INDOOR AIR QUALITY ASSESSMENT

Department of Children and Families
63 Fountain Street
Framingham, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health
Indoor Air Quality Program
April 2010

Background/Introduction

At the request of the Doug Shatkin, Human Resources Director for the Massachusetts Executive Office of Health and Human Services (EOHHS), the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health (BEH) provided assistance and consultation regarding indoor air quality concerns at the offices of the Massachusetts Department of Children and Families (DCF) located in the Kenwood Centre Building, 63 Fountain Street, Framingham, Massachusetts. The request was prompted by odor complaints and concerns associated with mold.

On January 8, 2010, a visit to conduct an indoor air quality assessment was made to the DCF by Cory Holmes, Environmental Analyst/Indoor Air Quality Inspector in BEH's Indoor Air Quality (IAQ) Program. During the assessment, Mr. Holmes was accompanied by Barry Kroening, Administrative Manager, DCF, and John Lopas, Construction Supervisor, Kenwood Organization, Inc.

The DCF is on the top/fifth floor of a former dye manufacturing facility that was built in 1910. The fifth floor was renovated to house the DCF, who have occupied their space since 1992. Windows and carpeting in hallways and common areas have reportedly been replaced over the last several years. In addition, repair of chronic roof leaks have reportedly been attempted. The other floors of the building are occupied by a child care center and gym/fitness facility, as well as other offices not occupied by DCF.

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. BEH staff also performed visual inspection of building materials for water damage and/or microbial growth. Moisture content of porous building materials was measured with a Delmhorst, BD-2100 Model, Moisture Detector equipped with a Delmhorst Standard Probe.

Results

The DCF had an employee population of approximately 80 and can be visited by up to 40 individuals daily. Tests 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 all areas surveyed at the time of the assessment, indicating poor air exchange. It is important to note that several areas were empty or sparsely populated at the time of testing, which should have resulted in reduced carbon dioxide levels. Carbon dioxide levels would be expected to increase with increased occupancy.

The ventilation system at the DCF consists of ceiling-mounted heat pumps located above the ceiling tile system (Picture 1). The system does not appear to be designed to provide either mechanical fresh air supply or exhaust ventilation but rather recycles existing air. Heated or cooled air is supplied to occupied areas via ceiling-mounted air diffusers (Pictures 2 and 3). Air is filtered and returned to the heat pumps by ducted ceiling-mounted return vents (Picture 4).

With a lack of fresh air supply and/or exhaust ventilation, stale air and associated interior pollutants will remain inside the building and be continuously re-circulated, which can lead to air quality/comfort complaints.

The system is controlled by digital wall-mounted thermostats (Picture 5). Thermostats have fan settings of “on” and “automatic”. At the time of the MDPH assessment, the thermostats were set to the “auto” setting. The “automatic” setting on the thermostat activates the HVAC system at a preset temperature. Once the preset temperature is reached, the HVAC system is deactivated, whereas the “on” setting provides *continuous* airflow/filtration, which is recommended by the MDPH. Some thermostats were older and did not appear to have an obvious fan-control (Picture 6). Without a mechanical means to provide air exchange, the only means to provide fresh air and remove pollutants from the indoor environment would be to open windows.

The Massachusetts Building Code requires that room have minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or 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 the day of the assessment ranged from 70° F to 76° F, which were within the MDPH recommended range in all areas surveyed (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. ***Although temperatures were within the MDPH recommended temperature range during the assessment, occupants expressed temperature control complaints in the conference room which shares a thermostat with the computer network/IT room. It is likely that the heat generated from IT/computer equipment will raise the thermostat and create discomfort in the conference room. These areas should be on separate units or themostats to provide better temperature/comfort control.***

The relative humidity measured in the building ranged from 22 to 33 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

As mentioned previously, the DCF has experienced chronic leaks over the years. In an effort to stem leaks the rear portion of the roof was repaired, which has appeared to be successful. However, several areas continue to have periodic leaks along the roof/window junction (Pictures 7 and 8), which may be related to window "headers" rather than roof leaks. It was reported by Mr. Lopas that replacement windows were smaller that the original windows. To fit properly, a header is installed at the top of the window frame to take up space (Picture 9). It is likely that water is infiltrating through failed sealant around the header.

