y	Y	CT 5 Door open

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

Comfort Guidelines

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

(1 Story – Red Brick)

TABLE 1

Indoor Air Test Results –Williamstown, MA – Mt. Greylock Regional High School - November 15, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
E 44	726	72	34	3	Y	Y	Y	Water cooler on carpet
N 43	1223	72	38	0	Y	Y	Y	Exhaust off CT 8, supply blocked by cabinet
N 42	673	71	35	1	Y	Y	Y	Exhaust blocked with box CT 10
Room 66	1119	71	38	16	Y	Y	Y	Water on floor Door open
Room 67	854	71	37	13	Y	Y	Y	Door open
Room 68	1153	71	40	18	Y	Y	Y	
Room 59	1014	71	39	16	N	Y	Y	Supply off Exhaust blocked by file cabinet
Room 58	992	71	38	1	Y	Y	Y	Supply off Exhaust blocked by file cabinet
Room 57	959	72	38	0	Y	Y	Y	Exhaust blocked with box
Room 56	1688	72	41	24	N	Y	Y	

*** ppm = parts per million parts of air**
UV = Univent
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%

(1 Story – Red Brick)

TABLE 1

Indoor Air Test Results –Williamstown, MA – Mt. Greylock Regional High School - November 15, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Library	576	72	34	3	Y	Y	Y	Exhaust off – repairing Plant on carpet
Room 60	540	73	33	0	N	Y	Y	CT 1, door open Exhaust off
Room 51	1118	73	37	3	Y	Y	Y	Exhaust blocked with box Door open
Room 52	1388	73	38	1	Y	Y	Y	Door open
Room S8	662	72	34	0	Y	Y	Y	
Room S9	1079	72	35	2	Y	Y	Y	CT 2 Door open
Room S10	1863	72	40	13	Y	Y	Y	Exhaust off CT 3
Room S11	1924	72	42	25	Y	Y	Y	Supply off, carpet odor CT 5
Room 512	1221	72	40	11	Y	Y	Y	Exhaust off
Room S13	661	73	33	1	Y	Y	Y	Window door open Exhaust off, tennis balls

*** ppm = parts per million parts of air**
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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%

(1 Story – Red Brick)

TABLE 1

Indoor Air Test Results –Williamstown, MA – Mt. Greylock Regional High School - November 15, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
Room S14	1333	73	38	8	Y	Y	Y	Exhaust off Door open
Room S15	761	73	34	0	Y	Y	Y	Exhaust off Plants on window
Room S16	487	72	31	7	Y	Y	Y	Supply/exhaust off Door open, CT 2
Room 63	948	71	37	0	Y	Y	Y	CT 9
Room 65	1201	71	37	15	Y	Y	Y	CT 1 Door open
E 45	947	73	38	16	Y	Y	Y	Exhaust covered by door Door open
E 46	1066	73	37	24	Y	Y	Y	Exhaust covered by door Door open
E 45	828	72	37	8	Y	Y	Y	Supply near plants Door open
Health Room	1290	72	38	23	Y	Y	?	
E 50	617	72	34	0	Y	Y	Y	Exhaust blocked by cabinet Door open, CT 20+

*** ppm = parts per million parts of air**
UV = Univent
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Comfort Guidelines

(1 Story – Red Brick)

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

TABLE 1

Indoor Air Test Results –Williamstown, MA – Mt. Greylock Regional High School - November 15, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
E 49	540	73	36	1	Y	Y	6	Photocopier Plants
Band Room	613	72	33	0	Y	Y	Y	Unit ventilator exhaust Door open
Room 54	1119	72	39	22	Y	Y	Y	Supply/exhaust off Door open
Room 55	2107	73	44	20	Y	Y	Y	Supply off
Room 56	1140	73	36	13	Y	Y	Y	Window open, 21 computers Exhaust off, CT 8
Room 57	1908	73	41	16	Y	Y	Y	Plants on cabinet Supply off
N 32	2102	72	41	18	Y	Y	Y	Plant near supply CT 10 – door open
W 28	1315	72	40	12	Y	Y	Y	Exhaust off Door open, 22 computers
W 27	871	73	39	2	Y	Y	Y	CT 5 Door open
W 26	1288	72	39	24	Y	Y	Y	CT 10

