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Technical Guide for Indoor Air Quality Surveys

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14. ABSTRACT
The purpose of this technical guide is to provide guidance for performing indoor air quality (IAQ) surveys at base level, including roles and responsibilities of all members and the steps necessary to perform proper IAQ surveys. Information covered includes specific factors that influence IAQ, performing IAQ surveys, and troubleshooting IAQ issues. This guide replaces IERA-RS-BR-TR-2003-0001, Guide for Indoor Air Quality Surveys, which replaced AL-TR-1992-0016. This document has undergone significant revision. Additional information is provided for areas of much interest, such as mold remediation.

15. SUBJECT TERMS
Indoor air quality, IAQ, fungi, mold, bioaerosols, sick building syndrome, building-related illness, ventilation, air ducts, building odor, building air, dust

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Summary of Changes

This document is substantially revised and must be completely reviewed. Significant revisions include incorporating guidance previously issued under the memorandum titled *Interim Policy and Guidance for the Prevention, Surveillance, and Remediation of Water Damage and Associated Mold Contamination in Air Force (AF) Facilities*, dated 10 May 2005; reorganization of document; Air Force Institute for Environment, Safety, and Occupational Health Risk Analysis changed to United States Air Force School of Aerospace Medicine; removal of microbial sampling guidelines with reference to the USAF School of Aerospace Medicine Laboratory Sampling and Analysis Guide; added recommendation to input investigation findings in the Defense Occupational and Environmental Health Readiness System; updated smoking standards in accordance with Air Force Instruction 40-102, *Tobacco Use in the Air Force*; added reference to the Occupational Safety and Health Administration's (OSHA's) guidance on indoor air quality investigations in OSHA Technical Manual (OTM) Section III; removed specific occupant density criteria and referenced readers to Air Force Manual 32-1084, *Facility Requirements* (2012); document renamed as a technical guide; specific National Ambient Air Quality Standards were removed. Refer to the Environmental Protection Agency's website (http://www.epa.gov/air/criteria.html) for the most recent standards. Many references date back as far as 1987, but these data have held true over time and are still applicable. Due to the significant revision of this document, this summary of changes is not all-inclusive.

Chapter 1. Introduction

The purpose of this guide is to provide the education and background necessary for Bioenvironmental Engineering (BE) to make informed decisions during indoor air quality (IAQ) surveys. Information provided includes the roles and responsibilities of all members and the steps necessary for BE to perform proper IAQ surveys. Guidance is included for the remediation of mold solely for the purpose of educating BE personnel. BE is not responsible for the remediation of mold- or water-damaged facilities. This guide replaces IERA-RS-BR-TR-2003-0001, Guide for Indoor Air Quality Surveys, which replaced AL-TR-1992-0016. This document has undergone significant revision.

Chapter 2. IAQ Defined

a. Background of IAQ Concerns: As defined by the Occupational Safety and Health Administration (OSHA), indoor air quality is a term that "describes how inside air can affect a person's health, comfort, and ability to work" [1]. Poor or inadequate IAQ are terms used to describe nonindustrial indoor spaces where occupants complain of health issues that may be associated with building occupancy. Therefore, occupant complaints appear while inside of a certain building and lessen upon leaving the building. Some common terms are used for this issue. Sick building syndrome (SBS) can be defined as follows: building occupants suffering from acute health or comfort effects that seem to be attributed to their time in a building, but no specific illness or cause of symptoms is identified. In contrast, a building-related illness (BRI) is when an occupant is diagnosed with an illness that is directly attributed to a building's IAQ [2]. SBS was once referred to as tight building syndrome, which was used to describe buildings with inadequate ventilation due to improper energy conservation efforts [3].

In the United States Air Force (USAF), the primary areas of concern are office buildings and base housing. An IAQ issue may begin when decisions are made about design, operation, or maintenance of a facility without considering the impact on occupants' health or comfort. The result can be reduced productivity and low morale due to occupants experiencing physical symptoms.

It is important to investigate IAQ complaints for several reasons. First, occupants may be affected by symptoms related to resolvable IAQ issues. Second, ignoring IAQ concerns can lead to the development of serious illness. Third, early involvement in any IAQ concern has a greater potential for success in solving the problem and ensuring a healthy environment.

Human beings spend the majority of their time indoors, so poor IAQ can have significant health effects on building occupants. One research estimated that approximately 50% of houses in the United States have prevalent dampness present [4]. However, buildings without obvious issues often present a larger problem. A comprehensive study of over 4,000 British office workers in buildings without known issues makes this clear [5]. Researchers reported that 57% of the occupants complained of lethargy. Forty to 50% listed blocked nose, dry throat, and headache as frequent symptoms, and about 25% suffered from itchy/dry eyes, runny nose, and flu-like symptoms. Studies such as these show that IAQ issues can become public health issues.

b. Standards: A number of federal agencies such as OSHA, the Department of Energy, and the Consumer Product Safety Commission are actively involved in IAQ research or policy guidance, but no one agency has a clear regulatory role [6]. Neither OSHA nor the USAF has published IAQ regulations. Establishing standards would be difficult, if not impossible, due to the variety of factors that affect what occupants believe is acceptable IAQ. The federal agencies most active in IAQ research are the National Institute of Occupational Safety and Health (NIOSH) and the Environmental Protection Agency (EPA), both of which publish guidance, case studies, and summaries of their findings. OSHA also provides guidance on IAQ in OSHA Technical Manual (OTM) Section III: Chapter 2 and provides details on investigating Legionnaire's disease in OTM Section III: Chapter 7 [7].

The most widely recognized standard on IAQ is from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). ASHRAE Standard 62.1-2010, *Ventilation for Acceptable Indoor Air Quality*, is most useful as a tool for heating, ventilation, and air conditioning (HVAC) experts, but it does make some important contributions to IAQ surveys. The standard includes design criteria for HVAC systems and describes procedures for providing acceptable air quality. Perhaps the most important contribution from ASHRAE 62.1-2010 is its definition of acceptable IAQ as "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction" [8]. ASHRAE also has published Standard 55-2010, *Thermal Environmental Conditions for Human Occupancy*, which describes thermal conditions acceptable to 80% or more of typical office workers [9].

Several international organizations have published standards or guidelines for IAQ. These organizations include the World Health Organization, the Nordic Committee on Building Regulations (NKB), the Swedish Council for Building Research [10,11], and the Ontario Ministry of Labor (MOL) [12]. These standards primarily set concentration limits for air contaminants, with values similar to the U.S. EPA National Ambient Air Quality Standards (NAAQS).

Many researchers believe indoor air should be regulated to satisfy both health and comfort requirements [13]. However, other researchers state that improvement of health should be the primary concern of IAQ regulation [14]. Within the Air Force, both health and comfort requirements should be considered in resolving IAQ complaints. Health concerns should receive emphasis because every worker has a right to a healthy work environment, yet comfort concerns (such as cold temperatures) should also be stressed for productivity and morale reasons.

Another controversial issue concerns setting chemical exposure limits for office work. In the past, ASHRAE has recommended using one-tenth of the threshold limit values of the American Conference of Governmental Industrial Hygienists (ACGIH) as standards for nonindustrial workers. Currently, ASHRAE has a more vague approach, stating "application of industrial exposure limits would not necessarily be appropriate for …other indoor settings, occupancies, and exposure scenarios. However, for certain contaminants that lack exposure limits for a specific nonindustrial target population, substantial downward adjustments to occupational limits have sometimes been used" [8]. The MOL and the NKB state that occupational standards or fractions of them are not relevant in nonindustrial settings [12,15].

c. Medical Effects of Poor IAQ: Symptoms of poor IAQ can vary depending on the problem in a building. However, typical IAQ symptoms include sleepiness; fatigue; dry throat; stuffy or running nose; headache; eye irritation; and dry, itchy skin or rash [16]. Other symptoms encountered may be frequent coughing or sneezing, dizziness, nausea, persistent colds, chest tightness, difficulty breathing, difficulty concentrating, flu-like symptoms, and an unusual taste or odor [17,18]. In addition, some specific conditions have been linked to building occupancy, such as hypersensitivity pneumonitis (inflammation of lung tissue), allergic asthma, and allergic rhinitis (allergies) [18].

Chapter 3. Factors Influencing Indoor Air Quality

a. Carbon Dioxide (CO_2) and Fresh Air: U.S. Air Force School of Aerospace Medicine (USAFSAM) consultants have observed that a correlation exists between high CO_2 levels, symptom intensity, and the number of affected individuals. Specifically, consultations have showed that occupants may begin to experience specific health effects at levels in excess of 600 parts per million (ppm). Symptoms may include headache, drowsiness, difficulty concentrating, and dizziness [18]. Other symptoms that may be attributed to high CO_2 levels include eye irritation, a sensation of stuffy or stale air, and fatigue [19]. Consultations have shown that approximately 15% to 33% of the population will have symptoms when the level is between 600 and 800 ppm, roughly one-third to one-half become symptomatic between 800 and 1,000 ppm, and virtually everyone will have some or all previously mentioned symptoms when the CO_2 level is greater than 1,500 ppm.

It is important to understand the basis for an acceptable level of CO_2 within a building. According to Trane Inc., "a high CO_2 concentration is an indicator of inadequate make-up (fresh) air and can be used as a 'tracer gas' to indicate the amount of people-generated contaminants (odors) in the space, but it does not reflect concentrations of other contaminants, such as those generated within the building or those brought in from outdoors" [20].

While typical outdoor air concentrations of CO_2 are typically 300-400 ppm, normal concentrations in office buildings range from 350 to 2,500 ppm [21]. ASHRAE 62.1-2010 points out that a CO_2 concentration of 700 ppm above outdoor air is **not** considered a health risk [8]. However, "no health risk" does not mean that no physiological effects will be experienced. Therefore, CO_2 levels below 1,000 ppm are acceptable, but levels below 600 ppm are ideal.

To show the correlation between CO_2 concentration and specific complaints, USAFSAM modeled human response to CO_2 by assuming there is a "no-effect" concentration of CO_2 where all persons are satisfied. It was also assumed that the concentration of CO_2 cannot rise high enough to dissatisfy everyone. CO_2 concentrations were correlated with the percentage of occupant satisfaction, based on complaints of fatigue, drowsiness, lack of concentration, and sensations of breathing difficulty. Figure 1 plots regression of the data from medical interviews and questionnaires performed in 18 buildings [22]. The 90% confidence limits are drawn in the figure. Stratification of CO_2 concentration in some buildings allowed for more than one data point per building.

The equation of the regression line in Figure 1 is:

$$S_c = 100 \text{ x } e^{[-0.0015 \text{ x } (C_s - 435)]}$$

Where: S_c = satisfaction rate (%),
And: C_s = steady state CO_2 concentration in the work space (ppm).

The correlation coefficient, R^2, is 0.79.

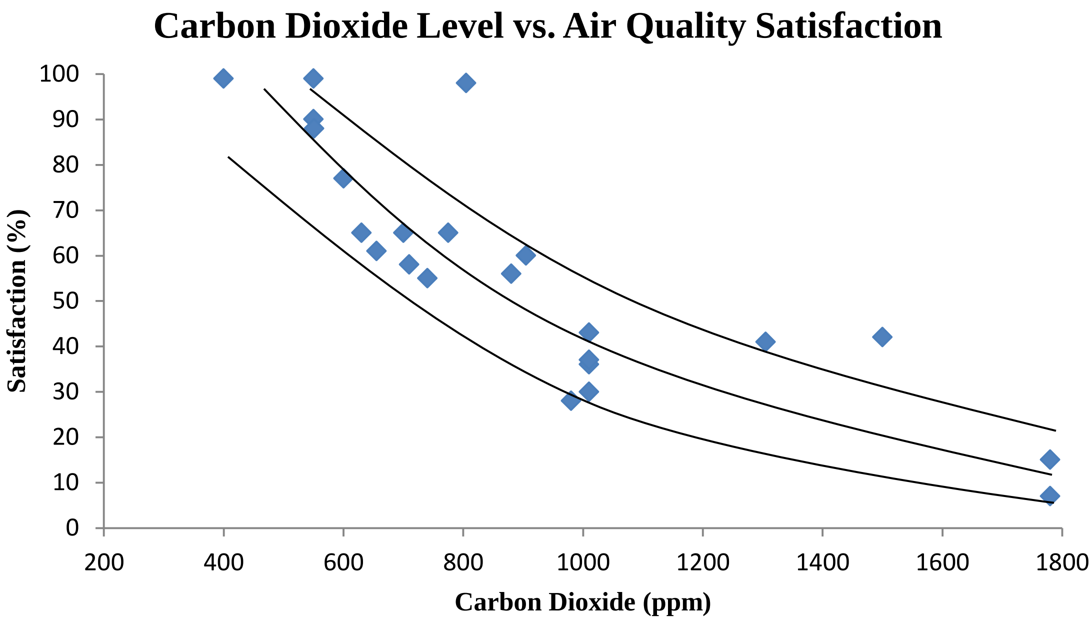

Figure 1. Rate of Satisfaction of Building Environment Based on Physiological Effects of Carbon Dioxide

An 80% satisfaction rate or better requires CO_2 concentrations below 580 ppm according to the model, which was rounded to 600 ppm. When C_s is 1,000 ppm, a 42% satisfaction rate is predicted.

