

Preventing Occupational Respiratory Disease from Exposures caused by Dampness in Office Buildings, Schools, and Other Nonindustrial Buildings

WARNING!

Occupants within damp office buildings, schools, and other nonindustrial buildings may develop respiratory symptoms and disease.

Office buildings, schools, and other nonindustrial buildings may develop moisture and dampness problems from roof and window leaks, high indoor humidity, and flooding events, among other things. For this Alert, we define "dampness" as the presence of unwanted and excessive moisture in buildings [AIHA 2008]. This can lead to growth of mold and bacteria, the release of volatile organic compounds, and the breakdown of building materials by the mold or by water damage. These exposures can lead to potentially harmful symptoms and illness. Exposures from building dampness and mold have been associated with respiratory symptoms, asthma, hypersensitivity pneumonitis, (HP) and sarcoidosis in research studies. Individuals with asthma or HP may be at risk for progression to more severe disease if the relationship between illness and exposure to the damp building is not recognized, and exposures continue.

Persistent building dampness and subsequent respiratory illness in some building occupants occurs in part from a lack of knowledge and understanding among builders, building owners, employers, and building occupants of the nature and severity of these problems. Building dampness problems frequently occur because of suboptimal design, construction, and commissioning (assessing the building's construction and operation prior to occupancy) of new buildings. These problems and associated health effects can be prevented by making dampness prevention a goal during the design, construction, and commissioning phases. Once built, buildings may also develop dampness problems from improper or insufficient maintenance or operation and weather events. The best current evidence suggests visible dampness, water damage, mold or mold odor are the best indicators of dampness-related health hazards, rather than microbiologic measurements. Owners, employers, workers or occupants should utilize the following approaches to minimize the likelihood of persistent building dampness and subsequent respiratory problems in exposed occupants:

Building Owners and Employers

- Regularly inspect building areas such as ceilings, walls, and basements for evidence of dampness; take immediate steps to identify and correct the causes of any dampness problems found.

- Conduct regularly scheduled heating, ventilating, and air-conditioning (HVAC) system inspections and correct any problems identified.

- Prevent high indoor humidity through the proper design and operation of HVAC systems.

- Dry any porous building materials that have become wet from leaks or flooding within 48 hours, or discard them.

- Remediate (clean and repair or replace) any building materials that are moisture-damaged or show evidence of mold growth.

- Follow remediation guidelines such as the Environmental Protection Agency (EPA) *Mold Remediation in Schools and Commercial Buildings*, or the New York City Department of Health and Mental Hygiene, *New York City Guidelines on Assessment and Remediation of Fungi in Indoor Environments.*

- Inform workers or occupants that respiratory effects from exposure in damp buildings can occur and implement a system for workers to report:

    - building dampness, musty or moldy odors, leaks, and flooding incidents
    - building-related respiratory symptoms or disease

- Encourage workers and/or occupants who have developed persistent or worsening respiratory symptoms while working in the building to see a health care provider; refer to local or state listings for occupational medicine physicians or the Association of Occupational and Environmental Clinics at: http://www.aoec.org/directory.htm.

- Follow health care provider recommendations for relocation of workers and/or occupants diagnosed with building-related respiratory disease.

- Establish an indoor environmental quality (IEQ) team consisting of a coordinator, representatives of the building employees, employers, and building management who would oversee implementation of an IEQ program. The EPA Indoor Air Quality Tools for Schools (http://www.epa.gov/iaq/schools/) can be used as a model for such a program.

Workers and Other Occupants

- Inform your employer or building owner about signs of leaks, flooding, dampness, musty or moldy odors, and ventilation problems in the building; also let your employer or building owner know of any respiratory problems that may be building-related.

- See your health care provider if you have developed persistent or worsening health symptoms while working in the building:

    - Refer to local or state listings for occupational medicine physicians or the Association of Occupational and Environmental Clinics at: http://www.aoec.org/directory.htm.

- Let your employer or building owner know if your health care provider recommends relocation to another work area to prevent exposure to mold or dampness-related contaminants that may be causing or exacerbating your symptoms

- Familiarize yourself with the IEQ program at your workplace and become an active member of the IEQ team if needed.

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The National Institute for Occupational Safety and Health (NIOSH) requests assistance in preventing respiratory symptoms and disease from work in damp office buildings, schools, and other nonindustrial buildings. This Alert describes the respiratory problems that occupants may experience from exposures in damp buildings, presents summary information on outbreaks of building-related respiratory disease, and provides recommendations on how to identify, respond to, and prevent building dampness and related respiratory symptoms and disease.

BACKGROUND

In recent years there has been much public interest in the health effects of living, attending school, or working in damp buildings. Occupants of damp office buildings, schools, and other nonindustrial buildings report a broad range of building-related symptoms and illnesses including headache, irritation of eyes, nose and throat, lack of concentration, rhinitis, lower respiratory symptoms, asthma exacerbation and onset, hypersensitivity pneumonitis, sarcoidosis, infections, nausea, and neurologic effects. The respiratory outcomes have been the most thoroughly studied, while the least studied are the possible health effects of fungal toxins (mycotoxins).

Research studies have shown consistent associations between the presence of dampness and mold in buildings and respiratory symptoms in building occupants [IOM 2004; WHO 2009]. The results of investigations in buildings where workers have developed asthma and the rare lung disease hypersensitivity pneumonitis indicate that exposures from dampness in buildings may cause these diseases in certain individuals (see case reports below).