*** ppm = parts per million parts of air**
UV = Univent
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%

(1 Story – Red Brick)

TABLE 1

Indoor Air Test Results –Williamstown, MA – Mt. Greylock Regional High School - November 15, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
W 23	1139	72	37	22	Y	Y	Y	Plant on radiator
W 23	670	72	34	1	Y	Y	Y	CT 10 Exhaust off, door open
W 21	828	72	35	0	Y	Y	Y	Door open Chemical hood off
W 20	878	71	37	1	Y	Y	Y	Supply/exhaust off, door open Water damage around sink
Main Office	841	70	37	2	Y	N	N	Plants Window open

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

Comfort Guidelines

(1 Story – Red Brick)

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
Particulate Testing

Area	Location in Area	Number of Ultrafine Particulates Particles per cc of air (in thousands)[a]
Outside (Background)	Side of building	4
N37B	Center of room	4
N38	Center of room	4
N35	Center of room	2
N36	Center of room	4
N34b	Center of room	5
Cafeteria	Center of room	25
Chorus room	Center of room	4
Teacher's lounge	Center of room	4
N44	Center of room	2
N43	Center of room	2
66	Center of room	3

* ppm = parts per million
[a] Device measures total airborne particulates of a diameter 0.02-1 micrometers

TABLE 2
Particulate Testing

Area	Location in Area	Number of Ultrafine Particulates Particles per cc of air (in thousands)[a]
67	Center of room	4
68	Center of room	3
59	Center of room	3
58	Center of room	3
56	Center of room	3
Lbrary	Center of room	3
60	Center of room	2
51	Center of room	2
52	Center of room	3
S8	Center of room	4
S9	Center of room	6
S10	Center of room	3

* ppm = parts per million
[a] Device measures total airborne particulates of a diameter 0.02-1 micrometers

TABLE 2
Particulate Testing

Area	Location in Area	Number of Ultrafine Particulates Particles per cc of air (in thousands)[a]
S11	Center of room	4
S12	Center of room	9
S13	Center of room	5
S14	Center of room	4
S15	Center of room	4
S16	Center of room	5
63	Center of room	2
65	Center of room	3
E46	Center of room	6
E45	Center of room	5
Health Room	Center of room	6
E50	Center of room	6

* ppm = parts per million
[a] Device measures total airborne particulates of a diameter 0.02-1 micrometers

TABLE 2

Particulate Testing

Area	Location in Area	Number of Ultrafine Particulates Particles per cc of air (in thousands)[a]
E49	Center of room	6
Band Room	Center of room	6
S4	Center of room	5
S5	Center of room	4
N32	Center of room	2
W28	Center of room	3
W27	Center of room	3
W26	Center of room	3
W21	Center of room	15
W20	Center of room	3

* ppm = parts per million
[a] Device measures total airborne particulates of a diameter 0.02-1 micrometers

Figure 1

Unit Ventilator (Univent)

