INDOOR AIR QUALITY ASSESSMENT

University of Massachusetts Amherst
Health Services Building
150 Infirmary Way
Amherst, Massachusetts

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

In response to a request from Judy LaDuc, Biological Safety Services Manager, University of Massachusetts (UMASS) Amherst, Environmental Health and Safety Department, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health (BEH) performed an indoor air quality investigation at the UMASS Amherst (UMA) Health Services Building (HSB) located at 150 Infirmary Way on the UMASS campus in Amherst, Massachusetts. The request was prompted by concerns of mold growth due to chronic moisture as well as respiratory issues reported by occupants in the building.

On April 21, 2011, a visit was conducted by Michael Feeney, Director of BEH's Indoor Air Quality (IAQ) Program along with Environmental Analysts/Inspectors Ruth Alfasso and Lisa Hebert, of BEH's IAQ Program. On July 29, 2011, Mr. Feeney, Ms. Alfasso, and Ms. Kathleen Gilmore, Environmental Analyst/Inspector in BEH's IAQ Program, returned to conduct assessment focused on issues relating to humidity and water damage. A third visit was made by Mr. Feeney and Ms. Alfasso on September 30, 2011, primarily to inspect the condition of fan coil and radiator units for leakage and water damage.

The HSB is a multi-story building that was built in 1962 as an infirmary with inpatient care units. An addition was built in the early 1970s which added a ground-level floor and an addition to the first floor. Currently, the HSB has a ground floor and three stories above, with three wings on the first and second floors and two on the third. Portions of the lower levels directly abut or are built into a hillside. While the buildings are connected, the heating, ventilation and air conditioning systems (HVAC) are different in the 1960s and 1970s portions of the building.

The building has a variety of uses including a walk-in clinic, exam rooms for pediatrics and general medicine, radiology, laboratory areas, specialty clinics such as eye care and physical therapy, a pharmacy, medical records storage and offices for student support and facility operations. It was reported by HSB staff and noted during the BEH/IAQ visits that many areas of the building have different functions than their original design. For example, many offices on the upper floors of the building had originally been designed as infirmary patient rooms containing individual bathrooms with toilets, sinks, and showers. Rooms that had been built as group shower facilities are now being used for storage, as is a stairwell on the upper floors. Original plumbing was in place despite new uses. In addition, some offices were placed in areas originally designed for storage, and other offices were subdivided from larger spaces without appropriate modifications to the HVAC systems.

The building has a flat multi-level roof with a rubber membrane. The building construction is brick. Windows in most areas of the building are openable.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature, relative humidity and dew point 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. Surface temperatures of building materials were measured with a General Tools and Instruments IRT207 infrared thermometer. BEH staff also performed visual inspection of building materials for water damage and/or microbial growth.

Results

About 200 staff work in the building, with up to several hundred visitors on a typical weekday during the school year. Tests conducted on April 21, 2011 were taken during normal operations and appear in Table 1. Tests on July 29, 2011 were conducted during summer recess, during which time the building was open for operation but not as heavily occupied as typical during the school year and appear in Tables 2 and 3.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million (ppm) in all but six of 158 areas, indicating an adequate supply of fresh air in the building during the April 21, 2011 visit. Table 2 shows that carbon dioxide levels were below 800 ppm in all but two of the 72 areas surveyed during the July 29, 2011 visit, again indicating an adequate supply of fresh air in the building at the time of that visit. Note that some areas during the April 21, 2011 visit were empty or sparsely populated when carbon dioxide measurements were taken; in particular to maintain patient privacy, exam rooms and other areas were inspected while there were no patients present. Many areas were also empty or sparsely populated during the July 29, 2011 visit due to summer vacation schedules. Carbon dioxide levels would be expected to increase with greater occupancy.

In the 1960s portion of the building, mechanical ventilation is provided by heating and ventilation units that reportedly supply 100 percent outside air. Three of these units are located in the 4th floor penthouse (Picture 1) and the fourth in a former kitchen area now being used for storage. A main supply duct delivers air to branch ductwork, which distributes it to occupied areas via individual supply vents (Picture 2). The ductwork, vents and pneumatic controls are reportedly original to the building and thus are greater than 50 years old.

Additional heating in this section of the building is provided by radiant metal ceiling tiles and supplemental equipment (Picture 3) using steam originating from the central campus steam plant. Cooling in this area is provided by individual window air conditioners (Picture 4) and ceiling-hung fan coil units (FCUs) installed during the 1970s construction of the new wing. FCUs do not provide fresh air to rooms; rather, FCUs re-circulate air and provide auxiliary heating and/or cooling. FCUs are adjusted individually via control knobs on the front of the units or via wall-mounted thermostats.

Air is drawn into a vent at the base of the FCU and is heated or cooled and provided to rooms by a diffuser on the side of the unit (Figure 1). These units are normally equipped with filters, which should be cleaned or changed as per the manufacturer's instructions to avoid the build-up and re-aerosolization of dirt, dust and particulate matter. Without proper filtration, the heating/cooling fins can become occluded with dust and debris, which can provide a mold growth media when moistened. In addition, poor filtration can accelerate the degradation of HVAC equipment by making the equipment work harder to draw air through clogged heating/cooling fins. Although filters were found in these units, they appeared to be of poor quality and poorly fitted (Picture 5).

In the 1970s portion of the building, mechanical ventilation is provided by an HVAC unit located in the basement mechanical room, which draws in outside air via a cement-lined subterranean pit located on the west exterior wall of the building (Map 1). Outside air is filtered, conditioned (heated or cooled), and distributed via ducted supply vents. Many of these supply vents were found to be covered with a white filter-type material (Picture 6). As mentioned, the fresh air intakes for this section of the building are below grade, which allows the grills to be covered with leaves and other debris, inhibiting the draw of fresh air. In addition, this condition allows snow to accumulate during winter months, further blocking air intake and providing a source of moisture to be drawn into the building.

According to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the service life[1] for a unit heater is 20 years, assuming routine maintenance of the equipment (ASHRAE, 1991). Despite attempts to maintain the HVAC system, the operational lifespan of this equipment has been exceeded. Maintaining the balance of fresh air to exhaust air will become more difficult as the equipment continues to age and as replacement parts become increasingly difficult to obtain.

Not all individual office spaces have supply vents; some are provided with fresh air from common areas through open office doors or from windows when they are available and open. Tables 1 and 2 show where open doors and windows were noted during each visit.

Exhaust vents in both portions of the building are present in restrooms, janitorial closets and other locations including the former kitchen, and are connected to exhaust fans on the roof. Exhaust systems were often found to be operating weakly or not at all in areas throughout the building (Tables 1 and 2).

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of 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

[1] The service life is the median time during which a particular system or component of …[an HVAC]… system remains in its original service application and then is replaced. Replacement may occur for any reason, including, but not limited to, failure, general obsolescence, reduced

adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available.

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, please see Appendix A.

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reliability, excessive maintenance cost, and changed system requirements due to such influences as building characteristics or energy prices (ASHRAE, 1991).

Temperature readings ranged from 69 ºF to 78 ºF on April 21, 2011, with all but one measurement within the MDPH recommended comfort range; the outdoor temperature at that time was in the 50s. During the July 29, 2011 visit, temperature readings ranged from 71 ºF to 81 ºF with an outdoor mid-day temperature of 88 ºF. Eleven out of 72 readings taken during that visit were above the MDPH comfort level The MDPH recommends that indoor air temperatures be maintained in a range of 70 ºF to 78 ºF 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. A number of temperature control complaints were expressed by occupants; these complaints are likely related to poor HVAC system design, building insulation, unbalanced HVAC operation and space arrangement considerations.