Workers are the only significant source of CO_2 in an office environment, so it is fairly simple to relate CO_2 concentration to flow of fresh air using tracer gas theory.

Using the steady state CO_2 concentration, the relation is:

$$Q = \frac{11{,}500n}{C_s - C_a}$$

Where: Q = fresh airflow rate (cubic feet per minute, cfm),

n = the number of persons served by the air handler,

C_s = steady state CO_2 concentration in the work space (ppm),

C_a = the concentration of CO_2 in the ambient (outdoor) air (ppm),

And: 11,500 is a constant based on the average human CO_2 generation rate of 0.0115 cfm per office worker. This constant comes from ASHRAE 62.1-2010, which assumes a breathing rate of 9 liters of air per minute and a concentration of CO_2 in the expired breath of 37,000 ppm [8].

This equation has been verified in several buildings. It is used to calculate the fresh airflow required per person to keep the CO_2 concentration at 600 ppm or below. Assuming that the average outdoor concentration of CO_2 is 325 ppm, Q/n = 11,500/(600-325) = 42 cfm/person [22].

b. Relative Humidity: Relative humidity below 40% can cause specific physiological effects that lead to discomfort and dissatisfaction with the environment. Symptoms include dry, sore nose and throat; bleeding nose; sinus and throat irritation; dry, scratchy eyes; inability to wear contact lenses; and dry, itchy, flaking skin [16,23]. The number of persons affected increases as the relative humidity decreases below 40%.

The inability to wear contact lenses in a building with low relative humidity results from fluid loss from the exposed outer eye surface (conjunctiva, cornea, and sclera) to the dry indoor atmosphere. The resultant loss of ocular fluid/lubrication causes an inflammation to the exposed eye and may enhance the possibility of an infection. Even without contact lenses, the eyes can feel dry, irritated, and itchy.

Low relative humidity also contributes to an increase in respiratory illness by weakening the defenses provided by the pulmonary mucous membranes. There are many examples in scientific literature that support the increased opportunity for human respiratory infections with long-term frequent exposure to buildings with low relative humidity [24-26]. A significant side effect of respiratory illness that often signals a low humidity problem is frequent headaches from sinus congestion and inflammation.

The same technique was used by USAFSAM to model human response to low relative humidity as was used for CO_2. It was assumed that there is a "no-effect" relative humidity where all persons are satisfied, but there is no relative humidity so low that all persons are dissatisfied.

Relative humidity measurements were correlated with percentage of occupant satisfaction, based on complaints of nasal congestion/problems, sinusitis, eye irritation and itching, dry and itchy skin, and headaches. The data collected showed a weak correlation between occupant satisfaction and relative humidity, but it might be attributed to the fact that HVAC systems do not control humidity. In other words, while the questionnaire responses are based on the prevailing humidity in a building, the relative humidity measured on a particular day may not have been indicative of the prevailing humidity.

The USAFSAM data predict an 80% satisfaction rate or better when the relative humidity is above 63%. While it is not convincing enough to flatly recommend a relative humidity of 63%, the data did show that relative humidity below 40% causes strong dissatisfaction with the environment. In fact, UFC 3-410-01, *Heating Ventilating, and Air Conditioning Systems*, states that "where the indoor relative humidity for comfort heating is expected to fall below 20% for extended periods, humidification must be added to increase the indoor relative humidity to 30%" [27]. At the other end of the spectrum, USAFSAM has found that relative humidity above 65% causes other problems. Carpets, curtains, furniture, etc. can absorb enough moisture at 65% relative humidity to promote microbial growth. Therefore, it is USAFSAM's recommendation to control the relative humidity in nonindustrial work areas to levels between 40% and 60%. ASHRAE 55-2010 recommends 30% to 60% relative humidity [9].

c. Temperature: USAFSAM consultants have performed surveys in office buildings where approximately half of the workers complain of being too cold and the other half complain of being too hot. Various issues such as wide temperature variations, lack of thermostat control, and draftiness are the most common complaints that cause such an environment.

Consultant surveys showed that office workers are tolerant of dry bulb temperatures between 68°F and 76°F. HVAC systems are designed to control temperatures within this range, and most do a good job on average. However, parts of a building are often found with wide temperature variations over short periods of time, such as cold blasts of air coming out of supply air diffusers. Workers sitting in front of such an air diffuser may feel that the building is too cold due to the short blasts of cold air, even if the building's relative temperature is average.

Denying temperature control to workers can also contribute to temperature dissatisfaction. In buildings where thermostats are nonexistent or tamper-proof, occupants are often found to be dissatisfied with the building's temperature, even if it is reasonably satisfactory. Giving workers some control over their environment can help boost morale and increase occupant satisfaction.

ASHRAE recommends cooling season operative temperatures of 23°C to 26°C (73°F to 79°F) and heating season operative temperatures of 20°C to 23.5°C (68°F to 75°F) in offices [9]. The difference in seasons occurs because ASHRAE assumes that persons in the winter will be wearing more clothing, such as sweaters and heavier pants. Thus, "summer" and "winter" settings should depend locally on what people ordinarily wear to work, not strictly on the calendar definitions of summer and winter.

Other factors reported in ASHRAE 55-2010 that affect human perception of "too hot" or "too cold" are high radiant temperatures; fluctuations in temperature of more than 4°F per hour; air movement greater than 50 feet per minute in the work space; a temperature difference from foot to head of more than 5°F; and radiant asymmetry from any direction (above, below, sideways) caused by a very warm or very cold surface, such as a radiator or window [9]. Effects of high temperatures are headache, fatigue or lethargy, and a sensation of dry air, while the effects of cold temperatures include clumsiness and complaints of draftiness and being chilly [10].

d. Occupant Density: Giving workers enough space is essential to their comfort and morale. CO_2 concentrations, odor, and relative humidity will increase with occupant density [28]. In addition, as the occupant density increases, the heat load from people and their office equipment can increase beyond the cooling capacity of the air conditioning system.

Occupant density criteria specific to facility type and function can be found in Air Force Manual 32-1084, *Facility Requirements* (2012) [29]. It is important to note that occupant densities should be determined for rooms that appear to be crowded, and not as an average for a whole building.

e. Dust and Fibers: It can typically be expected that dust levels inside buildings will be higher than outdoors. Poor housekeeping sometimes is the cause of high dust levels, but dust and fibers build up indoors primarily through the ventilation system. More often than not, air filters have less than 20% capture efficiency. Thus, dust from the outdoors is allowed to enter and collect in the building. Also, the inside of ductwork may be lined with fiberglass insulation rather than having it wrapped around the outside. After just a few years, the interior insulation can deteriorate and release fibers into the air. This fiberglass can cause epidemics of rash and itching, especially in buildings with low humidity, as low humidity increases the skin's reaction to irritants [18]. In fact, one office was surveyed where fiberglass fibers caused such an irritating rash that workers were certain the office was infested with fleas. When IAQ complaints are attributed to excessive dust and fibers, air filters and/or air ducts may likely be the source of the problem.

f. Volatile Organic Compounds (VOCs): VOCs have been implicated as a source of irritation in office buildings, with formaldehyde being the compound of most concern [18]. Other VOCs commonly found in the workplace are heavy alkanes (7 to 11 carbons in a hydrocarbon chain), aromatics (toluene, xylene, ethylbenzene), and cyclic compounds (cyclohexanol, butylcyclohexane) [16]. The NKB reports the range of VOC concentrations measured in offices has been from 0.05 to 1.3 milligrams per cubic meter (mg/m^3), compared to outdoor levels of 0.01 to 0.04 mg/m^3 [15]. Higher concentrations of VOCs will exist in new buildings or in buildings with new furniture or paint. Such levels will dissipate within a few weeks unless the air is highly recirculated.

One study showed that persons exposed to low concentrations of VOCs are likely to complain of eye and mucous membrane irritation, an unpleasant odor, a sensation of temperature increase, and difficulty concentrating [30]. The concentrations of VOCs studied were 5 mg/m^3 and 25 mg/m^3 or 4 to 100 times the typical concentrations found in offices. Other reported symptoms of elevated VOC concentrations are headache, nausea, dizziness, fatigue or lethargy, and respiratory irritation [16,23,31]. The symptoms associated with VOC concentrations above 5 mg/m^3 are nearly indistinguishable from symptoms associated with elevated CO_2 concentrations and low relative humidity. In addition, each of the three agents shares a common cause (i.e., high recirculation rates and little or no fresh air). Therefore, it can be difficult to distinguish if VOCs or the combination of high CO_2 and low relative humidity is the source of occupants' complaints.

Evaluating total VOCs can be difficult since so many compounds are present in low concentrations, but a few options for detection do exist. For example, the HAPSITE and/or a flame ionization detector can be used to screen for areas with high VOC levels. However, unless a probable source exists, it is not advised to do extensive sampling (beyond screening) for specific VOCs.

In buildings with high levels of VOCs, some researchers have advocated "baking out" the VOCs by raising the temperature above 26.6°C (80°F) for 1 week to 1 month during unoccupied periods [18]. However, others have found that baking out is fairly unsuccessful, and it tends to put cracks near windows and damage furnishings [32]. It has been recommended to ventilate the building with 100% outdoor air instead, for at least 1 week [32].

g. Smoking: Air Force Instruction (AFI) 40-102, *Tobacco Use in the Air Force*, was substantially revised in 2012. This revision should reduce smoking-related IAQ issues. The implementation of designated tobacco areas (DTAs) will help to ensure that cigarette smoke is not entering buildings through air intake units/vents. AFI 40-102 prohibits tobacco use on Air Force installations, except in DTAs and housing units [33].

The term "tobacco" includes, but is not limited to, cigars, cigarettes, electronic-cigarettes ("e-cigarettes"), stem pipes, water pipes, hookahs, and smokeless products. AFI 40-102 makes the following requirements that affect IAQ [33]:

- The use of tobacco products is permitted only in designated tobacco use areas.
- The Air Force prohibits indoor tobacco use in all Air Force facilities, except in assigned Government housing.
- DTAs will be located away from common points of facility entry/egress and not in front of buildings or air intake ducts.

BE and Public Health (PH) should refer to the specific requirements of the instruction if complaints about tobacco smoke in Air Force facilities are encountered. Ensure that personnel are only smoking in designated areas and that those areas are away from building air intakes. Tobacco smoke has been associated with a number of acute health effects. These effects include eye irritation, mucous membrane irritation, asthma and hypersensitivity reactions, headache, respiratory irritation, drowsiness, nausea, loss of appetite, an increased rate of respiratory illness, non-allergic rhinitis, and an unpleasant odor [10,12,18].

h. Combustion Gas By-Products: Boilers, fuel burning engines, parking garages, or busy streets near the fresh air intake of an air handler can be a potential source of IAQ complaints [23]. The three most likely combustion gas products are carbon monoxide, nitrogen dioxide, and sulfur dioxide. Carbon monoxide is odorless and can cause fatigue or drowsiness, nausea, headache, and difficulty breathing. The nitrogen and sulfur dioxides have characteristic odors and may cause respiratory system irritation as well as eye and mucous membrane irritations.