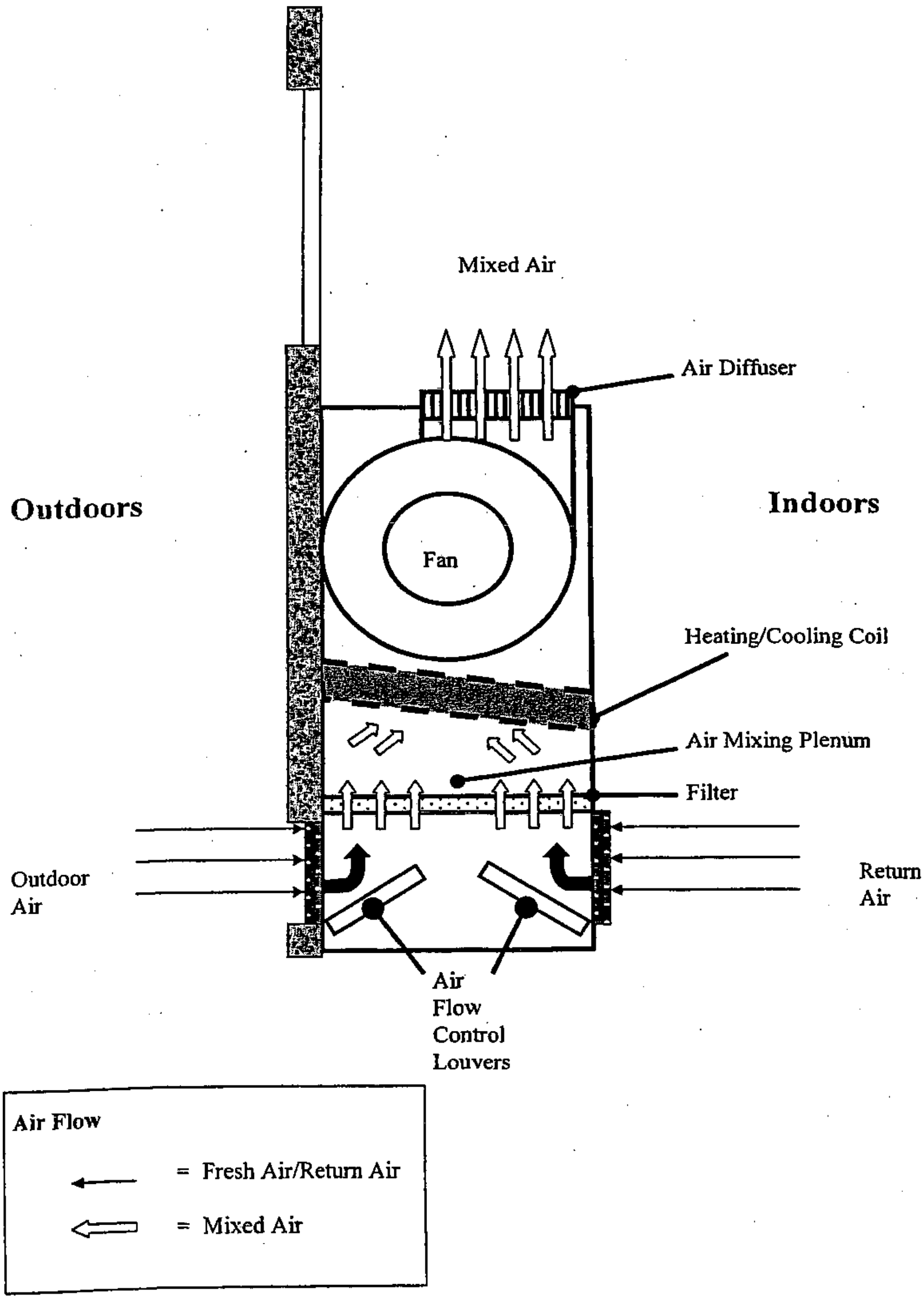
