Commercial and Educational Ventilation

Heating, Ventilating and Air-Conditioning Systems in Commerical and Educational Buildings

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Overview
Ventilation rates for offices and schools
Problems with ventilation systems
- **Temperature and humidity problems**
- **Poor outside air quality**
- **Chemicals**
- **Infectious diseases**
- **Recirculated air**

Inspection of ventilation systems
Correcting ventilation problems
Cleaning of air ducts

Overview

Inadequate ventilation is a significant problem associated with poor indoor air quality (IAQ). Ventilation is the process of bringing fresh clean air into the building and exhausting stale indoor air out of the building. This is often done by a heating, ventilation, and air-conditioning system called a heating, ventilating and air-conditioning (HVAC) system. The HVAC system controls the temperature of a building as well as the humidity levels. In addition to controlling temperature and humidity, HVAC systems can also control **odors** and dilute pollutants inside the building.

Some studies estimate that approximately 60 percent of all indoor air problems are due to ventilation. Of this 60 percent, 30 percent are a result of air contamination, 20 percent from inside the building and 10% from outside.[1] If there is not good ventilation, pollutants can build up inside the building and result in indoor air complaints. A **National Institute of Occupational Safety and Health** (NIOSH) study blamed about half the cases of indoor air pollution on poor ventilation.[2] According to a report from the US Government Accounting Office, an estimated 20 percent of all schools in the United States have indoor air problems and 25 percent have unsatisfactory ventilation. In addition, 36 percent of all school officials rated their facility's heating and ventilation systems as a "less than adequate building feature."[3]

Having good ventilation systems can decrease the number of indoor air complaints and health problems caused by poor air quality. A study by the Walter Reed Institute of Medical Research found that absentee rates in poorly ventilated buildings are 50 percent greater than in well-ventilated buildings.[4] Several studies have shown that the number of **building-related symptoms** (BRS) [also referred to as sick building syndrom] is 40 percent to 50 percent lower among office workers six months after moving into buildings with good ventilation systems. In a study in Quebec City, researchers showed that this large decrease in the number of SBS complaints was maintained three years later. In this study, one of the reasons for the fewer SBS problems was that in the new building the **copying machines** were in separate rooms away from workers. Another reason was the **smoking** area had its own exhaust system so that contaminated air was not recirculated throughout the building.[5] Nevertheless, poor ventilation can also affect the quality of work that one does. In a recent Danish study, researchers found that typists in offices with clean air had six percent more output than typists in other offices.[6]

There are many different parts to an HVAC system. These parts include furnaces or boilers, chillers, cooling towers, air handling units, exhaust fans, ductwork, filters, steam (or heating water) piping, dampers, louvers, cooling coils, drip pans, registers, and grills. All of these parts need to be kept clean, free of debris and **mold**, and in good working condition in order to provide good quality air to the building. In addition, it is important that the location of the air intake units be considered. It is possible for rooftop units to pull pigeon and other bird droppings into the HVAC system as part of the outside "fresh" air brought into the building. This increases the chance of people inside the building developing lung infections such as **histoplasmosis** or psittacosis. Intake units located near building exhausts, parking lots, loading docks, or busy highways increase the chance of

bringing into the building vehicular **exhaust**, **carbon monoxide**, **VOCs**, and **particulates**. Intakes located near or downwind of cooling towers increase the risk of ***Legionella*** bacteria entering the air supplies of buildings.

Ventilation Rates for Offices and Schools

Ventilation rates are measured in cubic feet per minute or cfm and guidelines are written in cfm per person. The guidelines that are often used for ventilation rates are provided by an organization called the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). ASHRAE recommendations are voluntary standards that only become enforceable when a state or locality adopts their standards in their building codes. In the United States, there are no federal laws requiring a minimum amount of fresh airflow into buildings.

The Society's guidelines have changed over the years. One of the first recommendations to improve indoor air quality was in 1836 when Tregold calculated the minimum amount of outdoor air needed for miners to be 4 cfm.[7] In 1895 ASHRAE adopted a recommendation of 30 cfm to reduce the spread of disease, especially **tuberculosis**. In the early and mid 1900's, building ventilation standards called for about 15 cfm of outside air for each building occupant. The purpose at that time was to mainly reduce body **odors** in the building.

Early ventilation recommendations for schools were first proposed in the early 1900s in Massachusetts and New York. These states recommended 30 cfm per student. States began realizing that by bringing in fresh outdoor air, they were able to reduce the spread of **respiratory infections**.

Because of the 1973 oil embargo, however, the amount of outdoor air for ventilation was reduced to 5 cfm per occupant. This was considered necessary to save energy as long as there were no major sources of pollutants. Another action that was taken to conserve energy around that time was that buildings were "tightened up" to prevent leaks and new buildings were built with windows that did not open. This tightening of the building along with reduced ventilation rates began causing discomfort and health problems in building occupants. The pollutants inside had no way to get out and began to build up. This became known as sick building syndrome, more properly referred to now as building-related symptoms.

The Society presently recommends 20 cfm of outdoor air per person for office spaces and conference rooms, and at least 15 cfm of outdoor air for other nonresidential environments such as school classrooms. However, this may not be enough. In a study of 399 workers in 14 mechanically ventilated office buildings in Helsinki, Finland, the researchers found that outdoor air ventilation rates below 32-53 **cfm** increases the risk of building-related symptoms.[8] In France, as compared to the United States, buildings are required to have three times more ventilation and two times more soundproofing, while using half as much energy.[6]

However, it is not enough to just increase the amount of outdoor air. In a study of 1838 buildings, the ventilation rates were increased from 20 cfm to 50 cfm for two weeks without the occupants knowing about the increase. However, this increase in ventilation rates did not change the workers' perceptions of the air in their offices or decrease the number of building-related symptoms complaints received.[9] Another well-controlled study has shown that increasing the supply of outdoor air does not affect workers' perceptions of their office environment or their reporting of symptoms considered typical of **building-related illness**.[10] From these studies, it would appear that increasing the ventilation rates does not make any difference. However, there is a variety of factors that need to be considered such as the layout of the space. For example, offices that use partitions to divide the space into individual cubicles are also creating barriers to adequate air reaching everybody. The activities going on inside the building are also important since indoor air pollutants are increased by activities such as **photocopying**, **smoking** or handling paper.

Problems with Ventilation Systems

Often problems with ventilation systems occur because the building is being used for a different purpose or has more people in it than were originally thought of when it was designed. First, look at these factors to see if they might explain some of the problems that may be happening:

- How was the building originally intended to function? For example, if the building was originally built as a factory with an open design, there may be ventilation problems if that open space is broken up with walls and partitions. The activities going on in the building may also be different than originally conceived.

- Is the building functioning as designed?

- What changes in building layout and use have occurred since the original design and construction? Find out if the HVAC system has been reevaluated to make sure it reflects the current use of the building.

When there are changes, there may be indoor air quality problems. For example, there was one building built in the early 1960s in Bonn, Germany that consisted of three naturally ventilated sections. Until the mid-1980s, the building was used by a pharmaceutical company. Some parts of this building were used for production and storage of pharmaceutical products. When a new company took over the building, they converted this production and storage space into offices. Later there were complaints of indoor air problems. Upon **investigation**, researchers found that the people who were complaining about indoor air problems were in the same areas that had at one time been the production and storage areas. These areas had been converted to office space without regard to the prior use of these parts of the building.[11]

When one study looked at HVAC problems in several buildings, they found the following problems[12]:

- 70 percent had inadequate amounts of outside air
- 50 percent to 70 percent had inadequate air distribution to the parts of the buildings where people worked
- 60 percent had inadequate filtration to remove outdoor pollutants
- 60 percent had **standing water** in the system which had the potential for microbial growth
- 40 percent with visible **mold and fungus** growing on the **insulation**
- 20 percent with malfunctioning **humidifiers**
- 75 percent had inadequate **maintenance** programs

Mechanical ventilation systems in large buildings are designed and operated not only to heat and cool the air, but also to draw in and circulate outdoor air. If they are poorly designed, operated, or maintained, however, ventilation systems can create indoor air problems. Ventilation problems are the biggest cause of indoor air quality problems: 75 percent do not get enough outside air; 65 percent have problems distributing the air to all occupants (partitions and other obstacles that may block supply and return vents); 60 percent have improper filtration; 75 percent have inadequate maintenance of the air handling system; and 45 percent have microbial contamination.[13] Some of these problems are due to poor initial design, outdoor vents or dampers closed to "save energy," inadequate maintenance of dampers and control linkages, and obstructed outdoor screens on the air intakes. There may also be fans that have been inoperative for a number of years or filters that have not been changed on a regular basis. Some of the other problems in the ventilation equipment itself include:

- Condensate in pans and ductwork. This can lead to microbial growth such as **bacteria**, slime, algae, and **mold**.
- **Fiber glass** being shed by a fiber glass interior duct lining. Fiber glass was used as a liner in buildings built in the late 1970s and the early 1980s in order to reduce noise from the HVAC fans and for thermal **insulation**. After several years, these linings begin releasing fibers. For example, there was an office in Richmond, Virginia in which workers thought they were suffering from insect bites for several months. When somebody was brought in to check out the problem, they found that some filters were missing and loose fiber glass was being blown through the vents onto workers. As soon as the filters were installed, their skin cleared up.[4]
- **Fiber glass** that is dirty and becomes wet can be a source of **mold** growth. Mold spores from this growth can become airborne and distributed throughout the occupied spaces of buildings.
- Broken dampers can prevent outdoor air from being brought into the building.
- Pneumatic controls that do not work properly can determine whether a sufficient amount of outdoor air is being brought into the building.
- Poor quality filters can reduce the efficiency of the mechanical system in distributing air. They can also allow dirt, particles, pollen and other debris to enter the building. Filters that become clogged with dirt can become sources of **mold** and **bacterial** growth.

These mechanical problems can create these following indoor air concerns:

Temperature and humidity problems
Poor outside Air Quality
Chemicals
Infectious diseases
Recirculated air

Temperature and Humidity Problems

Though temperature, relative humidity and air movement have usually been considered "comfort" factors, there is increasing evidence that these factors are important in building-related symptoms as well as sickness-related absence.[14] Not everybody is going to be happy with the temperature in a building. Age, gender, job activity, clothing, and physiologic differences all affect individual preferences in desired temperature. Since people differ on what temperatures they find comfortable, the recommendations from ASHRAE are designed to satisfy 80 percent to 95 percent of the building occupants. That is not always done. In one study, over half of the office workers surveyed said that the office temperature needed to be improved.[15] Because there are often comfort problems in workplaces where there are complaints about indoor air quality, thermal control of the indoor environment should be the first thing investigated when investigating indoor air problems.

The temperature range recommended by ASHRAE is from 68°F to 78°F, but it seems that temperatures higher than 75.2°F will usually increase complaints about indoor air quality and may increase building-related symptoms. For example, in one study the number of people reporting headaches increased from 10 percent to 60 percent when temperature was raised from 70°F to 76°F. Other building-related symptoms, including skin problems, showed similar effects.[15] In addition to physical symptoms, temperature differences can also affect work performance. For example, moderate heat can reduce reading speed, typewriting, and the kind of logical thinking required for mathematics by up to 30 percent.[15] However, it is not just environments that are too warm that are a problem. Studies have also show that moderate cold can reduce manual speed, sensitivity, and dexterity by up to 20 percent.[15]

However, air temperature alone does not determine thermal comfort. Both temperature and humidity are very important measures of IAQ since they directly influence the perceptions of the occupant as to comfort and health. For example, humidity levels that are too low (below 20%) can result in buildup of static electricity, complaints of eye and throat irritation, dry skin, and other problems. Static electricity can be a problem since it can result in unpleasant electric shocks if someone encounters a metal object. In addition, sparks created by static electricity may damage **computer** circuits. Because of problems like these, dryness is one of the most common complaints about indoor air.

High humidity levels can also cause problems such as equipment corrosion and microbial growth problems. At high humidity levels, occupants tend to describe the air quality in a room as "stale" and **odors** can be detected more often. For example, in a study of 20 panelists in Finland, researchers found that humidified air was perceived as being stuffier and having more odors than non-humidified air.[16] But the big problem with high humidity levels is that it may cause condensation on walls, floor, ceilings, and even air ducts on which **mold** may grow. In addition, **dust mites** thrive in humid environments.