When sampling for these combustion products, the most useful standards for comparison are the NAAQS published by the EPA [34]. Comparison to the current outside concentration is also useful. If there is a problem with combustion products, the solution is to properly ventilate the combustion source or to move the fresh air intake.

i. Other Contributors: Other contributors that have been implicated in IAQ surveys are pesticides, ergonomic issues, and the actual building occupants. Ergonomic issues are not typically grouped together with IAQ issues, but the design of a work area may have a surprisingly negative effect on occupants. For example, insufficient light, glare, and issues with workstation setup (such as an improper angle on the computer monitor or wrong height for the keyboard) can cause eyestrain, headaches, and back pain from poor posture. These complaints can be incorrectly attributed to the air quality.

Pesticide application can cause short-term irritant effects in some individuals, but if overused or used in a building with a high recirculation rate, the irritation can last for months. When overused, pesticides and their inert carriers (often petroleum products) can be absorbed by carpets, wall fabrics, and ceiling tiles, and then may desorb back into the air at a later time [18].

Building occupants are also a major contributor to IAQ. Occupants are increasingly responsible for housekeeping and may not know or utilize the best housekeeping practices. Untimely removal of garbage, improperly cleaned spills, and the lack of dusting/vacuuming can all lead to IAQ issues. Even the improper care of indoor plants can lead to microbial growth and pest infestation.

Chapter 4. Bioaerosols

a. Fungi and Bacteria: The usual bioaerosols implicated in building-related health effects are fungi and bacteria. The concentration of fungi and bacteria in buildings is related to the concentration of the microorganisms in the outdoor air, which is typically the source of indoor microorganisms.

It is important to remember that fungi and bacteria in buildings are normal and only become a problem when indoor amplification occurs. This is typically caused by water intrusion through the roof, walls, or floors, or as a result of high humidity. Once growth begins, fungal spores and bacteria amplify quickly. These microorganisms can produce new spores that may be introduced into the airstream from mold growth on wet building material, or may be from the disturbance of other building materials (e.g., renovations, repair work, etc.). Such growth also can lead to the release of VOCs and odors characteristic of fungal/microbial growth. Preventing and remediating water damage is the key to protecting the health and well-being of AF communities and AF infrastructure. However, moisture control must be combined with adequate housekeeping and active participation of facility occupants in inspecting and responding promptly to initial signs of mold. See Appendix A for further guidance on mold and water damage response procedures.

Outdoor air concentrations of fungi and bacteria are typically much higher than those found indoors. In fact, indoor air concentrations are usually equal to 20% of the concentrations found in outdoor air. Amplification is indicated when the indoor concentration is higher than that found in the outdoor air. However, there is no specific concentration of indoor fungi and environmental bacteria that is acceptable or unacceptable, and **there are no standards regulating microorganisms in the environment** [18]. ACGIH recommends gathering the best data possible and using knowledge, experience, expert opinion, logic, and common sense to interpret information and design control and remediation strategies [35].

Air sampling for microorganisms is difficult and expensive and is usually unnecessary because a contamination site is typically obvious. Water stains, visible mold growth, and decayed substrates would be indications of a contamination site that can be visually identified. Contamination sites should be cleaned up as soon as is feasible. Not only would microbial sampling delay clean-up efforts, it often costs more to sample a suspected contamination site than it does to clean it up. After careful consideration, if the decision to sample is made, refer to the USAFSAM Laboratory Sampling and Analysis Guide and contact the USAFSAM Laboratory Customer Service for assistance.

(1) Fungi: It is important to note that fungi *can* be present in the form of mold, but mold is not the only way that fungi can be present. In other words, all molds are fungi, but not all fungi are molds. Exposure to airborne fungal matter can cause the following effects on human health:

- Irritation: Symptoms are usually associated with the eyes, nose, throat, and skin. Although not often serious, these symptoms can be persistent and annoying, leading to disruption and loss of worker efficiency.

- Infections: Environmental fungi commonly found in buildings are very unlikely to cause infections. However, when illnesses due to fungi occur, they may be serious and difficult to treat. These can vary from superficial skin diseases (e.g., athlete's foot) to serious lung infections, or even invasive disease throughout the body. Two species of infectious fungi are of particular concern. These are *Histoplasma capsulatum var. capsulatum* and *Cryptococcus neoformans*. Both cause pulmonary infections by inhalation of airborne spores and are associated with bird or bat droppings, not mold.

- Allergies: Allergic reactions are far more common than infections. Individuals may be allergic to several different fungi. Asthma attacks can be triggered by a variety of environmental factors including fungi.

- Mycotoxins and toxic effects: Some fungi produce mycotoxins, which may be detrimental to humans, animals, and other microorganisms. Serious veterinary and human mycotoxicoses have been documented following ingestion of foods heavily overgrown with mold. In high concentrations, mycotoxins can also cause respiratory illnesses and are, in general, associated with agricultural settings in which workers have inhaled high concentrations of mixed organic dust. Current scientific evidence does not indicate that human health has been adversely affected by inhaled mycotoxins in the home, school, or office environment [36].

(2) Bacteria: Bacteria in the indoor environment can usually be categorized into one of three groups:

(a) Human-commensal bacteria: The human-commensal bacteria are those such as *Staphylococcus*, *Micrococcus*, *Streptococcus*, *Moraxella*, *Stomatococcus*, and *Escherichia coli* that commonly grow in harmony with humans and usually do not persist permanently in the environment. When found in the indoor environment, their most likely origin is the building occupants. Their growth is not usually associated with the building environment other than high occupant density or poor ventilation.

(b) Environmental bacteria: The environmental bacteria are those such as *Pseudomonas*, *Acinetobacter*, *Aeromonas*, *Arthrobacter*, *Bacillus*, and *Sphingomonas*. When high concentrations of these bacteria are found in the indoor environment, their most likely sources are through the outdoor air source or growth in a wet indoor environment. These are rarely from human sources. Heavy growth may occur very quickly, within 1 or 2 days, causing odors and health complaints. The bacteria, which are commonly found in water-damaged buildings, may produce endotoxins as a component of their cell walls. When these endotoxin-containing bacteria decompose, if they become aerosolized, they may cause an upper respiratory, mild flu-like disease.

(c) Thermophilic bacteria: Thermophilic bacteria are those that grow at high temperatures (50-56°C). They may be associated with compost heaps, moldy hay, and other sources of organic matter undergoing decomposition and are therefore more likely to be an agricultural problem than an IAQ issue. However, they can occur in water-damaged buildings on rare occasions. Long-term exposure may cause hypersensitivity pneumonitis.

(3) Bacteria of Special Interest: Due to exaggerated media coverage, two bacterial groups, *Legionella* and *Mycobacterium* species, are often overemphasized in IAQ investigations. However, these bacterial groups should be managed like any other microbial concern.

(a) *Legionella*: These bacteria occur naturally in rivers, lakes, and streams. *Legionella* bacteria only become a problem when amplified in warm (80°F to 120°F) building water systems where the water is aerosolized (cooling towers, hot water systems, whirlpool baths, and indoor decorative fountains). Two forms of disease may occur: Legionnaires' disease (pneumonia) and Pontiac fever (non-pneumonic flu-like disease). The most effective control is to prevent amplification. More information can be found on *Legionella* in OTM Section III: Chapter 7 [7].

(b) Environmental Mycobacteria: Environmental mycobacteria species are in the same genus with *Mycobacterium tuberculosis*, the agent that causes tuberculosis. Unlike *M. tuberculosis*, environmental mycobacteria do not cause tuberculosis and are naturally found in the environment [37].

b. Adverse Health Effects Associated with Mold: Approximately 5% of individuals are predicted to have some allergic airway symptoms from mold exposure over their lifetime [36]. However, it should be remembered that molds are not dominant allergens and that outdoor molds are generally more abundant and important in airway allergic disease than indoor molds.

Individuals with allergic airway disease should take steps to minimize their exposure to molds and other airborne allergens, such as animal dander, dust mites, and pollens. For these individuals, it is prudent to take feasible precautions to reduce exposure to aeroallergens both at work and at home and to remediate sources of indoor mold amplification. Precautions may include closing windows, removing pets, using dust mite covers, using high quality vacuum cleaners, or filtering outdoor air intakes.

c. Sampling Factors: Mold growth in buildings should be remediated and the cause of the growth eliminated. Regardless of the type of biological growth, the recommendation is the same: visible mold always requires remediation. According to Colonel Laura Torres-Reyes, Director of the Occupational Medicine Residency Program at USAFSAM, "It does not matter what type of mold is in a building. Mold is ubiquitous, and there is no value in determining what types are present inside. The notorious 'Black Mold' *Stachybotrys chatarum* has not been shown to cause health effects from exposures in home, school, or work environments." **Therefore, USAFSAM's recommendation is to not perform mold sampling**.

Interpretation of sampling data can be very problematic. There are no occupational and environmental exposure limits for mold, and the ACGIH Bioaerosols Committee has reiterated annually that they cannot recommend threshold limit values because of sampling variability, a wide variability of susceptibility of workers, the large number of different types of bioaerosols, and poor exposure-response relationship data.

If sampling indicates outside concentrations are much higher than inside, it might be concluded that there's not a mold problem inside, but good visual inspection would likely have resulted in the same conclusion, or there may be visible mold in the building while the air sampling indicates no significant problem. False negatives can potentially occur for many reasons. The mold may not be emitting spores due to the stage in its life cycle or another factor may have affected the sampling. Overall, mold samples provide very little (if any) useful information.

Chapter 5. HVAC Systems

a. Influence of Ventilation System: The design and maintenance of an HVAC system have the greatest influence on IAQ. In 70% of the buildings surveyed by USAFSAM consultants, the HVAC system played a major role in the symptoms experienced by occupants. In addition, many of the comfort parameters and contaminants discussed earlier can be made worse by the condition of the HVAC system. Dirt, mold, and moisture that can accumulate in a poorly maintained HVAC system can contribute to IAQ symptoms. Researchers have found that the design features of a building's ventilation system correlate with the number of IAQ symptoms [5]. Complex HVAC systems require greater maintenance man-hours and, if not provided, can be a contributing factor of poor IAQ.

The term "HVAC system" is used to refer to the equipment that can provide heating, cooling, filtered outdoor air, and humidity control to maintain comfort conditions in a building. Not all HVAC systems are designed to accomplish all these functions. Some buildings rely only on natural ventilation. Others lack mechanical cooling equipment (air conditioning), and many function with little or no humidity control. The features of the HVAC system in a given building will depend on several variables, including age of design, climate, building codes in effect at the time of design, budget that was available for the project, planned use of the building, owners' and designers' individual preferences, and subsequent modifications.

HVAC systems range in complexity from stand-alone units that serve individual rooms to large centrally controlled systems serving multiple zones in a building. In large modern office buildings with heat gains from lighting, people, and equipment, interior spaces often require year-round cooling. Rooms at the perimeters of the same building (i.e., rooms with exterior walls, floors, or roof surfaces) may need to be heated and/or cooled as hourly or daily outdoor weather conditions change. In buildings over one story in height, perimeter areas at the lower levels also tend to experience the greatest uncontrolled air infiltration.

Some buildings use only natural ventilation or exhaust fans to remove odors and contaminants. In these buildings, thermal discomfort and unacceptable IAQ are particularly likely when occupants keep the windows closed because of extreme hot or cold temperatures. Problems related to underventilation are also likely when infiltration forces are weakest (i.e., during the summer months and the periods of transition between seasons).

Modern public and commercial buildings generally use mechanical ventilation systems to introduce outdoor air when the buildings are occupied. Thermal comfort is commonly maintained by mechanically distributing conditioned (heated or cooled) air throughout the building. In some designs, air systems are supplemented by piping systems that carry steam or water to building perimeter zones. As this section is concerned with HVAC systems in relation to IAQ, the remainder of this discussion will focus on systems that distribute conditioned air to maintain occupant comfort.

The most notable HVAC failures are poorly maintained systems, poor or nonfunctioning controls, no fresh air intake, no exhaust, and poor placement or blockage of supply diffusers [38]. These failures typically occur either because maintenance workers do not have the proper training or a decision was made without realizing the impact on the occupants. For instance, condensation pans underneath cooling coils should be designed and pitched to be self-draining [8,28,32]. Yet, consultants have found countless condensation pans with standing water and microbial contamination because maintenance crews have never had the training or experience to see that pans drain properly. It has also been found that thin fiberglass or metal screen pre-filters are often used as the only particulate removal mechanism because they are inexpensive. What is not considered is that pre-filters are less than 20% efficient at dust removal.