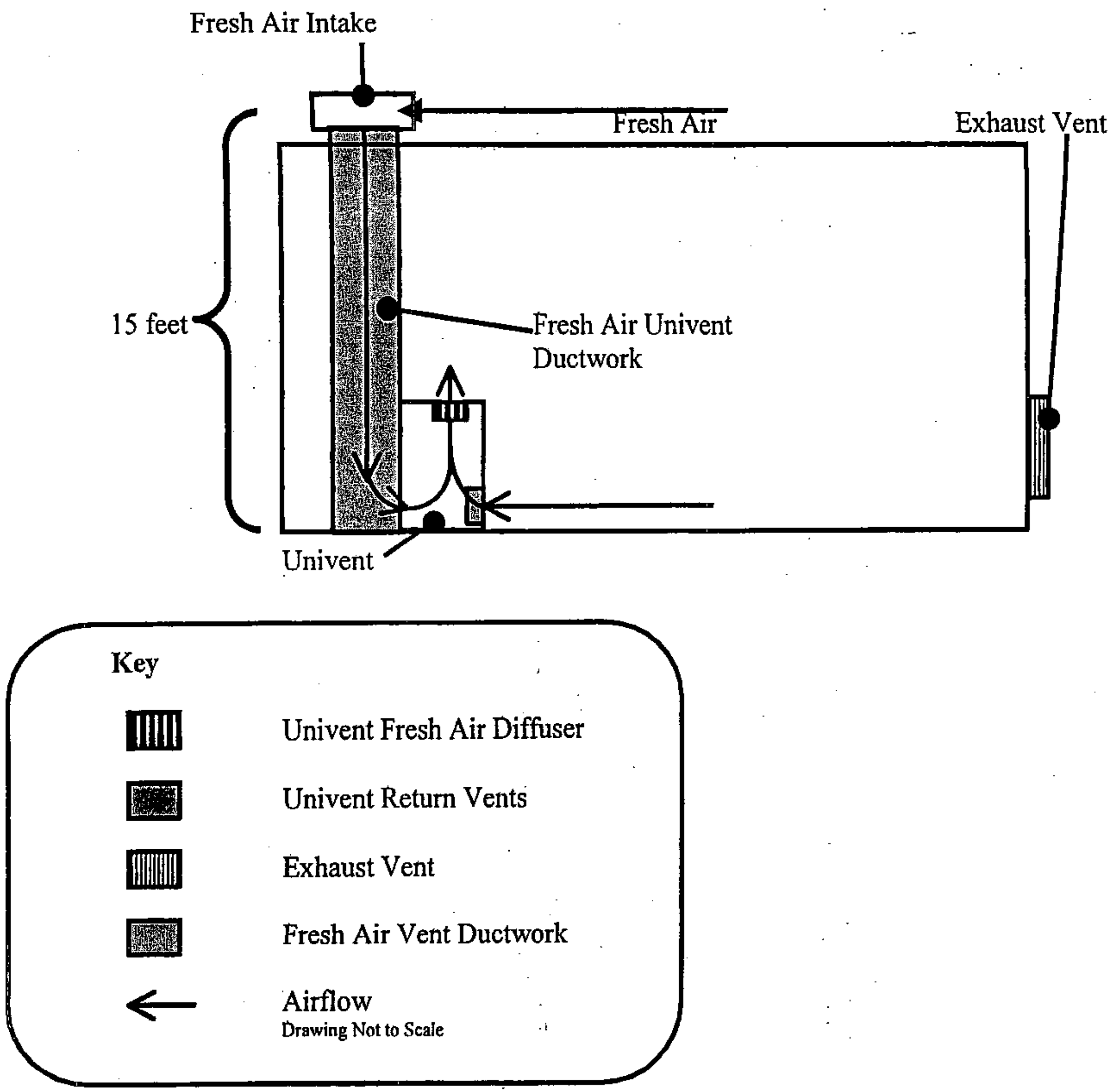