Poor Outside Air Quality

Ventilation systems can bring in pollutants from outside. Examples of pollutants that may be brought in from outside include:

- Smog
- Elevated **mold** spore or **pollen** levels during certain seasons: Naturally ventilated buildings are not always better. One study showed that the levels of fungi and pollen were much greater in a naturally ventilated building than in an air-conditioned building. This is because the HVAC system in the air-conditioned building prevented these contaminants from getting inside. The HVAC system also diluted the indoor concentration of mold and pollen that were already inside.[17]
- Vehicle **exhaust** from cars in underground garages or from forklift trucks on nearby loading docks
- *Legionella* or other **bacteria**
- Stale indoor air being exhausted from the HVAC system: This can happen when the exhaust vent is too close to the air

intake vent

Many variables can influence the outside levels of pollutants. These include:

- Outside concentration of the pollutant
- Seasonal and daily variations
- Climatic factors such as temperature, humidity, wind, rainfall and surrounding vegetation

Chemicals

There are several hazards that may be associated with HVAC systems. These include:

- Chemicals used to treat water used in the HVAC system. This is especially true of water treatment additives into the water that is made into steam in a boiler. The chemicals in this steam get into the **supply air**. ASHRAE/ANSI 62-2001, *Ventilation for Acceptable Indoor Air Quality*, says that steam is the preferred method of humidifying indoor air; therefore, steam is replacing water humidification systems in newer buildings. These systems can be sites for the growth of **mold** and **bacteria**.
- Chemicals in the ductwork. There may be **VOCs** found in the duct liner, duct sealing caulk, and/or neoprene gasket. For example, one type of duct liner is coated with a phenol **formaldehyde** polymer, hexamethylene tetramine. Another kind of duct liner is coated with a resin made of phenol-melamine-formaldehyde. These kinds of linings can emit VOCs that can get into the air and be distributed throughout the ventilation system if they are exposed to **ozone** gas (like from a **photocopier**). There is usually not a problem with them emitting VOCs unless they encounter ozone. This is because of an oxidation reaction between the ozone and the chemicals. One study showed that emissions from materials in the HVAC system were responsible for 80 percent of all the indoor emissions of VOCs in that building.[18]
- Improper venting of **combustion products**. For example, smoking rooms should have a dedicated exhaust system so that **environmental tobacco smoke** is not carried to other parts of the building. Ventilation in these rooms should be 60 **cfm** per smoker in the room. Of course, the best way to reduce exposure to these chemicals is to not allow smoking in buildings at all.
- Refrigerant leakage.
- Improper use of biocides, sealants, and/or **cleaning compounds**.
- Leaks such as natural gas or propane leaks that accidentally get pulled into the ventilation system
- Chemicals from activities going on in the building. These depend on what type of work is being done in the building and can include **ozone**, **pesticides**, **lead**, and VOCs.

Infectious Diseases

People are more likely to catch **infectious diseases** in buildings without enough ventilation. When someone coughs or sneezes, they spew a fine mist of droplets that contain an aerosolized **virus**. If there is not enough ventilation to blow away and disperse the infectious organism, the virus can stick to desks or to doorknobs and live for several hours. Therefore, if someone sneezes close to you and the air is not moving, you have a good chance of becoming infected.

Bacteria and Fungi

There should not be any problems with HVAC systems that are well designed, well maintained, and properly installed. For example, even a properly designed condensate drain system will malfunction and hold water if the pan is not correctly pitched when installed. If they are well maintained, these systems can even improve the quality of indoor air by filtering out **mold** and **pollen** that may be present in high concentrations outside and by maintaining proper humidity levels so that mold and fungi do not thrive inside. In one study, even though there was more fungus (mold) collected in the **dust** of buildings that were mechanically ventilated compared to those that were naturally ventilated, there was less fungus (mold) *in the air* of mechanically ventilated buildings compared to naturally ventilated ones.[19]

However, if HVAC systems are not properly cleaned and maintained, over time a lot of dirt can accumulate in the ducts and form an ideal breeding ground for **fungi** and **bacteria**. Then these microbes may get into the air supply and be blown throughout the building, possibly causing health problems. For example, at two office buildings in Rochester in 1984, a fungus got in the ventilation system. About 1,000 people were exposed to the fungus, which caused an outbreak of **hypersensitivity pneumonitis**. Of those exposed, 115 got sick. Though the company spent millions trying to get rid of the fungus, they ended up having to replace the entire ventilation system.[4] Bacteria and fungi found in HVAC systems can also trigger **allergies**, cause infections, and be the source of outbreaks of **building-related illnesses** such as **Legionnaires' disease**.

High levels of microbial pollutants have been found on many parts of HVAC systems including:

- Cooling coils
- Filters
- Drip pans
- Humidification systems
- Cooling towers
- Ductwork: Ducts can be a particular concern if they are lined with a **fiber glass** lining since these types of linings can retain **moisture**. Fiber glass sheets were commonly used for lining the interiors of air supply ducts and air handler compartments of buildings from the early 1960s through the late 1980s. Fiber glass sheeting is an excellent moisture retainer. In laboratory experiments, fiber glass liner has retained moisture for up to 16 days.[20] As **dust** gathers in the ducts, mold will begin growing in it. Some inspectors have found mushrooms several inches tall growing inside ventilation systems!

Recirculated Air

In an effort to save energy, there has been as much as a 50 percent decrease in the amount of fresh air brought into some buildings. Some of the HVAC systems in some buildings were not even designed to let in as much fresh air as they should. Recirculating stale air can lead to problems. For example, in a study of 1144 workers in three different office buildings in Paris, the workers in the buildings with HVAC systems that were supplied by 30 percent fresh air had slightly higher building-related symptoms complaints than workers in buildings that were naturally ventilated.

Recirculating too much stale air can raise contaminants (i.e. **dust**, **human** bioeffluents, and VOCs) to unhealthy levels. In a study of soldiers during the 1982-1986 period there were 2700 more hospitalization rates for acute respiratory disease hospitalizations among occupants of modern barracks that used mostly recirculated air (95 percent was recirculated) as opposed to old barracks with windows and ceiling exhaust fans (50 percent was recirculated).[21] Recirculation can also happen if special vents do not exhaust to the outside like in bathrooms or smoking rooms.

Inspection of Ventilation Systems

Some of these problems can be found by having the HVAC system inspected. Some of the things that an inspector may do are:

- Examine the system, possibly using a fiber-optic borescope. This tool can help visualize and videotape the inside of ducts.
- Take ventilation measurements to make sure that enough airflow is going through the system.
- Sample for things such as microbial contamination, dust or **fiber glass**

If you are going to investigate your ventilation system, make sure to follow these suggestions:

- Look to see if each room has an air supply. If windows cannot be opened, there should be two vents: a supply vent that

blows fresh air into the room and an exhaust vent that moves stale air out. Supply vents may be found near windowsills and exhaust vents may be in ceilings.

- Look to see if the vents are dirty. If so, a more efficient filter on the HVAC system may be needed, but the system would need to be checked first to make sure that it is powerful enough to blow air through a filter like a **HEPA**.
- See if the air is actually moving in the room. Put a strip of paper at the opening of each vent. The paper should flutter out for supply vents and be drawn into exhaust vents.
- Look to see if any of the vents are blocked. Often things like partitions, file cabinets, desks, and many other things may block a vent and interfere with airflow.
- See if the supply and exhaust vents are too close together. If they are just a few feet apart, the incoming air may immediately get sucked into the exhaust and leave the room with stale air.
- Check to see if **printing** and **copying** machines have adequate exhaust. It is preferable to have these types of machines in their own room with good exhaust and away from people.
- If you choose to have an investigator come in to do an evaluation, only hire someone who specializes in IAQ investigations.
- Be sure to check the person's references. Anyone claiming to be a professional should be able to provide references of similar projects they have successfully completed. They must know what to look for in evaluating an HVAC system. Since most IAQ problems involve the HVAC system, make sure that the person actually looks inside it.
- Knowledge of environmental microbiology. Many IAQ problems involve microbial contamination so they should be familiar with how to evaluate these kinds of problems.
- The inspector should put more emphasis on their inspections than on their tests. Somebody who crawls around parts of the system and talks to people about problems is more valuable than somebody who just takes measurements with fancy equipment.

Correcting Ventilation Problems

Simply increasing the ventilation rate may not resolve IAQ problems. There are several reasons for this:[22]

- Research findings show that IAQ complaints and building-related symptoms are caused by many things not related to the air like personal, occupational, and **psychological factors**.
- For example, some people are more sensitive or susceptible to the problems that cause indoor air problems.
- There may be enough airflow, but it may not be reaching its target due to problems like blocked vents. Do not put up things that might restrict air movement such as putting furniture over air vents.

The best ways to control indoor air pollutants from being distributed throughout the ventilation system include:

- Control pollutants at the source: This is the most effective strategy for maintaining clean indoor air.
- If installing an HVAC system, make sure that:
    - The HVAC system is properly designed for the needs of the building. This includes making sure there is enough ventilation for the number of people expected in the building and that ventilation rates are high enough given the activities that are going to be conducted in the building.
    - Air supply vents are not too close to building exhaust vents.
    - Supply vents are placed away from outdoor sources of pollution such as:

- Loading docks
- Parking and heavy traffic areas
- Chimneys
- Furnace, kitchen, or bathroom exhausts
- Trash dumpsters

- Conduct proper and regular HVAC inspection, cleaning, and maintenance. **Click here** for a detailed checklist recommended by NIOSH, including the following:
  - Make sure that vents are open, fans are on, and filters are cleaned on a regular maintenance schedule. Change air filters regularly. In many schools, air filter efficiency ranges from 10 percent to 40 percent. These are not good enough to minimize **dust** levels and they do a poor job of removing **pollen** from the air. Filters should be upgraded to 85 percent filters, but an HVAC engineer should be consulted first to make sure that the equipment can handle this kind of filter.
  - Use **air cleaners** that are part of the HVAC system. However, this should only be in addition to controlling pollutants at the source and properly maintaining the HVAC system. These air cleaners should include high efficiency filters that can remove some of the particles in the air. However, these filters will not be able to remove any of the gases or vapors unless the filters are specially treated with something like activated charcoal. In addition, the blower on the HVAC system must be designed to be powerful enough to blow air through a high-efficiency filter. Many HVAC systems have low efficiency filters that are only designed to prevent **dust** from damaging the blower fans.
  - Make sure that air intake vents are open, clean, and far from air pollution sources such as kitchen exhaust vents, truck-unloading areas, and smoke stacks and clear of other sources of contamination such as pigeon droppings.
  - Check the exhaust system to make sure that air can adequately be exhausted from the building.
  - Properly maintain and clean humidification and dehumidification systems to prevent the growth of harmful **bacteria** and **fungi**. This includes things like making sure there is no water in the drain pan. Failure to properly treat the water in cooling towers to prevent growth of organisms, such as *Legionella*, may introduce such organisms into the HVAC supply ducts and cause serious health problems.
  - Frequently inspect and clean the heating and cooling coils, cooling tower, and drip pan to prevent microbial contamination. Wall-mounted fan coil units are often found in educational facilities. These units are frequently not well maintained. This often results in dirty coils, dirty condensate pans, and dirty or missing filters.
  - Ensure that air dampers are clear of obstruction and operating properly. In educational facilities, supply grilles are often blocked by books or papers.
  - Inspect and clean as needed the inside of air handling units
  - Inspect fan motors and belts
  - Regularly inspect and clean air humidification equipment and controls
  - Inspect and clean as needed air distribution pathways and variable air volume (VAV) boxes.

- Maintain building temperatures and humidity levels within the recommended range
- Ventilate the building with at least 20 **cfm** unless occupant activities are such that higher ventilation rates are needed. ASHRAE/ANSI Standard 62-2001 says that mixed air (fresh and recirculated) should be distributed uniformly throughout

the area where occupants work and that it should reach their breathing zones.

- Install local exhaust ventilation to remove pollutants from areas where they may build-up such as rest rooms, **copy** rooms, and **printing** facilities.

- If the ducts have **fiber glass** liners that have gotten wet, the North American Insulation Manufacturers Association (NAIMA) recommends that they be removed and thrown out as soon as possible to prevent **mold and fungi** from growing on them. This is because it is so hard to properly clean these ducts. In one study, they were able to clean the ducts, but the same level of microbial contamination returned in just six weeks.[23] Clean air handlers yearly and ducts every 5 to 10 years or as needed. Use the best possible filtration that your system can handle.

- Have individually controlled ventilation systems for each worker. When workers in one study had control of their ventilation system, there were a lot fewer complaints about indoor air problems. When workstations that had individual climate control systems were examined, researchers found a wide range of temperatures and airflows.[24] More than 60% of the occupants in one study said they had no control over their thermal environment of their workstation. Only 1% said they had "complete control." Self-reports of health symptoms seemed to decrease with an increased amount of control over thermal environment.[25] In offices where people could individually control the temperature, there was a 34 percent reduction in sickness due to building-related symptoms. People who had windows in their offices that could be opened were 25 percent more likely to lose workdays due to building-related symptoms than those who did not have windows that opened.

- Investigate all indoor air complaints right away. A NIOSH form to assist with this may be found at **www.cdc.gov/niosh/pdfs/complain.pdf**.

Cleaning of Air Ducts

There is currently no hard data that shows that cleaning air ducts improves indoor air quality. The EPA/NIOSH publication, *Building Air Quality Guide*,[26] places its emphasis on prevention. Any HVAC system that is clean and dry should work well and provide enough quality air for good indoor air quality. All parts of the HVAC system, including the ducts, should be kept in proper working condition. Poorly maintained, poorly operated, "dirty" air handling units, and dirty air ducts create poor indoor air quality and increase operating costs by using more energy.