The relative humidity measured during the April 21, 2011 visit ranged from 15 to 34 percent (Table 1), which was below the MDPH recommended comfort range in all areas surveyed. The outdoor humidity was 17 percent. During the July 29, 2011 visit the outdoor relative humidity was 88 percent and the relative humidity indoors ranged from 43 to 74 percent with about half of all measurements above the MDPH recommended comfort range (Table 2). The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Occupant complaints were expressed regarding high humidity in the building, particularly during the summer months. As shown in Table 2, relative humidity was distinctly different between the two areas of the building during the July 29, 2011 visit with much higher levels in the 1960s portion of the building.

High relative humidity indoors can indicate that the HVAC system is insufficient to remove water vapor from multiple sources including moisture infiltration through breaches in exterior walls, infiltrated rain/groundwater, respiration from occupants, potential plumbing or steam leaks, water vapor from cooking and, in particular, accumulated water from FCU condensate drip pans.

Moisture removal is important since higher humidity at a given temperature reduces the ability of the body to cool itself by sweating; “heat index” and “apparent temperature” are measurements that take into account the impact of a combination of heat and humidity on how hot it feels. At a given indoor temperature, the addition of humid air increases occupant discomfort and may generate heat complaints. If moisture levels are decreased, the comfort of the individuals increases. In addition, as described in more detail in the Microbial/Moisture Concerns section, relative humidity in excess of 70 percent for extended periods of time can provide an environment for mold and fungal growth (ASHRAE, 1989). A 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 HSB appears to have a significant problem with water damage to interior components of the building. Evidence of water damage and mold colonization were observed throughout the HSB, including water-damaged ceiling tiles (Picture 7), stained carpets and filters inside FCUs. In order for mold to colonize these materials, chronic exposure to moisture must occur.

The interaction of FCUs with hot humid air, such as conditions occurring during the July 29, 2011 visit (and frequently during a typical New England summer) raises several concerns. When hot humid air impacts the FCU cooling coils, some of the water vapor condenses. Water leaks were both reported and observed from many of the operating FCUs examined during the

July 29, 2011 and September 30, 2011 visits. These leaks can moisten carpeting and other porous materials and lead to water damage and mold growth.

In addition, with limited exhaust, the moisture introduced and recirculated by the HVAC system has no means to vent from the building and will linger in the indoor environment, resulting in increased relative humidity and reduced occupant comfort. The water damage noted in the building is extensive and indicates a number of sources related to the design and maintenance of the HVAC system, including: the 1970s wing mechanical room, the junction of the lower roof of the 1970s wing to the original building, and breaches in the building envelope. Each of these issues considered individually would create conditions conducive to water damage/mold conditions. When combined, these conditions can be a significant contributor to water damage and building-related complaints reported throughout the building.

Unconditioned Outdoor Air

As discussed, the HSB has two separate types of HVAC systems in the 1960s and 1970s portions respectively. According to UMA facilities personnel, the 1960s portion of the HVAC system is *not equipped with cooling capacity*. The coils within the 1960s HVAC system only have the capacity to provide heat. When this system operates, hot, moist air is introduced into the building, with the intent that the FCUs provide chilled air. This type of design is contrary to basic HVAC principles. Conditioning of outdoor air typically occurs outside or near the point where it is drawn into a building to dehumidify the air, which prevents condensation on surfaces within the building below the dew point.

The building was evaluated on a warm day, with an outdoor temperature of 75 ºF and relative humidity of 88 percent, which would correlate to a dew point[2] of ~72 ºF.

Table 3 shows surface temperatures and dew point temperatures in selected rooms during the July 29, 2011 visit. Dew point temperature is another way of expressing the humidity. The dew point is the temperature at which the water in the air will start to condense. If a surface's temperature is below the dew point temperature in that area, condensation on that surface will occur. Surface temperatures were found to be as low as 52 ºF on the outlet side of operating FCUs; corresponding dew points were frequently found to be above 60 ºF. In 10 of the 22 FCUs tested in this manner, the dew point was above the surface temperature of the FCU (Table 3). This indicates that the continuous introduction of warm, moist air from outside is providing an ongoing source of condensate in the FCUs. It also appeared from some of these measurements as if the chilled water to the FCUs was too cold, possibly to try to compensate for an insufficient number and distribution of these units.

Other surface temperatures were tested in several areas, including walls and window frames, but none of these were shown to be lower than the dew point during the visit. It is possible, given the poor control of the HVAC systems, other surfaces might be chilled below the dew point during certain conditions and thus become moistened by condensate. In this instance, any surface that has a temperature below the dew point will be moistened. If chilled water pipes are not covered with a proper R value[3] insulation and/or the insulation is not continuous (resulting in exposure of chilled water pipes (Picture 8)), condensation will be generated as the air-conditioning system is operating.

[2] The temperature to which a given body must be chilled for it to become saturated with respect to water, so that condensation may begin. It may also be seen as the temperature of a chilled surface just low enough to attract dew from the ambient air.
[3] R Value is a measure of the ability to retard heat flow rather than to transmit heat (NIA, 2011).

BEH staff examined ceiling mounted FCUs which were found to have signs of significant and repeated water damage to the interior of their cabinets (Picture 9). During both the July 29, 2011, and September 30, 2011, visits BEH staff opened FCUs which had standing water inside due to condensation from inadequately insulated pipes. This resulted in wet filters that were found in a number of FCUs. Repeated water damage can lead to mold growth inside the FCUs and on filters. Standing water was noted in the drip pans of some FCUs, indicating both poor drainage and likely insufficient capacity to drain condensation (Picture 10). Inadequately draining drip pans may also serve as a source of microbial/bacterial growth and associated odors.

Also of note is the configuration of the examination rooms. Each room contains a fresh air supply and a FCU, but no exhaust vent. In this condition, moist air is introduced into rooms with no means of removal, resulting in increased relative humidity and in turn, condensation. Uncontrolled condensation then moistens building materials below inadequately insulated chilled water pipes during hot, humid weather, particularly if the examination room doors are closed. Based on these observations, it appears that the lack of HVAC system chilling capacity in the 1960s wing is a major cause of the water damage to FCUs and ceiling tiles, particulary in areas where ceiling-mounted FCU are installed.

Leaks from the Heating/Chilling System

As reported by UMA officials, the pipes, radiators and FCUs have experienced significant leaks. One of the corrosion control chemicals used in the heating/cooling system contains a red dye. This red dye was found in a significant number of areas, including the interior of some FCUs units and floors beneath some radiators including those inside examination rooms. The appearance of red dye throughout the building appears to indicate a widespread leakage problem that may be linked to the manner that heat is provided to the building and/or the lack of maintenance of the HVAC system. As previously mentioned, the UMA has a steam plant the supplies heat to campus buildings, including the HSB. It is customary to use either steel-fitted pipes or brazed copper pipes. Solder joints can be used if the steam provided to the building has a pressure less than 15 pounds per square inch and a temperature of 250^{o} F (CDA, 2011). If the pressure or temperature parameters are exceeded, leaks can develop due to different rates of expansion between the copper and solder. Joints in FCUs examined appeared to have soldered joints (Picture 11), which may explain the proliferation of leaks throughout the HSB.

Another factor may be a lack of routine maintenance. The steam system may not be self draining. This is likely due to the presence of stopcocks observed in radiators in the lowest part of the building (Picture 12). A non-self-draining system would require manual draining to prevent standing water in the system when the steam supply is turned off. Standing water should be drained from steam systems to prevent corrosion. Of note is the presence of red dye from a radiator leak, which may indicate that this heater may be *connected to the chilled water system* (Picture 13). Radiators should not be attached to the cooling system since chilling below the dew point can be a source of condensation.

The 1970s HVAC System - Fresh Air Intake and Mechanical Room

As previously mentioned, the fresh air intake for the 1970s wing is located at the bottom of a cement-lined subterranean pit located on the west wall of the building (Map 1). The pit is covered by a wire mesh bird screen, which was occluded by plant debris at the time of the BEH inspection (Pictures 14 and 15). Occlusion of the bird screen by accumulated leaves and other debris would tend to allow water vapor to accumulate in this area, which would then be drawn into the HVAC system.