As another example, inadequate balancing of ventilation systems often leads to marked variations in temperature over short distances in a building. The temperature may vary so widely in the same location over short periods of time that the anticipation of the next cold blast after a hot period detracts from attention to work. Problems of this nature occur because the control equipment responsible for directing airflow is positioned in places inaccessible for maintenance. After some time the controls become unresponsive to central control. Other obvious reasons for HVAC failures are reduction of the HVAC maintenance work force to save personnel costs and the creation of new rooms with floor-to-ceiling partitions that disrupt proper airflow patterns.

The IAQ impact of other common HVAC decisions is more subtle. For example, in many USAF buildings, the HVAC system is turned off during unoccupied periods (evenings and weekends). With proper design and system scheduling, night setback/shutdown can be used. It should be ensured that a proper ventilation purge cycle is used to reduce indoor air pollutants and humidity preheat/precool control is initiated prior to occupancy. Another common design decision is to not provide operable windows in buildings. Although not commonly found in most modern office buildings, windows that can be opened by the occupants have been effectively integrated with pressurized buildings. Such designs can prevent a significant percentage of building IAQ issues, especially temporary temperature control or air contaminant problems [38].

b. Types of HVAC Systems: The various types of HVAC systems will each affect IAQ in different ways.

(1) Single Zone: A single air-handling unit (AHU) can only serve more than one building area if the areas served have similar heating, cooling, and ventilation requirements, or if the control system compensates for differences in heating, cooling, and ventilation needs among the spaces served. Areas regulated by a common control (e.g., a single thermostat) are referred to as zones.

Thermal comfort problems can result if the design does not adequately account for differences in heating and cooling loads between rooms that are in the same zone. This can easily occur if:

- The cooling load in some area(s) within a zone changes due to an increased occupant population, increased lighting, or the introduction of new heat-producing equipment (e.g., computers, copiers).

- Areas within a zone have different solar exposures. This can produce radiant heat gains and losses that, in turn, create unevenly distributed heating or cooling needs (e.g., as the sun angle changes daily and seasonally).

(2) Multiple Zone: Multiple zone systems can provide each zone with air at a different temperature by heating or cooling the airstream in each zone. Alternative design strategies involve delivering air at a constant temperature while varying the volume of airflow, or modulating room temperature with a supplementary system (e.g., perimeter hot water piping).

(3) Constant Volume: Constant volume systems, as their name suggests, generally deliver a constant airflow to each space. Changes in space temperatures are made by heating or cooling the air or switching the AHU on and off, not by modulating the volume of air supplied. These systems often operate with a fixed minimum percentage of outdoor air or with an "air economizer" feature.

(4) Variable Air Volume: Variable air volume (VAV) systems maintain thermal comfort by varying the amount of heated or cooled air delivered, rather than by changing the air temperature. However, many VAV systems also have provisions for resetting the temperature of the delivery air on a seasonal basis, depending on the severity of the weather. Overcooling or overheating can occur within a given zone if the system is not adjusted to respond to the load. Underventilation frequently occurs if the system is not arranged to introduce at least the minimum quantity of outdoor air as the VAV system throttles back from full airflow, or if the system supply air temperature is set too low for the loads present in the zone.

c. HVAC Duct Cleaning: Most concerns about HVAC duct cleaning arise when there is visible dust, dirt, or fungi on some or all supply air diffusers (grills) in a particular building. In most of these cases, the assumption was made that the HVAC ducts needed to be cleaned, without doing a thorough inspection of the HVAC system. After further inspection, it is often found that the HVAC system is actually fairly clean and that the dust or dirt on the supply air diffusers is not coming from the HVAC system. Dust, dirt, or even mold can occur on the air diffusers for several reasons without any problem or contamination of the HVAC system. Air flowing past the diffuser can create an electrical charge that attracts dust particles. Cool air exiting the diffuser can cause moisture to condense on the vents that allows dirt to adhere and provides a media for microbial growth. However, every case is unique, and a proper evaluation must be made to determine the extent of any contamination in the HVAC system.

The EPA has published a guide titled *Should You Have the Air Ducts in Your Home Cleaned* (1997), aimed at residential occupants [39], but the same principles apply to office buildings with HVAC systems. In addition, in the EPA publication *Building Air Quality* (1991), duct cleaning is discussed [40]. The following information has been extracted from these two EPA publications.

The same HVAC system that distributes conditioned air throughout a building can distribute dust and other pollutants, including biological contaminants. Dirt or dust accumulation on any components of an air-handling system, cooling coils, plenums, ducts, and equipment housing, may lead to contamination of the air supply.

Consider having the air ducts cleaned if:

- There is substantial visible mold growth inside hard surface (e.g., sheet metal) ducts or on other components of the heating and cooling system. There are several important points to understand concerning mold detection in heating and cooling systems:

    - Many sections of the heating and cooling system may not be accessible for a visible inspection, but the service provider can point out any mold.

    - Be aware that although a substance may look like mold, a positive identification can only be made by an expert.

    - If the insulation in insulated air ducts gets wet or moldy, it cannot be effectively cleaned and should be removed and replaced.

    - If the conditions causing the mold growth are not corrected, mold growth will reoccur.

- Ducts are infested with vermin (e.g., rodents or insects).

- Ducts are clogged with excessive amounts of dust and debris and/or particles are being released into the building from the supply registers.

d. Other Important Considerations for Duct Cleaning: It is important to keep in mind that dirty air ducts are only one possible source of particulates that are present in buildings. Pollutants that enter a building both from outdoors and indoor activities such as cooking, cleaning, or just moving around can cause greater exposure to contaminants than dirty air ducts. Moreover, there is no evidence that a light amount of household dust or other particulate matter in air ducts poses any risk to health.

The EPA recommends that air ducts be cleaned only on an as-needed basis because of the continuing uncertainty about the benefits of duct cleaning in most circumstances [39]. The EPA does, however, recommend that fuel burning furnaces, stoves, or fireplaces be inspected for proper functioning and serviced before each heating season to protect against carbon monoxide poisoning [41]. Some research also suggests that cleaning dirty cooling coils, fans, and heat exchangers can improve the efficiency of heating and cooling systems [39]. However, little evidence exists to indicate that simply cleaning the duct system will increase a system's efficiency [39].

NOTE: BE personnel will need to discuss duct cleaning with Civil Engineering (CE) personnel. Work with CE HVAC technicians and engineers when deciding whether duct cleaning is needed and when choosing a duct cleaning service. Contracts for duct cleaning must be coordinated through CE.

e. Energy Efficiency: Unfortunately, an emphasis on energy conservation efforts and budget cutbacks has led many to forget that the primary function of office buildings is to provide occupants with a comfortable and healthy environment in which to work. Providing this environment is largely dependent on the proper design, operation, and maintenance of a building's HVAC system [28]. The Ontario Ministry of Labor has concluded that the single most effective solution to IAQ issues is an adequate fresh air supply from a properly designed, operated, and maintained HVAC system [12]. The requirements of proper ventilation should dominate design and construction decisions, not the cost of heating, cooling, or equipment [42].

HVAC systems can be made energy efficient without compromising the fresh air quantity, and the costs of human productivity losses far outweigh any savings realized by minimizing fresh air. The EPA states that increasing outdoor air to meet ASHRAE Standard 62-1999 in most of the office buildings in their study resulted in very modest increases in energy costs. The main factor affecting the energy cost of raising outdoor airflow was occupant density, such that buildings with higher occupant density experienced higher energy cost increases. But for office buildings with 7 persons per thousand square feet, with moderate chiller and boiler efficiencies, and operating in daytime mode for 12 hours per workday, raising outdoor airflow from 5-20 cfm (2-9 L/s) per occupant raised HVAC energy costs by 2%-10% depending upon system and climate variations. Considering the total energy bill, this increase amounted to approximately 1%-4%. This is generally less than is commonly perceived [43]. Table 1 below describes methods to reduce energy use while maintaining acceptable IAQ.

f. Productivity and Economic Impact: The World Health Organization has estimated that 30% of new or renovated office buildings have identifiable IAQ issues [16]. The general nature of this phenomenon translates into a huge productivity loss. In a New England study of 3,500 office workers, 54% felt poor IAQ resulted in some productivity loss for themselves [44]. Using the most conservative interpretation of these data, an overall 3% loss in national productivity was estimated, which equates to $60 billion in lost time per year [44]. According to the National Center for Health Statistics, the average number of respiratory infections involving colds and flu is one per person per year. Tight buildings can increase that number to between 1.5 and 3.0 episodes per person per year, which can double the cost of so-called energy efficient measures [22].

Wyon has reported some specific productivity losses. Typing productivity dropped by 30% at a room temperature of 23.8°C compared to 20°C (68°F). His data also showed assembly line production dropped by 1% for each 1.1°K (2°F) variation from the ideal, and track drivers missed 50% more signals at 26.6°C (80°F) compared to 21.1°C (70°F). Workers who had individualized control over their temperature had 69% fewer sick days than those under centralized temperature control. He also found that persons not currently suffering from IAQ symptoms are 5% more productive than when suffering from two symptoms (an average figure in offices). In addition, persons suffering from six or more symptoms (not unusual) are 10% less productive than when suffering from two symptoms [45].

Table 1. Energy Measures Compatible with Maintaining IAQ*

Measure	Comment
Improve building shell	• May reduce infiltration. May need to increase mechanically supplied outdoor air to ensure applicable ventilation standards are met.
Reduce internal loads (e.g., lights, office equipment)	• Reduced loads will reduce supply air requirements in VAV systems. May need to increase outdoor air to meet ventilation standards. • Lighting must be sufficient for general and task lighting needs.
Fan/motor/drives	• Negligible impact on IAQ.
Chiller/boiler	• Negligible impact on IAQ.
Air-side economizer	• Uses outdoor air to provide free cooling. Potentially improves IAQ when economizer is operating by helping to ensure that the outdoor air ventilation rate meets IAQ requirements. • On/offset points should be calibrated to both the temperature and moisture conditions of outdoor air to avoid indoor humidity problems. May need to disengage economizer during an outdoor air pollution episode.
Night pre-cooling	• Cool outdoor air at night may be used to pre-cool the building while • simultaneously exhausting accumulated pollutants. However, to prevent microbiological growth, controls should either halt pre-cooling or activate dehumidification if the dew point of outside air is high enough to cause humidity to rise above 60%.
CO_2-controlled ventilation	• CO_2-controlled ventilation varies the outdoor air supply in response to CO_2. May reduce energy use for general meeting rooms, studios, theaters, etc. where occupancy is highly variable and irregular. A typical system will increase outdoor air when CO_2 levels rise to 600-800 ppm to ensure that maximum levels do not exceed 1000 ppm. The system should incorporate a minimum outside air setting to dilute building-related contaminants during low occupancy periods.
Reducing demand charges	• Night pre-cooling and sequential startup of equipment to eliminate demand spikes are examples of strategies that are compatible with IAQ. Caution is advised if load-shedding strategies involve changing the space temperature set points or reducing outdoor air ventilation.
Supply air temperature reset	• Supply air temperature may sometimes be increased to reduce chiller energy use. However, fan energy will increase. Higher supply air temperatures in a VAV system will increase supply airflow. Note that the supply air temperature should not be raised above a level where indoor humidity cannot be maintained below 60%.

*Derived from EPA *Energy Cost and IAQ Performance of Ventilation Systems and Controls,* Jan 2000 [43].

The average sickness absence rate reported by the Bureau of Labor Statistics is 3.6 days per person per year. Data from "healthy" buildings in the USAF agrees with this figure. In a typical building with IAQ issues, the sickness absence rate is found to be approximately 9 days per person per year. (Sickness absence rates are determined by collecting sick leave data from civilian timekeepers and subtracting out sick leave obviously unrelated to the building, such as pregnancy, injury, or alcohol abuse.) Based on sickness absence alone and 220 workdays per year, the productivity loss in an average building with poor IAQ is (9 - 3.6)/220, or 2.5%. Add this time lost on the job suffering from IAQ symptoms, and it becomes obvious that operating an HVAC system properly with the proper level of maintenance is more cost effective than any attempt to save money by cutting down the fresh air or reducing the maintenance staff.