If duct cleaning is needed, the following recommendations should be followed:

- Any duct cleaning should be done when people are not in the building in order to prevent exposure to chemicals and excess **dust**.

- Avoid application of biocides, sealants or other chemical treatments.

- Choose consultants and air duct cleaning specialists with experience and training in cleaning office building HVAC systems.

- Make sure proper methods are used. In one study, Florida International University researched which of three commercial HVAC duct-cleaning processes was most effective in reducing the level of airborne particulate matter. They found the most effective method to be the "air sweep" in which compressed air blows out dirt and debris, which is collected by a vacuum system.[27]

  NIOSH/EPA recommend that this type of cleaning also include gentle, well-controlled brushing of duct surfaces or other methods to dislodge dust and other particles. Duct cleaning that relies only on a high velocity airflow through the ducts may not get good results since there may be caked on dirt on the edges that gets missed. This type of power brushing should use HEPA (high-efficiency particle arrestor) filtered vacuum cleaners since dust may go through the filters of regular vacuum cleaners or shop-vacs. The only downside is that this method cannot be used on inaccessible ducts.

  Methods that are not recommended are:

  - Using sealants/encapsulants?these may cause more problems in the end. None of these techniques has been proven to stop microbiological growth nor have many of these materials been evaluated for their potential health effects on occupants. In addition, the use of sealants may void the fire safety rating of the ductwork.

- Truck-mounted vacuum or portable high power vacuum?this also does not work. No matter how powerful the vacuum is, the airflow at the edges of the duct is minimal. If the vacuum is too powerful, it can cause the duct to collapse or develop a leak.

- The use of biocides?this can expose all the building occupants to these chemicals. There is some question about whether any of these techniques use enough biocide to actually kill the **bacteria**, germs, or **mold** that may be present. **Deodorizers** may provide a fresh smell, but they are not meant to provide any real control of the underlying problem. They add chemicals.

  Careful cleaning and sanitizing of part of the HVAC system, such as coils and drip pans, can reduce microbiological growths. Before using sanitizers or any **cleansing agents**, carefully read the directions on the product label. Once cleaned, these components should be thoroughly rinsed and dried to prevent exposure of building occupants to the cleaning chemicals.

- Where possible, vacuum equipment or fans should be used during cleaning and sanitizing to make sure that vapors and dust are exhausted to the outside and do not enter parts of the building where people may be.

- Any water-damaged or contaminated materials in the ductwork, such as **fiber glass**, should be removed and replaced. Even when such materials are completely dried, there is no way to guarantee that all microbial growth has been eliminated.

After the duct system has been cleaned and restored to use, a preventive maintenance program will prevent the recurrence of problems. Such a program should include particular attention to the use and maintenance of adequate filters, control of **moisture** in the HVAC system, and periodic inspection and cleaning of HVAC system components.

References

1. Spaul WA. Building-related factors to consider in indoor air quality evaluations. Journal of Allergy Clin Immunol. 1994 August;(number 2, part 2):385-389.

2. Saltzman A, Silberner J. When each day is a sick day: How to get a breath of fresh air in a polluted office. U.S. News and World Report. March 13, 1989;65-67.

3. The Florida Times-Union. What's ailing you? Air quality problems in schools. August 29, 2000.

4. Rice F. Do you work in a sick building? Fortune, July 2, 1990; 86-88.

5. Bourbeau J, Brisson C, Allaire S. Prevalence of sick building syndrome symptoms in office workers before and six months and three years after being exposed to a building with an improved ventilation system. Occupational and Environmental Medicine. 1997;54:49-53.

6. Echikson W. Why the air and light are so much better in Paris. Business Week. 3684, June 5, 2000;124.

7. Turner WA, Bearg DW, Brennan T. Ventilation. Occupational Medicine: State of the Art Reviews. 1995;10(1):41-57.

8. Jaakkola JK, Miettinen P. Ventilation rate in office buildings and sick building syndrome. Occupational and Environmental Medicine. 1995;52:709-714.

9. Menzies R, Tamblyn R, Farant JP, Hanley J, Nunes F. The effect of varying levels of outdoor air supply on the symptoms of sick building syndrome. N Engl J Med. 1993;328(12):821-827.

10. Salvaggio JE. Psychological aspects of "environmental illness," "multiple chemical sensitivity," and building-related illness. J Allergy Clin Immunol. 1994;94(2, part 2):366-370.

11. Engelhart S, Burghardt H, Neumann R, Ewers U, Exner M, Kramer MH. Sick building syndrome in an office building formerly used by a pharmaceutical company: A case study. Indoor Air. 1999;9:139-143.

12. Woods JE. Cost avoidance and productivity. Occup Med State Art Rev 1989;4:753-770.

13. Holzman D. Elusive culprits in workplace ills. Insight, June 26, 1989;44-45.

14. Menzies D, Pasztor J, Nunes F, Leduc J, Chan CH. Effect of a new ventilation system on health and well-being of office workers. Archives of Environmental Health. 1997;52(5):360-367.

15. Levin H. "Physical factors in the indoor environment." Occupational Medicine: State of the Art Reviews. Volume 10, No. 1, Jan - March 1995. Philadelphia, Hanley and Belfus, inc., page 61.

16. Reinikainen LM, Aunela-Tapola L, Jaakola JK. Humidification and perceived indoor air quality in the office environment. Occup Environ Med. 1997;54:322-327.

17. Parat S, Perdrix A, Fricker-Hidalgo H, Saude I, Grillot R, Baconnier P. Multivariate analysis comparing microbial air content of an air-conditioned building and a naturally ventilated building over one year. Atmos Enviro. 1997;31(3):441-449.

18. Morrison GC, Nazaroff WW, Cano-Ruiz JA, Hodgson AT, Modera MP. Indoor air quality impacts of ventilation ducts: ozone removal and emissions of volatile organic compounds. J Air Waste Manag Assoc. 1998;48:941-952.

19. Vincent D, Annesi I, Festy B, Lambrozo J. Ventilation system, indoor air quality, and health outcomes in Parisian modern office workers. Environ Res. 1997;75:110-112.

20. Samimi BS. The environmental evaluation: Commercial and home. Occup Med: State of the Art Reviews. 1995;10 (1):95-118.

21. Mills E, Rosenfeld A. Consumer non-energy benefits as a motivation for making energy-efficiency improvements." Energy. 1996;21(7/8):707-720.

22. Addressing the psychological aspects of indoor air quality by Professor Alan Hedge, Dept. Design and Environmental Analysis, Cornell Univ. Paper presented at the 1st Asian Indoor Air Quality Seminar in Urumqi, China, Sept. 22-23, 1996.

23. Foarde K, VanOsdell D, Meyers E, Chang J. Investigation of contact vacuuming for remediation of fungally contaminated duct materials. Environ Int. 1997;23(6):751-762.

24. Menzies D, Pasztor J, Rand T, Bourbeau J. Germicidal ultraviolet irradiation in air conditioning systems; effect on office worker health and well being: a pilot study. Occup Environ Med. 1999;56:397-402.

25. Haghighat F, Donnini G. Impact of psychosocial factors on perception of the indoor air environment studies in 12 office buildings. Building and Environment. 1999;34:492.

26. *Building Air Quality: A Guide for Building Owners and Facility Managers*. EPA Publication No. 400/1-91/003; DHHS (NIOSH) Publication No. 91-114; December 1991. **www.cdc.gov/niosh/baqtoc.html**

27. Florida Energy Extension Service and Gary Cook, "Energy Efficiency and Environmental News: Duct Cleaning and Indoor Air Quality," [**http://edis.ifas.ufl.edu/EH293**], Date accessed September 2000.

Guidelines for Environmental Infection Control in Health-Care Facilities

Recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC)

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention (CDC)
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Centers for Disease Control and Prevention Healthcare Infection Control Practices Advisory Committee (HICPAC)

Guidelines for Environmental Infection Control in Health-Care Facilities

Abstract

Background:
Although the environment serves as a reservoir for a variety of microorganisms, it is rarely implicated in disease transmission except in the immunocompromised population. Inadvertent exposures to environmental opportunistic pathogens (e.g., *Aspergillus* spp. and *Legionella* spp.) or airborne pathogens (e.g., *Mycobacterium tuberculosis* and varicella-zoster virus) may result in infections with significant morbidity and/or mortality. Lack of adherence to established standards and guidance (e.g., water quality in dialysis, proper ventilation for specialized care areas such as operating rooms, and proper use of disinfectants) can result in adverse patient outcomes in health-care facilities.

Objective:
The objective is to develop an environmental infection-control guideline that reviews and reaffirms strategies for the prevention of environmentally-mediated infections, particularly among health-care workers and immunocompromised patients. The recommendations are evidence-based whenever possible.

Search Strategies:
The contributors to this guideline reviewed predominantly English-language articles identified from MEDLINE literature searches, bibliographies from published articles, and infection-control textbooks.

Criteria for Selecting Citations and Studies for This Review:
Articles dealing with outbreaks of infection due to environmental opportunistic microorganisms and epidemiological- or laboratory experimental studies were reviewed. Current editions of guidelines and standards from organizations (i.e., American Institute of Architects [AIA], Association for the Advancement of Medical Instrumentation [AAMI], and American Society of Heating, Refrigeration, and Air-Conditioning Engineers [ASHRAE]) were consulted. Relevant regulations from federal agencies (i.e., U.S. Food and Drug Administration [FDA]; U.S. Department of Labor, Occupational Safety and Health Administration [OSHA]; U.S. Environmental Protection Agency [EPA]; and U.S. Department of Justice) were reviewed. Some topics did not have well-designed, prospective studies nor reports of outbreak investigations. Expert opinions and experience were consulted in these instances.

Types of Studies:
Reports of outbreak investigations, epidemiological assessment of outbreak investigations with control strategies, and *in vitro* environmental studies were assessed. Many of the recommendations are derived

from empiric engineering concepts and reflect industry standards. A few of the infection-control measures proposed cannot be rigorously studied for ethical or logistical reasons.

Outcome Measures:

Infections caused by the microorganisms described in this guideline are rare events, and the effect of these recommendations on infection rates in a facility may not be readily measurable. Therefore, the following steps to measure performance are suggested to evaluate these recommendations:

1. Document whether infection-control personnel are actively involved in all phases of a health-care facility's demolition, construction, and renovation. Activities should include performing a risk assessment of the necessary types of construction barriers, and daily monitoring and documenting of the presence of negative airflow within the construction zone or renovation area.
2. Monitor and document daily the negative airflow in airborne infection isolation rooms (AII) and positive airflow in protective environment rooms (PE), especially when patients are in these rooms.
3. Perform assays at least once a month by using standard quantitative methods for endotoxin in water used to reprocess hemodialyzers, and for heterotrophic, mesophilic bacteria in water used to prepare dialysate and for hemodialyzer reprocessing.
4. Evaluate possible environmental sources (e.g., water, laboratory solutions, or reagents) of specimen contamination when nontuberculous mycobacteria (NTM) of unlikely clinical importance are isolated from clinical cultures. If environmental contamination is found, eliminate the probable mechanisms.
5. Document policies to identify and respond to water damage. Such policies should result in either repair and drying of wet structural materials within 72 hours, or removal of the wet material if drying is unlikely within 72 hours.

Main Results:

Infection-control strategies and engineering controls, when consistently implemented, are effective in preventing opportunistic, environmentally-related infections in immunocompromised populations. Adherence to proper use of disinfectants, proper maintenance of medical equipment that uses water (e.g., automated endoscope reprocessors and hydrotherapy equipment), water-quality standards for hemodialysis, and proper ventilation standards for specialized care environments (i.e., airborne infection isolation [AII], protective environment [PE], and operating rooms [ORs]), and prompt management of water intrusion into facility structural elements will minimize health-care–associated infection risks and reduce the frequency of pseudo-outbreaks. Routine environmental sampling is not advised except in the few situations where sampling is directed by epidemiologic principles and results can be applied directly to infection control decisions, and for water quality determinations in hemodialysis.

Reviewers' Conclusions:

Continued compliance with existing environmental infection control measures will decrease the risk of health-care–associated infections among patients, especially the immunocompromised, and health-care workers.