The floor of the mechanical room had standing water, due to a non–functioning floor drain (Picture 16). Water vapor from this pooling water can then be drawn into the HVAC system through breaches in the ductwork, such as one seen around an access door (Picture 17). Failure to drain water from the mechanical room floor and water vapor retention in the fresh air intake pit can lead to increased water vapor levels in the HSB.

Ceiling Damage Attributable to Roof Leaks

Water damage to ceiling tiles in the main lobby were attributed to roof leaks. The area of water damage occurs below the junction where the 1960s wing meets the 1970s wing (Picture 18). While the roof appears to be intact, the windowsills above this area have significant mortar erosion which can allow rainwater to penetrate into the exterior wall, bypassing the roof membrane (Picture 19). Since the roof is held in place by strapping with mortar bolts, no flashing or weep holes were installed in the 1960s wing wall to transfer water from the brick wall interior onto the roof membrane. Without flashing and weep holes, moisture penetrating the brick cannot exit the building envelope, and therefore can cause water damage to ceiling tiles in the main lobby. In addition, low points on the roof were identified by accumulation of plant debris (Pictures 20 and 21), which can hold moisture against the roof membrane causing damage in freezing temperatures.

Breaches in the Building Envelope

BEH staff examined the outside perimeter of the building to identify breaches in the building envelope[4] and/or other conditions that could provide a source of water penetration. The following were noted:

- Groundwater and storm water infiltration in the lower levels, particularly in the 1970s building.
- Some of what were assumed to be FCU condensation drain lines were draining directly against the building where the water can infiltrate via exterior brick and/or the foundation (Picture 22).
- Efflorescence was noted on exterior brickwork (Picture 22). Efflorescence is a characteristic sign of water damage to brick and mortar, but it is not mold growth. As moisture penetrates and works its way through mortar, brick or plaster, water-soluble compounds dissolve, creating a solution. As the solution moves to the surface of the material, the water evaporates, leaving behind white, powdery mineral deposits.
- Some windows and sills were reported to leak during heavy rain events. Damaged windowsills and related flashing were found during the investigation (Pictures 19 and 23).
- Roof leaks were reported and water was noted pooling in areas on the roof (Picture 21).
- During a period of heavy rain prior to one of the BEH visits, the back door of the pharmacy area was reportedly forced open by a flood of water causing significant water damage. Although evidence of water damage had been repaired, conditions along the

[4] The building envelope consists of the roof, walls, door windows and foundation/slab of a building, which are the components of a building in contact with the outdoor environment.

outside of the building exist such that this might occur again under similar weather conditions.

- Plants were noted close to or in contact with exterior walls (Picture 24). The growth of roots against exterior walls can bring moisture in contact with the foundation. Plant roots can eventually penetrate the wall, leading to cracks and/or fissures in the sublevel foundation. The freezing and thawing action of water during the winter months can also create cracks and fissures in the foundation resulting in additional penetration points for both water and pests. These conditions can undermine the integrity of the building envelope and provide a means of water entry by capillary action into the building through exterior walls, foundation concrete and masonry (Lstiburek & Brennan, 2001).

Each of these conditions can provide a source for water/water vapor to enter the building in an uncontrolled manner. In addition, these conditions will also result in heat loss which will increase energy costs.

Due to the changes from previous use, particularly in the former infirmary sections of the 1960s building, there are many areas which still contain plumbing and fixtures which are used irregularly or not at all. Old shower rooms are used for storage, with the original fixtures still in place (Picture 25). These may be subject to leaks and should be shut off and properly capped. In addition, the drains in unused showers can be a source of infiltration of moist air and odorous sewer gases that should be removed or capped.

Each of these water sources can serve to moisten building materials and cause mold growth. The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend that porous materials (e.g., pipe insulation, gypsum wallboard, carpeting) 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.

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 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).

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 each assessment (Tables 1 and 2). No measureable levels of carbon monoxide were detected in the building during either visit (Tables 1 and 2).

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 micrograms per cubic meter (μg/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 μg/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.

The outdoor PM2.5 concentration on April 21, 2011, was measured at 6 μg/m^3 (Table 1). PM2.5 levels measured indoors ranged from 2 to 14 μg/m^3 (Table 1), which were below the NAAQS PM2.5 level of 35 μg/m^3. Measurements of PM2.5 were not taken during the July 29, 2011 visit, which was focused on humidity and water damage issues in the building. 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, use of stoves and/or microwave ovens in kitchen areas; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Volatile Organic Compounds

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 areas for products containing these respiratory irritants.

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

Cleaning products and sanitization chemicals were also observed in offices and other areas (Tables 1 and 2). Like dry erase materials, cleaning products contain VOCs and other chemicals that can be irritating to the eyes, nose and throat. These types of materials may be required or useful in a health care setting; use of the appropriate products may be more easily achieved through central purchasing of cleaning, sanitizing and disinfecting products for the facility so that compatible types are used and information regarding the characteristics and hazards of these products (i.e., MSDSs) are available.

Air fresheners and deodorizers were observed in use. 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.

Other Conditions

Many floor surfaces are covered by wall-to-wall carpeting which is original to the building and in many areas in poor condition. During the July 29, 2011 visit it was reported that some HEPA vacuum cleaners had been acquired for cleaning carpets since the April 21, 2011 visit. The Institute of Inspection, Cleaning and Restoration Certification (IICRC), recommends that carpeting be cleaned annually (or semi-annually in soiled high traffic areas) (IICRC, 2005).

A number of breaches were observed in walls, especially around pipes. Ceiling tiles were noted to be ajar or missing and other interior holes were noted. Unintended openings can be a pathway for contaminants to migrate between rooms and floors, or from mechanical areas to occupied areas instead of being removed from the building.

It was reported by staff that mice had been observed in the building as well as cockroaches. To penetrate the exterior of a building, rodents require a minimal breach of ¼ inch (MDFA, 1996). The most likely route for pests to enter the HSB is the gaps under doors and unsealed penetrations of utility lines on the exterior of the building, although it is likely that the cockroaches are endemic to the building. Rodent and insect infestation results from easy access to food, water, and harborage in a building. Mouse urine and cockroach fragments contain proteins that are a known sensitizer (US EPA, 1992). A sensitizer is a material that can produce allergic symptoms including runny nose or skin rashes in sensitive individuals following repeated exposure.

A three-step approach is necessary to eliminate pest infestation:

1. removal of the insects and rodents;
2. cleaning of waste products from the interior of the building; and
3. reduction/elimination of pathways/food sources that are attracting pests.

To eliminate exposure to allergens, rodents and cockroaches must be removed from the building. Please note that removal, even after cleaning, may not provide immediate relief since allergens can exist in the interior for several months after these pests are eliminated (Burge, 1995). A combination of cleaning, increase in ventilation, and filtration should serve to reduce rodent and cockroach associated allergens once the infestation is eliminated.

A number of air diffusers, exhaust/return vents and personal fans were observed to have accumulated dust/debris (Tables 1 and 2). If exhaust vents are not functioning, backdrafting can occur, which can re-aerosolize accumulated dust particles. Re-activated supply vents and fans can also aerosolize dust accumulated on vents/fan blades. It was particularly noted that the filter material in place over many of the supply vents in the first floor was often very dirty. This suggests that dust and dirt is being entrained from outside and/or is accumulating in the ductwork.

In several areas, items were observed on windowsills, tabletops, counters, bookcases and desks as well as in storage rooms. The large number of items in offices and storage areas provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up. In addition, dust can accumulate on flat surfaces (e.g., desktops, shelving and carpets) in occupied areas and subsequently be re-aerosolized causing further irritation.

