INDOOR AIR QUALITY ASSESSMENT

Massachusetts Emergency Management Agency
Region 3 and 4 Office
1002 Suffield Street
Agawam, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health
Indoor Air Quality Program

April 2010

Background/Introduction

At the request of Martha Goldsmith, Director, Office of Leasing and State Office Planning, Division of Capital Asset Management (DCAM), the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health (BEH) provided assistance and consultation regarding indoor air quality concerns at the Massachusetts Emergency Management Agency (MEMA) Region 3 and 4 office located at 1002 Suffield Street, Agawam, Massachusetts. The request was prompted by reports of vehicle exhaust odors within the workspace. On December 23, 2009, a visit to conduct an assessment was made to the MEMA office by Mike Feeney, Director, and Lisa Hébert, Environmental Analyst/Regional Inspector in BEH's Indoor Air Quality (IAQ) Program. BEH staff were accompanied by Bruce Tebo, Senior Leasing Project Manager, DCAM.

The building is a one story brick building originally constructed in the 1950s as a tool manufacturing facility. The town of Agawam subsequently acquired the facility, and converted it for use as a public works garage, where snow plows and other vehicles are housed and repaired. The front of the building was reconfigured into office space, and presently houses the western regional MEMA office. Offices are located on the east side of the building, while the remainder of the building contains the town of Agawam's Department of Public Works (DPW) offices and garage (Picture 1). BEH staff were unable to access the DPW; therefore IAQ testing was conducted in MEMA areas only. Windows throughout the MEMA office do not open.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 7565. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for ultrafine particulates was conducted with a P-Trak Ultrafine Particle Counter (UPC) Model 8525. BEH staff also performed visual inspection of building materials for water damage and/or microbial growth.

Results

The MEMA office has an employee population of approximately 9 and can be visited by up to 100 individuals during training and/or incident response. Air sampling measurements were taken under normal operating conditions and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in 4 of 13 areas at the time of the assessment, indicating adequate air exchange in the majority of areas surveyed. However, it is also important to note that several rooms were empty or sparsely populated, which can greatly reduce carbon dioxide levels. Carbon dioxide levels would be expected to increase with full occupancy.

Fresh air is supplied to each room by means of ducted air diffusers. Fresh air is drawn by a duct on the roof to an air handling unit (AHU) located in a mechanical room, air is returned via ducted exhaust vents (Pictures 2 and 3). BEH staff were informed that the HVAC system is not always in operation while the MEMA offices are occupied. BEH staff could not confirm this fact as they did not have access to the roof during the assessment.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of building occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires a minimum ventilation rate of 20 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 MDPH 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, consult Appendix A.

Temperature measurements in the building ranged from 70° F to 74° F, which were within the MDPH recommended range (Table 1). The MDPH recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity measured in the building ranged from 15 to 24 percent at the time of the assessment, which was below the MDPH recommended comfort range (Table 1). The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

BEH staff examined the exterior of the building to identify breaches in the building envelope and/or other issues that could provide a source of water penetration. Several potential sources were identified:

- A number of holes were observed in exterior brick (Picture 4).
- A cracked pane of glass was seen in a window (Picture 5).
- Downspouts terminate in close proximity to the building. In addition to causing erosion of soil along the foundation, moisture adjacent to the building can eventually penetrate

the foundation wall. Additionally, a condition of high moisture at the base of a building encourages plant growth in the crevices between the foundation and the pavement. Over time, the roots from these weeds can compromise the building's foundation as well as the integrity of the pavement adjacent to the building. The weeds themselves can also provide harborage for insects and rodents if allowed to proliferate.

The aforementioned conditions represent potential water penetration sources. Over time, these conditions can undermine the integrity of the building envelope and provide a means of water entry into the building via capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001). In addition, these breaches may provide a means for pests/rodents to enter the building.

Inside the building, one room contained a water damaged ceiling tile that can indicate a leak from either the roof or plumbing system. Water damaged tiles can also provide a medium for mold growth and should be replaced after a water leak is discovered and repaired.

The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If not dried within this time frame, mold growth may occur. Once mold has colonized porous materials, they are difficult to clean and should be removed and discarded.