Exposures in damp buildings can be highly complex, and vary from building to building and at different locations within a building. Moisture allows increased indoor microbial growth on building materials or other surfaces. Building occupants may be exposed to structural components of microbial growth (for example, spores and fungal fragments) and to specific substances the microorganisms may produce; the potential exposures will vary depending on the species that are present and on environmental conditions. Moisture also provides a favorable environment for cockroaches, rodents and dust mites. Exposure to chemical compounds such as volatile organic compounds released by moisture-damaged building materials (for example, vinyl flooring and carpets) may also occur. The levels at which different dampness-related exposures may pose health risks for building occupants have not been established.

Many research studies have attempted to identify the specific exposures in damp buildings that may cause health effects in occupants. Since moldiness is a common characteristic of damp buildings, much research has focused on mold exposures. It is well known that some individuals can develop

allergic diseases such as asthma and rhinitis (nasal inflammation) from exposure to certain molds in the environment. It is also well known that, under certain environmental conditions, molds can produce substances (mycotoxins) that are toxic to humans if inhaled or ingested. Currently, research is lacking on whether or not inhalation exposure to mycotoxins at the levels which may occur in damp buildings poses a health risk to building occupants. Research on these outcomes is ongoing.

Office buildings, schools, and other nonindustrial buildings can develop persistent dampness through a variety of mechanisms. These commonly include roof and window leaks, flooding events, condensation, plumbing leaks, and high indoor humidity. A wet foundation can also cause persistent dampness. Foundations can become wet due to water runoff from land that slopes toward the building, an inadequate gutter system that does not direct water away from the building, or a building site with a high water table. Problems with dampness in buildings can begin during the construction phase because of inadequate design of building components and poor construction work or improper storage of materials. These and other causes can be prevented through careful attention to the design, construction, operation, and maintenance of buildings. Prevention and control of building dampness will minimize the chance that workers will develop respiratory symptoms and disease from exposures related to the dampness. Prevention can also help avoid potentially costly remediation of moisture damage in buildings.

RESPIRATORY SYMPTOMS AND DISEASE IN OCCUPANTS OF DAMP BUILDINGS

The Institute of Medicine (IOM) concluded that there is an association between exposure to damp indoor environments and cough, wheeze, upper respiratory tract (nasal and throat) symptoms, and exacerbation of asthma. The IOM also concluded that there is an association between the presence of mold and bacteria in damp indoor environments and hypersensitivity pneumonitis [IOM 2004]. A statistical analysis of well-designed published research studies found that individuals living in damp or moldy homes are 50% more likely to have current asthma, 33% more likely to have ever been diagnosed with asthma, 50% more likely to cough, 44% more likely to wheeze, and 52% more likely to have upper respiratory tract symptoms than individuals living in dry, non-moldy homes [Fisk et al. 2007].

In 2009, the World Health Organization (WHO) published *Guidelines for Indoor Air Quality, Dampness and Mold* [WHO 2009]. Based on its review of the scientific literature, the WHO stated that there was sufficient epidemiological evidence to conclude that occupants of damp buildings are at risk of developing upper and lower respiratory tract symptoms (including cough and wheeze), respiratory infections, asthma, and exacerbation of asthma. The WHO report further stated that limited evidence suggests an association between damp buildings and bronchitis and allergic rhinitis, and clinical evidence suggests that exposure to mold and other microbial agents in damp buildings is associated with hypersensitivity pneumonitis.

RHINITIS AND SINUSITIS

Rhinitis is characterized by nasal stuffiness, sneezing, and a runny or itchy nose. Occupants in damp buildings who experience these symptoms while in the building and experience improvement or disappearance of symptoms when away from the building may have rhinitis due to exposures in the building.

Sinusitis (inflammation of the paranasal sinuses) can cause symptoms similar to those of rhinitis or a cold. Sinusitis is usually caused by viruses or bacteria and less often by fungi. Inhalation of irritant substances can also be a cause.

ASTHMA

Asthma is a chronic disease of the lung airways characterized by inflammation and episodes of airway obstruction. Asthma is a fairly common disease. The occurrence of currently active asthma in adults in the U.S. was approximately 7% in 2008; the adult lifetime prevalence (asthma at any point in a person's life) was approximately 13% [NHIS 2008].

Some individuals have allergic asthma, and others have non-allergic asthma. Symptoms associated with obstruction of the airways include wheeze, chest tightness, shortness of breath, and cough. The airways obstruction can be reversed partially with medications (for example, inhaled bronchodilators such as albuterol) or may resolve spontaneously with time. Lung function testing with spirometry (a test of exhaled air flow and volumes) may reveal obstruction in airflow. A methacholine challenge test for airways hyper-reactivity involves inhaling increasing concentrations of methacholine before spirometry tests to measure how sensitive the airways are. This test may be useful to establish an asthma diagnosis in individuals with symptoms who have normal spirometry.

It is well known that workers can develop asthma or experience worsening (exacerbation) of existing asthma from exposure to a variety of substances at work. Examples of such exposures include cobalt used in the production of hard metal tools and enzymes used in detergent manufacturing. Irritating substances, such as cleaners and acids, can cause previously stable asthma to worsen, or cause non-allergic asthma, especially after a high level exposure. NIOSH has estimated that 29% to 33% of new-onset adult asthma is attributable to work-related exposures, and 23% of existing adult asthma is exacerbated by work [Henneberger et al. 2006, Vollmer et al. 2005, Sama et al. 2006]. A worker may also develop asthma symptoms or asthma exacerbation while working in a damp building. It is important to recognize this possibility, as medical treatment may not be effective if the worker or building occupants continue to be exposed. A worker or occupant with allergic asthma may experience symptoms after exposure to very low levels of a sensitizing agent that may still be present after remediation; such a worker or occupant may require relocation to another area.