Centers for Disease Control and Prevention
Healthcare Infection Control Practices Advisory Committee (HICPAC)

Guidelines for Environmental Infection Control in Health-Care Facilities

Table of Contents

Executive Summary 1
Part I. Background Information: Environmental Infection Control in Health-Care Facilities 3
A. Introduction 3
B. Key Terms Used in this Guideline 5
C. Air 6
1. Modes of Transmission of Airborne Diseases 6
2. Airborne Infectious Diseases in Health-Care Facilities 7
3. Heating, Ventilation, and Air Conditioning Systems in Health-Care Facilities 13
4. Construction, Renovation, Remediation, Repair, and Demolition 21
5. Environmental Infection-Control Measures for Special Health-Care Settings 34
6. Other Aerosol Hazards in Health-Care Facilities 40
D. Water 40
1. Modes of Transmission of Waterborne Diseases 40
2. Waterborne Infectious Diseases in Health-Care Facilities 41
3. Water Systems in Health-Care Facilities 46
4. Strategies for Controlling Waterborne Microbial Contamination 53
5. Cooling Towers and Evaporative Condensers 57
6. Dialysis Water Quality and Dialysate 59
7. Ice Machines and Ice 65
8. Hydrotherapy Tanks and Pools 67
9. Miscellaneous Medical/Dental Equipment Connected to Main Water Systems 69
E. Environmental Services 71
1. Principles of Cleaning and Disinfecting Environmental Surfaces 71
2. General Cleaning Strategies for Patient-Care Areas 74
3. Cleaning Strategies for Spills of Blood and Body Substances 77
4. Carpeting and Cloth Furnishings 78
5. Flowers and Plants in Patient-Care Areas 80
6. Pest Control 81
7. Special Pathogen Concerns 82
F. Environmental Sampling 88
1. General Principles: Microbiologic Sampling of the Environment 88
2. Air Sampling 89
3. Water Sampling 94
4. Environmental Surface Sampling 95
G. Laundry and Bedding 98
1. General Information 98
2. Epidemiology and General Aspects of Infection Control 98
3. Collecting, Transporting, and Sorting Contaminated Textiles and Fabrics 99

4. Parameters of the Laundry Process 100
5. Special Laundry Situations 102
6. Surgical Gowns, Drapes, and Disposable Fabrics 103
7. Antimicrobial-Impregnated Articles and Consumer Items Bearing Antimicrobial Labeling .. 103
8. Standard Mattresses, Pillows, and Air-Fluidized Beds 104

H. Animals in Health-Care Facilities 105
1. General Information 105
2. Animal-Assisted Activities, Animal-Assisted Therapy, and Resident Animals 106
3. Service Animals 108
4. Animals as Patients in Human Health-Care Facilities 110
5. Research Animals in Health-Care Facilities 111

I. Regulated Medical Waste 112
1. Epidemiology 112
2. Categories of Medical Waste 112
3. Management of Regulated Medical Waste in Health-Care Facilities 113
4. Treatment of Regulated Medical Waste 113
5. Discharging Blood, Fluids to Sanitary Sewers or Septic Tanks 116
6. Medical Waste and CJD 116

Part II. Recommendations for Environmental Infection Control in Health-Care Facilities 117

A. Rationale for Recommendations 117
B. Rating Categories 117
C. Recommendations—Air 118
D. Recommendations—Water 125
E. Recommendations—Environmental Services 133
F. Recommendations—Environmental Sampling 138
G. Recommendations—Laundry and Bedding 138
H. Recommendations—Animals in Health-Care Facilities 141
I. Recommendations—Regulated Medical Waste 143

Part III. References 145

Part IV. Appendices 201

Appendix A. Glossary of Terms 201
Appendix B. Air 210
1. Airborne Contaminant Removal 210
2. Air Sampling for Aerosols Containing Legionellae 210
3. Calculation of Air Sampling Results 211
4. Ventilation Specifications for Health-Care Facilities 212

Appendix C. Water 220
1. Biofilms 220
2. Water and Dialysate Sampling Strategies in Dialysis 222
3. Water Sampling Strategies and Culture Techniques for Detecting Legionellae 223
4. Procedure for Cleaning Cooling Towers and Related Equipment 225
5. Maintenance Procedures Used to Decrease Survival and Multiplications of *Legionella* spp. in Potable-Water Distribution Systems 227

Appendix D. Insects and Microorganisms 228
Appendix E. Information Resources 229
Appendix F. Areas of Future Research 230

Index—Parts I and IV 231

List of Figures, Boxes, and Tables

Figures

Figure 1. Diagram of a ventilation system 14
Figure 2. Example of positive-pressure room control for protection from airborne environmental microbes (PE) 35
Figure 3. Example of negative-pressure room control for airborne infection isolation (AII) 36
Figure 4. Example of airborne infection isolation (AII) room with anteroom and neutral anteroom 37
Figure 5. Diagram of a typical air conditioning (induced draft) cooling tower 58
Figure 6. Dialysis water treatment system 60

Boxes

Box 1. Environmental infection control: performance measures 2
Box 2. Eight criteria for evaluating the strength of evidence for environmental sources of infection 4
Box 3. Chain of infection components 4
Box 4. Suggested members and functions of a multi-disciplinary coordination team for construction, renovation, repair, and demolition projects 24
Box 5. Construction design and function considerations for environmental infection control 25
Box 6. Unresolved issues associated with microbiologic air sampling 28
Box 7. Construction/repair projects that require barrier structures 32
Box 8. Strategy for managing TB patients and preventing airborne transmission in operating rooms 39
Box 9. Recovery and remediation measures for water-related emergencies 52
Box 10. Contingency planning for flooding 53
Box 11. Steps in an epidemiologic investigation for legionellosis 56
Box 12. General steps for cleaning and maintaining ice machines, dispensers, and storage chests 66
Box 13. Preliminary concerns for conducting air sampling 90
Box 14. Selecting an air sampling device 93
Box 15. Undertaking environmental-surface sampling 95
Box C.1. Potential sampling sites for *Legionella* spp. in health-care facilities 224
Box C.2. Procedures for collecting and processing environmental specimens for *Legionella* spp. 225

Tables

Table 1. Clinical and epidemiologic characteristics of aspergillosis 7
Table 2. Environmental fungal pathogens: entry into and contamination of the health-care facility 8
Table 3. Clinical and epidemiologic characteristics of tuberculosis (TB) 10
Table 4. Microorganisms associated with airborne transmission 13
Table 5. Filtration methods 15
Table 6. Engineered specifications for positive- and negative pressure rooms 19
Table 7. Ventilation hazards in health-care facilities that may be associated with increased potential of airborne disease transmission 22
Table 8. Strategies to reduce dust and moisture intrusion during external demolition and construction 30

Table 9. Infection-control measures for internal construction and repair projects 32
Table 10. Summary of ventilation specifications in selected areas of health-care facilities 39
Table 11. Clinical and epidemiologic characteristics of legionellosis/Legionnaires disease 41
Table 12. *Pseudomonas aeruginosa* infections in health-care facilities 42
Table 13. Other gram-negative bacteria associated with water and moist environments 43
Table 14. Nontuberculous mycobacteria—environmental vehicles 45
Table 15. Water and point-of-use fixtures as sources and reservoirs of waterborne pathogens 47
Table 16. Water demand in health-care facilities during water disruption emergencies 50
Table 17. Additional infection-control measures to prevent exposure of high-risk patients to waterborne pathogens 57
Table 18. Microbiologic limits for hemodialysis fluids 62
Table 19. Factors influencing microbial contamination in hemodialysis systems 63
Table 20. Microorganisms and their sources in ice and ice machines 65
Table 21. Infections associated with use of hydrotherapy equipment 67
Table 22. Levels of disinfection by type of microorganism 72
Table 23. Air sampling methods and examples of equipment 91
Table 24. Examples of eluents and diluents for environmental-surface sampling 96
Table 25. Methods of environmental-surface sampling 97
Table 26. Examples of diseases associated with zoonotic transmission 105
Table 27. Microorganisms and biologicals identified as select agents 115
Table B.1. Air changes/hour (ACH) and time required for airborne-contaminant removal efficiencies of 99% and 99.9% 210
Table B.2. Ventilation requirements for areas affecting patient care in hospitals and outpatient facilities 212
Table B.3. Pressure relationships and ventilation of certain areas of nursing facilities 217
Table B.4. Filter efficiencies for central ventilation and air conditioning systems in general hospitals 219
Table B.5. Filter efficiencies for central ventilation and air conditioning systems in outpatient facilities 219
Table B.6. Filter efficiencies for central ventilation and air conditioning systems in nursing facilities 220
Table B.7. Filter efficiencies for central ventilation and air conditioning systems in psychiatric hospitals 220
Table D.1. Microorganisms isolated from arthropods in health-care settings 228

List of Abbreviations Used in This Publication

AAA	animal-assisted activity
AAMI	Association for the Advancement of Medical Instrumentation
AAT	animal-assisted therapy
ACGIH	American Council of Governmental Industrial Hygienists
ACH	air changes per hour
ADA	Americans with Disabilities Act
AER	automated endoscope reprocessor
AFB	acid-fast bacilli
AHA	American Hospital Association
AHJ	authorities having jurisdiction
AIA	American Institute of Architects
AII	airborne infection isolation
AmB	amphotericin B
ANC	absolute neutrophil count
ANSI	American National Standards Institute
AORN	Association of periOperative Registered Nurses
ASHE	American Society for Healthcare Engineering
ASHRAE	American Society of Heating, Refirgeration, and Air-Conditioning Engineers
BCG	Bacille Calmette-Guérin
BCYE	buffered charcoal yeast extract medium
BHI	brain-heart infusion
BMBL	CDC/NIH publication "Biosafety in Microbiological and Biomedical Laboratories"
BOD	biological oxygen demand
BSE	bovine spongiform encephalopathy
BSL	biosafety level
C	Centigrade
CAPD	continuous ambulatory peritoneal dialysis
CCPD	continual cycling peritoneal dialysis
CMAD	count median aerodynamic diameter
CDC	U.S. Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
CFU	colony-forming unit
CJD	Creutzfeldt-Jakob disease
cm	centimeter
CMS	U.S. Centers for Medicare and Medicaid Services
CPL	compliance document (OSHA)
CT/EC	cooling tower/evaporative condenser
DFA	direct fluorescence assay; direct fluorescent antibody
DHHS	U.S. Department of Health and Human Services
DHBV	duck hepatitis B virus
DNA	deoxyribonucleic acid
DOP	dioctylphthalate
DOT	U.S. Department of Transportation
EC	environment of care (JCAHO)
ELISA	enzyme-linked immunosorbent assay
EPA	U.S. Environmental Protection Agency
ESRD	end-stage renal disease

EU	endotoxin unit
F	Fahrenheit
FDA	U.S. Food and Drug Administration
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FRC	free residual chlorine
ft	foot (feet)
FTC	U.S. Federal Trade Commission
GISA	glycopeptide intermediate resistant *Staphylococcus aureus*
HBV	hepatitis B virus
HCV	hepatitis C virus
HEPA	high efficiency particulate air
HICPAC	Healthcare Infection Control Practices Advisory Committee
HIV	human immunodeficiency virus
HPV	human papilloma virus
HSCT	hematopoietic stem cell transplant
HVAC	heating, ventilation, air conditioning
ICRA	infection control risk assessment
ICU	intensive care unit
ID_{50}	50% median infectious dose
IPD	intermittent peritoneal dialysis
JCAHO	Joint Commission on Accreditation of Healthcare Organizations
kg	kilogram
L	liter
MAC	*Mycobacterium avium* complex; also used to denote MacConkey agar
MDRO	multiple-drug resistant organism
MIC	minimum inhibitory concentration
µm	micrometer; micron
mL	milliliter
min	minute
mg	milligram
MMAD	mass median aerodynamic diameter
MMWR	"Morbidity and Mortality Weekly Report"
MRSA	methicillin-resistant *Staphylococcus aureus*
MSDS	material safety data sheet
N	Normal
NaCl	sodium chloride
NaOH	sodium hydroxide
NCID	National Center for Infectious Diseases
NCCDPHP	National Center for Chronic Disease Prevention and Health Promotion
NCCLS	National Committee for Clinical Laboratory Standards
ng	nanogram
NICU	neonatal intensive care unit
NIH	U.S. National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
nm	nanometer
NNIS	National Nosocomial Infection Surveillance
NTM	nontuberculous mycobacteria
OPL	on-premises laundry
OSHA	U.S. Occupational Safety and Health Administration
Pa	Pascal
PCP	*Pneumocystis carinii* pneumonia

PCR	polymerase chain reaction
PD	peritoneal dialysis
PE	protective environment
PEL	permissible exposure limit
PPE	personal protective equipment
ppm	parts per million
PVC	polyvinylchloride
RAPD	randomly amplified polymorphic DNA
RODAC	replicate organism direct agar contact
RSV	respiratory syncytial virus
RO	reverse osmosis
SARS	severe acute respiratory syndrome
SARS-CoV	SARS coronavirus
sec	second
spp	species
SSI	surgical site infection
TB	tuberculosis
TLV®-TWA	threshold limit value-time weighted average
TSA	tryptic soy agar
TSB	tryptic soy broth
TSE	transmissible spongiform encephalopathy
U.S.	United States
USC	United States Code
USDA	U.S. Department of Agriculture
USPS	U.S. Postal Service
UV	ultraviolet
UVGI	ultraviolet germicidal irradiation
VAV	variable air ventilation
vCJD	variant Creutzfeldt-Jakob disease
VISA	vancomycin intermediate resistant *Staphylococcus aureus*
VRE	vancomycin-resistant *Enterococcus*
VRSA	vancomycin-resistant *Staphylococcus aureus*
v/v	volume/volume
VZV	varicella-zoster virus

Note: Use of trade names and commercial sources is for identification only and does not imply endorsement by the U.S. Department of Health and Human Services. References to non-CDC sites on the Internet are provided as a service to the reader and does not constitute or imply endorsement of these organization s or their programs by CDC or the U.S. Department of Health and Human Services. CDC is not responsible for the content of pages found at these sites.