Chapter 6. Conducting an IAQ Survey

a. IAQ Survey Team: The quality of an IAQ survey reflects the capabilities of the survey team. BE, the Occupational Health Physician/Flight Surgeon, PH, and the facility manager all have specific expertise to apply and must work closely with CE to identify and correct problems. With appropriate effort, quality environments can be achieved and maintained. It is also important to involve management and employee representatives. The most important factor in the long-term solution of building-related issues is effective on-going communication between the investigating team, the facility manager, and employees [23].

b. Survey Protocols: Steps for a successful survey include an initial walk-through evaluation of the building, possible self-administered questionnaires, personal interviews with the employees, air sampling (only if absolutely necessary), a detailed report of findings and recommendations, and follow-up visits to assess the success of the recommendations [23]. If air sampling is conducted, a cross-sectional analysis of interviews and air sampling results can be used to develop conclusions and test hypotheses [23]. A cross-sectional analysis determines frequencies of symptoms by area of a building, job description, or ventilation unit and compares to air sampling results in affected areas as well as control areas. Control areas can be "healthy" buildings or an unaffected part of the building being surveyed. The outdoor air is also a useful control [18].

The most important functions of the physician, BE, and PH in any IAQ survey are educating the building occupants and communicating with them. Building occupants and management (base and hospital commanders, unit commanders, or supervisors of affected workers) should be treated as members of the IAQ team. Since they have an impact on (and experience the effects of) IAQ daily, their roles are of the utmost importance. Occupants need to know what is causing health issues and what can be done to improve the working environment, and management needs to be informed about their building occupants. When all groups are kept in the loop, they can communicate effectively and achieve effective results.

c. USAFSAM Protocol for Comprehensive IAQ Surveys:

(1) BE should first tour the building and check for any obvious indications that could lead to an IAQ issue. To ensure that the HVAC system is thoroughly and properly inspected, inspect each air handler with an engineer from CE who specializes in HVAC systems. It is important to have CE involved from the beginning because CE will often be responsible for the repair and will have to advocate for the money to fix the problem. Some of the items to look at in each air handler include:

- Are the fresh air intakes located away from pollution sources, such as busy streets, loading docks, or exhaust vents?

- What is the designed minimum outdoor airflow rate? Does the system currently meet this minimum?

- Are the fresh air dampers really open during normal operation? Are the damper controls connected and functional?

- Do the temperature controls work properly?

- Is there a comprehensive maintenance schedule, and is enough manpower available to perform it? Are provisions made for the cleaning of cooling coils and drain pans? Are the air-handling and fan-coil units easily accessible for inspection and preventive maintenance?

- Is the HVAC system (including the cooling coils, ductwork, all plenums, and chambers) reasonably free of dust, oil, and fibers?

- Do the air filters have a minimum efficiency reporting value of no less than 6?

- Is the HVAC system free of standing water?

- Are the drip pans under the cooling coils double sloped and made of a noncorrosive material? Is the drain mounted and functioning in a manner that prevents water from accumulating in the pan? Are the drip pans free of mold growth and evidence of past growth?

- Is there a return fan? If so, are the air handlers positively pressurizing the building (i.e., is the supply fan stronger than the return fan)? If the supply fan speed can vary, is there fan-tracking control so the return fan is never stronger than the supply fan? Does it seem to work?

- Are contaminants from the mechanical room (e.g., heater) exhausted so they cannot enter the air handler? If the mechanical room acts as a return air plenum, is it free of trash, dirt, standing water, and chemical storage?

- If insulation is used inside air handlers, is it fixed so fibers cannot enter the air handler? Is it kept dry? Are the sections of the air handlers and ductwork that are expected to become wet during normal operation constructed of a material with cleanable surfaces?

- Do all rooms have supply air vents? Do they deliver the designed airflow?

- Are the supply and exhaust vents in rooms free of dust, dirt, and obstructions?

- Does the diffuser distribute supply air evenly? Does the office setup (room dividers, etc.) allow supply air to reach occupants?

- If there are mechanical dampers for the room supply vents, are they open wide enough? If there are automatic dampers, such as VAV boxes, do they work and are they calibrated? There are various types of VAV boxes. Some open and close the damper based on room thermostat readings. Others work on a pressure principle. The HVAC engineer can explain the dampers encountered--when they open, how wide, etc. and verify that they work as described.

- Are the walls and the ceiling free of water stains? If not, what caused the stain? Has the source been fixed? Is there visible mold growth?

(2) If there are complaints of odor or irritation, find and remove the source. Typical sources are untrapped drain lines connected to the sewer, gas-fired heater exhaust, new furniture or carpet, off-gassing from office equipment, stagnant air, insulation fibers, paints, glues, cleaning solvents, and external emissions brought into the building by the fresh air intakes. Possible screening samples to collect are methane, hydrogen sulfide, carbon monoxide, hydrocarbons, ammonia, formaldehyde, particulates (dust and fibers), sulfur dioxide, nitrogen dioxide, VOCs, and ozone. Ensure direct reading instruments are calibrated. If any of the samples are significantly above outdoor levels, trace the source and remove it. If the samples are not significantly above outdoor levels, use the data for negative documentation.

(3) Note any areas of visible mold or bacteria. Look for signs of contamination, such as visible growths in the drain pan, a moldy odor, or water-stained ceiling tiles. The primary concern is to identify the cause of the contamination and repair the affected areas. A moisture meter can be used to assess the amount of moisture in construction materials. It is non-destructive and an effective means of determining the scope of water-damaged materials.

(4) Measure the CO_2 concentration, relative humidity, and temperature. When these "comfort" parameters fall outside their ideal range, complaints are likely. The ideal ranges are 1000 ppm CO_2 or less, relative humidity between 40% and 60%, and temperature from 68°F to 76°F. Take measurements in several representative rooms for each air handler (both affected and unaffected rooms). Also, take measurements outside for comparison and in the return air plenum if possible. A CO_2 meter with data logger should be run for 24 hours in the return air plenum and in an affected area. Ensure that the meter is calibrated and the batteries will last for 24 hours. The CO_2 concentration will rise exponentially as the workday begins and will usually stabilize 3 to 4 hours later. At least four instantaneous readings per representative room are recommended for each comfort parameter. Spread the measurements throughout a day when the air handlers are in their usual operating mode. If there are two (or more) modes, sample when the outside air is minimized and also when the fresh air dampers are open the widest.

(5) Upon completion of the initial inspection, the IAQ survey team should meet to discuss the results and formulate a strategy. In most cases, the IAQ issue will be identified during the walk-through inspection. Additional testing is not required if the cause of the issue is identified. However, it remains of the utmost importance to communicate with the building occupants the findings of the inspection. Risk communication is often the key to a successful remediation. If a cause is not identified, or the complaints associated with the building do not correlate with the survey findings, additional investigation may be required.

(6) An IAQ questionnaire can help determine if the building occupants feel the indoor environment is affecting their health. However, a questionnaire is not needed in most cases and should only be used when it will make a difference in the course of action or has been command directed. An example questionnaire is available in Appendix B. The questionnaire allows occupants to select symptoms believed to be building related. As a control measure, some of the symptoms listed are unrelated to IAQ. If a questionnaire is used, it is important to obtain responses from a representative sample of the building population. For instance, there should be responses from appropriate percentages (based on the demographics of the building occupants) of men and women; officer, enlisted, and civilian; older and younger; blue and white collar; sick and well; from each floor and/or section of the building; etc. In general, if a questionnaire is used, it should be offered to everyone in the building. In the case of a very large building with hundreds or thousands of occupants, a smaller representative sample is reasonable. The questionnaire response rate is also important. Sending out questionnaires without local coordination (managers, unions, building occupants, etc.) and an accompanying education program will often result in a poor response rate, on the order of 10-20%. Letting people know why their input is needed, the importance of honest answers, how privacy will be maintained, and what will be done with the information provided will dramatically increase the overall response rate. There is no magic numerical goal, but a 50% response rate or more will usually provide good information that will help in the assessment of the building. A dissatisfaction rate from 20% or more of the building occupants is an indication of unacceptable IAQ as defined in ASHRAE 62.1-2010 [8].

(7) PH or the Occupational Health Physician/Flight Surgeon may formally interview occupants who have reported symptoms resulting from exposure to the building environment. This can serve two purposes. First, the interviews will independently check the questionnaire results, help narrow down the cause of the problem, and identify the most affected building areas. Second (and just as important), the occupants will perceive that someone cares and understands, thus reducing anxiety over the issue.

(8) Compare results of the inspections and any air sampling to questionnaire and interview data. Compile the collected data plus conclusions and recommendations into a report. Use the report to generate action items. Use the troubleshooting guideline in Appendix C to aid in the recognition, evaluation, and control of IAQ issues.

(9) If BE believes there is an IAQ issue, but cannot determine the source of the issue after performing appropriate sampling and/or evaluation of occupant questionnaires, contact the ESOH Service Center at USAFSAM for guidance and assistance.

(10) Conduct an outbrief including management and employees. Risk communication is one of the most critical parts of the survey. Generally, people who show an interest in this meeting will often be the employees with concerns. Reassuring them that their issues are being addressed is of the utmost importance to a successful remediation. Overhead slides of sampling results and photos from the survey can add support to the recommendations. Conclude the outbrief with a list of action items that each office of responsibility will accomplish.

(11) Enter the findings from the IAQ survey into the Defense Occupational and Environmental Health Readiness System (DOEHRS). Refer to the *Bioenvironmental Engineer's Guide to IAQ* for specific information about entering IAQ surveys into DOEHRS.

(12) The last step is to follow up on the action items. A month or so after the survey outbrief, call or visit the building and talk to the individuals who were noted to have symptoms or conditions that may be related to the workplace environment. Find out if conditions have improved after recommended changes have been made. Follow up at 6 months and 1 year to check on the situation.

d. Risk Communication: Risk communication is an integral part of IAQ evaluations. A simple working definition of risk communication is, "Communicating honestly with stake-holders in a way they understand, to allow them to make informed decisions about risks." Effective communication requires actions at every step of the risk assessment process. Table 2 describes the required actions.

Table 2. Risk Communication Actions Required During the Risk Assessment Process*

Risk Assessment Process Steps	Risk Communication Actions
Step 1 – Identify hazard. (high CO_2, odors, mold, etc.)	• Identify and learn about the stakeholders (building occupants, chain of command, etc.) and determine the target population's interests, needs, and concerns to assist in key message development. • If approached, talk with stakeholders about the nature of the hazard and the risks involved. • Inform stakeholders about the situation with emphasis on answering what, when, and where type questions. • Inform stakeholders about the process that will be used to investigate the hazard. • Ask stakeholders how they would prefer to receive information about the process. • Inform them about follow-up communication • methods.
Step 2 – Identify the organization responsible for managing and/or mitigating the risk, if applicable. (e.g., contact CE for HVAC issues)	• Communicate with responsible organization(s) and individuals. • Communicate with stakeholders about the nature of the responsibilities (what is required by whom).

Table 2. Risk Communication Actions Required During the Risk Assessment Process* (Concluded)

Risk Assessment Process Steps	Risk Communication Actions
Step 3 – Conduct a risk assessment. (characterize the risk and determine the effect on occupants)	• Determine stakeholder perceptions. • Inform stakeholders of the details of the risk assessment process (using appropriate language). • Inform stakeholders of the results.
Step 4 – Determine the appropriate action to mitigate the risk. (HVAC filter change, mold remediation, etc.)	• Talk about how the mitigation action was determined. • Involve target population in developing solutions to concerns/issues, when possible. • Tell stakeholders about the data used to make a determination about mitigation actions. • Talk about the story behind the data.
Step 5 – Identify the desired nature of stakeholder involvement. (inform, persuade, gain consensus, motivate to action)	• Determine if stakeholder perceptions have been improved by their involvement in the process. • Collaborate with internal stakeholders to determine the purpose or intent for communicating with stakeholders (inform, persuade, gain consensus, motivate to action). • Balance the needs of competing stakeholders. • Keep everyone informed of status and progress.
Step 6 – Communicate final decision on mitigation actions.	• Tell stakeholders how their input was used during the process. • Be sincere, frank, open, and ready to present different approaches. • Keep communication channels open.
Step 7 – Monitor the situation, follow up with stakeholders, and modify the process as needed.	• Follow through on commitments by delivering what was promised. • Communicate organizational commitment to meet needs. • Modify the technical solution when warranted by information learned through risk assessment and risk communication processes.