HYPERSENSITIVITY PNEUMONITIS (HP)

HP is a serious lung disease induced by an immune system response to repeatedly inhaling organic matter (material from living things such as plants, animals, bacteria, or fungi) or other sensitizing agents. Dozens of different fungi, bacteria, animal proteins, plants, and chemicals are known causes of HP [Patel et al. 2001]. Examples of occupations in which HP is known to occur include farmers exposed to dust from moldy hay and machinists exposed to metalworking fluid mists. There also have been many reports in the scientific literature of individuals who have developed HP while working in damp office buildings and schools or living in homes with evidence of moisture damage and mold [Hoffman et al. 1993, Weltermann et al. 1998, Thorn et al. 1996, Apostolakos et al. 2001].

Two symptom patterns exist with HP. Some individuals experience episodic shortness of breath and flu-like symptoms including cough, muscle aches, chills, fever, sweating, and fatigue (acute disease). These symptoms start within hours of exposure and last for one to three days if there is no further exposure. Other individuals develop gradual and progressive shortness of breath and cough, often accompanied by weight loss. HP is often misdiagnosed as a respiratory infection. The first signs that

the illness is due to exposures in a building may be improvement in symptoms and medical tests during a period of time away from the building and worsening on return.

The main treatment for HP is removal from exposure to the causative agent or environment. This may be accomplished by relocation. Acute disease may resolve completely with exposure termination; corticosteroid (a type of steroid) medications may shorten disease duration. With long-term exposure, the disease may not improve or may continue to worsen and progress to permanent lung scarring even after exposure ends.

SARCOIDOSIS

In sarcoidosis the lungs and other organ systems can develop scars called granulomas and have abnormal function. The cause is unknown. Sarcoidosis can have symptoms and medical findings similar to HP. There are no definitive medical tests that establish a diagnosis of sarcoidosis. It is a diagnosis of exclusion once other known causes of granulomatous lung disease (e.g., HP, chronic beryllium disease, certain infections) have been ruled out [Newman et al. 1997]. The environment may be a factor in some cases [Newman et al. 1997]; including exposure to dampness and mold [Kucera GP et al, Chest 2003;123:127-35, Newman LS et al, American Journal of Respiratory and Critical Care Medicine 2004;170:1324-30, Rossman MD et al, ACCESS Group 2008;25(2):125-32].

CASE REPORTS

Case 1 – Development of asthma and hypersensitivity pneumonitis in a damp office building

A single-story office building had a history of recurrent wet carpets due to plumbing problems. Ceiling tiles also showed evidence of leaks. Part of the building was below ground level. A 48-year-old worker was diagnosed with asthma within six months of starting work in this building. Lung function measurements revealed airflow limitation shortly after entering the building, with partial recovery on lunch breaks outside the building and full recovery on weekends. After relocation to another office building, the worker no longer had asthma symptoms, no longer needed asthma medications, and no longer had work-related airflow limitation as documented by peak flow measurements [Hoffman et al. 1993].

A 37-year-old worker in the same building developed shortness of breath on exertion two years after starting work in the building. A chest x-ray showed abnormalities. She was treated for pneumonia with two courses of antibiotics without improvement. After referral to a pulmonary physician, spirometry testing had a restrictive pattern of scarred and inflamed lungs. Symptoms improved with treatment with 60 milligrams per day of prednisone pills (corticosteroid). After discontinuation of prednisone, the worker experienced a return of symptoms and weight loss of 20 pounds. The worker's symptoms improved during a one-month period away from work. After return to work, she experienced shortness of breath, flu-like symptoms, and fatigue; these symptoms would improve on weekends but progressively worsened over two weeks; lung function tests worsened. The worker was referred to an occupational medicine clinic where the worker was diagnosed with HP. The worker's symptoms again improved after treatment with prednisone, and she is no longer working in the building [Hoffman et al. 1993].

Case 2 – Hypersensitivity pneumonitis in a damp office building

A 49-year-old office worker sought medical evaluation and treatment for progressive shortness of breath, cough, and fatigue. Symptoms improved during weekends but reoccurred during days at work. A chest x-ray revealed changes of inflammation and scarring in both lungs. The lungs were small and tests showed gas transport from lung air sacs to the blood stream was reduced. A lung biopsy showed granulomas and other scars. Blood analysis showed antibodies to a mold species that was present in the worker's work area. Physicians diagnosed HP based on these findings. While on sick leave, the worker's lung tests and symptoms improved without corticosteroid medications. After return to the workplace, the worker's symptoms, lung tests, and chest x-ray worsened. The worker's symptoms and tests again improved while on sick leave. After being reassigned to a new worksite, the worker's symptoms did not recur and lung tests remained stable [Weltermann et al. 1998].

The building was located 50 feet from a swamp. Ceiling tiles and carpeting in two areas showed evidence of recurrent leaks. Workers reported several incidents of water leakage. Indoor humidity on the day of the evaluation was high at 72%; this was higher than the outdoor humidity on that day. Reportedly, humidity was typically this high inside the building during the summer, and often above 50% during the winter. The high indoor humidity may have been due to HVAC units that were incorrectly sized, causing the coils to freeze up or the units to shut off too soon [Weltermann et al. 1998].