Water damaged ceiling tiles were observed in a number of areas, which indicate current/historic plumbing or other building envelope leaks (Table 1). Water damaged ceiling tiles can provide a source of mold and should be replaced after a water leak is discovered and repaired.

BEH staff examined areas that had been water damaged previously. At the time of the inspection, all areas appeared dry and no visible mold growth and/or associated odors were observed/detected. MDPH staff also conducted moisture testing of building materials (e.g., wallboard, ceiling tiles, carpeting). Materials with increased moisture content *over normal* concentrations may indicate the possible presence of mold growth. All materials tested were found to have low (i.e., normal) moisture content (Table 1). Moisture content of materials measured is a real-time measurement of the conditions present at the time of the assessment.

As indicated previously, odor complaints were one of the issues that prompted the assessment. According to Mr. Kroening and DCF staff, musty/mold-like odors were reported in several areas near the rear quadrant of the 5th floor. It was suspected that the odors may have been associated with operation of the HVAC system, particulary during the change over from cooling to heating. A visual inspection of the heat pump that services this portion of the building was conducted to determine whether condensation was accumulating. Since the heating, ventilating and air-conditioning (HVAC) system provides air conditioning, each unit with cooling coils is attached to a PVC pipe system that drains condensate. Drainage for the heat pump in this area is provided by a clear plastic flexible hose. Each hose is looped in a manner to create a trap to prevent sewer odors from backing up into the heat pumps. A trap uses drainage water to create a liquid seal that prevents sewer gas odor from backing up the line. The trap system works while the heat pump is draining condensation during air-conditioning operation. During the heating season, these traps dry out because no condensation drains from the heat pump. Standing water in heat pumps can serve as a growth medium for mold.

It appears that the interior of the flexible hose is coated with a heavy deposition of scale and debris, which can also provide a source of microbial growth and/or foul odors (Picture 10). As the heat pump operates, negative pressure is created which can draw air from the drain system through these hoses and into the unit. This can be a means for microbial growth and/or odors to be drawn into the unit and be distributed by the HVAC system. At the time of the assessment BEH staff recommended that the tubing be replaced. In subsequent correspondence with Mr. Kroening, it was reported that the tubing for this unit, as well as another, was replaced.

A green algae/mold growth was observed in the metal window tray in interview room 2 (Picture 11). Although metal is not a good mold growth medium, dirt, dust and debris that builds up in the trays can become moistened and provide a source for mold growth. In subsequent correspondence with Mr. Kroening, it was reported that the trays were being cleaned.

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/discarded.

Other IAQ Evaluations

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor, and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the indoor environment, BEH staff obtained measurements for carbon monoxide and PM2.5.

Carbon Monoxide

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide 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. Outdoor carbon monoxide concentrations were non-detect (ND) the day of the assessment (Tables 1). No measureable levels of carbon monoxide were detected in the building during the assessment (Table 1).

Particulate Matter

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 6 $\mu g/m^3$. PM2.5 levels measured inside the building ranged from 5 to 14 $\mu g/m^3$ (Table 1). Indoor PM 2.5 levels were below the NAAQS PM2.5 level of 35 $\mu g/m^3$ during the assessment. 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 indoors can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to: particles generated during the operation of fan belts in the HVAC system; cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner; and, heavy foot traffic indoors.

Other Conditions

Other conditions that can affect indoor air quality were observed during the assessment. Air handling equipment (e.g., HVAC units, heat pumps) is normally equipped with filters that strain particulates from airflow. The filters in heat pumps at the DCF are installed within the return vent frame and provide minimal filtration (Picture 4). 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, 2000; MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced through increased resistance, a condition known as 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 more efficient filters.