During the September 30, 2011 assessment, the FCU in Room 167 was opened. As the unit was opened, a piece of loose pipe insulation fell from the FCU onto the floor. Unlike other fiberglass insulation and foam pipe wrap installed on pipes in the FCU, the hand-sized piece of insulation appeared to be cementitious (Picture 26). Based on its appearance and the date of construction of the 1960s wing, BEH staff advised the occupants to discontinue the use of the room until properly cleaned and to have the debris tested for asbestos. According to a laboratory analysis report, the pipe insulation contained five percent chrysotile asbestos (PAS, Inc., 2011).

It is possible that asbestos-containing pipe insulation could have been disposed of by inserting debris into breaches into the original buildings ceiling. This is possible because state law (M.G.L. c. 149, sec. 6A) and federal asbestos remediation regulations (65 FR 69216, Nov. 15, 2000) were not enacted until 1986 and 2000 respectively, subsequent to the renovation of the building in 1976. Asbestos in this condition may be friable and pose a respiratory risk.

Conclusions/Recommendations

The conditions noted at the UMASS Amherst HSB raise a number of indoor air quality issues. The general building design and maintenance of HVAC equipment (AHUs and FCUs), present conditions that could affect indoor air quality. Some factors can be associated with a range of IAQ related health and comfort complaints (e.g., eye, nose, and respiratory irritation). Some conditions can be remedied by actions taken by building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons a two-phase approach is recommended. The approach consists of **short-term** measures to improve air quality and **long-term** measures that would likely need planning and resources to adequately address overall indoor air quality concerns.

Short-Term Recommendations:

1. All penetrations in the ceiling where FCUs are installed should be examined for the presence of discarded asbestos pipe insulation. Where asbestos-containing materials are found damaged, these materials should be removed or remediated in a manner consistent with Massachusetts asbestos remediation laws (MDLI, 1993).

2. Make modifications to condensate drip pans on FCUs to direct water outdoors. Ensure that the drip pans are properly sloped and that all drain connections are sufficient to direct the collected water outside. Ensure that proper plumbing and engineering practices are used in materials selection and implementation on existing FCUs and any new ones that are installed. Direct the collected water away from the side of the building.
3. Remove mold-colonized and water-damaged building materials (e.g., pipe insulation, ceiling tiles, gypsum wallboard and carpeting under FCUs) in a manner consistent with *Mold Remediation in Schools and Commercial Buildings* published by the US Environmental Protection Agency (US EPA) (US EPA, 2001). Copies of this document can be downloaded from the US EPA website at: http://www.epa.gov/iaq/molds/mold_remediation.html.
4. Repair drain in the floor of the 1975 mechanical room.
5. Routinely inspect and remove accumulated debris from the bird screen of the HVAC system subterranean pit.
6. Ensure the sump pump at the bottom of the HVAC system subterranean pit is operational.
7. Properly insulate all chilled water supply pipes above the ceiling to prevent condensation. Check to ensure that cooling water is not excessively cold.
8. Drain the heating system as needed. This action should happen when the HVAC system switches between heating and cooling modes (twice a year). Inspect drain stopcocks and repair or replace as needed.
9. Disconnect radiators from the system when the HVAC system is operating in chilling mode.
10. Ensure windows are shut during AC system operation in hot, humid weather.

11. Seal all floor and shower drains in areas in which water service is no longer used. Consult with a plumber for the best way to do this-temporarily sealing each floor drain thoroughly with duct tape or plug will work as a temporary measure.

12. 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).

13. Repair breaches identified in AHUs, fix any holes found around pipe penetrations, replace missing or damaged ceiling tiles, and close any other holes or penetrations allowing unwanted air exchange.

14. Work with a pest control expert to perform an IPM program. Ensure that breaches along building exterior are sealed to prevent pest/rodent entry into the building. Make sure food is properly stored and food residue cleaned up daily.

15. Clean leaves and dirt from fresh air grills (Picture 7).

16. Remove accumulated plant debris from the roof.

17. Trim plants away from the perimeter of the building.

18. Clean air diffusers, return vents and exhaust vents periodically of accumulated dust. Clean ductwork, particularly in the 1970s section.

19. Continue work to remove unneeded materials from storage areas. Reassess need for stored items in offices, and move items periodically to allow for cleaning.

20. Consider adopting a balancing schedule of every 5 years for all mechanical ventilation systems, as recommended by ventilation industrial standards (SMACNA, 1994).

21. Initiate a work order or logbook system to track building maintenance issues, including locations and when the issues have been resolved.

22. Refer to resource manual and other related indoor air quality documents located on the MDPH's website for further advice on maintaining public buildings. These documents are available at: http://mass.gov/dph/iaq.

Long-Term Recommendations:

1. Identify whether the heating system has proper joints for use in a steam-supplied heating system. If not, replacement of all leaking joints should be considered.

2. Consider working with an HVAC engineering firm to evaluate installing cooling coils on the fresh air intakes for the 1960s portion of the building to pre-cool and dehumidify air entering the building during hot humid weather. If not feasible, this portion of the HVAC system should be abandoned and replaced.

3. Consult with an HVAC engineering firm regarding the feasibility of repair vs. replacement of ventilation system components given their age. In the interim, work with an HVAC engineering firm to adjust/repair supply and exhaust vents to improve air exchange.

4. Repoint the window mortar and bricks of the exterior wall above the 1975 short roof.

5. Seal all breaches in the building envelope (e.g., exterior walls, windowsills and foundations areas) to prevent/reduce moisture infiltration and cooling/heat loss. Consider contacting a building envelope specialist to examine the building for best methods.

6. Consider having a plumber remove all unused piping and fittings from old showers and shower rooms being used for storage.

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Map 1: Aerial layout of the Health Services Building showing building wings, complex roof, and ground topography (arrow indicates subterranean pit)

Picture 1

4th Floor Penthouse Housing AHUs for 1960s Portion

Picture 2

Supply Vent in the 1960s Section

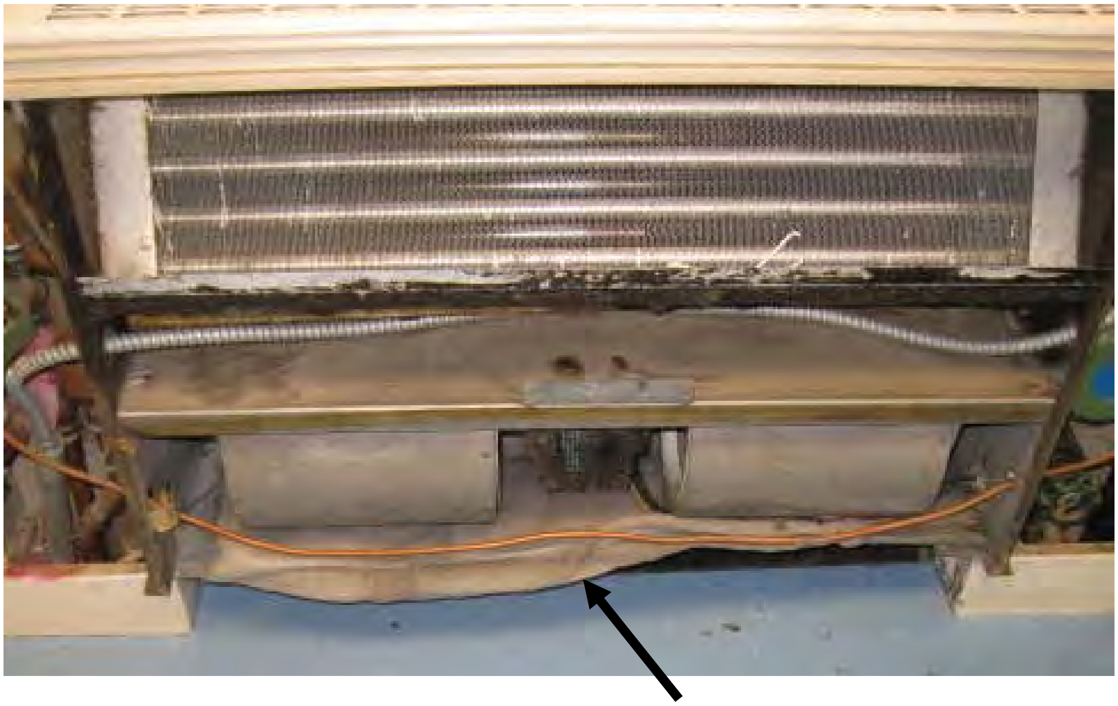
Picture 3

Radiant Metal Ceiling Tiles and Fan Coil Unit (FCU)