*Derived from the *Air Force Bioenvironmental Engineering Risk Communication Guide*, May 2011 [46].

Effective communication requires a plan. Even though creating a plan may seem unnecessary, it makes success much more likely. It is valuable to draft a basic outline early in the IAQ evaluation process. This is especially critical if BE is asked to consult late in the process, i.e., the situation is highly charged with emotions and distrust. In such cases, all members of the survey team should be aware of the issues and how they are being resolved. Of equal importance is to involve local public affairs staff early.

Plans should evolve over time and be reassessed frequently. Modifications can be made based on how the situation may have changed. Also, BE should not work in isolation. Other organizations can offer helpful opinions. So it is important to communicate with public affairs, major command staff, USAFSAM, and the concerned individuals throughout the process.

Chapter 7. Responsibilities

a. Facility Managers: The job of facility mangers is to ensure that a facility is operating optimally, so they will likely be the first person to identify maintenance issues that can lead to poor IAQ. As stated in Air Force Pamphlet 32-1004 Volume 3, *Working in the Operations Flight Facility Maintenance*) [47], facility managers should:

- Ensure thermostats are set at correct temperatures.
- Ensure all windows and doors are closed when the building is being heated or cooled.
- Ensure plumbing fixtures are not leaking.
- Call CE if a contractor performs custodial services and the services are not being performed sufficiently.

Facility managers should report all suspected IAQ issues immediately. Issues involving moisture, spills, or leaks are especially urgent and should be reported before mold and related microbial contamination become problematic. A clean and dry environment should be maintained within the facility.

A facility that has a history of water damage or HVAC problems may initially be placed on a 30-day CE evaluation cycle. Later, as maintenance requirements subside, the cycle may be extended. Facility managers (with necessary HVAC support personnel) must perform the following actions during scheduled facility visits:

- Monitor the facility for signs of water damage (e.g., spotted ceiling tiles, water marks near windows/doors, damp floors, etc.).
- Check for signs of condensation and/or suspected mold growth around diffusers or HVAC vents.
- Verify HVAC condensate drain pans are functioning properly.
- Confirm that HVAC is operating within design criteria.

Facility managers must clean and correct any small mold problems or water damage within their capability (such as replacing ceiling tiles with minor water damage after ensuring CE has fixed the roof leak and caulking foundation cracks) promptly (within 48 hours) following the guidelines in Appendix D. If mold contamination or water damage exceeds the facility manager's abilities, the manager should contact the CE Customer Service Center to request a work order.

Before a mold or water damage remediation project is accomplished, the facility manager, in coordination with BE and CE, shall notify the building occupants and the building's organizational commander of the affected area(s). While small-scale projects do not dictate "whole building" notifications, activities should be coordinated with the supervisors of the affected areas. Supervisors are then responsible for notifying affected personnel. Notification must include a description of the planned remedial measures and an estimated completion date. Notification should also include points of contact for any occupant health concerns.

If a facility manager receives occupant health complaints due to IAQ issues, he/she should refer the potentially affected personnel to their medical provider.

b. CE: CE evaluates facility maintenance requests, HVAC issues, and mold contamination complaints. They will also resource all aspects of remediation and repair activities to control and prevent infrastructure deterioration. CE HVAC technicians or engineers should be contacted about HVAC duct cleaning.

c. CE Operations (CEO): CEO conducts facility evaluations (upon facility manager request) in dormitories, family housing, lodging, industrial, and administrative buildings. They can identify persistent water problems or maintenance issues that require repair.

In facilities where mold, moisture, or excess humidity problems are present, CEO should determine the source. CE may request BE assistance with the facility evaluation as required and will coordinate with the facility manager and complete necessary facility alterations or repairs to remediate mold problems or water damage.

Water-damaged building materials should be repaired/removed in accordance with Appendix D and Table D-1. These guidelines are designed to help avoid the need for remediation of mold re-growth by taking quick action before growth starts. However, once mold becomes established in a facility, clean, repair, or remove mold-contaminated building materials following guidelines described in Appendix E and Table E-1. During mold cleaning and removal operations, workers will wear the appropriate BE-approved personal protective equipment (PPE). Guidelines for PPE selection are listed in Table E-1. CEO will incorporate mold awareness and preventative issues into the Building Managers Handbook and Facility Managers program.

d. Asset Management Flight (CEA): Housing managers should initially investigate occupant IAQ complaints to screen out complaints associated with problems due to poor housekeeping. If mold-related contamination, water damage, air duct issues, or other maintenance problems exist that exceed the housing manager's abilities, the manager should contact the CE Customer Service Center to request a work order. The housing manager should refer occupant health complaints to the occupants' medical provider.

Housing managers should also distribute copies of the EPA Mold Guide to all incoming military family housing occupants.

e. Programs Flight (CEP): IAQ optimization should start in facility design to reduce, to the greatest extent possible, the conditions that lead to occupant complaints. CEP designs new construction and renovation projects and, therefore, has a vital role in ensuring that a building is designed with occupant health in mind.

f. Medical Treatment Facility (MTF) Commander: The MTF commander provides personnel and expertise to evaluate occupant building-related health complaints (these complaints may or may not be due to the indoor environment within a building).

g. Physicians: Physicians provide medical evaluation and appropriate care to personnel with health complaints that may be building related. In addition, physicians will work with Team Aerospace members when requested to evaluate facilities for potential building-related illnesses. Military members seeking initial medical care for suspected building-related illnesses or nonspecific indoor-related symptom complaints should notify their supervisor and schedule an appointment with their primary care provider. If the medical provider believes the symptoms are related to the building, he/she will then work with PH to create an AF Form 190, *Occupational Illness/Injury Report*. Civilian members seeking initial medical care for suspected building-related illnesses or nonspecific indoor-related symptom complaints should notify their supervisor and seek medical care from their primary care provider. If the provider believes the symptoms are related to the building, civilian personnel should be contacted for completion of a U.S. Department of Labor CA-2, *Notice of Occupational Disease and Claim for Compensation*.

h. BE: BE will work with other Team Aerospace members to determine the need for health risk assessments in response to a physician-identified illness that may be building related. When remediation of mold-damaged areas is required, BE will recommend appropriate PPE, review/validate the remediation plan, and coordinate with CE in accordance with Appendix E and Table D-1. After remediation is conducted, BE will work with CE and other Team Aerospace members to evaluate and visually verify the facility is suitable for re-occupancy.

i. PH: In coordination with BE and the Aerospace Medicine physician, PH will provide risk communication and education for building managers and exposed or concerned personnel. PH will investigate any disease trends for occupationally related illnesses and report them appropriately.

j. Base Housing Occupants: Housing occupants should practice sound housekeeping: vacuum floors, remove trash frequently, prevent excessive dust accumulation, and use typical household cleaning products to control mold and mildew. When water leaks or spills occur indoors, quick action is vital. If wet or damp materials are dried within 48 hours of a leak or spill, mold will not grow in most cases. Occupants should:

- Call maintenance immediately upon noticing that roof gutters are blocked, need to be cleaned, or are in need of repairs.
- Keep air conditioning drip pans clean and the drain lines unobstructed and flowing properly.
- To help reduce moisture buildup in the home, when cooking, always operate the stove exhaust hood or, when bathing, use the bathroom exhaust fan. Make sure the laundry clothes dryer vent is clear of lint debris and connected properly and exhausting outdoors.

- If condensation or moisture is collecting on windows, walls, or pipes, ACT QUICKLY to dry the wet surface and reduce the moisture/water source.

- Report all plumbing/building leaks and moisture problems immediately to the housing manager.

k. All Other Facility Occupants: Occupants should practice sound housekeeping practices including vacuuming floors, removing trash frequently, and preventing excessive dust accumulation. Quick cleanup of water leaks or spills is vital to reducing the chance for microbial growth, and all plumbing/building leaks and moisture problems should be reported immediately to the facility manager.

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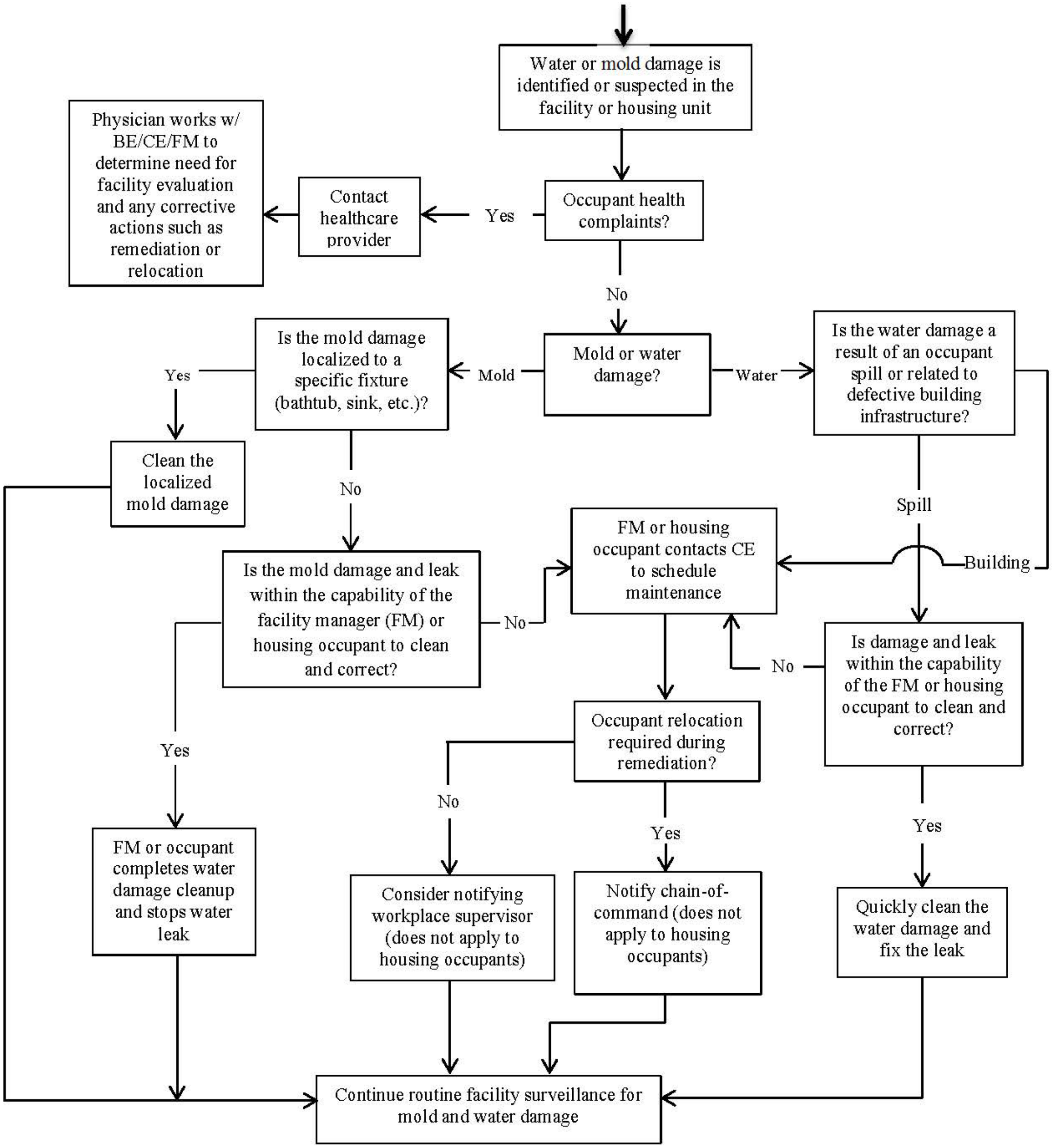
Appendix A
Mold/Water Damage Flow Chart



Appendix B
Questionnaire

*****Note: attach a Health Insurance Portability and Accountability Act and Privacy Act statement to ensure that this information is secured if any identifying personal characteristics are listed.*****

INDOOR AIR QUALITY SURVEY BUILDING #______________

This questionnaire is being distributed to assess the satisfaction of building occupants with building conditions. Your cooperation in giving us accurate data is appreciated. Answer the questions below as accurately as possible.