Restrooms are equipped with mechanical exhaust vents (Picture 12). The vents were not drawing air at the time of the assessment. BEH staff removed ceiling tiles to determine if the vents were properly vented and found that the ductwork was of extreme length and folding back upon itself (Picture 13). Further, it could not be determined if these vents were ducted to the exterior of the building. Exhaust ventilation is necessary in restrooms to remove excess moisture and to prevent odors from penetrating into adjacent areas.

Finally, large spaces were observed beneath stairwell doors (Picture 14). Spaces beneath doors can serve as sources of drafts and serve as pathways for insects, rodents and other pests into the occupied space.

Conclusions/Recommendations

The conditions related to indoor air quality problems at the DCF raise a number of issues. The general building conditions, maintenance, work hygiene practices and the condition/configuration of HVAC equipment, if considered individually, present conditions that could impact indoor air quality. When combined, these conditions can serve to further impact indoor air quality. Some of these issues can be remedied by actions of building occupants.

Other remediation efforts will require alteration to the building structure and equipment. For these reasons, a two-phase approach is required for remediation. The first consists of **short-term** measures to improve air quality and the second consists of **long-term** measures that will require planning and resources to adequately address the overall indoor air quality concerns.

Short-Term Recommendations

1. Consider setting digital thermostats for the HVAC system in the fan “on" mode (as opposed to the fan “auto” setting) to supplement the use of windows and provide continuous air circulation and filtration.
2. Consider replacing older model thermostats with digital thermostats.
3. Provide air exchange by using openable windows to control for comfort. Care should be taken to ensure windows are properly closed as needed to avoid the freezing of pipes and potential flooding.
4. Increase the dust-spot efficiency of HVAC filters. Prior to any increase of filtration, each piece of air handling equipment should be evaluated by a ventilation engineer as to whether it can maintain function with more efficient filters.
5. Change filters as per manufacturer’s instructions or more frequently if needed.
6. ***Ensure that restroom exhaust ventilation is operating and ducted to the outside of the building.***
7. 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).

8. Ensure all roof leaks are repaired, and replace water damaged ceiling tiles. Examine the area above and around water-damaged areas for mold growth. Disinfect areas with an appropriate antimicrobial as needed.
9. Seal seams/spaces around window headers to prevent further moisture infiltration.
10. Discard plastic tubing connecting the condensation drains to the cooling units. Examine flexible hosing for mold growth during routine changing of filters. Replace or disinfect this tubing with an appropriate antimicrobial prior to the air-conditioning season on a routine basis.
11. Clean window trays on a regular schedule.
12. Install weather-stripping/door sweeps beneath stairwell doors to prevent drafts and pest entry.
13. 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 indoor environmental conditions in public buildings. These documents are available at: http://mass.gov/dph/iaq.

Long-Term Recommendations

1. Contact an HVAC engineering firm to evaluate the HVAC system for retrofitting fresh air intake and exhaust to increase air exchange and removal environmental pollutants from the building.
2. Work with an HVAC firm to the modify system in IT/Family Meeting Room to control comfort. Consider separate thermostats or units. Consider installing a spot-cooling AC unit in the IT room.