Other IAQ Evaluations

Vehicle Exhaust

BEH detected vehicle exhaust odors upon entering the MEMA office space. Under normal operating conditions, several sources of environmental pollutants can be present in a maintenance garage. These sources of pollutants can include:

- Vehicle exhaust containing carbon monoxide and soot;
- Vapors from diesel fuel, motor oil and other vehicle liquids which contain volatile organic compounds; and
- Rubber odors from vehicle tires.

Of particular importance is vehicle exhaust. The process of combustion produces a number of pollutants, depending on the composition of the material. In general, common combustion emissions can include carbon monoxide, carbon dioxide, water vapor and smoke. In order to determine the source of the vehicle exhaust entering the MEMA offices, air monitoring for carbon monoxide, airborne particles and ultrafine particles was conducted, with particular attention to locations that share a common wall with the garage, such as the emergency operations center (EOC).

Carbon Monoxide

Exposure to carbon monoxide can produce immediate and acute health effects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems

(ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2006). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2006).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. On the day of the assessment, outdoor carbon monoxide concentrations were 0.4 ppm (Table 1). Carbon monoxide levels measured in MEMA's occupied space ranged from ND to 1.2 ppm. Operation of vehicles within the maintenance bays of the DPW is believed to be responsible for this increase over background levels.

Particulate Matter (PM2.5)

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2006). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA established a more protective standard for fine airborne particles. This more stringent PM2.5 standard requires outdoor air particle levels be maintained below 35 $\mu g/m^3$ over a 24-hour average (US EPA, 2006). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations the day of the assessment were measured at 20 $\mu g/m^3$. PM2.5 levels measured inside the building ranged from 17 to 49 $\mu g/m^3$ (Table 1), which were equal to or above the NAAQS PM2.5 level of 35 $\mu g/m^3$ in three of thirteen areas surveyed. Of note is that each location with PM2.5 measurements above or equal to 35 $\mu g/m^3$ shares a common wall with the garage, which would indicate a possible pathway between the MEMA office space and the garage. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in the indoor environment can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during operation of fossil fuel motors, the operation of fan belts in the HVAC system, use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Ultrafine Particulates

Air monitoring for airborne ultrafine particulates was also conducted. An ultrafine particle has a diameter of 0.02 micrometers (μm) to 1 μm that is produced by combustion of fuels, cutting processes and other operations that aerosolize particles. This type of air monitor is useful as a screening device, in that it can be used to track sources of airborne pollutants by counting the actual number of airborne particles. The source of particles can be identified by moving the ultrafine particle counter (UPC) through a building towards the highest measured concentration of airborne particles. Measured levels of particles/cc of air increases as the UPC is moved closer to the source of particle production. While this equipment can ascertain whether unusual sources of ultrafine particles exist in a building or that particles are penetrating through spaces in doors or walls, it cannot be used to quantify whether the NAAQS PM_{10} or $PM_{2.5}$ standard was exceeded. The primary purpose of these tests was to identify and reduce/prevent pollutant pathways. Air monitoring for ultrafine particles was conducted around the shared wall with the garage as well as within each room in the MEMA office space.

Outdoor ultrafine particulate concentrations were measured at 7,000 pt/cc. Ultrafine particulate levels measured inside the building ranged from 7,000 to 22,000 pt/cc at floor level. The highest reading was found in the EOC. The EOC contains a raised floor (called a plenum floor system) that is used typically in rooms with computers to aid in the installation of electrical outlets and other cables. The EOC has a number of electrical outlets installed in the floor (Picture 6). Each outlet housing has a number of holes which are open to the floor plenum (Picture 7). The highest ultrafine particle counts were obtained at the outlet openings, which indicates that the most likely source of vehicle exhaust odor is garage pollutants entering the floor plenum through breaches that exist in the shared wall between the EOC and garage. BEH staff also removed ceiling tiles in the EOC and detected a cold draft of air emanating from the ceiling plenum, which indicates that the ceiling plenum is pressurized. This is unusual since ceiling plenums are usually depressurized (if part of the HVAC system) or neutral pressure to occupied space. This draft indicates cold air penetration through the shared wall above the ceiling. This observation is supported by the finding of elevated ultrafine particle readings in the ceiling plenum (Table 1). Areas with higher ultrafine particle counts also had higher levels of carbon monoxide.