NAME (optional)____

ROOM______________________ WORK PHONE (optional)________________________

I. WORKPLACE INFORMATION

1. During what period of time did you work in this building? In which room?

From:_______________ To:________________ Room:________________

From:_______________ To:________________ Room:________________

From:_______________ To:________________ Room:________________

From:_______________ To:________________ Room:________________

From:_______________ To:________________ Room:________________

2. On average, how many HOURS per WEEK do you work in this building?

_____ Hours per week

3. During the LAST WEEK, how many days did you work in this building?

_____ Days

4a. Which best describes the space in which your current workstation is located?

__ Private office
__ Shared private office
__ Open space with partitions
__ Open space without partitions
__ Other (specify) ____

4b. How many people work in the room in which your workstation is located (including yourself)?

__ 1 __ 2-3 __ 4-7 __ 8 or more

5. Is there carpeting on most or all of the floor at your workstation?

__ Yes __ No

6. In general, how clean is your workspace area?

__ Very clean
__ Reasonably clean
__ Somewhat dusty or dirty
__ Very dusty or dirty

7. Please rate the lighting at your workstation.

__ Much too dim
__ A little too dim
__ Just right
__ A little too bright
__ Much too bright

8. Do you experience a reflection or “glare” in your field of vision when at your workstation?

__ Rarely
__ Occasionally
__ Sometimes
__ Fairly often
__ Very often

9. How comfortable is the current setup of your desk or worktable (i.e., height and general arrangement of the table, chair, and equipment you work with)?

__ Very comfortable
__ Reasonably comfortable
__ Somewhat uncomfortable
__ Very uncomfortable
__ Don’t have one specific desk or work table

10a. About how many HOURS per DAY do you work with a computer, to the nearest hour?

___ Hours per day ___ Don’t use one

10b. If you use a computer, do you usually wear glasses/contact lenses during use?

___ Glasses ___ Contacts ___ None ___ Not applicable

10c. Do you use an anti-glare screen on your computer?

___ Yes ___ No ___ Not applicable

11. Which one of the following statements best describes the windows in your work area?
    - ___ There are no windows in my personal workspace and none in the general area visible from my workspace (when I am either standing or seated).
    - ___ There are no windows in my personal workspace, but I can see one or more windows in the general area.
    - ___ There are one or more windows in my personal workspace.

12. If there is a window visible from your workspace, about how far (in feet) is the closest window from your desk chair?

___ feet ___ Not applicable, no window

13. During the PAST 3 MONTHS, have the following changes taken place within 15 feet of your current workstation?

	Yes	No
New carpeting	___	___
Walls painted	___	___
New furniture	___	___
New partitions	___	___
New wall covering	___	___
Water damage	___	___

14. How often do you use the following at work? (Check the appropriate box for each item.)

	Several times per day	About once per day	3-4 times per week	Less than 3 times/week	Never
Photocopier	___	___	___	___	___
Laser printer	___	___	___	___	___
Fax machine	___	___	___	___	___
Cleanser, glue, correction fluid, or other strong-smelling chemical	___	___	___	___	___

15. Do you presently have any of the following pets at your home?

Dog: ___ Yes ___ No Cat: ___ Yes ___ No

Bird: ___ Yes ___ No Other: ______________

II. INFORMATION ABOUT HEALTH AND WELL-BEING

1. Have you ever been told by a doctor that you have or had any of the following?

Sinus infection	___ Yes	___ No	-If yes, what year was the first diagnosis made? ____
Asthma	___ Yes	___ No	-If yes, what year was the first diagnosis made? ____
Migraine	___ Yes	___ No	
Eczema	___ Yes	___ No	
Hay fever	___ Yes	___ No	
Allergy to dust	___ Yes	___ No	
Allergy to molds	___ Yes	___ No	
Allergy to cats	___ Yes	___ No	

Other: ______________________

2. How often do you consume alcoholic beverages?
   - ___ Never
   - ___ Monthly
   - ___ Weekly
   - ___ Daily

3. How many alcoholic beverages do you consume per sitting?
   - ___ 1 to 2
   - ___ 3 to 4
   - ___ 4 to 5
   - ___ More than 5

4. What is your tobacco smoking status?
   - ___ Never smoked
   - ___ Former smoker
     - How many cigarettes per day ____
     - Number of months/years smoked ____
     - When did you quit? _______________
   - ___ Current smoker
     - How many cigarettes per day ___
     - Number of months/years smoked _____

5. Do you consider yourself to be sensitive to the presence of tobacco smoke?

   ___ Yes ___ No

6. Do you consider yourself especially sensitive to the presence of chemicals in the air of your workspace?

   ___ Yes ___ No

7. What type of corrective lenses do you usually wear at work? (Check all that apply)
___ None
___ Glasses
___ Bifocals
___ Contact lenses

8. How old are you?

___ under 20 ___ 20-29 ___ 30-39 ___ 40-49 ___ 50-59 ___ over 59

9. Are you: ___ Male ___ Female

10. Are you currently seeing a doctor for treatment of a medical condition that is related to the building?

___ Yes ___ No -If yes, please list the condition below.

____

____

____

	How often have you experienced each of the following symptoms while working in this building?				What happens to symptoms during the time you are away from work?			Have you experienced any of these at work today?	
SYMPTOMS	Not in last month	1-3 days in last month	1-3 days per week in last month	Almost every workday in last month	Got worse	Stayed the same	Got better	Yes	No
Dry/itching/irritated eyes									
Wheezing									
Headache									
Ringing in ears									
Sore or dry throat									

	How often have you experienced each of the following symptoms while working in this building?				What happens to symptoms during the time you are away from work?			Have you experienced any of these at work today?	
SYMPTOMS	Not in last month	1-3 days in last month	1-3 days per week in last month	Almost every workday in last month	Got worse	Stayed the same	Got better	Yes	No
Unusual tiredness, fatigue, drowsiness									
Chest tightness									
Cough									
Stuffy/runny nose, sinus congestion									
Toothache									
Tired or strained eyes									
Tension/irritability/ nervousness									
Leg cramps									
Pain/stiffness in back/shoulders/neck									
Memory/ concentration problems									
Dizziness/ lightheaded									
Feeling depressed									
Shortness of breath									
Hiccups									
Nausea or upset stomach									
Dry or itchy skin									

III. DESCRIPTION OF WORKPLACE CONDITIONS

	How often have you experienced each of the following conditions while working in this building?				Have you experienced any of these at work today?	
CONDITIONS	Not in last month	1-3 days in last month	1-3 days per week in last month	Almost or every workday in last month	Yes	No
Too much airflow						
Too little airflow						
Too hot						
Too cold						
Too humid						
Too dry						
Tobacco/combustion odors						
Chemical odors						
Other unpleasant odors						

1. Please describe your hobbies or other activities outside your normal workday (for example, woodworking, stained glass design, car repairs, athletics, other jobs).

____

____

____

____

2. Please use the remaining space to discuss any aspects of the building environment or employee health that you feel appropriate.

____

____

____

____

____

Appendix C
IAQ Troubleshooting Guidelines

Cause	Symptom/Complaint	Observation	Recommendation*
Low relative humidity (below 40%)	-Dry, scratchy eyes, nose, or throat -Sore throat -Inability to wear contact lenses -Headache or body ache -Sinusitis	-Relative humidity less than 40%	-Rehumidify air in air handlers
High CO_2 concentration (above 1000 ppm)	-Sleepiness -Fatigue -Poor concentration -Restlessness -Stuffy feeling -Sensation of breathing difficulty	-CO_2 levels elevated, especially in the afternoon -Fresh air dampers nearly closed -No supply air in room or supply air blocked	-Increase fresh air rate -Open dampers -Decrease occupant density -Add supply vents -Rearrange office
Improper HVAC balance	-Hot/cold spots -Stuffy feeling	-High CO_2 levels -Airflow imbalance	-Rebalance HVAC system
Negative pressure building	-Hot/cold spots -Dusty	-Wide temperature variations -Doors slam shut or are hard to open -Supply flow rate less than return -Humidity-damaged paint, wallpaper	-Increase supply air fan to 5% greater than return fan -Rebalance HVAC system
Fiberglass insulation dust	-Irritative cough -Dermatitis	-Dust/fibers in room or air handler -Exposed insulation in AHU	-Replace or remove insulation -Vacuum ducts -Clean AHU
Bioaerosols	-Allergy confined to building -Musty smell -Nausea/diarrhea	-Water-stained ceiling -Drip pans with standing water -Mold smell -Visible mold growth -Humidity >65%	-Clean and disinfect HVAC system -Replace filters -Eliminate water source

Cause	Symptom/Complaint	Observation	Recommendation
Pollution source	-Smells -Headaches -Nausea/diarrhea	-Fresh air intake located near loading dock/road/water tower -Combustion source in return air -No J-traps on drains or traps are dry	-Relocate fresh air intake -Remove combustion source -Add J-traps and fill with water -Absorb offending chemical
Cigarette smoke	-Tobacco smell -Complaints about smokers	-Tobacco smoke in return air	-Ensure compliance with AFI 40-102, *Tobacco Use in the Air Force*
Air handler neglect	-Any of the above complaints -*Legionella*	-No air filters -Clogged air filters -Duct work or coils oily or dirty -Standing water in AHU -Exhaust/supply air grill dirty -Less than 20°C (68°F) or more than 24.4°C (76°F)	-Add or replace air filters -Clean and disinfect HVAC system -Begin maintenance schedule -Calibrate controls -Balance system

*CE will be involved in many of these recommendations.

Appendix D
Response Activities for Wet Building Materials

[Adapted from EPA 402-K-01-001: Mold Remediation in Schools and Commercial Buildings, March 2001, to apply to all AF facilities]

<u>Prevention</u>:

1. When water-damaged materials are identified in a building, coordinate with CE to repair/alleviate the water or humidity problem and remediate mold-contaminated materials. If more damage is discovered during remediation, revise remediation plan as necessary. CE must carry out and complete a repair plan, as appropriate. CE will revise, if necessary, and perform recurring maintenance. Facility manager must revise housekeeping requirements, as required.

2. Facility managers should continue to communicate with building occupants, as appropriate depending on the situation. Be sure to address all concerns. Consider developing public awareness guidance for base distribution.

3. Facility managers should clean up visible spills and contact CE to manage the cleanup of the remaining water-damaged areas. Select appropriate cleaning and drying methods for water-damaged materials (see Table D-1). Carefully contain and remove wet building materials. Use only PPE approved by installation BE (guidelines for PPE selection are listed in Table E-1). Arrange for outside professional contract support, if necessary.

Table D-1 presents strategies to respond to water damage within 24-48 hours. These guidelines are designed to help avoid the need for remediation of mold growth by taking quick action before growth starts. If mold growth is found on the materials listed in Table D-1, refer to Table E-1 for guidance on remediation. Depending on the size of the area involved and resources available, professional assistance may be needed to dry an area quickly and thoroughly.