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Executive Summary

The *Guidelines for Environmental Infection Control in Health-Care Facilities* is a compilation of recommendations for the prevention and control of infectious diseases that are associated with health-care environments. This document a) revises multiple sections from previous editions of the Centers for Disease Control and Prevention [CDC] document titled *Guideline for Handwashing and Hospital Environmental Control*;[1,2] b) incorporates discussions of air and water environmental concerns from CDC's *Guideline for the Prevention of Nosocomial Pneumonia*;[3] c) consolidates relevant environmental infection-control measures from other CDC guidelines;[4–9] and d) includes two topics not addressed in previous CDC guidelines — infection-control concerns related to animals in health-care facilities and water quality in hemodialysis settings.

Part I of this report, *Background Information: Environmental Infection Control in Health-Care Facilities*, provides a comprehensive review of the scientific literature. Attention is given to engineering and infection-control concerns during construction, demolition, renovation, and repairs of health-care facilities. Use of an infection-control risk assessment is strongly supported before the start of these or any other activities expected to generate dust or water aerosols. Also reviewed in Part I are infection-control measures used to recover from catastrophic events (e.g., flooding, sewage spills, loss of electricity and ventilation, and disruption of the water supply) and the limited effects of environmental surfaces, laundry, plants, animals, medical wastes, cloth furnishings, and carpeting on disease transmission in healthcare facilities.

Part II of this guideline, *Recommendations for Environmental Infection Control in Health-Care Facilities*, outlines environmental infection control in health-care facilities, describing measures for preventing infections associated with air, water, and other elements of the environment. These recommendations represent the views of different divisions within CDC's National Center for Infectious Diseases (NCID) (e.g., the Division of Healthcare Quality Promotion [DHQP] and the Division of Bacterial and Mycotic Diseases [DBMD]) and the consensus of the Healthcare Infection Control Practices Advisory Committee (HICPAC), a 12-member group that advises CDC on concerns related to the surveillance, prevention, and control of health-care–associated infections, primarily in U.S. health-care facilities.[10] In 1999, HICPAC's infection-control focus was expanded from acute-care hospitals to all venues where health care is provided (e.g., outpatient surgical centers, urgent care centers, clinics, outpatient dialysis centers, physicians' offices, and skilled nursing facilities). The topics addressed in this guideline are applicable to the majority of health-care venues in the United States. This document is intended for use primarily by infection-control professionals (ICPs), epidemiologists, employee health and safety personnel, information system specialists, administrators, engineers, facility managers, environmental service professionals, and architects for health-care facilities.

Key recommendations include a) infection-control impact of ventilation system and water system performance; b) establishment of a multidisciplinary team to conduct infection-control risk assessment; c) use of dust-control procedures and barriers during construction, repair, renovation, or demolition; d) environmental infection-control measures for special care areas with patients at high risk; e) use of airborne particle sampling to monitor the effectiveness of air filtration and dust-control measures; f) procedures to prevent airborne contamination in operating rooms when infectious tuberculosis [TB] patients require surgery; g) guidance regarding appropriate indications for routine culturing of water as part of a comprehensive control program for legionellae; h) guidance for recovering from water system disruptions, water leaks, and natural disasters [e.g., flooding]; i) infection-control concepts for equipment that uses water from main lines [e.g., water systems for hemodialysis, ice machines, hydrotherapy equipment, dental unit water lines, and automated endoscope reprocessors]); j) environmental surface cleaning and disinfection strategies with respect to antibiotic-resistant

microorganisms; k) infection-control procedures for health-care laundry; l) use of animals in health care for activities and therapy; m) managing the presence of service animals in health-care facilities; n) infection-control strategies for when animals receive treatment in human health-care facilities; and o) a call to reinstate the practice of inactivating amplified cultures and stocks of microorganisms on-site during medical waste treatment.

Whenever possible, the recommendations in Part II are based on data from well-designed scientific studies. However, certain of these studies were conducted by using narrowly defined patient populations or for specific health-care settings (e.g., hospitals versus long-term care facilities), making generalization of findings potentially problematic. Construction standards for hospitals or other health-care facilities may not apply to residential home-care units. Similarly, infection-control measures indicated for immunosuppressed patient care are usually not necessary in those facilities where such patients are not present. Other recommendations were derived from knowledge gained during infectious disease investigations in health-care facilities, where successful termination of the outbreak was often the result of multiple interventions, the majority of which cannot be independently and rigorously evaluated. This is especially true for construction situations involving air or water.

Other recommendations are derived from empiric engineering concepts and may reflect an industry standard rather than an evidence-based conclusion. Where recommendations refer to guidance from the American Institute of Architects (AIA), the statements reflect standards intended for new construction or renovation. Existing structures and engineered systems are expected to be in continued compliance with the standards in effect at the time of construction or renovation. Also, in the absence of scientific confirmation, certain infection-control recommendations that cannot be rigorously evaluated are based on a strong theoretical rationale and suggestive evidence. Finally, certain recommendations are derived from existing federal regulations. The references and the appendices comprise Parts III and IV of this document, respectively.

Infections caused by the microorganisms described in these guidelines are rare events, and the effect of these recommendations on infection rates in a facility may not be readily measurable. Therefore, the following steps to measure performance are suggested to evaluate these recommendations (Box 1):

Box 1. Environmental infection control: performance measures

1. **Document whether infection-control personnel are actively involved in all phases of a health-care facility's demolition, construction, and renovation. Activities should include performing a risk assessment of the necessary types of construction barriers, and daily monitoring and documenting of the presence of negative airflow within the construction zone or renovation area.**
2. **Monitor and document daily the negative airflow in airborne infection isolation (AII) rooms and positive airflow in protective environment (PE) rooms, especially when patients are in these rooms.**
3. **Perform assays at least once a month by using standard quantitative methods for endotoxin in water used to reprocess hemodialyzers, and for heterotrophic and mesophilic bacteria in water used to prepare dialysate and for hemodialyzer reprocessing.**
4. **Evaluate possible environmental sources (e.g., water, laboratory solutions, or reagents) of specimen contamination when nontuberculous mycobacteria (NTM) of unlikely clinical importance are isolated from clinical cultures. If environmental contamination is found, eliminate the probable mechanisms.**
5. **Document policies to identify and respond to water damage. Such policies should result in either repair and drying of wet structural or porous materials within 72 hours, or removal of the wet material if drying is unlikely with 72 hours.**

Topics outside the scope of this document include a) noninfectious adverse events (e.g., sick building syndrome); b) environmental concerns in the home; c) home health care; d) bioterrorism; and e) health-care–associated foodborne illness. This document includes only limited discussion of a) handwashing/hand hygiene; b) standard precautions; and c) infection-control measures used to prevent instrument or equipment contamination during patient care (e.g., preventing waterborne contamination of nebulizers or ventilator humidifiers). These topics are mentioned only if they are important in minimizing the transfer of pathogens to and from persons or equipment and the environment. Although the document discusses principles of cleaning and disinfection as they are applied to maintenance of environmental surfaces, the full discussion of sterilization and disinfection of medical instruments and direct patient-care devices is deferred for inclusion in the *Guideline for Disinfection and Sterilization in Health-Care Facilities*, a document currently under development. Similarly, the full discussion of hand hygiene is available as the *Guideline for Hand Hygiene in Health-Care Settings: Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force*. Where applicable, the *Guidelines for Environmental Infection Control in Health-Care Facilities* are consistent in content to the drafts available as of October 2002 of both the revised *Guideline for Prevention of Health-Care–Associated Pneumonia* and *Guidelines for Preventing the Transmission of Mycobacterium tuberculosis in Health-Care Facilities*.

This guideline was prepared by CDC staff members from NCID and the National Center for Chronic Disease Prevention and Health Promotion (NCCDPHP) and the designated HICPAC advisor. Contributors to this document reviewed predominantly English-language manuscripts identified from reference searches using the National Library of Medicine's MEDLINE, bibliographies of published articles, and infection-control textbooks. Working drafts of the guideline were reviewed by CDC scientists, HICPAC committee members, and experts in infection control, engineering, internal medicine, infectious diseases, epidemiology, and microbiology. All recommendations in this guideline may not reflect the opinions of all reviewers.

Part I. Background Information: Environmental Infection Control in Health-Care Facilities

A. Introduction

The health-care environment contains a diverse population of microorganisms, but only a few are significant pathogens for susceptible humans. Microorganisms are present in great numbers in moist, organic environments, but some also can persist under dry conditions. Although pathogenic microorganisms can be detected in air and water and on fomites, assessing their role in causing infection and disease is difficult.[11] Only a few reports clearly delineate a "cause and effect" with respect to the environment and in particular, housekeeping surfaces.

Eight criteria are used to evaluate the strength of evidence for an environmental source or means of transmission of infectious agents (Box 2).[11, 12] Applying these criteria to disease investigations allows scientists to assess the contribution of the environment to disease transmission. An example of this application is the identification of a pathogen (e.g., vancomycin-resistant enterococci [VRE]) on an environmental surface during an outbreak. The presence of the pathogen does not establish its causal role; its transmission from source to host could be through indirect means (e.g., via hand transferral).[11] The surface, therefore, would be considered one of a number of potential reservoirs for the pathogen, but not the "de facto" source of exposure. An understanding of how infection occurs after exposure,

based on the principles of the "chain of infection," is also important in evaluating the contribution of the environment to health-care–associated disease.[13] All of the components of the "chain" must be operational for infection to occur (Box 3).

Box 2. Eight criteria for evaluating the strength of evidence for environmental sources of infection* +

1. **The organism can survive after inoculation onto the fomite.**
2. **The organism can be cultured from in-use fomites.**
3. **The organism can proliferate in or on the fomite.**
4. **Some measure of acquisition of infection cannot be explained by other recognized modes of transmission.**
5. **Retrospective case-control studies show an association between exposure to the fomite and infection.**
6. **Prospective case-control studies may be possible when more than one similar type of fomite is in use.**
7. **Prospective studies allocating exposure to the fomite to a subset of patients show an assication between exposure and infection.**
8. **Decontamination of the fomite results in the elimination of infection transmission.**

* These criteria are listed in order of strength of evidence.
\+ Adapted from references 11 and 12.

Box 3. Chain of infection components*

1. **Adequate number of pathogenic organisms (dose)**
2. **Pathogenic organisms of sufficient virulence**
3. **A susceptible host**
4. **An appropriate mode of transmission or transferal of the organism in sufficient number from source to host**
5. **The correct portal of entry into the host**

* Adapted from reference 13.

The presence of the susceptible host is one of these components that underscores the importance of the health-care environment and opportunistic pathogens on fomites and in air and water. As a result of advances in medical technology and therapies (e.g., cytotoxic chemotherapy and transplantation medicine), more patients are becoming immunocompromised in the course of treatment and are therefore at increased risk for acquiring health-care–associated opportunistic infections. Trends in health-care delivery (e.g., early discharge of patients from acute care facilities) also are changing the distribution of patient populations and increasing the number of immunocompromised persons in non-acute-care hospitals. According to the American Hospital Association (AHA), in 1998, the number of hospitals in the United States totaled 6,021; these hospitals had a total of 1,013,000 beds,[14] representing a 5.5% decrease in the number of acute-care facilities and a 10.2% decrease in the number of beds over the 5-year period 1994–1998.[14] In addition, the total average daily number of patients receiving care in U.S. acute-care hospitals in 1998 was 662,000 (65.4%) – 36.5% less than the 1978 average of 1,042,000.[14] As the number of acute-care hospitals declines, the length of stay in these facilities is concurrently decreasing, particularly for immunocompetent patients. Those patients remaining in acute-care facilities are likely to be those requiring extensive medical interventions who therefore at high risk for opportunistic infection.

The growing population of severely immunocompromised patients is at odds with demands on the health-care industry to remain viable in the marketplace; to incorporate modern equipment, new diagnostic procedures, and new treatments; and to construct new facilities. Increasing numbers of health-care facilities are likely to be faced with construction in the near future as hospitals consolidate to reduce costs, defer care to ambulatory centers and satellite clinics, and try to create more "home-like" acute-care settings. In 1998, approximately 75% of health-care–associated construction projects focused on renovation of existing outpatient facilities or the building of such facilities;[15] the number of projects associated with outpatient health care rose by 17% from 1998 through 1999.[16] An aging population is also creating increasing demand for assisted-living facilities and skilled nursing centers. Construction of assisted-living facilities in 1998 increased 49% from the previous year, with 138 projects completed at a cost of $703 million.[16] Overall, from 1998 to 1999, health-care–associated construction costs increased by 28.5%, from $11.56 billion to $14.86 billion.[16]

Environmental disturbances associated with construction activities near health-care facilities pose airborne and waterborne disease threats risks for the substantial number of patients who are at risk for health-care–associated opportunistic infections. The increasing age of hospitals and other health-care facilities is also generating ongoing need for repair and remediation work (e.g., installing wiring for new information systems, removing old sinks, and repairing elevator shafts) that can introduce or increase contamination of the air and water in patient-care environments. Aging equipment, deferred maintenance, and natural disasters provide additional mechanisms for the entry of environmental pathogens into high-risk patient-care areas.