Picture 4

One of the Types of Window Air Conditioners Used

Picture 5



Poorly Fitted Filter in FCU

Picture 6

Filter Material Covering Supply Vent in General Medicine Area
(Note Dirt on Material)

Picture 7

Water-Damaged Ceiling Tile

Picture 8

Water Droplets due to Condensation between Insulation Sections

Picture 9

Moisture Damage to FCU Cabinet

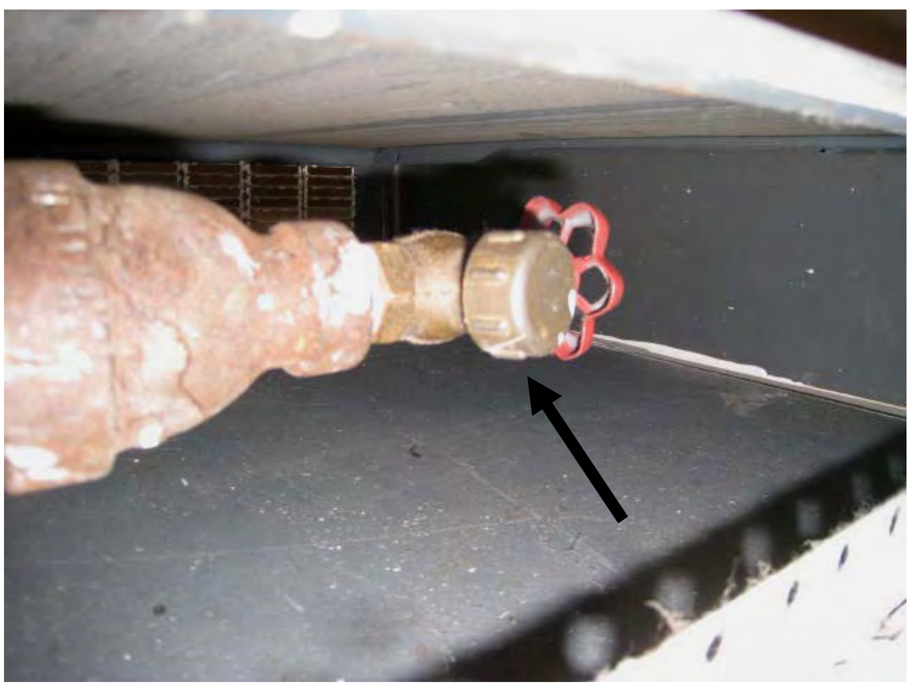
Picture 10

FCU Drip Pan Filled With Water

Picture 11

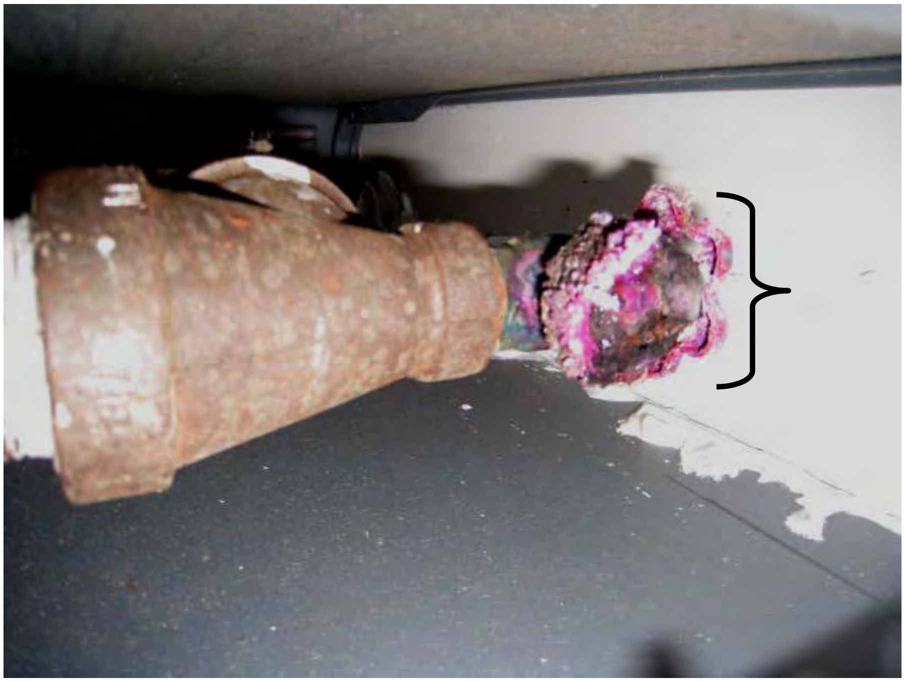
FCUs Appeared to Have Soldered Joints

Picture 12



Stopcock on Radiator

Picture 13



Leaking Stopcock, Note Corrosion and Red Dye (highlighted by bracket)

Picture 14

Debris on Fresh Air Intake

Picture 15

Fresh Air Intake (Underside View)

Picture 16

Flooded Mechanical Room Floor beneath HVAC Equipment

Picture 17

Large Gap in AHU Ducting for the 1970s Section (Dollar Used to Depict Scale of Breach)

Picture 18

The Junction Where the 1960s Wing Meets the 1970s Wing

Picture 19

Cracks around Sills and Window Frame

Picture 20

Debris on Roof

Picture 21

Additional Debris on Roof

Picture 22

Drain Presumed to be From FCU Condensate Discharges to Side of Building (Note Efflorescence on Brickwork and Staining/Puddle below)

Picture 23

Towel under Leaking Window

Picture 24

Plants Growing Close to Base of Building

Picture 25

Shower Fixtures in Old Shower Room Currently Used for Storage
(Note stored boxes)

Picture 26

Hand-Sized Piece of Insulation (arrow), Appeared to be Cementitious

Location: UMass Amherst, Health Services Building **Indoor Air Results**

Address: 150 Infirmary Way, Amherst MA **Table 1** **Date: 4/21/2011**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Background	349	ND	53	17	6					Chilly and dry
020 Physical Therapy	336	ND	73	20	3	1	N	Y	Y	WD-CTs, presumed supply vent covered with filter fabric
012	504	ND	74	18	3	0 (recently vacant)	N	Y	Y	
013	564	ND	74	17	3	0	N	Y	Y	Plant
014	483	ND	74	17	3	0	N	Y	Y	
016	401	ND	74	21	3	0	N	Y	Y	WD-CTs, vent obstructed
017	316	ND	73	18	3	0	N	Y	Y	DO
018	410	ND	73	19	3	0	N	Y	Y	DO, WD-CTs, dirty CT
019	504	ND	73	17	3	0	N	Y	Y	
019 (Room outside)	548	ND	73	18	3	0	N	Y	N	
035 Phlebotomy	343	ND	73	20	3	0	N	Y	Y	Supply obstructed by closet Presumed supply vent covered with filter, dirty
040	393	ND	73	19	3	1	N	Y	Y	Presumed supply with filter fabric, dirty