Case 3 – Six Cases of Occupational Asthma in a Damp Hospital

Over a two-year period, 6 of 53 workers (11%) located on the top floor of an eight-story hospital building developed asthma. The hospital had experienced multiple episodes of significant roof and window leaks during heavy rains over several years. Walls and ceilings showed mold growth. Five of the six affected workers had no previous asthma history, while one worker reported childhood asthma but had not experienced any asthma symptoms in 20 years. All six workers reported asthma symptoms that improved away from work. All six had evidence of asthma on methacholine challenge testing. Blood analyses showed that none of the workers demonstrated an allergic response to latex or common environmental allergens (e.g., house dust mites, grass, cat, dog). In four of the six affected workers, serial peak flow measurements showed a work-related symptom pattern (declines in peak flow during work days and improvement when off work); of the other two affected workers, one had a mixed pattern (drops in peak flow at work and at home) and the other showed some declines in peak flow over the work week [Cox-Ganser et al. 2009].

Case 4 – Hypersensitivity Pneumonitis in a Damp School Building

A 34-year-old school teacher with no past history of respiratory problems became acutely ill with shortness of breath at the beginning of the school year in September 1988. A blood clot was suspected at the time but not found with medical tests. She improved and returned to work in the middle of October 1988. Several months later she sought additional medical evaluation for persistent shortness of breath on exertion, cough, and mild fever. Chest x-rays showed a pattern consistent with inflammation and scarring in both lungs. Spirometry showed a restrictive pattern consistent with small inflamed lungs, and a gas transfer test was low at 45% of predicted. Based on many other tests, she was diagnosed with atypical sarcoidosis. Over several years her shortness of breath worsened. A lung computed tomography (CT) scan in 1994 showed severe lung scarring in a pattern called honeycombing. Her arterial blood oxygen level was low. Blood tests showed antibodies which

indicated exposure to several different molds. Her diagnosis was revised to HP and she was treated with corticosteroid medications. While off work during summer vacation, her condition improved and her arterial oxygen level increased. On return to work at the end of the summer, her cough and shortness of breath worsened and her arterial oxygen level declined. She improved somewhat after medical restriction from work at the school [Thorn et al. 1996].

The school, a one-story, flat-roofed, mechanically ventilated building, was built in 1980. It had a long history of roof and plumbing leaks. Many employees had complained of symptoms (especially fatigue) and smells due to poor air quality. Building investigations had identified high water content in walls and floors. The flat roof was replaced with an inclined-roof in 1992; there was severe water damage during the construction period. Water-damaged materials such as wall boards were replaced by 1995 [Thorn et al. 1996].

For information on IEQ-related evaluations, go to the NIOSH Workplace Health Hazard Evaluation weblink at: http://www.cdc.gov/niosh/hhe/.

Failure to Prevent Building Dampness Can Be Expensive

Preventing dampness in buildings and rapidly correcting dampness problems when they occur are important considerations not only for protecting the health of workers and other occupants, but for minimizing costs associated with repair or replacement of moisture-damaged building materials. Extensive remediation costs can amount to millions of dollars. In addition, there may be costs from relocation of employees, sick leave, workers' compensation, decreased productivity, consultant evaluations, and litigation.

A costly example is a county courthouse and attached office building built in southern Florida from 1986 through 1989. Within weeks of moving into the building, workers reported a variety of symptoms, including eye and throat irritation, fatigue, and headaches. They also reported visible mold growth under the wall paper on the perimeter walls of the building [NIOSH 1996].

The exterior walls of each building consisted of a brick veneer on the first floor and a stucco veneer on the upper floors. In 1988, the exterior walls developed cracks which allowed rainwater to enter the exterior wall cavities over the next several years. Weep holes to allow rainwater in wall cavities to drain to the outside were missing or plugged with mortar at the base of the brick veneer. Vinyl wall paper trapped moisture within these walls. By 1992, approximately 100 square meters of wall board (mostly along the perimeter walls) appeared to have mold growth. Carpet along the perimeter of each floor was chronically wet from rainwater intrusion. The ventilation systems could not properly dehumidify outdoor air brought into the buildings. From 1988 to 1992, the relative humidity in both buildings often exceeded 70% and sometimes exceeded 80%. Water leaked on to ceiling tiles from ventilation units located above the suspended ceiling on each floor, and from condensation on cold water pipes that were insufficiently insulated. By 1992, almost all ceiling tiles in both buildings were sagging or warped due to high indoor relative humidity. More than 100 ceiling tiles were water stained and visually moldy. The air in both buildings smelled musty [Hodgson et al. 1998].

Among the approximately 200 employees working in the buildings, at least 14 submitted workers' compensation claims for building-related illness. The employees were relocated to other locations for two years during remediation work. The cost of the remediation and restoration exceeded $24 million, more than twice the $11 million it originally cost to build the buildings. In a jury trial, Martin County, Florida, the owner of the buildings was awarded $13.7 million in damages from a

construction company and three insurance companies. Martin County also settled related law suits against other parties for close to $3 million [Chen et al. 1998].