References

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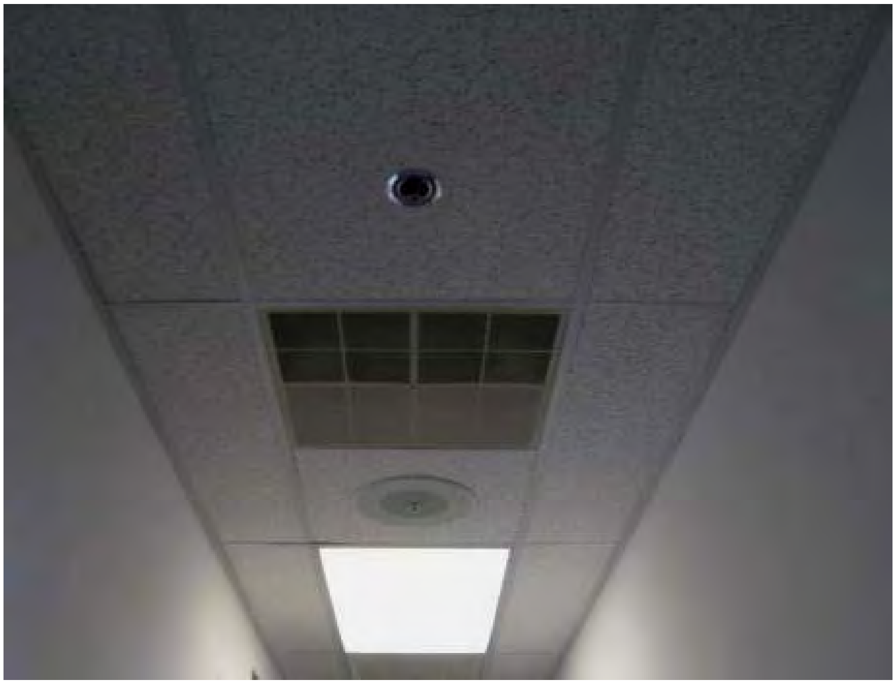
Picture 1

Heat Pump Located above Ceiling Tile System

Picture 2

Ceiling-Mounted Supply Diffuser

Picture 3

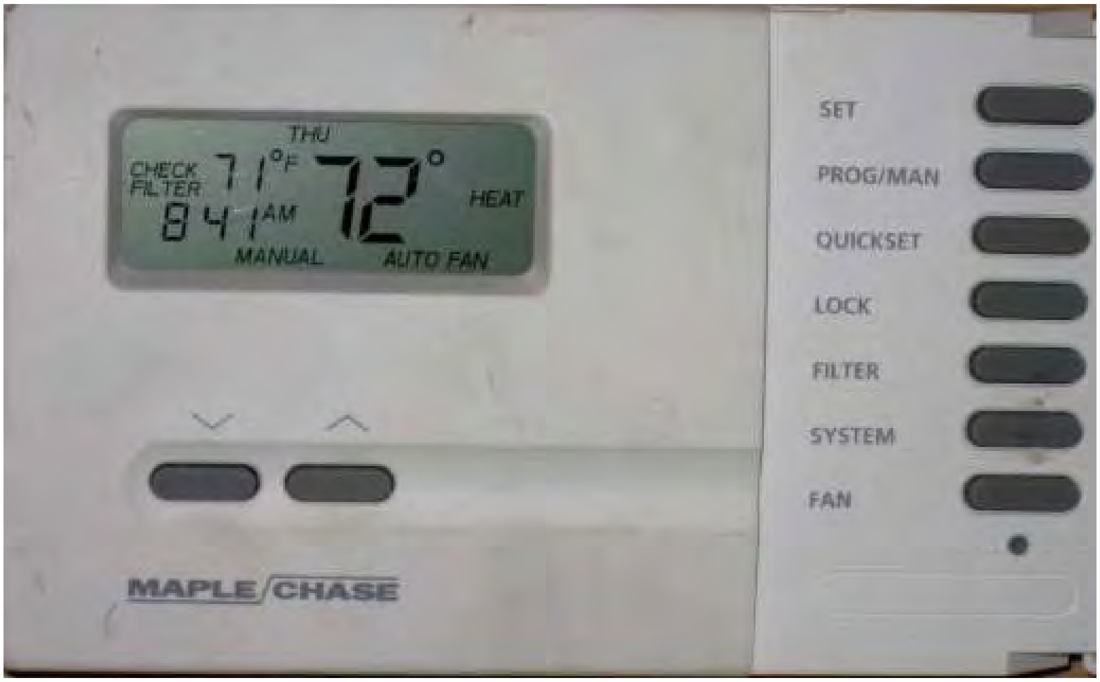


Ceiling-Mounted Supply Diffuser

Picture 4

Ceiling-Mounted Return Vent, Note Filter

Picture 5



Digital Thermostat, Note Fan Button (Lower Left) and Display of Fan in "Auto" Position