Figure 2

Configuration of Airflow in Interior Classrooms of Mount Greylock Regional High School



Note: The original version of this report includes 8 pages of photographs which are omitted from this version.

Appendix I

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

1. **In order to improve indoor air quality, an increase in the percentage of fresh air supply into the univent system may be necessary. Preventing access to univent controls may be a necessary step to make sure these systems cannot be turned off. Preventing the use of univents as book shelving/storage areas is necessary to have this system function properly.**

   Action taken: While univents were operating, their ability to introduce fresh air appears to vary throughout the building, as confirmed by carbon dioxide measurements (see Tables). Univents were blocked in some classrooms.

2. **Evaluate the exhaust system for function and repair. Prevent obstruction of exhaust vents.**

   Action taken: Exhaust ventilation was operating in most areas evaluated.

3. **Once both fresh air supply and the exhaust ventilation are functioning in all areas of the building, the ventilation system needs to be balanced.**

   Action taken: see **Ventilation** section of main report.

4. **Replace water stained ceiling tiles. Examine the area above these tiles for continuing water leaks and repair. Examine all water-damaged materials for mold growth. Disinfect areas of water leaks with an**

appropriate antimicrobial. If material is porous, discard and replace. Replace water damaged floor tiles. Disinfect if mold contamination.

Action taken: Water damaged ceiling tiles were noted in a number of areas of the building (see **Mold/Moisture Concerns** section of main report).

5. **Examine area behind sinks in Room E-50 for friable asbestos. If asbestos is present and not encapsulated, consult an asbestos remediation consultant to assess the condition of the asbestos and remove in accordance with Massachusetts statutes and regulations.**

   Action taken: These materials appeared to be intact. School personnel should consult their Asbestos Hazard Emergency Response Act (AHERA) plan, which requires an inspection of this material every three years.

6. **Stain glass window assembling and rock grinding should not occur without proper exhaust ventilation and safety equipment. Consult the Division of Occupational Safety for information concerning proper exhaust methods and safety equipment.**

   Action taken: Operations moved to metal shop.

7. **Locate, identify and eliminate the odor in Room W-21. If it is a propane leak, stop propane flow at the source to assess whether odor dissipates. Consult the municipal fire prevention program to assess this problem.**

   Action taken: No odors were noted or reported in this area.

8. **Keep biology lab sinks clear of debris to eliminate odors.**

   Action taken: Sinks clear of debris.

9. **Drain standing water from fish tanks and tub in Room 62 and the hot house. Clean out these containers and disinfect with an appropriate antimicrobial. Use the local exhaust to vent exhaust hothouse odors.**

Action taken: Fish tanks cleaned. No standing water found in hothouse. New hothouse added to rear of building.

10. **Consider moving all automotive materials and front end loader from the Metal Shop area. If the Metal Shop area is to remain a garage, limit access to this area to school personnel only. Provide adequate ventilation that is consistent with the ASHRAE Standard 62-1989, *Ventilation for Acceptable Air Quality* for automobile garages.**

Action taken: Automotive shop discontinued.

Appendix II

Carbon Dioxide and its Use in Evaluating Adequacy of Ventilation in Buildings

The Bureau of Environmental Health Assessment (BEHA), Emergency Response/Indoor Air Quality (ER/IAQ) Program examines indoor air quality conditions that may have an effect on building occupants. The status of the ventilation system, potential moisture problems/microbial growth and identification of respiratory irritants are examined in detail, which are described in the attached report. In order to examine the function of the ventilation system, measurements for carbon dioxide, temperature and relative humidity are taken. Carbon dioxide measurements are commonly used to assess the adequacy of ventilation within an indoor environment.

Carbon dioxide is an odorless, colorless gas. It is found naturally in the environment and is produced in the respiration process of living beings. Another source of carbon dioxide is the burning of fossil fuels. Carbon dioxide concentration in the atmosphere is approximately 250-600 ppm (NIOSH, 1987, Beard, R.R., 1982).

Carbon dioxide measurements within an occupied building are a standard method used to gauge the adequacy of ventilation systems. There are a number of reasons why carbon dioxide is used in this process. Any occupied building will have normally occurring environmental pollutants in its interior. Human beings produce waste heat, moisture and carbon dioxide as by-products of the respiration process. Equipment, plants, cleaning products or school supplies normally found in any school can produce gasses, vapors, fumes or dusts when in use. If a building has an adequately operating mechanical ventilation system, these normally occurring

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environmental pollutants will be diluted and removed from the interior of the building. This particular building has unit ventilators, which provide heat and fresh air during operation. The introduction of fresh air both increases the comfort of the occupants and serves to dilute normally occurring environmental pollutants.

An operating exhaust ventilation system physically removes air from a room and thereby removes environmental pollutants. The operation of univents in conjunction with the exhaust ventilation system creates airflow through a room, which increases the comfort of the occupants. If all or part of the ventilation system becomes non-functional, a build up of normally occurring environmental pollutants may occur, resulting in an increase in the discomfort of occupants.