CURRENT STANDARDS AND RECOMMENDATIONS

There are no Occupational Safety and Health Administration (OSHA) regulations or NIOSH recommended exposure limits pertaining to moisture in indoor environments or the associated microbial contamination. Nonetheless, public health agencies recommend that indoor dampness be remediated because it poses health risks. Two States have regulations on workplace exposures to indoor dampness. California OSHA requires the correction of water entry, leakage from interior water sources, or other uncontrolled accumulation of water in workplaces. The New Jersey Public Employees Occupational Safety and Health Indoor Air Quality Standard (N.J.A.C 12:100-13.4) requires prompt repair of water leaks, prompt drying or replacement of water-damaged materials, and removal of visible microbial contamination from ductwork, ventilation systems, carpet, and building surfaces in office buildings and schools where public employees work. Recommended methods for mold prevention and remediation have been published by the Centers for Disease Control and Prevention, OSHA, the EPA, the American Industrial Hygiene Association (AIHA), and the New York City Department of Health and Mental Hygiene. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published ventilation standards for nonindustrial workplaces, and the Sheet Metal and Air Conditioning Contractors' National Association published indoor air quality guidelines for occupied buildings under construction [see Guidance Documents]. State and municipal building codes may provide guidance on appropriate construction methods that will prevent water entry and accumulation in buildings.

CONCLUSIONS

Office and school buildings may develop persistent excessive moisture due to roof and window leaks, high indoor humidity, and flooding events, among other contributors. Workers and other occupants (including children) may be exposed to microbial contaminants and emissions from breakdown of water-damaged building materials. Some exposed workers and occupants may develop respiratory symptoms and diseases such as asthma and HP.

Many building dampness problems occur because of suboptimal design, construction, and commissioning of new buildings. These problems and associated health effects can be prevented by making dampness prevention a goal in these early development phases. Continued prevention requires on-going attention to building maintenance and operation. This includes regular monitoring and maintenance of HVAC systems and other building components that are subject to moisture problems, and prompt identification and correction of causes. Moisture-damaged or moldy building materials should be remediated, with precautions taken to prevent remediation workers and building occupants from being exposed to mold or dust during the remediation. Prevention and control of building dampness will minimize the chance that workers will develop respiratory symptoms and disease from exposures related to the dampness.

RECOMMENDATIONS

Preventive Building Design, Construction, and Commissioning

Many causes of persistent building dampness can be prevented through careful attention to details in the design, construction, and commissioning phases. Owners and developers should be aware of the importance of preventing building dampness and the reasons why buildings can become persistently damp. Special attention should be paid to the design and construction of buildings with prevention of building dampness as a goal. Contracts should provide specific details on the design and choice of building materials and how they are to be assembled and installed. Contracts should also specify which individuals (e.g., general contractor; construction manager) are responsible for ensuring that correct construction techniques are used and that, once installed, the different building systems function as designed to prevent building dampness. Building mechanical systems, which are critical to indoor environmental quality, should be reviewed by the maintenance personnel that will be responsible for maintaining the equipment. Provided below are examples of important building dampness prevention issues that owners, architects, engineers, contractors, and others involved in the construction of new buildings should consider.

Keep the foundation dry

A foundation that is frequently affected by flooding or is chronically damp can lead to moisture damage of building materials and microbial growth. A damp foundation can occur due to a high water table or poorly managed rainwater drainage [AIHA 2008]. For this reason, careful selection and preparation of the building site are extremely important issues for prevention of building dampness problems. The foundation should have an adequate drainage system and the adjacent land should slope downward and away from the building.

Keep moisture-sensitive building materials dry during the construction process

Porous building materials which can support microbial growth should be protected from getting wet during construction. Stored wall board which has become wet should be dried out quickly or not used; gypsum board which has become fully-saturated as a result of wicking through the exposed edge typically will not dry without becoming damaged and/or moldy [AIHA 2008]. Wall board and flooring materials should not be installed over masonry block or a cement slab, respectively, that is not sufficiently dry. If active drying of a building is necessary during construction to allow installation of interior finish materials, a professional drying service should be used rather than using the HVAC system; starting the HVAC system early before it is fully commissioned, tested and balanced can damage the equipment, and construction dust can clog cooling coils and reduce their useful life and cooling capacity. ASHRAE recommends that HVAC system components and duct work should be kept clean and dry prior to installation, as insulation lining which becomes wet and dirty will support mold growth [ASHRAE 2009a]. Interior insulated duct lining should be avoided, especially downstream of coils.

Minimize the amount of rainwater that penetrates the building envelope

Leaks through the building envelope can begin during construction due to inadequate design and/or installation of building components. Thirty-five percent of new buildings show evidence of leaks through or around windows as a result of improper installation [ASHRAE 2009a]. Entry of rainwater into exterior building walls at openings for windows, doors, and balconies is typically prevented through the installation of flashing. Proper installation of flashing at the corners of these openings is a complicated process and involves many different construction workers installing various building materials. Problems often arise when workers do not have the necessary information and instructions to perform the installation. Architects or contactors can prevent this problem by providing (1) detailed 3-D drawings that clearly show all the layers and the installation sequence for all flashing

details at all corners in addition to all straight joints in the exterior wall and (2) mockup wall sections that show these details for construction workers to refer to on the jobsite. Correct installation of flashing material is also important for other openings in the building envelope (e.g., openings for ducts, pipes, and wires).

Exterior walls should be designed so any rain water that penetrates openings in the exterior cladding (e.g., brick veneer) can dry and/or drain out of the wall. Typically this is accomplished by maintaining an air space between the cladding and the next wall layer (the sheathing) and covering the sheathing with a continuous and completely sealed water barrier. Drain holes and flashing are provided at the bottom of the space and air vents at the top. This design is sometimes referred to as a "rain-screen wall" [ASHRAE 2009a].

