# MULTIDISCIPLINARY EVALUATION OF A PUBLIC HIGH SCHOOL

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## ABSTRACT
The Indoor Air Quality Committee of the Boston Society of Architects was invited to evaluate a large brick school building erected in 1963 to serve 1600 students. The investigation included a written questionnaire, evaluation of air using the ASTM E981 (modified) bioassay, fungal and bacterial testing, real time monitoring of carbon dioxide, carbon monoxide, respirable particulate, total volatile organic compounds, relative humidity and temperature. The survey and testing enumerated many potential causes for poor IAQ. The walkthrough included evaluations by a building envelope specialist, HVAC specialists, non-industrial indoor air quality investigators and filter use specialists. The reported human data, the animal bioassay data, the microbial data, real time monitoring and observations provided strong support for remediation actions.

## INDEX TERMS
Bioassay, Health Survey, Microbial Contamination, Building Envelope Defects, Ventilation Survey

## INTRODUCTION
On June 11, 2001 the Boston Society of Architects Committee on Indoor Air Quality project participated in a multidisciplinary indoor quality survey at a typical public high school in a low-income area of Eastern Massachusetts, USA. The investigation included a written survey of the school staff; a mouse bioassay which evaluated sensory and pulmonary irritation and neurological toxicity from room air samples; microbial sampling of carpet and air handler deposited dust; real time measuring of airborne contaminant parameters (carbon dioxide, carbon monoxide, respirable particulate, total volatile organic compounds, relative humidity and temperature); visual inspection of the building envelope; HVAC systems inspection; evaluation of chemicals used within the building and a review of maintenance practices within the building.

## TEST METHODS
Screening tests for acute toxic effects following exposure by the inhalation route (ASTM E981 modified) and the Functional Observational Battery were conducted at Anderson Laboratories, Inc., West Hartford, Vermont. Air samples were collected in Tedlar bags. Discrete air samples were collected for $CO_2$, CO, relative humidity and temperature with a Metrosonics IAQ Aq 5000 analyzer. A direct reading, respirable mass monitor (TSI) was

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utilized to collect discrete air samples for respirable suspended particulate over 120 second intervals. A direct reading Photovac photo ionization detector was used for measuring volatile organic compounds. The microbiological dust samples were collected with cassettes containing MCE filters and utilizing a vacuum pump. Samples were sent for culturing and evaluation to P&K Microbiology Services of Cherry Hill NJ.

## RESULTS

### Written Survey Summary

The schools 197 faculty and staff were given a written questionnaire regarding recent experience with 27 possible health symptoms. Of the 82 forms returned, 57 individuals linked their symptoms (headaches, irritation of eyes-nose-throat, cough, difficulty breathing, difficulty with concentration or memory, and/or unusual fatigue) to exposure to the building.

### Bioassay

Mice breathing air obtained from inside this school developed eye irritation, airflow decrease, and neurobehavioral abnormalities; outside air caused none of these effects. The health survey and air test results thus demonstrated that an IAQ problem existed.

### Microbial Data

Microbial results from the floor of the library indicated a high level of bacteria and a moderate level of fungi. It was recommended that the carpet be cleaned with high temperature steam and periodically vacuumed with a HEPA vacuum cleaner. This carpet was installed on a slab on grade and subject to moisture condensing from the air on to a cold surface. Although noise considerations are significant in libraries, this carpet requires frequent and high intensity maintenance to prevent microbial growth. It was recommended that non-porous flooring be considered.

The deposited dust in a unit ventilator (C18) had a high level of fungal spores and a moderate level of bacteria. The deposited dust in another unit ventilator had a moderate level of fungal spores and a low moderate level of bacteria. The dominant species of fungal spores was Cladosporium a common non-pathogenic species, but capable of causing allergic and irritant responses in sensitive individuals. The unit ventilator maintenance should include periodic cleaning/disinfecting.

### Real Time Air Monitoring

The real time monitoring of indoor air quality parameters indicated areas were chemical storage was inadequately exhausted (total volatile organic compounds readings), areas where supply and exhaust ventilation were inadequate (based on carbon dioxide levels) and where filter/ventilation adequacy was limited (based on carbon dioxide and respirable particulate readings). In some locations temperature was high enough to cause thermal discomfort. See Table 1 for guidelines and Table 2 for real time monitoring data.