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

AC = air conditioner
AT = ajar ceiling tile
CT = ceiling tile

DEM = dry erase materials
DO = door open
FC = fan coil unit

PC = photocopier
PF = personal fan
WD = water-damaged

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%

Location: UMass Amherst, Health Services Building **Indoor Air Results**

Address: 150 Infirmary Way, Amherst MA **Table 1 (continued)** **Date: 4/21/2011**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
041	317	ND	74	19	3	1	N	Y	Y	Presumed supply with filter fabric, dirty
043	341	ND	71	19	3	0	N	Y	Y	supply vent modified
045A Radiology	346	ND	71	21	3	1	N	Y	N	WD-CTs
100B	572	ND	72	21	4	0	Y	Y	Y	Presumed supply vent covered with fabric (filter)
101	697	ND	74	22	4	0	N	Y	Y	DO
103	396	ND	75	22	2	0	N	Y	N	Supply dirty, no air movement felt
105 Exam	584	ND	75	20	3	0	Y	Y		Window open
105 Lobby	437	ND	75	22	2	2	N	N	N	
106	374	ND	75	21	2	0	Y	Y	N	
107	603	ND	75	20	3	1	Y	N	N	
108	611	ND	75	21	3	0	Y	Y	Y	
109	611	ND	74	20	3	0	N	Y	N	
110	424	ND	74	21	3	1	Y	Y	N	

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Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
111	535	ND	74	19	4	0	Y	Y	Y	
115	636	ND	74	20	4	0	N	N	N	Closet with folding doors and one desk
121 Exam	548	ND	74	19	4	0	N	Y	N	Dirty supply vent
122 Exam	565	ND	73	19	4	0	Y	Y	Y	
123 Exam	515	ND	74	21	4	0	Y	Y		
124 Outer	426	ND	75	20	4	0	N	Y Weak	Y	DO
124 Exam	672	ND	75	21	4	0	N	Y	N	Material on supply vent
125 Exam	551	ND	75	20	4	0	N	Y	Y	
126	491	ND	75	23	3	1	Y	Y	N	
127 Exam	582	ND	75	22	3	0	Y	Y	Y	
128	412	ND	75	22	2	0	N	Y	Y	
129 Exam	540	ND	75	20	3	0	Y	Y	Y	
130 Exam	611	ND	76	19	4	1	N	Y	Y	Dirty supply vent
133	485	ND	75	17	4	1	N	Y	Y	Stained CT

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Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
134 R	346	ND	75	19	3	0	N	Y	Y	
135	328	ND	75	19	2	0	Y	Y	N	DO
136	353	ND	74	20	3	0	Y	Y	N	DO
137	518	ND	75	19	3	0	Y	Y	Y	
139	996	ND	75	22	4	5	Y	Y		
139 Left	501	ND	75	17	4	0	N			
140	528	ND	75	19	3	0	N	Y	Y	
143 Exam	578	ND	76	19	3	0	N	Y	Y	
144	375	ND	75	21	2	0	N	Y	Y	
146	421	ND	75	21	2	0	N	Y	Y	Filter fabric over presumed supply vent
147	678	ND	76	19	5	1	Y	Y		
149 Exam	541	ND	76	18	3	0	N	Y	Y	
154 Pharmacy	390	ND	71	22	6	1	N	Y	Y	Egg crate, possible plenum
155	447	ND	73	25	5	1	N	N	N	WD-CTs, mold colonization

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Location: UMass Amherst, Health Services Building **Indoor Air Results**

Address: 150 Infirmary Way, Amherst MA **Table 1 (continued)** **Date: 4/21/2011**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
155 Bathroom							Y	N	Y	Buckled CT
164	653	ND	73	22	8	0	N	Y	Y	Broken CT, fan coil
165	605	ND	73	24	9	0	N	Y	N	DO, Surface mold colonization
166	606	ND	73	23	5	1	Y	Y	N	WD-CTs, mold colonization, CTs bucke4d together
167	791	ND	73	23	10	0	Y			FC, supply and exhaust not identified
170	765	ND	73	23		1	Y	Y	Y	Large room with respiratory and other equipment, missing CT
172	720	ND	72	23	9	0	N	Y	Y	FC
174	463	ND	72	22	11	0	N	Y	Y	
176	605	ND	73	23	5	0	N	Y	Y	Dedicated cooling system here
200	480	ND	72	21	7	0	Y	N	N	AC unit, broken window
201	504	ND	72	21	7	3	Y	N	N	Occupant report she can't open window without coughing. vent on roof outside window
202	697	ND	74	18	6	0				FC, unknown if supply/exhaust here
203 C	415	ND	72	21	6	0	Y	N	N	AC unit leaks all the time, water damage to wall

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Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 (µg/m^3)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
203 Right (optician)	580	ND	72	18	7	0	Y	Y	N	FC, broken CT, AT
204	680	ND	72	19	6	1	Y	N	N	AT
204 Left (optical care)	701	ND	73	20	6	1	N	N	N	Window AC
205 Bathroom						0	N	N	Y	DO
205 L	397	ND	72	19	7	0	Y	N	N	DO
205 R	548	ND	73	17	6	0	Y	Y	Y	FC
207 B	519	ND	74	19	9	1	Y	N	N	Plants on AC unit
207 Left	599	ND	73	17	7	0	Y	N	N	Window AC, fan coil, air freshener odor from attached restroom, PF
207 Right	591	ND	73	17	6	3	Y	Y	Y	2 FCs, 2 PF
246	346	ND	72	22	6	0	N	N	N	
248	488	ND	73	16	7	0	N	N	N	PF
248 (Billy)	670	ND	75	19		2	N	Y	N	

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Address: 150 Infirmary Way, Amherst MA **Table 1 (continued)** **Date: 4/21/2011**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
249	561	ND	75	21	11	0	Y	Y	N	DO
249C	487	ND	75	22	10	0	Y	Y	N	Bird seed on window sill, PF
250B	667	ND	75	20	7	1	N	N	N	Damaged CT (metal)
250	618	ND	76	23	7	0	N	N	N	
250A	642	ND	75	20	9	1	Y	Y	N	PF, plants, stained CT
251	632	ND	76	21	9	1	N	Y	N	DO, PF
251D	656	ND	75	19	8	1	Y	N	N	Window AC, AT
251B	685	ND	76	19	7	0	Y	Y	N	Window AC
2nd floor Men's							N	Y	Y	WD-CTs
300	609	ND	74	20	8	0	Y	Y	Y	
300B	1186	ND	74	29	7	3	Y	N	N	AC unit
301 Bathroom							N	Y	Y	
301B	422	ND	74	19	4	1	Y	N	N	AC unit
301 vestibule	661	ND	75	19	6	0	N	N	N	Small vestibule for office 301

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								Supply	Exhaust	
301C	685	ND	75	20	6	0	Y	Y	Y	Carpeted
302 (conference 2)	1330	ND	72	34	5	10	Y	Y	Y	Exhaust vent in bathroom, plants, metal CT
303 R	775	ND	76	19	6	1	Y open	Y	Y	PF plant
303	607	ND	73	27	4	0	N	N	N	DO
303B	662	ND	73	26	5	0	Y	Y	N	AC unit, plants, PF, DO
304 staff lounge	636	ND	75	22	6	0	Y	Y	Y	PF, DO
305B	645	ND	75	22	5	1	Y	Y	Y	
305	440	ND	76	20	5	1	Y	N	N	DO, removed door in shower
307 kitchen	636	ND	75	21	6	0	Y	Y	Y	Window open
342B	670	ND	78	20	5	0	Y	Y	Y	
342C	655	ND	78	21	5	0	Y	Y	Y	
343	424	ND	78	21	7	1	N	Y	Y	DO, PFs
344	751	ND	78	22	5	2	Y	Y	Y	
344 Side	745	ND	78	23	6	1	Y	Y	Y	PF

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

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
346										Shower room
347 Lobby	474	ND	77	21	3	0	N	N	N	PC, bathroom has supply and exhaust
347 Right	638	ND	77	20	5	1	Y open	Y	Y	Open plan cube, PF
348	481	ND	77	21	3	1	Y	N	N	AC unit
348C	721	ND	77	28	4	1	Y	Y	N	DO, plants
349C	475	ND	77	22	4	3	Y	N	N	Plants
349B	614	ND	77	19	5	0	Y	Y	Y	
350	933	ND	77	29	3	6	N	N	N	DO
350C	933	ND	77	29	3	6	Y	N	N	DO
351	658	ND	76	21	4	0	Y	Y	Y	Plant, DO, open plan offices
364 Left	649	ND	76	21	5	2	Y open	Y	Y	
364 Right	703	ND	76	20	4	2	Y open	Y	Y	Plants, PF, window AC
365B	576	ND	76	23	5	2	Y	N	N	AC unit window, PF
365C	845	ND	76	25	5	1	Y	N	N	Window AC

ppm = parts per million
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CT = ceiling tile
DEM = dry erase materials
DO = door open
FC = fan coil unit
PC = photocopier
PF = personal fan
WD = water-damaged