Table D-1. Cleanup and Mold Prevention Procedures Following Water Damage

Water-Damaged Material	Required Actions
Books and papers	For non-valuable items, discard books and papers
	Photocopy valuable/important items, discard originals
	Freeze in frost-free freezer or meat locker or freeze dry
Carpet and backing – dry within 24 to 48 hours	Remove water with water extraction vacuum
	Reduce ambient humidity levels with dehumidifier
	Accelerate drying process with fans
Ceiling tiles	Discard and replace
Cellulose insulation	Discard and replace
Concrete or cinder block surfaces	Remove water with water extraction vacuum
	Accelerate drying process with dehumidifiers, fans, and/or heaters
Fiberglass insulation	Discard and replace (discard at least 2 feet around damaged materials)
Hard surface, porous floorings (linoleum, ceramic tile, vinyl)	Vacuum or damp wipe with water and mild detergent and allow to dry; scrub if necessary
	Check to make sure under flooring is dry; dry the area under flooring if necessary
Hard surface, non-porous (plastics, metals)	Vacuum or damp wipe with water and mild detergent and allow to dry; scrub if necessary
Upholstered furniture	Remove water with water extraction vacuum
	Accelerate drying process with dehumidifiers, fans, and/or heaters
	May be difficult to completely dry within 48 hours; if piece is valuable, consult with a restoration/water damage professional who specializes in furniture
Wallboard (drywall and gypsum board)	May be dried in place if there is no obvious swelling and the seams are intact; if not, remove, discard, and replace (discard at least 2 feet around damaged materials)
	Ventilate the wall cavity, if possible
Window drapes	Follow laundering or cleaning instructions recommended by the manufacturer
Wood surfaces	Remove moisture immediately and use dehumidifiers, gentle heat, and fans for drying (use caution when applying heat to hardwood floors)
	Treated or finished wood surfaces may be cleaned with mild detergent and clean water and allowed to dry
	Wet paneling should be pried away from the wall for drying

Note: If mold growth has occurred or materials have been wet for more than 48 hours, consult Table E-1. Even if materials are dried within 48 hours, mold growth may have occurred.

Appendix E
Remediation of Mold-Contaminated Building Materials

[Adapted from EPA 402-K-01-001: Mold Remediation in Schools and Commercial Buildings, March 2001, and UFGS-02 85 00.00 20: Mold Remediation, May 2011, to apply to all AF facilities]

Remediation:

Table E-1 presents remediation guidelines for building materials that have or are likely to have mold growth. The guidelines in Table E-1 are designed to protect the health of occupants and cleanup personnel during remediation. These guidelines are based on the area and type of material affected by water damage and/or mold growth. Note: these are guidelines; some professionals may prefer other cleaning methods.

Remediation activities should ideally be scheduled during off-hours when building occupants are less likely to be affected or remediation activities could be contained in a specific room or area and occupants moved accordingly. Although the level of personal protection suggested in these guidelines is based on the total surface area contaminated and the potential for remediator and/or occupant exposure, every situation is different and **BE should be contacted for specific information on personal protective equipment.** BE will make decisions about PPE based on identified hazards and professional judgment. These remediation guidelines are based on the size of the affected area to make it easier for remediators to select appropriate techniques, **not on the basis of health effects or research showing there is a specific method appropriate at a certain number of square feet**. The guidelines have been designed to help construct a remediation plan. The remediation manager will then use professional judgment and experience to adapt the guidelines to particular situations. When in doubt, caution is advised. Consult an experienced mold remediator for more information.

If building occupants are reporting serious health concerns, the local MTF should be contacted for medical care or guidance. Remediators and building occupants should be protected from exposure to potentially hazardous building conditions and materials.

Note: Remove 2 feet of building materials on both sides of mold-contaminated porous building materials. Chemical disinfectants should not be used to clean porous building materials in AF facilities; instead, replace porous building materials in accordance with Table E-1.

Containment Options:

The purpose of containment during remediation activities is to limit release of mold into the air and surroundings to minimize the exposure of remediators and building occupants to mold. Mold and moldy debris should not be allowed to spread to areas in the building beyond the contaminated site. The larger the area of moldy material, the greater the possibility of human exposure and the greater the need for containment. In general, the size of the area helps determine the level of containment. However, a heavy growth of mold in a relatively small area could release more spores than a lighter growth of mold in a relatively large area. The primary object of containment should be to minimize occupant and remediator exposure to mold.

A. Limited Containment: Limited containment is generally recommended for areas involving between 10 and 100 ft^2 of mold contamination. The enclosure around the moldy area should consist of a single layer of 6-mil, fire-retardant polyethylene sheeting. The containment should have a slit entry and covering flap on the outside of the containment area. For small areas, the polyethylene sheeting can be affixed to floors and ceilings with duct tape. For larger areas, a steel or wooden stud frame can be erected and polyethylene sheeting attached to it. All supply and air vents, doors, chases, and risers within the containment area must be sealed with polyethylene sheeting to minimize the migration of contaminants to other parts of the building. Heavy mold growth on ceiling tiles may impact HVAC systems if the space above the ceiling is used as a return air plenum. In this case, containment should be installed from the floor to the ceiling deck, and the filters in the AHUs serving the affected area must be replaced once remediation is finished. For small, easily contained areas, an exhaust fan ducted to the outdoors can also be used. The surfaces of all objects removed from the containment area should be "wet" cleaned prior to removal. Some remediation activities in limited containments may require the use of a negative air machine or air scrubber to prevent airborne contaminants from migrating throughout the duct system or to other areas of the facility.

B. Full Containment: Full containment is recommended for the cleanup of mold-contaminated surface areas greater than 100 ft^2 or in any situation in which it appears likely that the occupant space would be further contaminated without full containment. Double layers of polyethylene should be used to create a barrier between the moldy area and other parts of the building. A decontamination room or airlock should be constructed for entry into and exit from the remediation area. The entryways to the airlock from the outside and from the airlock to the main containment area should consist of a slit entry with covering flaps on the outside surface of each slit entry. The chamber should be large enough to hold a waste container and allow a person to put on and remove PPE. All supply and air vents, doors, chases, and risers within the containment area must be sealed with polyethylene sheeting to minimize the migration of contaminants to other parts of the building. The containment area must be maintained under negative pressure relative to surrounding areas. This will ensure that contaminated air does not flow into adjacent areas. This can be done with a high-efficiency particular air (HEPA)-filtered fan unit exhausted outside of the building. All contaminated PPE, except respirators, should be placed in a sealed bag while in this chamber. Respirators should be worn until remediators are outside the decontamination chamber (e.g., airlock). PPE must be worn throughout the final stages of HEPA vacuuming and damp-wiping of the contained area. PPE must also be worn during HEPA vacuum filter changes or cleanup of the HEPA vacuum. The surfaces of all objects removed from the containment area and the containment area itself should be "wet" cleaned and HEPA vacuumed prior to reoccupancy.

Table E-1. Procedures for Remediating Building Materials with Mold Growth Caused by Clean Water*

Material or Furnishing Affected	Cleanup Methods**	Minimum Personal Protective Equipment***	Minimum Containment***
SMALL – Total Surface Area Affected Less Than 10 ft^2			
Books and papers	3	NIOSH-approved N-95 particulate filtering facepiece respirator, nitrile gloves, and unventilated goggles	None required
Carpet and backing	1,3		
Concrete or cinder block	1,3		
Hard surface, porous flooring (linoleum, ceramic tile, vinyl) Hard surface, non-porous (plastics, metals)	1,2,3		
Upholstered furniture and drapes	1,3		
Wallboard (drywall and gypsum board)	3		
Wood surfaces	1,2,3		
MEDIUM – Total Surface Area Affected Between 10 ft^2 and 100 ft^2			
Books and papers	3	Limited or Full (Consult installation BE due to the potential for remediator exposure and size of contaminated area)	Limited (Consult installation BE due to the potential for remediator exposure and size of contaminated area)
Carpet and backing	1,3,4		
Concrete or cinder block	1,3		
Hard surface, porous flooring (linoleum, ceramic tile, vinyl) Hard surface, non-porous (plastics, metals)	1,2,3		
Upholstered furniture and drapes	1,3,4		
Wallboard (drywall and gypsum board)	3,4		
Wood surfaces	1,2,3		
LARGE – Total Surface Area Affected Greater Than 100 ft^2 or Potential for Increased Occupant or Remediator Exposure During Remediation Estimated to be Significant			
Books and papers	3	Full (Consult installation BE due to the potential for remediator exposure and size of contaminated area)	Full (Consult installation BE due to the potential for remediator exposure and size of contaminated area)
Carpet and backing	1,3,4		
Concrete or cinder block	1,3		
Hard surface, porous flooring (linoleum, ceramic tile, vinyl)	1,2,3,4		
Hard surface, non-porous (plastics, metals)	1,2,3		
Upholstered furniture and drapes	1,3,4		
Wallboard (drywall and gypsum board)	3,4		
Wood surfaces	1,2,3,4		

Table E-1. Procedures for Remediating Building Materials with Mold Growth Caused by Clean Water* (Concluded)

*These guidelines are for damage caused by clean water. If it is suspected that the water source is contaminated with sewage, or chemical or biological pollutants, then OSHA requires PPE and containment. Installation BEs must oversee removal jobs requiring mold remediation caused by contaminated water.
**Select method most appropriate to situation. If mold growth is not addressed promptly, some items may be damaged such that cleaning will not restore their original appearance. If mold growth is heavy and items are valuable or important, consult a restoration/water damage/remediation expert. Please note that these are guidelines; other cleaning methods may be preferred by some professionals.
***This list is only intended as a general guideline for PPE selection. Consult with the installation BE to determine prudent levels of PPE and containment for each situation, particularly as the remediation site size increases and the potential for exposure and health effects rises. The BE will assess the need for increased PPE if, during the remediation, more extensive contamination is encountered than was expected.
Cleanup Methods -Method 1: Wet vacuum (in the case of porous materials, some mold spores/fragments will remain in the material but will not grow if the material is completely dried). Steam cleaning may be an alternative for carpets and some upholstered furniture. -Method 2: Damp-wipe surfaces with plain water or with water and detergent solution (except wood – use floor cleaner); scrub as needed. -Method 3: HEPA vacuum after the material has been thoroughly dried. Dispose of the contents of the HEPA vacuum in well-sealed plastic bags. -Method 4: Discard – Remove water-damaged materials and seal in plastic bags while inside of containment, if present. Dispose of as normal waste. HEPA vacuum area after it is dried.
PPE -Minimum: Gloves, NIOSH-approved N-95 particulate filtering facepiece respirator, goggles/eye protection. -Limited: Gloves, NIOSH-approved N-95 particulate filtering facepiece respirator or half-face respirator with HEPA filter, disposable overalls, goggles/eye protection. -Full: Gloves, disposable full body clothing, head gear, foot coverings, full-face respirator with HEPA filter. **Containment** -Limited: Use polyethylene sheeting ceiling to floor around affected area with a slit entry and covering flap; maintain area under negative pressure with HEPA-filtered fan unit. Block supply and return air vents within containment area. -Full: Use two layers of fire-retardant polyethylene sheeting with one airlock chamber. Maintain area under negative pressure with HEPA-filtered fan exhausted outside of building. Block supply and return air vents within containment area.
Table developed from literature and remediation documents including Bioaerosols: Assessment and Control (American Conference of Governmental Industrial Hygienists, 1999) and IICRC S500, Standard and Reference Guide for Professional Water Damage Restoration (Institute of Inspection, Cleaning and Restoration, 1999)

LIST OF ABBREVIATIONS AND ACRONYMS

ACGIH .... American Conference of Industrial Hygienists
AFI .... Air Force Instruction
AHU .... air-handling unit
ASHRAE .... American Society of Heating, Refrigerating and Air-Conditioning Engineers
BE .... Bioenvironmental Engineering
BRI .... building-related illness
CE .... Civil Engineering
CEA .... Civil Engineering Asset Management Flight
CEO .... Civil Engineering Operations
CEP .... Civil Engineering Programs Flight
cfm .... cubic feet per minute
CO_2 .... carbon dioxide
DOEHRS .... Defense Occupational and Environmental Health Readiness System
DTA .... designated tobacco area
EPA .... Environmental Protection Agency
FM .... facility manager
HEPA .... high-efficiency particulate air
HVAC .... heating, ventilating, and air conditioning
IAQ .... indoor air quality
mg/m^3 .... milligrams per cubic meter
MOL .... Ministry of Labor
MTF .... medical treatment facility
NAAQS .... National Ambient Air Quality Standards
NIOSH .... National Institute of Occupational Safety and Health
NKB .... Nordic Committee on Building Regulations
OSHA .... Occupational Safety and Health Administration
OTM .... OSHA Technical Manual

LIST OF ABBREVIATIONS AND ACRONYMS (concluded)

PH .... Public Health
PPE .... personal protective equipment
ppm .... parts per million
SBS .... sick building syndrome
USAF .... United States Air Force
USAFSAM .... United States Air Force School of Aerospace Medicine
VAV .... variable air volume
VOC .... volatile organic compound