### HVAC System Evaluation

Unit ventilators installed prior to 1998 have controls that typically provide outside air to an area based on temperature needs. Current building codes require constant outside air supplies. It was recommended that upgrades to unit ventilators be considered in order to provide minimum constant outside air supplies to classrooms. Several unit ventilators had been installed with no access to outside air. Roof top air intakes (passive) for interior classroom unit ventilator may not have had sufficient power to provide adequate outside air from the

roof. Resistance from extended ductwork might have exceeded the capacity of the unit ventilator fans. Inspection of the unit ventilator in Room C-18 revealed friable fiberglass on the door panel, a dirty filter and a large accumulation of dust. Microbial analysis of the unit ventilator dust indicated moderate to high levels of bacteria and fungi. The unit ventilator in Room A-18 had no filter and a microbial analysis of the deposited dust indicated a moderate fungal and low bacteria level. It was recommended that improved maintenance of the unit ventilators include cleaning/disinfection of surfaces, more frequent filter changes in areas where they are used and have a history of dirt accumulation.

A number of exhaust fans were not operating. This included the library and F4 wing. Some exhaust fans were reported not to be utilized at this time in A wing. Some of the bird screens (6) were missing from the exhaust fans. There was little or no exhaust for high pollutant sources such as photographic darkroom and jewelry crafts.

A review of HVAC documents indicated that incomplete reports were provided for recent HVAC improvement including balancing reports and with maintenance records.

HVAC filters were MERV1-4 in unit ventilators and either MERV 6 in the roof top units or MERV 1-4 in larger air handlers. Some air handlers had no filters. Several filters had been installed incorrectly with pleats in a horizontal direction and one had been installed backwards. The recommendations included training in filter efficiency, proper installation, timing of filter changes and appropriate record keeping.

**Operation, maintenance and design issues**

- MSD sheets documented that many products used had health hazard ratings of 3.
- Solvent based dry erase markers were used in classrooms
- Improper storage of hazardous chemicals was evident in various shops.
- Welding activities in a room without exhaust ventilation.
- Jewelry craft work using solder and abrasives without adequate ventilation.
- A grinder did not have exhaust ventilation.
- Wood dust collector exhausted within the classroom rather than outside.
- Lab sink appeared dry, allowing sewer gases to enter the classroom.
- Air fresheners used to masked unit ventilator supply air
- Numerous defects in the integrity of the roof and walls allowed water penetration and mold growth. Site grading fed water toward the foundation and crawl space. This produced pools of water in the stage prop storage room.
- A portion of the roof that had a PVC membrane also had some asphalt patching which are not compatible and likely to create leaks.
- Roof drainage was inadequate with evidence of ponding near air intakes. Roof pitch should be ¼" per 1' per the building code.
- External brickwork had cracks from settling. Inadequate gutters on a curved roof caused water damage to brick work. Repointing of brickwork and new joint sealants were recommended where needed. A lack of expansion joints was noted and cited as a cause of brick cracking.
- The swimming pool area had inadequate ventilation and may have had structural damage. Wall to deck joints were not air tight in some cases causing stack air effect loss and energy loss. These joints should be sealed.
- Exterior smoke release panels for the roof were not sealed and a source of water entry into the Auditorium.

- Standing water was observed in "dry wells" which provide access to pipe tunnels from outside the building. This standing water had pathways leading to pipes supplying the unit ventilators thus allowing moisture to enter the building.
- School Bus drop off locations were located near unit ventilator air intakes. On the day of the survey, wind direction and speed appeared adequate to prevent the entrainment of vehicle emissions. However this will depend on weather conditions and efforts to minimize bus idling and/or moving the drop off/pick up areas away from air intakes is recommended.
- Maintenance of the dry well in front of the unit ventilator air intakes is needed (plants observed growing in the drywells).
- Upholstered furniture in several locations released dust clouds when disturbed. It is recommended that upholstered furniture be periodically vacuumed in order to avoid dust mite allergens and microbial spores.
- Room C-19 had a fur-bearing animal in the classroom. It is recommended that if fur-bearing animals are required for learning purposes they be housed somewhere beside classroom spaces. This is to avoid impacting students with allergies, attracting insects into classrooms and microbial growth related to bedding and waste.