Ensure dehumidification of indoor air through proper design, installation, and operation of building HVAC systems

High indoor humidity can lead to increased moisture content of building materials or to condensation on cold surfaces (which can then wet nearby moisture-sensitive materials such as wallboard). This can cause deterioration of building materials and microbial growth. Therefore, air should be dehumidified as needed to prevent high indoor humidity. For example, an HVAC system which dehumidifies solely through the operation of air conditioning cooling coils may not be able to lower indoor humidity sufficiently without making the occupied space overly cool. An additional dedicated unit to dehumidify outdoor ventilation air may be necessary for times when the cooling demand is low (e.g., when the building is unoccupied) but humidity is still high. The EPA recommends maintaining indoor relative humidity below 60% and ideally in a range from 30% to 50% to prevent mold growth and ASHRAE recommends that relative humidity be maintained at or below 65%. For hot and humid climates, ASHRAE recommends that HVAC units monitor and control the air dew point rather than the relative humidity of the air, as the latter provides no information on the relative humidity on cool surfaces (where increased moisture content or condensation may occur). The dew point is a better indicator of this potential problem; ASHRAE recommends maintaining the indoor air dew point below 55°F [ASHRAE 2009a]. ASHRAE also recommends making sure that connections in ventilation return air ducts and in exhaust ducts are tightly sealed to prevent negative air pressure in building cavities (i.e., inside walls and above the ceiling); negative air pressure in building cavities can cause humid outdoor air to be drawn into the building through cracks in the building envelope, which in turn can lead to increased moisture content in, or condensation on, building materials in building cavities (e.g., increased moisture content on the back of gypsum board and condensation on pipes).

Other issues

- Vinyl wall coverings should not be used on the indoor surface of exterior walls in air conditioned buildings in hot and humid climates. Instead, these walls should be painted or covered with highly permeable wall coverings attached with adhesives which pass water vapor freely [ASHRAE 2009a].
- The risk of mold growth on paper-faced gypsum board can be minimized by specifying that it be installed with a gap (¼ inch is the minimum) between the finished floor and the bottom of the wall. The gap acts as a capillary break so that water on the floor or behind the wall cannot wick up into the wall during mopping, carpet cleaning, or a minor flooding event (i.e., the water would have to be at least ¼ inch deep before it could reach the wall) [ASHRAE 2009a].
- Cold water pipes should be adequately insulated to prevent condensation.

- Water supply lines should be located in an area of the building where freezing temperatures are unlikely to occur. Freezing water pipes could result in flooding.

Greater detail on the issues discussed above and on other considerations for building dampness prevention through proper building design and construction can be found in journal articles and books specifically dedicated to this subject. One source for such information is the *Indoor Air Quality Guide: Best Practices for Design, Construction, and Commissioning*, published by ASHRAE (http://www.ashrae.org/publications/page/1936 [2009b]. *IAQ Design Tools for Schools (www.**epa**.gov/**iaq/schools/**)*, published by the EPA, gives detailed guidance on school design and construction, the general principles of which can be applied to most buildings, and *Indoor Air Quality Solutions for Stationary Engineers*, published by the American Technical Publishers, features an overview of indoor air quality and HVAC systems for institutional and commercial facilities.

Building Maintenance and Operation

Proper operation and maintenance of the HVAC system and prompt identification and elimination of sources of excess building moisture are important for prevention of damage to building materials and microbial growth. Building management and maintenance staff should implement protocols that indicate specific maintenance tasks that will be performed on a regular basis; they should also implement mechanisms that allow early identification of moisture problems and have written policies that outline the steps that will be taken for prompt correction of any problems identified.

Ensure proper operation and maintenance of the HVAC system

A properly operated and maintained HVAC system should provide for the thermal and ventilation needs of building occupants and should dehumidify air as needed to keep indoor humidity low. As noted above, ASHRAE recommends monitoring and keeping the indoor air dew point below 55°F. The HVAC system should be capable of maintaining low indoor humidity when outdoor ventilation air is humid. This is especially important when the building is unoccupied and thermostats are reset to save energy. During unoccupied periods, closing off the outdoor ventilation air, or decreasing it to a code-required minimum and dehumidifying it, will minimize increased indoor humidity [ASHRAE 2009b].

It is important to minimize the amount of dust and dirt that gets into the HVAC system. This can be accomplished by using filters that are efficient at capturing fine airborne particles. ASHRAE currently recommends using filters with a Minimum Efficiency Reporting Value (MERV) of 6 as the minimum requirement for Standard 62.1-2010. Installing filters with higher MERV values will provide better filtration. The filters must also fit properly in the system's filter racks which will prevent unfiltered air from leaking into the occupied space. It is also important to regularly replace air filters on a schedule recommended by the system manufacturer or HVAC consultants.