Architects, engineers, construction contractors, environmental health scientists, and industrial hygienists historically have directed the design and function of hospitals' physical plants. Increasingly, however, because of the growth in the number of susceptible patients and the increase in construction projects, the involvement of hospital epidemiologists and infection-control professionals is required. These experts help make plans for building, maintaining, and renovating health-care facilities to ensure that the adverse impact of the environment on the incidence of health-care–associated infections is minimal. The following are examples of adverse outcomes that could have been prevented had such experts been involved in the planning process: a) transmission of infections caused by *Mycobacterium tuberculosis*, varicella-zoster virus (VZV), and measles (i.e., rubeola) facilitated by inappropriate air-handling systems in health-care facilities;[6] b) disease outbreaks caused by *Aspergillus* spp.,[17–19] *Mucoraceae*,[20] and *Penicillium* spp. associated with the absence of environmental controls during periods of health-care facility-associated construction;[21] c) infections and/or colonizations of patients and staff with vancomycin-resistant *Enterococcus faecium* [VRE] and *Clostridium difficile* acquired indirectly from contact with organisms present on environmental surfaces in health-care facilities;[22–25] and d) outbreaks and pseudoepidemics of legionellae,[26, 27] *Pseudomonas aeruginosa*,[28–30] and the nontuberculous mycobacteria (NTM)[31, 32] linked to water and aqueous solutions used in health-care facilities. The purpose of this guideline is to provide useful information for both health-care professionals and engineers in efforts to provide a safe environment in which quality health care may be provided to patients. The recommendations herein provide guidance to minimize the risk for and prevent transmission of pathogens in the indoor environment.

B. Key Terms Used in this Guideline

Although Appendix A provides definitions for terms discussed in Part I, several terms that pertain to specific patient-care areas and patients who are at risk for health-care–associated opportunistic infections are presented here. Specific engineering parameters for these care areas are discussed more

fully in the text. **Airborne Infection Isolation (AII)** refers to the isolation of patients infected with organisms spread via airborne droplet nuclei <5 μm in diameter. This isolation area receives numerous air changes per hour (ACH) (≥12 ACH for new construction as of 2001; ≥6 ACH for construction before 2001), and is under negative pressure, such that the direction of the airflow is from the outside adjacent space (e.g., corridor) into the room. The air in an AII room is preferably exhausted to the outside, but may be recirculated provided that the return air is filtered through a high efficiency particulate air (HEPA) filter. The use of personal respiratory protection is also indicated for persons entering these rooms.

Protective Environment (PE) is a specialized patient-care area, usually in a hospital, with a positive airflow relative to the corridor (i.e., air flows from the room to the outside adjacent space). The combination of HEPA filtration, high numbers of air changes per hour (≥12 ACH), and minimal leakage of air into the room creates an environment that can safely accommodate patients who have undergone allogeneic hematopoietic stem cell transplant (HSCT).

Immunocompromised patients are those patients whose immune mechanisms are deficient because of immunologic disorders (e.g., human immunodeficiency virus [HIV] infection, congenital immune deficiency syndrome, chronic diseases [such as diabetes, cancer, emphysema, and cardiac failure]) or immunosuppressive therapy (e.g., radiation, cytotoxic chemotherapy, anti-rejection medication, and steroids). Immunocompromised patients who are identified as **high-risk patients** have the greatest risk of infection caused by airborne or waterborne microorganisms. Patients in this subset include those who are severely neutropenic for prolonged periods of time (i.e., an absolute neutrophil count [ANC] of ≤500 cells/mL), allogeneic HSCT patients, and those who have received intensive chemotherapy (e.g., childhood acute myelogenous leukemia patients).

C. Air

1. Modes of Transmission of Airborne Diseases

A variety of airborne infections in susceptible hosts can result from exposures to clinically significant microorganisms released into the air when environmental reservoirs (i.e., soil, water, dust, and decaying organic matter) are disturbed. Once these materials are brought indoors into a health-care facility by any of a number of vehicles (e.g., people, air currents, water, construction materials, and equipment), the attendant microorganisms can proliferate in various indoor ecological niches and, if subsequently disbursed into the air, serve as a source for airborne health-care–associated infections.

Respiratory infections can be acquired from exposure to pathogens contained either in droplets or droplet nuclei. Exposure to microorganisms in droplets (e.g., through aerosolized oral and nasal secretions from infected patients[33]) constitutes a form of direct contact transmission. When droplets are produced during a sneeze or cough, a cloud of infectious particles >5 μm in size is expelled, resulting in the potential exposure of susceptible persons within 3 feet of the source person.[6] Examples of pathogens spread in this manner are influenza virus, rhinoviruses, adenoviruses, and respiratory syncytial virus (RSV). Because these agents primarily are transmitted directly and because the droplets tend to fall out of the air quickly, measures to control air flow in a health-care facility (e.g., use of negative pressure rooms) generally are not indicated for preventing the spread of diseases caused by these agents. Strategies to control the spread of these diseases are outlined in another guideline.[3]

The spread of airborne infectious diseases via droplet nuclei is a form of indirect transmission.[34] Droplet nuclei are the residuals of droplets that, when suspended in air, subsequently dry and produce

particles ranging in size from 1–5 µm. These particles can a) contain potentially viable microorganisms, b) be protected by a coat of dry secretions, c) remain suspended indefinitely in air, and d) be transported over long distances. The microorganisms in droplet nuclei persist in favorable conditions (e.g., a dry, cool atmosphere with little or no direct exposure to sunlight or other sources of radiation). Pathogenic microorganisms that can be spread via droplet nuclei include *Mycobacterium tuberculosis*, VZV, measles virus (i.e., rubeola), and smallpox virus (i.e., variola major).[6] Several environmental pathogens have life-cycle forms that are similar in size to droplet nuclei and may exhibit similar behavior in the air. The spores of *Aspergillus fumigatus* have a diameter of 2–3.5 µm, with a settling velocity estimated at 0.03 cm/second (or about 1 meter/hour) in still air. With this enhanced buoyancy, the spores, which resist desiccation, can remain airborne indefinitely in air currents and travel far from their source.[35]

2. Airborne Infectious Diseases in Health-Care Facilities

a. Aspergillosis and Other Fungal Diseases

Aspergillosis is caused by molds belonging to the genus *Aspergillus*. *Aspergillus* spp. are prototype health-care–acquired pathogens associated with dusty or moist environmental conditions. Clinical and epidemiologic aspects of aspergillosis (Table 1) are discussed extensively in another guideline.[3]

Table 1. Clinical and epidemiologic characteristics of aspergillosis

		References
Causative agents	***Aspergillus fumigatus*** (90%–95% of *Aspergillus* infections among hematopoietic stem cell transplant (HSCT) patients; *A. flavus, A. niger, A. terreus, A. nidulans*	36–43
Modes of transmission	Airborne transmission of fungal spores; direct inhalation; direct inoculation from environmental sources (rare)	37
Activities associated with infection	Construction, renovation, remodeling, repairs, building demolition; rare episodes associated with fomites	44–51
Clinical syndromes and diseases	***Acute invasive:*** **pneumonia**; ulcerative tracheobronchitis; osteomyelitis; abscesses (aspergillomas) of the lungs, brain, liver, spleen, and kidneys; thrombosis of deep blood vessels; necrotizing skin ulcers; endophthalmitis; and sinusitis ***Chronic invasive***: chronic pneumonitis ***Hypersensity***: allergic bronchopulmonary aspergillosis ***Cutaneous***: primary skin and burn-wound infections	44, 45, 52–58
Patient populations at greatest risk	**Hematopoietic stem cell transplant patients (HSCT):** immunocompromised patients (i.e., those with underlying disease), patients undergoing chemotherapy, organ transplant recipients, preterm neonates, hemodialysis patients, patients with identifiable immune system deficiencies who receive care in general intensive care units (ICUs), and cystic fibrosis patients (may be colonized, occasionally become infected)	36, 59–78
Factors affecting severity and outcomes	The immune status of the patient and the duration of severe neutropenia	79, 80
Occurrence	Rare and sporadic, but increasing as proportion of immunocompromised patients increases; 5% of HSCT patients infected, <5% of solid organ transplant recipients infected	36, 37, 81–88
Mortality rate	Rate can be as high as 100% if severe neutropenia persists; 13%–80% mortality among leukemia patients	58, 83, 89, 90

Aspergillus spp. are ubiquitous, aerobic fungi that occur in soil, water, and decaying vegetation; the organism also survives well in air, dust, and moisture present in health-care facilities.[91–93] The presence of aspergilli in the health-care facility environment is a substantial extrinsic risk factor for opportunistic invasive aspergillosis (invasive aspergillosis being the most serious form of the disease).[69, 94] Site renovation and construction can disturb *Aspergillus*-contaminated dust and produce bursts of airborne

fungal spores. Increased levels of atmospheric dust and fungal spores have been associated with clusters of health-care–acquired infections in immunocompromised patients.[17, 20, 44, 47, 49, 50, 95–98] Absorbent building materials (e.g., wallboard) serve as an ideal substrate for the proliferation of this organism if they become and remain wet, thereby increasing the numbers of fungal spores in the area. Patient-care items, devices, and equipment can become contaminated with *Aspergillus* spp. spores and serve as sources of infection if stored in such areas.[57]

Most cases of aspergillosis are caused by *Aspergillus fumigatus*, a thermotolerant/thermophilic fungus capable of growing over a temperature range from 53.6°F–127.4°F (12°C–53°C); optimal growth occurs at approximately 104°F (40°C), a temperature inhibitory to most other saprophytic fungi.[99] It can use cellulose or sugars as carbon sources; because its respiratory process requires an ample supply of carbon, decomposing organic matter is an ideal substrate.

Other opportunistic fungi that have been occasionally linked with health-care–associated infections are members of the order *Mucorales* (e.g., *Rhizopus* spp.) and miscellaneous moniliaceous molds (e.g., *Fusarium* spp. and *Penicillium* spp.) (Table 2). Many of these fungi can proliferate in moist environments (e.g., water-damaged wood and building materials). Some fungi (e.g., *Fusarium* spp. and *Pseudoallescheria* spp.) also can be airborne pathogens.[100] As with aspergillosis, a major risk factor for disease caused by any of these pathogens is the host's severe immunosuppression from either underlying disease or immunosuppressive therapy.[101, 102]

Table 2. Environmental fungal pathogens: entry into and contamination of the health-care facility

Implicated environmental vehicle	References
***Aspergillus* spp.**	
Improperly functioning ventilation systems	20, 46, 47, 97, 98, 103, 104
Air filters*,+	17, 18, 105–107
Air filter frames	17, 18
Window air conditioners	96
Backflow of contaminated air	107
Air exhaust contamination+	104
False ceilings	48, 57, 97, 108
Fibrous insulation and perforated metal ceilings	66
Acoustic ceiling tiles, plasterboard	18, 109
Fireproofing material	48, 49
Damp wood building materials	49
Opening doors to construction site	110
Construction	69
Open windows	20, 108, 111
Disposal conduit door	68
Hospital vacuum cleaner	68
Elevator	112
Arm boards	57
Walls	113
Unit kitchen	114
Food	21
Ornamental plants	21
***Mucorales / Rhizopus* spp.**	
Air filter	20, 115
False ceilings	97
Heliport	115
***Scedosporium* spp.**	
Construction	116

(Table 2. continued)

Implicated environmental vehicles	References
***Penicillium* spp.**	
Rotting cabinet wood, pipe leak	21
Ventilation duct fiberglass insulation	112
Air filters	105
Topical anesthetic	117
***Acremonium* spp.**	
Air filters	105
***Cladosporium* spp.**	
Air filters	105
Sporothrix	
Construction (pseudoepidemic)	118

*. Pigeons, their droppings and roosts are associated with spread of *Aspergillus, Cryptococcus,* and *Histoplasma* spp. There have been at least three outbreaks linked to contamination of the filtering systems from bird droppings[98, 103, 104] Pigeon mites may gain access into a health-care facility through the ventilation system.[119]

+. The American Institute of Architects (AIA) standards stipulate that for new or renovated construction a) exhaust outlets are to be placed >25 feet from air intake systems, b) the bottom of outdoor air intakes for HVAC systems should be 6 feet above ground or 3 feet above roof level, and c) exhaust outlets from contaminated areas are situated above the roof level and arranged to minimize the recirculation of exhausted air back into the building.[120]