Picture 6

Older Model Non-Digital Thermostat

Picture 7

Water Damaged Ceiling Tiles along Top of Windows, Also Note Stain Down Side of Wall

Picture 8

Water Damaged Ceiling Tiles along Top of Windows in Office

Picture 9

Window "Header"

Picture 10

Clear Plastic Heat Pump Condensation Tube, Note Tube Should be Clear in Appearance

Picture 11

Algae/Mold Growth in Window Tray

Picture 12

Restroom Exhaust Vent

Picture 13

Flexible Ductwork for Restroom Exhaust Vent above Ceiling Plenum

Picture 14

Spaces under Stairwell Door

Location: Framingham DCF **Indoor Air Results**

Address: 63 Fountain Street, Framingham, MA **Table 1** **Date: 1/8/2010**

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	PM2.5 ($\mu g/m^3$)	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
background		< 32	28	345	ND	6				Cold, snow flurries, cloudy
Nardine	0	70	28	843	ND	5	Y	Y	Y	
Rando	0	72	26	1003	ND	7	Y	Y	Y	WD CT along windows-dry/low moisture, active leaks reported
Clerical Unit/Visiting Staff	1	73	25	941	ND	6	N	Y	Y	
Teaming Unit	4	74	25	1074	ND	6	N	Y	Y	Periodic leaks reported along windows
McMahon	1	75	25	1134	ND	8	Y	Y	Y	
IT Room	0	76	25	1206	ND	9	N	Y	Y	Shares HVAC unit with Family Mtg Room-temp control issues
Shearer	0	76	22	1151	ND	7	Y	Y	Y	
Adoption Unit	2	75	26	1252	ND	7	Y	Y	Y	

ppm = parts per million
$\mu g/m^3$ = micrograms per cubic meter
ND = non detect
UV = univent

AC = air conditioner
aqua. = aquarium
CD = chalk dust
CT = ceiling tile

DEM = dry erase materials
DO = door open
PC = photocopier
PF = personal fan

TB = tennis balls
terra. = terrarium
WD = water-damaged
GW = gypsum wallboard

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%
Particle matter 2.5 < 35 ug/m^3

Location: Framingham DCF **Indoor Air Results**

Address: 63 Fountain Street, Framingham, MA **Date: 1/8/2010**

Table 1 (continued)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	PM2.5 ($\mu g/m^3$)	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Ongoing D	4	75	25	1330	ND	8	Y	Y	Y	Heat pump hose occluded with debris
Desimone	0	75	25	1402	ND	7	Y	Y	Y	
Adolescent Ongoing	4	74	25	1375	ND	6	Y	Y	Y	
Family Resource Unit A	0	74	25	1335	ND	8	Y	Y	Y	
Family Resource B	2	74	26	1352	ND	7	Y	Y	Y	Plants
Adolescent	2	73	27	1327	ND	6	Y	Y	Y	
Intake Unit A	2	71	33	1449	ND	7	Y	Y	Y	WD CTs along windows-dry/low moisture, no visible mold growth above CTs
Ongoing C	4	73	29	1442		7	N	Y	Y	
Intake Unit B	4	74	28	1424	ND	9	Y	Y	Y	WD CTs-dry/low moisture, no visible mold growth above CTs

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Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	PM2.5 ($\mu g/m^3$)	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
DaSilva	1	75	28	1608	ND	8	Y	Y	Y	WD CTs and GW along windows-dry/low moisture
Interview Room 3	0	73	26	1085	ND	13	Y	Y	N	WD CTs along windows-dry/low moisture
Interview Room 4	0	73	25	1646	ND	14	Y	Y	N	WD CTs along windows-dry/low moisture
Interview Room 2	0	73	26	1066	ND	14	Y	Y	Y	Green algae/mold/debris on window treys, WD CTs
Conference Room B	0	72	26	1243	ND	12	Y	Y	Y	Window condensation
Assessment A	3	72	27	1188	ND	11	Y	Y	Y	WD CTs

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