During regularly scheduled preventive maintenance checks, maintenance personnel should make sure that the system is still in balance and ventilating all areas of the building according to the design specifications. Changes in the use of different areas of the building may necessitate rebalancing the system. Maintenance personnel should also make sure that all condensate drip pans and drain lines are draining adequately; cleaning out drain lines at least once a year will minimize the likelihood that lines will clog and drip pans will overflow [ASHRAE 2009a]. Outdoor air intakes and damper controls should ensure adequate function; control settings should be checked to ensure that the volume of outdoor air brought in by the HVAC system is sufficient for the expected number of building

occupants. Systems must be designed, sized and operated to be able to condition (dehumidify) the outdoor air. (Information on how to determine how much outdoor air should be brought into the building is provided in the ASHRAE standard *Ventilation for Acceptable Indoor Air Quality* (ANSI/ASHRAE Standard 62.1-2010.) Other components of the HVAC system should be evaluated as recommended by the system manufacturer or HVAC consultant recommendations and any identified problems should be corrected. (An example of a detailed HVAC system checklist is provided as part of the EPA Tools for Schools Action Kit at http://www.epa.gov/iaq/schools/pdfs/kit/checklists/ventchklst.pdf). Management should ensure that building occupants know to report any ventilation problems or concerns (e.g., temperature, smells) to maintenance personnel and not to obstruct supply or return air ducts.

Remove settled dust

A large amount of settled dust in the occupied spaces or in the HVAC systems is a practical indicator of IAQ problems. Be sure to remove settled dust, including dust present on above-floor surfaces, by using a high efficiency particulate air (HEPA) vacuum.

Promptly identify and correct sources of excess building moisture

Mold growth on wall board.

Most buildings will periodically experience events that will contribute to excess moisture or water damage, such as roof leaks, window leaks, and condensation and leaks from pipes. Building materials such as wall board and carpets that become wet during leaks or floods will eventually deteriorate and can allow bacteria and mold to grow unless they dry quickly. Although some materials will require replacement due to any water or moisture damage, complete drying in less than 48 hours will prevent moisture damage and microbial growth in many wet materials [EPA 2001]. For this reason, building management should have policies in place that specify steps that will be taken to address rapid drying or replacement of building materials within 48 hours of becoming wet. Management should also identify and correct all sources of excess building moisture (e.g., roof and window leaks; inadequate drainage around the foundation), as not doing so will increase the likelihood that building occupants will develop respiratory symptoms or disease, and costly repairs and remediation will be necessary in the future. Regularly scheduled inspections of the building by maintenance personnel (focusing on ceilings, dry wall and carpets adjacent to exterior walls, and basement areas) may help to identify evidence of leaks or dampness that can be addressed before extensive damage to building materials occurs (see Appendix A, Building Inspection Checklist). Management should encourage employees to report evidence of leaks or excessive building moisture (e.g., stained ceiling tiles; musty odors) to supervisors as soon as they become aware of the moisture.

Remediation

Building materials which show evidence of mold growth or moisture damage should be cleaned and repaired or replaced to minimize the risk of health effects in building occupants. Remediation activities should correct the underlying causes of the moisture problem and then clean and dry or remove and replace the damaged building materials, including cleaning of particulate (dust) which may contain mold spores and other dampness-related contaminants from indoor surfaces. In addition

to building materials and furnishings, it may also be necessary to clean or replace books and other paper documents which have sustained moisture damage or mold growth, especially if workers have reported respiratory symptoms in relation to handling them. A detailed remediation plan should be developed after careful assessment and investigation of the moisture problem and affected area. It might be possible for the employer to undertake small remediation projects using in-house personnel. Larger projects may require a qualified outside contractor. The ASHRAE *Guide for Buildings in Hot and Humid Climates* [2009a] contains a review of remediation guidelines that have been developed by organizations such as the New York City Department of Health, Health Canada, the EPA, the American Conference of Governmental Industrial Hygienists, the AIHA, and others; it also discusses many other important considerations for remediation work (e.g., use of biocides; management of hidden mold and mold in the HVAC system).

Precautions are necessary to prevent exposure of remediation workers and building occupants to dampness-related contaminants during remediation work. Guidance on the extent of the precautions that may be necessary is generally based on the size of the affected area. For example, the EPA recommends increasing levels of containment of the area and use of respirators and other personal protective equipment (PPE) by remediation workers for affected areas smaller than 10 square-feet, larger than 10 square-feet, and larger than 100 square-feet [EPA 2001]. Containment is accomplished by (1) isolating the affected area with polyethylene sheeting, (2) using HEPA-filtered exhaust ventilation to maintain negative air pressure within the enclosure (to prevent contaminants from migrating to other areas of the building), and (3) sealing off HVAC system ducts within the isolated area. Damaged materials should be sealed within polyethylene sheeting for removal from the containment area. Once cleaning and repairs are completed, the area is further cleaned with a HEPA-filtered vacuum cleaner. Even with containment, building occupants may be exposed to dampness-related contaminants during remediation work. Therefore, prior to the start of any remediation work, management should strongly consider relocating workers who might be exposed during the remediation. This is especially true if several building occupants have developed building-related respiratory symptoms or disease which suggests high health risk from dampness-related exposures [AIHA 2008].

Is Air Sampling for Mold Necessary?