Infections due *Cryptococcus neoformans*, *Histoplasma capsulatum*, or *Coccidioides immitis* can occur in health-care settings if nearby ground is disturbed and a malfunction of the facility's air-intake components allows these pathogens to enter the ventilation system. *C. neoformans* is a yeast usually 4–8 μm in size. However, viable particles of <2 μm diameter (and thus permissive to alveolar deposition) have been found in soil contaminated with bird droppings, particularly from pigeons.[98, 103, 104, 121] *H. capsulatum*, with the infectious microconidia ranging in size from 2–5 μm, is endemic in the soil of the central river valleys of the United States. Substantial numbers of these infectious particles have been associated with chicken coops and the roosts of blackbirds.[98, 103, 104, 122] Several outbreaks of histoplasmosis have been associated with disruption of the environment; construction activities in an endemic area may be a potential risk factor for health-care–acquired airborne infection.[123, 124] *C. immitis*, with arthrospores of 3–5 μm diameter, has similar potential, especially in the endemic southwestern United States and during seasons of drought followed by heavy rainfall. After the 1994 earthquake centered near Northridge, California, the incidence of coccidioidomycosis in the surrounding area exceeded the historical norm.[125]

Emerging evidence suggests that *Pneumocystis carinii*, now classified as a fungus, may be spread via airborne, person-to-person transmission.[126] Controlled studies in animals first demonstrated that *P. carinii* could be spread through the air.[127] More recent studies in health-care settings have detected nucleic acids of *P. carinii* in air samples from areas frequented or occupied by *P. carinii*-infected patients but not in control areas that are not occupied by these patients.[128, 129] Clusters of cases have been identified among immunocompromised patients who had contact with a source patient and with each other. Recent studies have examined the presence of *P. carinii* DNA in oropharyngeal washings and the nares of infected patients, their direct contacts, and persons with no direct contact.[130, 131] Molecular analysis of the DNA by polymerase chain reaction (PCR) provides evidence for airborne transmission of *P. carinii* from infected patients to direct contacts, but immunocompetent contacts tend to become transiently colonized rather than infected.[131] The role of colonized persons in the spread of *P. carinii* pneumonia (PCP) remains to be determined. At present, specific modifications to ventilation systems to control spread of PCP in a health-care facility are not indicated. Current recommendations

outline isolation procedures to minimize or eliminate contact of immunocompromised patients not on PCP prophylaxis with PCP-infected patients.[6, 132]

b. Tuberculosis and Other Bacterial Diseases

The bacterium most commonly associated with airborne transmission is *Mycobacterium tuberculosis*. A comprehensive review of the microbiology and epidemiology of *M. tuberculosis* and guidelines for tuberculosis (TB) infection control have been published.[4, 133, 134] A summary of the clinical and epidemiologic information from these materials is provided in this guideline (Table 3).

Table 3. Clinical and epidemiologic characteristics of tuberculosis (TB)*

Causative agents	*Mycobacterium tuberculosis, M. bovis, M. africanum*
Mode of transmission	Airborne transmission via droplet nuclei 1–5 µm in diameter
Patient factors associated with infectivity and transmission	▪ Disease of the lungs, airways, or larynx; presence of cough or other forceful expiratory measures ▪ Presence of acid-fast bacilli (AFB) in the sputum ▪ Failure of the patient to cover the mouth and nose when coughing or sneezing ▪ Presence of cavitation on chest radiograph ▪ Inappropriate or shortened duration of chemotherapy
Activities associated with infections	▪ Exposures in relatively small, enclosed spaces ▪ Inadequate ventilation resulting in insufficient removal of droplet nuclei ▪ Cough-producing procedures done in areas without proper environmental controls ▪ Recirculation of air containing infectious droplet nuclei ▪ Failure to use respiratory protection when managing open lesions for patients with suspected extrapulmonary TB[135]
Clinical syndromes and disease	**Pulmonary TB**; extrapulmonary TB can affect any organ system or tissue; laryngeal TB is highly contagious
Populations at greatest risk	▪ Immunocompromised persons (e.g., HIV-infected persons) ▪ Medically underserved persons, urban poor, homeless persons, elderly persons, migrant farm workers, close contacts of known patients ▪ Substance abusers, present and former prison inmates ▪ Foreign-born persons from areas with high prevalence of TB ▪ Health-care workers
Factors affecting severity and outcomes	▪ Concentration of droplet nuclei in air, duration of exposure ▪ Age at infection ▪ Immunosuppression due to therapy or disease, underlying chronic medical conditions, history of malignancies or lesions or the lungs
Occurrence	Worldwide; incidence in the United States is 5.6 cases/100,000 population (2001)[136]
Mortality	930 deaths in the United States (1999)[136]
Chemoprophylaxis / treatment	Treatment of latent infection includes isoniazid (INH) or rifampin (RIF).[4, 134, 137–139] Directly observed therapy (DOT) for active cases as indicated: INH, RIF, pyrazinamide (PZA), ethambutol (EMB), streptomycin (SM) in various combinations determined by prevalent levels of specific resistance.[4, 134, 137–139] Consult therapy guidelines for specific treatment indications.[139]

* Material in this table is compiled from references 4, 133–141.

M. tuberculosis is carried by droplet nuclei generated when persons (primarily adults and adolescents) who have pulmonary or laryngeal TB sneeze, cough, speak, or sing;[139] normal air currents can keep these particles airborne for prolonged periods and spread them throughout a room or building.[142] However, transmission of TB has occurred from mycobacteria aerosolized during provision of care (e.g., wound/lesion care or during handling of infectious peritoneal dialysis fluid) for extrapulmonary TB patients.[135, 140]

Gram-positive cocci (i.e., *Staphylococcus aureus*, group A beta-hemolytic streptococci), also important health-care–associated pathogens, are resistant to inactivation by drying and can persist in the

environment and on environmental surfaces for extended periods. These organisms can be shed from heavily colonized persons and discharged into the air. Airborne dispersal of *S. aureus* is directly associated with the concentration of the bacterium in the anterior nares.[143] Approximately 10% of healthy carriers will disseminate *S. aureus* into the air, and some persons become more effective disseminators of *S. aureus* than others.[144–148] The dispersal of *S. aureus* into air can be exacerbated by concurrent viral upper respiratory infection, thereby turning a carrier into a "cloud shedder."[149] Outbreaks of surgical site infections (SSIs) caused by group A beta-hemolytic streptococci have been traced to airborne transmission from colonized operating-room personnel to patients.[150–153] In these situations, the strain causing the outbreak was recovered from the air in the operating room[150, 151, 154] or on settle plates in a room in which the carrier exercised.[151–153] *S. aureus* and group A streptococci have not been linked to airborne transmission outside of operating rooms, burn units, and neonatal nurseries.[155, 156] Transmission of these agents occurs primarily via contact and droplets.

Other gram-positive bacteria linked to airborne transmission include *Bacillus* spp. which are capable of sporulation as environmental conditions become less favorable to support their growth. Outbreaks and pseudo-outbreaks have been attributed to *Bacillus cereus* in maternity, pediatric, intensive care, and bronchoscopy units; many of these episodes were secondary to environmental contamination.[157–160]

Gram-negative bacteria rarely are associated with episodes of airborne transmission because they generally require moist environments for persistence and growth. The main exception is *Acinetobacter* spp., which can withstand the inactivating effects of drying. In one epidemiologic investigation of bloodstream infections among pediatric patients, identical *Acinetobacter* spp. were cultured from the patients, air, and room air conditioners in a nursery.[161]

Aerosols generated from showers and faucets may potentially contain legionellae and other gram-negative waterborne bacteria (e.g., *Pseudomonas aeruginosa*). Exposure to these organisms is through direct inhalation. However, because water is the source of the organisms and exposure occurs in the vicinity of the aerosol, the discussion of the diseases associated with such aerosols and the prevention measures used to curtail their spread is discussed in another section of the Guideline (see Part I: Water).

c. Airborne Viral Diseases

Some human viruses are transmitted from person to person via droplet aerosols, but very few viruses are consistently airborne in transmission (i.e., are routinely suspended in an infective state in air and capable of spreading great distances), and health-care–associated outbreaks of airborne viral disease are limited to a few agents. Consequently, infection-control measures used to prevent spread of these viral diseases in health-care facilities primarily involve patient isolation, vaccination of susceptible persons, and antiviral therapy as appropriate rather than measures to control air flow or quality.[6] Infections caused by VZV frequently are described in health-care facilities. Health-care–associated airborne outbreaks of VZV infections from patients with primary infection and disseminated zoster have been documented; patients with localized zoster have, on rare occasions, also served as source patients for outbreaks in health-care facilities.[162–166] VZV infection can be prevented by vaccination, although patients who develop a rash within 6 weeks of receiving varicella vaccine or who develop breakthrough varicella following exposure should be considered contagious.[167]

Viruses whose major mode of transmission is via droplet contact rarely have caused clusters of infections in group settings through airborne routes. The factors facilitating airborne distribution of these viruses in an infective state are unknown, but a presumed requirement is a source patient in the early stage of infection who is shedding large numbers of viral particles into the air. Airborne transmission of measles has been documented in health-care facilities.[168–171] In addition, institutional outbreaks of influenza virus infections have occurred predominantly in nursing homes,[172–176] and less frequently in medical and neonatal intensive care units, chronic-care areas, HSCT units, and pediatric

wards.[177–180] Some evidence supports airborne transmission of influenza viruses by droplet nuclei,[181, 182] and case clusters in pediatric wards suggest that droplet nuclei may play a role in transmitting certain respiratory pathogens (e.g., adenoviruses and respiratory syncytial virus [RSV]).[177, 183, 184] Some evidence also supports airborne transmission of enteric viruses. An outbreak of a Norwalk-like virus infection involving more than 600 staff personnel over a 3-week period was investigated in a Toronto, Ontario hospital in 1985; common sources (e.g., food and water) were ruled out during the investigation, leaving airborne spread as the most likely mode of transmission.[185]

Smallpox virus, a potential agent of bioterrorism, is spread predominantly via direct contact with infectious droplets, but it also can be associated with airborne transmission.[186, 187] A German hospital study from 1970 documented the ability of this virus to spread over considerable distances and cause infection at low doses in a well-vaccinated population; factors potentially facilitating transmission in this situation included a patient with cough and an extensive rash, indoor air with low relative humidity, and faulty ventilation patterns resulting from hospital design (e.g., open windows).[188] Smallpox patients with extensive rash are more likely to have lesions present on mucous membranes and therefore have greater potential to disseminate virus into the air.[188] In addition to the smallpox transmission in Germany, two cases of laboratory-acquired smallpox virus infection in the United Kingdom in 1978 also were thought to be caused by airborne transmission.[189]

Airborne transmission may play a role in the natural spread of hantaviruses and certain hemorrhagic fever viruses (e.g., Ebola, Marburg, and Lassa), but evidence for airborne spread of these agents in health-care facilities is inconclusive.[190] Although hantaviruses can be transmitted when aerosolized from rodent excreta,[191, 192] person-to-person spread of hantavirus infection from source patients has not occurred in health-care facilities.[193–195] Nevertheless, health-care workers are advised to contain potentially infectious aerosols and wear National Institute of Occupational Safety and Health (NIOSH) approved respiratory protection when working with this agent in laboratories or autopsy suites.[196] Lassa virus transmission via aerosols has been demonstrated in the laboratory and incriminated in health-care–associated infections in Africa,[197–199] but airborne spread of this agent in hospitals in developed nations likely is inefficient.[200, 201] Yellow fever is considered to be a viral hemorrhagic fever agent with high aerosol infectivity potential, but health-care–associated transmission of this virus has not been described.[202] Viral hemorrhagic fever diseases primarily occur after direct exposure to infected blood and body fluids, and the use of standard and droplet precautions prevents transmission early in the course of these illnesses.[203, 204] However, whether these viruses can persist in droplet nuclei that might remain after droplet production from coughs or vomiting in the latter stages of illness is unknown.[205] Although the use of a negative-pressure room is not required during the early stages of illness, its use might be prudent at the time of hospitalization to avoid the need for subsequent patient transfer. Current CDC guidelines recommend negative-pressure rooms with anterooms for patients with hemorrhagic fever and use of HEPA respirators by persons entering these rooms when the patient has prominent cough, vomiting, diarrhea, or hemorrhage.[6, 203] Face shields or goggles will help to prevent mucous-membrane exposure to potentially-aerosolized infectious material in these situations. If an anteroom is not available, portable, industrial-grade high efficiency particulate air (HEPA) filter units can be used to provide the equivalent of additional air changes per hour (ACH).