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
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Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
366D	501	ND	76	21	3	3	Y	Y	N	AC unit, deterioration of window sill, plants
366B	639	ND	76	20	4	0	Y	N	N	Window AC, plants, AT
367 Shower										Floor drains under storage, abandoned stairwell used
368	449	ND	76	21	4	1	Y	Y	Y	DO, ATs
369C	449	ND	76	21	3	1	Y	N	N	AC window unit
369 Entry	570	ND	76	24		0	N	N	N	Missing CT
369 left	639	ND	76	21	5	2	Y	Y	N	Window AC
371C	413	ND	76	21	3	1	Y	Y	N	AC in window, WD-CTs, DEM
371B	593	ND	76	21	7	1	Y	Y	Y	
3rd floor Old Shower Room										Used for storage, CT, floor drains and fixtures
3rd floor Shower										Has at least 1 floor drain under carpet
Back of lab	497	ND	71	20	4	0	N	N	N	
Back office of X-Ray room	558	ND	71	21	3	0	N	Y	Y	

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

Location: UMass Amherst, Health Services Building **Indoor Air Results**

Address: 150 Infirmary Way, Amherst MA **Table 1 (continued)** **Date: 4/21/2011**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 (μg/m³)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Cashier office	522	ND	74	15	7	0	Y	Y	N	Attached shower/toilet room (with floor drain)
Center for Health promotion	556	ND	77	21	4	1	N	N	N	Buckled CTs, PF, dry trap in copy room sink
Central CMA	472	ND	75	21	3	1	N	N	N	
Clinic Public Bathroom							N	N	Y	
Dead Records	383	ND	74	21	6	0	Y	Y	Y	outside air supply
Doctor Dictation Room	623	ND	73	24	14	0	N	Y	N	WD-CTs, mold colonization
Exam 104	640	ND	74	19	11	1	Y	Y		Window open, AT
Former Kitchen	375	ND	74	19	9	0	Y	Y	N	Floor drains
GM1 (pediatrics)	683	ND	74	20	4	0	N	N	N	
Ground floor ladies room								Y		Odor of deodorant
Lab area waiting	461	ND	73	20	6	4	N	Y down hall	Y	filter fabric on presumed supply vent
Lab left	458	ND	73	17	3	2	N	Y	Y	filter fabric on presumed supply vent
Lab office	590	ND	73	18	4	0	N	N	Y	Very tiny office, hand sanitizer

ppm = parts per million	AC = air conditioner	DEM = dry erase materials	PC = photocopier
μg/m³ = micrograms per cubic meter	AT = ajar ceiling tile	DO = door open	PF = personal fan
ND = non detect	CT = ceiling tile	FC = fan coil unit	WD = water-damaged

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
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Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Location: UMass Amherst, Health Services Building **Indoor Air Results**

Address: 150 Infirmary Way, Amherst MA **Table 1 (continued)** **Date: 4/21/2011**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Lab right	480	ND	74	17	4	0	N	Y	Y	Contains various lab equipment items
Mail Room		ND	69	20	6	0	N	Y	N	WD-CTs
Medical Record Reception	522	ND	73	24	7	43	N	N	Y	PF dirty, Broken CTs
Medical Records Lobby	640	ND	72	24	6	19	N	N	Y	Presumed supply vent with filter fabric Broken CTs, WD-CTs
Medical records center	593	ND	72	20	4	0	Y	N	Y	Presumed supply vent covered with fabric (filter), PF
Medical records rear, center	637	ND	72	20	7	1	Y	N	Y	Exhaust covered by batting
Medical records room	690	ND	72	22	5	1	N	Y	Y	
Medical records, left rear	568	ND	72	19	5	1	Y	Y	Y	
Men's Rest Room							N	N	Y	Cold air in vent, potential down draft
North nursing station	378	ND	75	21	2	2	N	N	Y	WD-CTs filter fabric over presumed supply vent
North Waiting Area	401	ND	75	21	4	1	N	N	Y	2 presumed supply vents with filter fabric
Nursing CMA Area	575	ND	75	22	3	1	N	Y	N	

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FC = fan coil unit
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Carbon Dioxide: < 600 ppm = preferred
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Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Location: UMass Amherst, Health Services Building **Indoor Air Results**

Address: 150 Infirmary Way, Amherst MA **Table 1 (continued)** **Date: 4/21/2011**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Nursing Station	605	ND	74	24	10	3	N	N	Y	DEM
Office 42	785	ND	73	19	4	0	N		Y	Dirty exhaust
Pharmacy back area	650	ND	72	31	7	3	Y	Y	Y	This back area was reportedly flooded during a big storm, wall, floor completely redone. Has back door (currently closed)
Pharmacy office	575	ND	71	29	6	0	Y	Y	Y	
Pharmacy right	608	ND	72	27	6	2	Y	Y	Y	
Pharmacy waiting area	537	ND	72	21	5	3	N	Y	Y	Pharmacy area reportedly newly tiled, with new fan coil units
PT 20 left	528	ND	74	19	4	3	N	Y		
Purchasing office	477	ND	73	15	6	0	Y	N	N	
Radiology records										WD-CTs
Reception	390	ND	75	20	3	1	N	Y	Y	Presumed supply in hall covered in filter fabric
Shower Room										Cockroaches in room
Specialty Clinic	559	ND	73	19	3	0	N	Y	N	

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

AC = air conditioner
AT = ajar ceiling tile
CT = ceiling tile

DEM = dry erase materials
DO = door open
FC = fan coil unit

PC = photocopier
PF = personal fan
WD = water-damaged

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
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Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Location: UMass Amherst, Health Services Building **Indoor Air Results**

Address: 150 Infirmary Way, Amherst MA **Table 1 (continued)** **Date: 4/21/2011**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Storekeeper's office	499	ND	74	15	6	0	N	N	N	PF
Urgent clinic office	742	ND	73	23	13	0	N	N	N	
Women's Rest Room							N	N	Y	Cold air in vent, potential down draft
X ray office	487	ND	71	20	4	0	N	Y	Y	water intrusion potentially in pipe

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FC = fan coil unit
PC = photocopier
PF = personal fan
WD = water-damaged

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
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Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Location: UMass Amherst, Health Services Building
Address: 150 Infirmary Way, Amherst MA

Table 2

Indoor Air Results
Date: 7/29/2011

Location/ Room	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	Dew Point (°F)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Background	370	ND	75	88	71		NA			Measurements taken by ramp in front of building at approximately 12:30 pm, one vehicle running nearby
016 Exam Room	485	ND	75	56	58	0	N	Y		
017 Exam Room	490	ND	73	56	57	0	N	Y		
018 Exam Room	429	ND	74	57	57	0	N	Y		
019 Exam Room	452	ND	73	57	57	0	N	Y		
041	615	ND	71	62	57	0	N	Y		Carpet with water cooler on it
100B	629	ND	73	64	60	1	Y	Y		Dusty filter on supply.
108	685	ND	74	63	61	0	Y	N	N	FC filter not clean, filter material inadequate
122	841	ND	73	64	61	5	Y	Y	N	DO, FC opened and no filters found/filter bypassed
154 Pharmacy	490	ND	75	72	66	2	N	Y	N	
155 Pharmacy	492	ND	74	73	65	3	N	N	N	