The MDPH approach to resolving indoor air quality problems in schools and public buildings is generally two-fold, 1) improving ventilation to dilute and remove environmental pollutants and 2) reducing or eliminating exposure opportunities from materials that may be adversely affecting indoor air quality. In the case of an odor complaint of unknown origin, it is common for BEHA staff to receive several descriptions from building occupants. A description of odor is subjective, based on the individual's life experiences and perception. Rather than test for a potential series of thousands of chemicals to identify the unknown material, carbon dioxide is used to judge the adequacy of airflow as it both dilutes and removes indoor air environmental pollutants.

As previously mentioned, carbon dioxide is used as a diagnostic tool to evaluate air exchange by building ventilation systems. The presence of increased levels of carbon dioxide in

Appendix II

indoor air of buildings is attributed to occupancy. As individuals breathe, carbon dioxide is exhaled. The greater the number of occupants, the greater the amount of carbon dioxide produced. Carbon dioxide concentration build up in indoor environments is attributed to inefficient or non-functioning ventilation systems. 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).

Carbon dioxide can be a hazard within enclosed areas with **no air supply**. These types of enclosed areas are known as confined spaces. Manholes, mines and sewer systems are examples of confined spaces. An ordinary building is not considered a confined space. Carbon dioxide air exposure limits for employees and the general public have been established by a number of governmental health and industrial safety groups. Each of these standards of air concentrations is expressed in parts per million (ppm). *Table 1* is a listing of carbon dioxide air concentrations and related health effects and standards.

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings (SMACNA, 1998; Redlich, 1997; Rosenstock, 1996; OSHA, 1994; Gold, 1992; Burge et al., 1990; Norback, 1990). 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. Several sources indicate that indoor air problems *are significantly reduced* at 600 ppm or less of carbon dioxide (ACGIH, 1998; Bright et al.,

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1992; Hill, 1992; NIOSH, 1987). Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches.

Air levels for carbon dioxide that indicate that indoor air quality may be a problem have been established by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE). Above 1,000 ppm of carbon dioxide, ASHRAE recommends adjustment of the building's ventilation system (ASHRAE, 1989).

Carbon dioxide itself has no acute (short-term) health effects associated with low level exposure (below 5,000 ppm). The main effect of carbon dioxide involves its ability to displace oxygen for the air in a confined space. As oxygen is inhaled, carbon dioxide levels build up in the confined space, with a decrease in oxygen content in the available air. This displacement of oxygen makes carbon dioxide a simple asphyxiant. At carbon dioxide levels of 30,000 ppm, severe headaches, diffuse sweating, and labored breathing have been reported. No **chronic** health effects are reported at air levels below 5,000 ppm.

Air testing is one method to determine if carbon dioxide levels exceed the comfort levels recommended. If carbon dioxide levels are over 800-1,000 ppm, the MDPH recommends adjustment of the building's ventilation system. The Department recommends that corrective measures be taken at levels above 800 ppm of carbon dioxide in office buildings or schools. (Please note that carbon dioxide levels measured below 800 ppm may not decrease indoor air quality complaints). Sources of environmental pollutants indoors induce symptoms in exposed individuals regardless of the adequacy of the ventilation system. As an example, an idling bus

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outside a building may have minimal effect on carbon dioxide levels, but can be a source of carbon monoxide, particulates and odors via the ventilation system.

Therefore, the MDPH strategy of adequate ventilation coupled with pollutant source reduction/removal serves to improve indoor air quality in a building. Please note that each table included in the IAQ assessment lists BEHA comfort levels for carbon dioxide levels at the bottom (i.e. carbon dioxide levels between 600 ppm to 800 ppm are acceptable and <600 ppm is preferable). While carbon dioxide levels are important, focusing on these air measurements in isolation to all other recommendations is a misinterpretation of the recommendations made in these assessments.