## TEST RESULTS SUMMARIES

**Table 2.** Indoor Air Quality Monitoring Results

| Location | Occupant | Respirable Suspended Particulate ($ug/m^3$) | Carbon Dioxide (ppm) | Carbon Monoxide (ppm) | TVOC (ppm) | Relative Humidity (%) | Temp ($^oF$) |
|---|---|---|---|---|---|---|---|
| Cafeteria | 300-400 | 170 | 1778 | 0 | 0.6 | 55 | 80 |
| Room 112 | 21 | 0 | 1340 | 0 | 0.0 | 54 | 74 |
| Room K-31 | 21 | 50 | 2099 | 0 | 0.0 | 53 | 77 |
| Room A-6 | 17 | 0 | 871 | 0 | 0.7 | 52 | 74 |
| Room M-10 | 24 | 30 | 1189 | 0 | 0.0 | 52 | 77 |
| Room L-5 | 11 | 70 | 1100 | 0 | 0.0 | 52 | 77 |
| Room A-1 | 2 | 10 | 979 | 0 | 1.3 | 51 | 74 |
| Nurse's Office | 4 | 90 | 1374 | 0 | 0.0 | 51 | 77 |
| Faculty Library | 3 | 0 | 606 | 0 | 1.8 | 50 | 79 |
| Room A-2 | 0 | 10 | 979 | 0 | 1.0 | 50 | 75 |
| Room A-5 | 14 | 10 | 838 | 0 | 0.9 | 50 | 75 |
| Room A-18 | 14 | 20 | 822 | 0 | 1.9 | 49 | 78 |
| Print Shop | 0 | 0 | 664 | 0 | 0.7-3.0 | 49 | 73 |
| Room A-11 | 9 | 10 | 681 | 0 | 0.6 | 49 | 77 |
| Biology 118 | 12 | 20 | 1148 | 0 | 0.0 | 49 | 76 |
| Room 209 | 15 | 70 | 1285 | 0 | 0.0 | 48 | 80 |
| Room 228 | 18 | 30 | 1110 | 0 | 0.0 | 47 | 80 |
| Room A-13 | 17 | 140 | 802 | 0 | 14.7 | 46 | 76 |

**Table 3.** Microbiological Monitoring Results

| Location | Microbiological Type | Sample Type | Organisms Identified | Sample Result |
|---|---|---|---|---|
| C-18 Unit Ventilator Dust | Fungi | Dust | Alternaria alternata (20,000)<br>Cladosporium (760,000)<br>Epicoccum nigrum (40,000)<br>Mucor plumbeus (20,000)<br>Penicillium (40,000) | 920,000 CFU/g |
| | Bacteria | Dust | Bacillus (190,000)<br>gram negative bacteria (30,000)<br>Pseudomonas sp. Non aeruginosa (20,000)<br>Stenotrophomonas maltophilia (30,000) | 270,000 CFU/g |
| Library Carpet | Fungi | Dust | Alternaria alternata (8,276)<br>Aspergillus fumigatus (690)<br>Aureobasidium pullulans (1,379)<br>Cladosporium (120,000) | 137,931 CFU/g |
| | Bacteria | Dust | Bacillus (84,828)<br>gram negative bacteria and others (141,379)<br>Methylobacterium (367,586)<br>Micrococcus roseus (84,828)<br>Shewanella putrefaciens (565,517)<br>Staphylococcus (84,828) | 1,357,241 CFU/g |

## DISCUSSION

The use of this multidisciplinary team allowed both (1) documentation that there was an IAQ problem causing adverse health effects in at least a quarter of the staff, and (2) identification of many of the probable causes of the poor IAQ and an extensive action item list to assist the school administration handling these issues.

## CONCLUSION AND IMPLICATIONS

Major structural, operational and design changes are needed at the school to achieve a building that will have minimum air quality issues.

## AKNOWLEDGEMENTS

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## REFERENCE

Boston Society of Architects Reports and References from the various participants are available from the Indoor Air Quality Committee of 52 Broad Street, Boston, MA 02109-4301