TVOCs

Indoor air concentrations can be greatly impacted by the use of products containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to identify materials that can potentially increase indoor VOC concentrations, BEH staff examined rooms for products containing these respiratory irritants.

Some rooms 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), which can be irritating to the eyes, nose and throat (Sanford, 1999).

A plug-in air deodorizer was observed in the women's rest room. Air deodorizers contain chemicals that can be irritating to the eyes, nose and throat of sensitive individuals. Many air fresheners contain 1,4-dichlorobenzene, a VOC which may cause reductions in lung function (NIH, 2006). Furthermore, deodorizing agents do not remove materials causing odors, but rather mask odors that may be present in the area.

Conclusions/Recommendations

In view of the findings at the time of the assessment, the following recommendations are made:

1. In order to eliminate products of combustion from entering MEMA occupied office

space, all breaches in the shared wall (e.g., utility holes, light switch holes, cracks, seams or crevices) must be identified and sealed on both sides to render the shared wall airtight.

2. In order to draw combustion products away from MEMA offices, the DPW garage should install and/or operate (if present) local exhaust ventilation.
3. Operate all ventilation systems throughout the building continuously during periods of occupancy.
4. Ensure restrooms have operable local exhaust ventilation vented to the outside of the building. Inspect motors and belts for proper function, and perform repairs as necessary.
5. 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).
6. Monitor areas of the building for roof/plumbing leaks, make repairs and change water damaged ceiling tiles as necessary.
7. Repair/replace broken window panes.
8. Seal holes/breaches in exterior brickwork.
9. Extend downspouts to drain water away from the foundation.
10. Remove plants/vegetation from along the foundation.
11. Refrain from using plug-in air fresheners or other air deodorizers.
12. Refer to resource manual and other related indoor air quality documents located on the

MDPH's website for further building-wide evaluations and advice on maintaining public buildings. These documents are available at: http://mass.gov/dph/iaq.

References

ACGIH. 1989. Guidelines for the Assessment of Bioaerosols in the Indoor Environment. 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

BOCA. 1993. The BOCA National Mechanical Code/1993. 8th ed. Building Officials and Code Administrators International, Inc., Country Club Hill, IL.

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.

MDPH. 1997. Requirements to Maintain Air Quality in Indoor Skating Rinks (State Sanitary Code, Chapter XI). 105 CMR 675.000. Massachusetts Department of Public Health, Boston, MA.

NIH. 2006. Chemical in Many Air Fresheners May Reduce Lung Function. NIH News. National Institute of Health. July 27, 2006. http://www.nih.gov/news/pr/jul2006/niehs-27.htm.

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.

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.

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

US EPA. 2006. National Ambient Air Quality Standards (NAAQS). US Environmental Protection Agency, Office of Air Quality Planning and Standards, Washington, DC. http://www.epa.gov/air/criteria.html.

Picture 1

Aerial View of MEMA Building, Shaded Area Indicated Approximate Location of Town of Agawam Offices and Garage