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Table 1
Carbon Dioxide Air Level Standards

Carbon Dioxide Level	Health Effects	Standards or Use of Concentration	Reference
250-600 ppm	None	Concentrations in ambient air	Beard, R.R., 1982 NIOSH, 1987
600 ppm	None	Most indoor air complaints eliminated, used as reference for air exchange for protection of children	ACGIH, 1998; Bright et al., 1992; Hill, 1992; NIOSH 1987
800 ppm	None	Used as an indicator of ventilation inadequacy in schools and public buildings, used as reference for air exchange for protection of children	Bell, A. A., 2000; SMACNA, 1998; Redlich, 1997; Rosenstock, 1996; OSHA, 1994; Gold, 1992; Burge et al., 1990; Norback, 1990
1000 ppm	None	Used as an indicator of ventilation inadequacy concerning removal of odors from the interior of building.	ASHRAE, 1989
950-1300 ppm*	None	Used as an indicator of ventilation inadequacy concerning removal of odors from the interior of building.	ASHRAE, 1999
5000 ppm	No acute (short term) or chronic (long-term) health effects	Permissible Exposure Limit/Threshold Limit Value	ACGIH, 1999 OSHA, 1997
30,000 ppm	Severe headaches, diffuse sweating, and labored breathing	Short-term Exposure Limit	ACGIH, 1999 ACGIH. 1986

* outdoor carbon dioxide measurement +700 ppm

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References

ACGIH. 1999. Guide to Occupational Exposures-1999. American Conference of Governmental Industrial Hygienists, Cincinnati, OH.

ACGIH. 1998. Industrial Ventilation A Manual of Recommended Practice. 23rd Edition. American Conference of Governmental Industrial Hygienists. Cincinnati, OH.

ACGIH. 1986. Documentation of the Threshold Limit Values. American Conference of Governmental Industrial Hygienists. Cincinnati, OH.

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

ASHRAE. 1999. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-1999.

Beard, R.R. 1982. Chapter Fifty-two, Inorganic Compounds of Oxygen, Nitrogen, and Carbon. *Patty's Industrial Hygiene and Toxicology, Vol. IIc. 3rd ed.* Clayton, G. D. & Clayton, F. E., eds. John Wiley & Sons, New York, NY.

Bright, P.; Mader, M.; Carpenter, D.; and Hermon-Cruz, I.Z. 1992. Guideline for Indoor Air Surveys. Brooks Air Force Base, TX. Armstrong Laboratory, Occupational and Environmental Health Directorate. NTIS AL-TR-1992-0016.

Burge, H. and Hoyer, M. 1990. Focus On … Indoor Air Quality. Appl. Occup. Environ. Hyg. 5(2):88.

Gold, D. 1992. Indoor Air Pollution. Clinics in Chest Medicine. 13(2):224-225.

Hill, B.; Craft, B.; and Burkart, J. 1992. Carbon Dioxide, Particulates and Subjective Human Responses in Office Buildings without Histories of Indoor Air Quality Problems. Appl. Occup. Environ. Hyg. 7(2): 101-111.

NIOSH. 1987. Guidance for Indoor Air Quality Investigations. Cincinnati, OH. National Institute for Occupational Safety and Health, Hazards Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluation and Field Studies.

Norback, D.; Torgen, M.; and Edling, C. 1990. Volatile Organic Compounds, Respirable Dust, and Personal Factors Related to Prevalence and Incidence of Sick Building Syndrome in Primary Schools. British Journal of Industrial Medicine. 47:740.

OSHA. 1994. Occupational Safety and Health Administration. Indoor Air Quality (Proposed Regulation), Federal Register 59:15968-16039, (1994) Appendix A.

Appendix II

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.

Redlich, C.; Sparer, J.; and Cullen, M. 1997. Sick-building Syndrome. Lancet. 349:1016.

Rosenstock, L. 1996. NIOSH Testimony to the U.S. Department of Labor on Air Quality, Appl. Occup. Environ. Hyg. 11(12):1368.

SMACNA. 1998. Indoor Air Quality: A Systems Approach. 3rd ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc, Chantilly, VA.
National Association, Inc.