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DO = door open
FC = fan coil unit
PC = photocopier
PF = personal fan
WD = water-damaged

comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
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Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Location: UMass Amherst, Health Services Building **Indoor Air Results**

Address: 150 Infirmary Way, Amherst MA **Table 2 (continued)** **Date: 7/29/2011**

Location/ Room	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	Dew Point (°F)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
164 (walk-in area)	554	ND	74	69	63	0	N	Y	N	
165	545	ND	72	69	62	0	N			FC, when opened drip pan full of standing water, no pitch for drainage, stained material from coil leaks (pink staining)
166	580	ND	72	73	63	0	Y	Y	Y	FC not properly drained,
170	536	ND	72	70	62	0	Y	Y	Y	DO, FC outlet surface FC loud, area around FC open/missing wallboard
201	662	ND	76	66	56	2	Y			FC reportedly leaks during hot weather.
202	572	ND	76	69	65	0	Y			FC off
203 (right side)	557	ND	75	69	64	0	Y	Y	N	Open space in wall/ceiling around FC, FC off
204	605	ND	75	65	64	2	Y			FC on
205	571	ND	75	69	65	0	Y	Y	N	FC on
206	565	ND	75	67	63	0	Y			FC on, PF
207B	574	ND	74	70	64	0	Y	Y		FC off, exposed pipes around FC

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

Location: UMass Amherst, Health Services Building **Indoor Air Results**

Address: 150 Infirmary Way, Amherst MA **Table 2 (continued)** **Date: 7/29/2011**

Location/ Room	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	Dew Point (°F)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
207C	565	ND	74	66	64	0	Y	Y		FC, FC reported drips, exposed pipes around FC
208	553	ND	74	66	63	0	Y	Y	N	2 FC on
242	566	ND	80	56	64	0	N	N	N	Maintenance supplies, musty "litter box" odor.
260	474	ND	76	72	66	1	Y	N	N	DO, window AC on
262	430	ND	80	74	71	0	N	N	N	PF on, no AC, room very small
2nd floor copy center	642	ND	81	56	64	0	N			PCs, supply or exhaust vent not operating
2nd floor shower room/storage										Shower fixtures still present, including drains, dead roaches on floor at back of room
300	582	ND	75	60	60	1	Y	Y	Y	FC
300 (side)	589	ND	73	56	57	1	Y			FC leaks, often turned off due to occupant discomfort, plants
301 B	551	ND	76	60	62	0	Y	Y	Y	FC not on (reported usually on)
301 C	605	ND	76	55	58	0	Y	Y	Y	Musty smell FC on cool,
303 (main)	613	ND	78	58	62	1	N	N	N	PF

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FC = fan coil unit
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Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Location/ Room	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	Dew Point (°F)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
303 C	470	ND	78	66	67	0	Y	N	N	PF on,
304	614	ND	78	61	64	0	Y	Y		FC reported not working, FC reported leaks, PF
305	635	ND	79	59	64	0	Y	Y	Y	PF, no AC
342C	510	ND	77	53	59	1	Y			PF, plants
343 (Sterile supply)	531	ND	79	62	62	1	Y	Y	Y	AC not operating, PF
344	510	ND	78	63	65	1	Y	Y	Y	Window AC, FC off
347 B	499	ND	79	65	66	0	Y			Afternoon sun reported as problem in this room, room 347 C has ducted AC unit
348	455	ND	79	65	66	1	Y	N	N	FC off
348 C	438	ND	77	63	64	0	Y			FC off
349B	462	ND	79	64	66	0	Y	Y	Y	FC off. Room not occupied until August.
349C	489	ND	78	68	68	1	Y	N	N	PF, window AC
350B	453	ND	79	61	64	0	Y			No FC, No AC

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

Location/ Room	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	Dew Point (°F)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
351	536	ND	77	63	63	0	Y	Y	N	Window AC on.
364	716	ND	76	46	53	3	Y	Y	N	Window AC
365 B	635	ND	77	43	52	1	Y	N	N	Window AC, PF, items
366C	694	ND	77	43	53	5	Y	N		Plants, window AC, PF
369 C	732	ND	77	46	53	1	Y	N	N	Window AC, PF
369B	766	ND	77	46	55	3	Y	Y	Y	Window AC
371 B	684	ND	75	45	53	0	Y	Y		Plants, window AC
371C	694	ND	75	45	53	3	Y	N	N	PC, window AC
3rd floor copy room	738	ND	78	49	57	0	N	N	N	Supply/exhaust off, PCs
3rd floor Storage closet (old shower room)	839	ND	77	46	57	0	N	N	N	Lots of materials/items, sink and other fixtures still present. Probable floor drains.
Blood draw room	622	ND	75	54	57	0	N	Y	Y	DO
Fax area/supply	520	ND	77	61	63	0	N	N		FC or UV in this room. Surface temp FC outlet 74°F

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

Location: UMass Amherst, Health Services Building **Indoor Air Results**

Address: 150 Infirmary Way, Amherst MA **Table 2 (continued)** **Date: 7/29/2011**

Location/ Room	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	Dew Point (°F)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
General Medicine Clinic main area	599	ND	76	58	60	0	N	Y	N	Ceiling vent covered with batting/filter material
General Medicine Clinic Main staff area (left side)	625	ND	74	62	60	1	N	Y	N	PF, filter material/batting over supply vent
GMC area outside rooms 125-130	595	ND	74	60	60	0	N	Y	N	
GMC Waiting Area	594	ND	74	60	59	0	N	Y	N	filter material/batting over supply vent
health office	669	ND	76	55	59	2	N	Y	N	DO (no door), dusty
Janitor's storage	654	ND	79	60	64	0	N	N	N	Storage of cleaning supplies, odor of cleaning supplies
Lab left	611	ND	75	56	58	2	N	Y	Y	AC supply surface temp = 64°F
Lab right	615	ND	73	56	58	2	N	Y	Y	
Med records area (center)	600	ND	73	65	60	1-3	N	N		Very dirty batting/filter on supply vent
Med records area (left)	560	ND	72	67	61	1-3	N	Y		Batting/filter on supply vent, PCs
Open area storage	444	ND	81	69	70	0	Y (open)	N	N	PFs, AT, storage of cleaning products

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

Location/ Room	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	Dew Point (°F)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Phys therapy (room 20)	588	ND	76	53	57	0	N	Y	Y	PF on
Radiology main area	579	ND	73	57	57	1	N	Y		Pink stain on ceiling tile, PC, slop sink, plants, ATs in exam room
Radiology Waiting Room	488	ND	72	59	57	0	N	Y	Y	
Specialty Clinic Waiting Room Ground Floor	459	ND	75	55	58	1	N	Y	Y	
Staff kitchen	565	ND	78	61	34	0	Y	N	N	2 refrigerators, ice machine, other kitchen equip.

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

Location: **UMass Amherst, Health Services Building**

Address: 150 Infirmary Way, Amherst MA

Indoor Air Results

Date: 7/29/2011

Table 3

Location	Temperature of Fan Coil Outlet Surface (^oF)	Dew Point (^oF)
170	62	62
166	63	63
204	60	64
206	59	63
203 (right side)	69 (FC off)	64
205	64	65
208	56 (both of two FCs)	63
207C	54	64
207B	71 (FC off)	64
303C	73	67
301C	52	58
300	57	60
300 (side)	57	46
202	71 (off)	65
201	59	57
342C	69	62
3rd floor Fax Area/supply	74	63

AC = air conditioner

NA = not available/not tested

FC = Fan Coil Unit

Indoor Air Results

Date: 7/29/2011

Table 3 (continued)

Location	Temperature of Fan Coil Outlet Surface (^oF)	Dew Point (^oF)
344	69	65
348	73 (not on)	66
348C	73 (not on)	64
351	NA	63
304	76 (not working)	64
305		
371C	None (window AC)	53
369B	“”	55
369C	“”	53
364	“”	53
365B	“”	53

AC = air conditioner

NA = not available/not tested

FC = Fan Coil Unit