Picture 2

Fresh Air Supply

Picture 3

Return Vent

Picture 4

Exterior Wall Holes

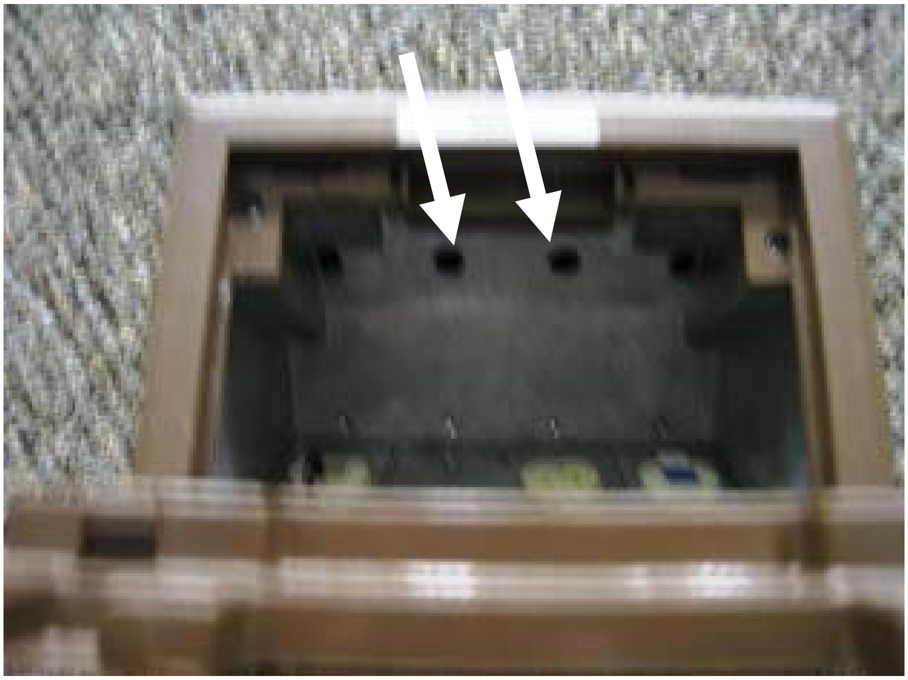
Picture 5

Broken Window Panes

Picture 6

Electrical Outlets in False Floor

Picture 7



Holes in Electrical Outlet Open to Floor Plenum

Location: MEMA Region 3 & 4 Office **Indoor Air Results**

Address: 1002 Suffield Street - Agawam **Table 1** **Date: 12/23/09**

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	PM2.5 ($\mu g/m^3$)	Ultrafine Particles (pt/cc)-	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background:	-	73	15	620	0.4	20	7,000	N	Y	Y	DC
EOC	1	70	19	837	1.2	19	22,000 at floor	N	Y	Y	DO, DEM, 9,000 at breathing level, 14,000 in plenum above EOC
DPW Hall	0	71	17	671	0.8	40	13,000	N	Y	Y	
Women's Room	0	71	17	612	1.1	49	17,000	N	Y	Y	DC, plug-in
Men's Room	0	70	17	672	0.5	35	13,000	N	Y	Y	DC
Private Office off EOC	0	71	17	691	ND	26	9,000	N	Y	Y	DC
Lunch Room	9	73	21	917	ND	21	8,000	N	Y	Y	DO
Training Coordinator	0	73	16	691	ND	21	8,000	N	Y	Y	DO, DEM

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

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

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

design = proximity to door
DO = door open
FC = food container
GW = gypsum wallboard
MT = missing ceiling tile
NC = non-carpeted

ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings
sci. chem. = science chemicals

TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WD = water-damaged
WP = wall plaster

Comfort Guidelines

Carbon Dioxide:	< 600 ppm = preferred	Temperature:	70 - 78 °F
	600 - 800 ppm = acceptable	Relative Humidity:	40 - 60%
	> 800 ppm = indicative of ventilation problems	Particle matter 2.5	< 35 ug/m^3

Location: MEMA Region 3 & 4 Office **Indoor Air Results**

Address: 1002 Suffield Street – Agawam, MA **Table 1 (continued)** **Date: 12/23/09**

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	PM2.5 (μg/m³)	Ultrafine Particles (pt/cc)-	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Training Room	0	73	15	644	ND	18	8,000	N	Y	Y	DO, WD CT
Front Lobby	0	73	15	620	0.4	20	7,000	N	N	Y	DC
Admin. Asst.	0	73	15	665	0.1	17	7,000	N	Y	Y	DO
Open Room with cubicles	0	73	15	640	ND	21	8,000	N	Y	Y	DO
Office – Bruce Augusti	0	74	16	900	0.1	23	7,000	N	Y	Y	DO
Office – Regional Manager	3	72	24	1287	0.6	21		N	Y	Y	DO

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

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

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

design = proximity to door
DO = door open
FC = food container
GW = gypsum wallboard
MT = missing ceiling tile
NC = non-carpeted

ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings
sci. chem. = science chemicals

TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WD = water-damaged
WP = wall plaster

Comfort Guidelines

Carbon Dioxide:	< 600 ppm = preferred	Temperature:	70 - 78 °F
	600 - 800 ppm = acceptable	Relative Humidity:	40 - 60%
	> 800 ppm = indicative of ventilation problems	Particle matter 2.5	< 35 ug/m³