NIOSH does not recommend routine air sampling for mold in damp building evaluations because air concentrations of molds or spores cannot be interpreted with regard to health risk and they are highly variable over time. Instead, NIOSH encourages detection by thorough visual inspections and detection via musty odors. Building consultants can sometimes identify sources of dampness with moisture meters and infrared cameras. In cases where there is no visible sign of dampness, destructive inspections may be necessary to find hidden water intrusion or mold. Destructive inspections involve removal of the surfaces of building materials, such as to inspect wall cavities, under floor coverings, or behind wall coverings in order to determine hidden sources. In certain conditions, air sampling may aid in the determination of hidden mold; this is discussed further in Chapter 6 and Chapter 10 of the AIHA publication "*Recognition, Evaluation, and Control of Indoor Mold*" [AIHA 2008]. Building consultants often recommend and perform "clearance" air sampling after remediation work has been completed in an attempt to demonstrate that the building is safe for occupants. However, NIOSH does not recommend this practice, as there is no scientific basis for the use of air sampling for this purpose. No consistent exposure-response relationships have been demonstrated for specific bioaerosol measurements which allow reassurance of building occupants that an indoor environment is safe or that a health hazard continues after remediation. Once remediation is completed (moldy and damaged materials removed; musty odors no longer evident), the best evidence that the building is safe may be that workers or occupants no longer experience

building-related symptoms. Unfortunately, even if most workers or occupants experience improvement in their symptoms, and new workers or occupants remain free of building-related symptoms, some with allergic conditions may not notice an improvement. Such individuals may have to avoid the building even after an otherwise successful remediation because their immune systems may continue to react to very small amounts of substances to which they are allergic.

Identification and Management of Affected Workers and Occupants

As discussed previously, some building occupants may develop respiratory symptoms and disease in response to dampness-related exposures. Individuals who develop asthma or HP may be at risk for progression to more severe disease if the relationship to building-related exposures is not recognized and they continue to be exposed. Employers and building owners should ensure that all workers and occupants are aware of the potential for building dampness to cause respiratory problems and should provide a mechanism by which workers and occupants can notify management of any suspected building dampness, ventilation problems, or respiratory illness concerns. Management can instruct workers and occupants to report such issues to designated health and safety personnel who can work with maintenance staff to investigate and identify any necessary corrective measures. Workers and occupants who have developed persistent or worsening respiratory symptoms while in the building should be instructed to see a physician for evaluation and treatment recommendations; workers can see their own physicians or management can arrange for an evaluation by a physician.

A health and safety committee should develop a mechanism to accept reports of building-related symptoms or illness with protection of privacy. Collected information should be maintained and analyzed to assess patterns from reports of building-related health concerns and building dampness and ventilation problems. Evaluating such information over time may help to determine the exact nature of a particular building problem that may not be readily apparent in information from individual incident reports. For example, the occurrence of several reports from areas of a building that are served by one particular HVAC unit would indicate that the unit and associated ventilation ducts should undergo a detailed inspection; the inspection may reveal that these components are a source of exposure to dampness-related or other contaminants that may be responsible for respiratory symptoms or illness.

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We greatly appreciate your assistance in protecting the health of U.S. workers.

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***Some guidance documents and references have recommendations that differ with those provided in this NIOSH Alert.**

APPENDIX A: BUILDING INSPECTION CHECKLIST

(Modified from U.S. Environmental Protection Agency's Indoor Air Quality Tools for Schools Action Kit)

Ground Level

	YES	NO	N/A
• Proper drainage away from the building (including roof downspouts)	☐	☐	☐
• Sprinklers spray away from the building and outdoor air intakes	☐	☐	☐
• Walk-off mats are used at exterior entrances and are regularly cleaned	☐	☐	☐

Roof

• Roof is in good condition	☐	☐	☐
• Evidence of water pooling (flat roofs)	☐	☐	☐
• HVAC units operate properly (air flows in)	☐	☐	☐
• Exhaust fans operate properly (air flows out)	☐	☐	☐
• HVAC outdoor air intakes (dampers) are clear of obstruction and remain open, even at minimum setting	☐	☐	☐
• Nests, droppings, or collected leaves or debris near outdoor air intakes	☐	☐	☐
• Entrainment of air from plumbing stacks and exhaust outlets into HVAC outdoor air intakes	☐	☐	☐

All Rooms, Attic, and Plenums

• Rooms are dusted and vacuumed regularly	☐	☐	☐
• Odors (especially moldy or musty) in rooms, attic, or plenums	☐	☐	☐
• Visible signs of mold and mildew growth in attic or plenums; on walls, ceilings, floors, or air supply and return vents; or under plumbing	☐	☐	☐
• Visible signs of water damage in attic or plenums, or on walls, ceilings, or floors	☐	☐	☐
• Condensation on inside exterior walls, windows, windowsills, and window frames	☐	☐	☐

- Condensation on cold water pipes ..... ☐ ☐ ☐
- Evidence of plumbing leaks in attic or in rooms ..... ☐ ☐ ☐

Ventilation

Air Supply and Air Exhaust

- Air flows from supply vents ..... ☐ ☐ ☐
- Air supply pathway is not obstructed ..... ☐ ☐ ☐
- Obstructions exist in supply and exhaust vents ..... ☐ ☐ ☐
- Bathrooms, restrooms, and kitchens have operating exhaust fans ..... ☐ ☐ ☐

Filters

- Filters are dirty ..... ☐ ☐ ☐
- Filters fit properly..... ☐ ☐ ☐
- Filters are properly installed (correctly for direction of airflow)... ☐ ☐ ☐
- Filters have been changed according to the change-out schedule ☐ ☐ ☐

Drain Pans and Coils

- Drain pans slant toward the drain (to prevent water from accumulating)..... ☐ ☐ ☐
- Drain pans do not have accumulated water and/or are not clogged..... ☐ ☐ ☐
- Drain pans are clean and free of mold and mildew..... ☐ ☐ ☐
- Heating and cooling coils are clean ..... ☐ ☐ ☐

General

- Temperature and humidity are maintained within acceptable ranges ..... ☐ ☐ ☐