Table 4. Microorganisms associated with airborne transmission*

	Fungi	Bacteria	Viruses
Numerous reports in health-care facilities	*Aspergillus* spp.+ *Mucorales* (*Rhizopus* spp.)[97, 115]	*Mycobacterium tuberculosis*+	Measles (rubeola) virus[168-170] Varicella-zoster virus[162-166]
Atypical, occasional reports	*Acremonium* spp.[105, 206] *Fusarium* spp.[102] *Pseudoallescheria boydii*[100] *Scedosporium* spp.[116] *Sporothrix cyanescens*¶[118]	*Acinetobacter* spp.[161] *Bacillus* spp.¶[160, 207] *Brucella* spp.**[208-211] *Staphylococcus aureus*[148, 156] Group A *Streptococcus*[151]	Smallpox virus (variola)§[188, 189] Influenza viruses[181, 182] Respiratory syncytial virus[183] Adenoviruses[184] Norwalk-like virus[185]
Airborne in nature; airborne transmission in health care settings not described	*Coccidioides immitis*[125] *Cryptococcus* spp.[121] *Histoplasma capsulatum*[124]	*Coxiella burnetii* (Q fever)[212]	Hantaviruses[193, 195] Lassa virus[205] Marburg virus[205] Ebola virus[205] Crimean-Congo virus[205]
Under investigation	*Pneumocystis carinii*[131]	—	—

* This list excludes microorganisms transmitted from aerosols derived from water.
\+ Refer to the text for references for these disease agents.
§ Airborne transmission of smallpox is infrequent. Potential for airborne transmission increases with patients who are effective disseminators present in facilities with low relative humidity in the air and faulty ventilation.
¶ Documentation of pseudoepidemic during construction.
** Airborne transmission documented in the laboratory but not in patient-care areas

3. Heating, Ventilation, and Air Conditioning Systems in Health-Care Facilities

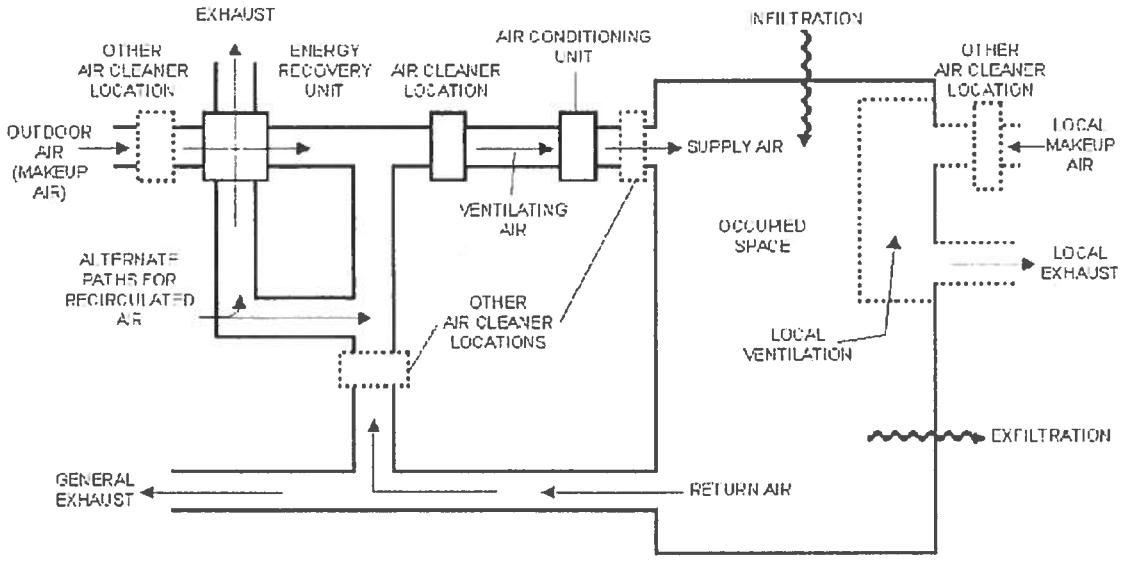
a. Basic Components and Operations

Heating, ventilation, and air conditioning (HVAC) systems in health-care facilities are designed to a) maintain the indoor air temperature and humidity at comfortable levels for staff, patients, and visitors; b) control odors; c) remove contaminated air; d) facilitate air-handling requirements to protect susceptible staff and patients from airborne health-care–associated pathogens; and e) minimize the risk for transmission of airborne pathogens from infected patients.[35, 120] An HVAC system includes an outside air inlet or intake; filters; humidity modification mechanisms (i.e., humidity control in summer, humidification in winter); heating and cooling equipment; fans; ductwork; air exhaust or out-takes; and registers, diffusers, or grilles for proper distribution of the air (Figure 1).[213, 214] Decreased performance of healthcare facility HVAC systems, filter inefficiencies, improper installation, and poor maintenance can contribute to the spread of health-care–associated airborne infections.

The American Institute of Architects (AIA) has published guidelines for the design and construction of new health-care facilities and for renovation of existing facilities. These AIA guidelines address indoor air-quality standards (e.g., ventilation rates, temperature levels, humidity levels, pressure relationships, and minimum air changes per hour [ACH]) specific to each zone or area in health-care facilities (e.g., operating rooms, laboratories, diagnostic areas, patient-care areas, and support departments).[120] These guidelines represent a consensus document among authorities having jurisdiction (AHJ), governmental regulatory agencies (i.e., Department of Health and Human Services [DHHS]; Department of Labor, Occupational Safety and Health Administration [OSHA]), health-care professionals, professional organizations (e.g., American Society of Heating, Refrigeration, and Air-Conditioning Engineers [ASHRAE], American Society for Healthcare Engineering [ASHE]), and accrediting organizations (i.e., Joint Commission on Accreditation of Healthcare Organizations [JCAHO]). More than 40 state agencies that license health-care facilities have either incorporated or adopted by reference these

guidelines into their state standards. JCAHO, through its surveys, ensures that facilities are in compliance with the ventilation guidelines of this standard for new construction and renovation.

Figure 1. Diagram of a ventilation system*



Outdoor air and recirculated air pass through air cleaners (e.g., filter banks) designed to reduce the concentration of airborne contaminants. Air is conditioned for temperature and humidity before it enters the occupied space as supply air. Infiltration is air leakage inward through cracks and interstitial spaces of walls, floors, and ceilings. Exfiltration is air leakage outward through these same cracks and spaces. Return air is largely exhausted from the system, but a portion is recirculated with fresh, incoming air.

* Used with permission of the publisher of reference 214 (ASHRAE)

Engineering controls to contain or prevent the spread of airborne contaminants center on a) local exhaust ventilation [i.e., source control], b) general ventilation, and c) air cleaning.[4] General ventilation encompasses a) dilution and removal of contaminants via well-mixed air distribution of filtered air, b) directing contaminants toward exhaust registers and grilles via uniform, non-mixed airflow patterns, c) pressurization of individual spaces relative to all other spaces, and d) pressurization of buildings relative to the outdoors and other attached buildings.

A centralized HVAC system operates as follows. Outdoor air enters the system, where low-efficiency or "roughing" filters remove large particulate matter and many microorganisms. The air enters the distribution system for conditioning to appropriate temperature and humidity levels, passes through an additional bank of filters for further cleaning, and is delivered to each zone of the building. After the conditioned air is distributed to the designated space, it is withdrawn through a return duct system and delivered back to the HVAC unit. A portion of this "return air" is exhausted to the outside while the remainder is mixed with outdoor air for dilution and filtered for removal of contaminants.[215] Air from toilet rooms or other soiled areas is usually exhausted directly to the atmosphere through a separate duct exhaust system. Air from rooms housing tuberculosis patients is exhausted to the outside if possible, or passed through a HEPA filter before recirculation. Ultraviolet germicidal irradiation (UVGI) can be used as an adjunct air-cleaning measure, but it cannot replace HEPA filtration.

b. Filtration

i. Filter Types and Methods of Filtration

Filtration, the physical removal of particulates from air, is the first step in achieving acceptable indoor air quality. Filtration is the primary means of cleaning the air. Five methods of filtration can be used (Table 5). During filtration, outdoor air passes through two filter beds or banks (with efficiencies of 20%–40% and ≥90%, respectively) for effective removal of particles 1–5 μm in diameter.[35, 120] The low-to-medium efficiency filters in the first bank have low resistance to airflow, but this feature allows some small particulates to pass onto heating and air conditioning coils and into the indoor environment.[35] Incoming air is mixed with recirculated air and reconditioned for temperature and humidity before being filtered by the second bank of filters. The performance of filters with ≤90% efficiency is measured using either the dust-spot test or the weight-arrestance test.[35, 216]

Table 5. Filtration methods*

Basic method	Principle of performance	Filtering efficiency
Straining	Particles in the air are larger than the openings between the filter fibers, resulting in gross removal of large particles.	Low
Impingement	Particles collide with filter fibers and remain attached to the filter. Fibers may be coated with adhesive.	Low
Interception	Particles enter into the filter and become entrapped and attached to the filter fibers.	Medium
Diffusion	Small particles, moving in erratic motion, collide with filter fibers and remain attached.	High
Electrostatic	Particles bearing negative electrostatic charge are attracted to the filter with positively charged fibers.	High

* Material in this table was compiled from information in reference 217.

The second filter bank usually consists of high-efficiency filters. This filtration system is adequate for most patient-care areas in ambulatory-care facilities and hospitals, including the operating room environment and areas providing central services.[120] Nursing facilities use 90% dust-spot efficient filters as the second bank of filters,[120] whereas a HEPA filter bank may be indicated for special-care areas of hospitals. HEPA filters are at least 99.97% efficient for removing particles ≥0.3 μm in diameter. (As a reference, *Aspergillus* spores are 2.5–3.0 μm in diameter.) Examples of care areas where HEPA filters are used include PE rooms and those operating rooms designated for orthopedic implant procedures.[35]

Maintenance costs associated with HEPA filters are high compared with other types of filters, but use of in-line disposable prefilters can increase the life of a HEPA filter by approximately 25%. Alternatively, if a disposable prefilter is followed by a filter that is 90% efficient, the life of the HEPA filter can be extended ninefold. This concept, called progressive filtration, allows HEPA filters in special care areas to be used for 10 years.[213] Although progressive filtering will extend the mechanical ability of the HEPA filter, these filters may absorb chemicals in the environment and later desorb those chemicals, thereby necessitating a more frequent replacement program. HEPA filter efficiency is monitored with the dioctylphthalate (DOP) particle test using particles that are 0.3 μm in diameter.[218]

HEPA filters are usually framed with metal, although some older versions have wood frames. A metal frame has no advantage over a properly fitted wood frame with respect to performance, but wood can compromise the air quality if it becomes and remains wet, allowing the growth of fungi and bacteria. Hospitals are therefore advised to phase out water-damaged or spent wood-framed filter units and replace them with metal-framed HEPA filters.

HEPA filters are usually fixed into the HVAC system; however, portable, industrial grade HEPA units are available that can filter air at the rate of 300–800 ft^3/min. Portable HEPA filters are used to a) temporarily recirculate air in rooms with no general ventilation, b) augment systems that cannot provide adequate airflow, and c) provide increased effectiveness in airflow.[4] Portable HEPA units are useful engineering controls that help clean the air when the central HVAC system is undergoing repairs,[219] but these units do not satisfy fresh-air requirements.[214] The effectiveness of the portable unit for particle removal is dependent on a) the configuration of the room, b) the furniture and persons in the room, c) the placement of the units relative to the contents and layout of the room, and d) the location of the supply and exhaust registers or grilles. If portable, industrial-grade units are used, they should be capable of recirculating all or nearly all of the room air through the HEPA filter, and the unit should be designed to achieve the equivalent of $\geq$12 ACH.[4] (An average room has approximately 1,600 ft^3 of airspace.) The hospital engineering department should be contacted to provide ACH information in the event that a portable HEPA filter unit is necessary to augment the existing fixed HVAC system for air cleaning.

ii. Filter Maintenance

Efficiency of the filtration system is dependent on the density of the filters, which can create a drop in pressure unless compensated by stronger and more efficient fans, thus maintaining air flow. For optimal performance, filters require monitoring and replacement in accordance with the manufacturer's recommendations and standard preventive maintenance practices.[220] Upon removal, spent filters can be bagged and discarded with the routine solid waste, regardless of their patient-care area location.[221] Excess accumulation of dust and particulates increases filter efficiency, requiring more pressure to push the air through. The pressure differential across filters is measured by use of manometers or other gauges. A pressure reading that exceeds specifications indicates the need to change the filter. Filters also require regular inspection for other potential causes of decreased performance. Gaps in and around filter banks and heavy soil and debris upstream of poorly maintained filters have been implicated in health-care–associated outbreaks of aspergillosis, especially when accompanied by construction activities at the facility.[17, 18, 106, 222]

c. Ultraviolet Germicidal Irradiation (UVGI)

As a supplemental air-cleaning measure, UVGI is effective in reducing the transmission of airborne bacterial and viral infections in hospitals, military housing, and classrooms, but it has only a minimal inactivating effect on fungal spores.[223–228] UVGI is also used in air handling units to prevent or limit the growth of vegetative bacteria and fungi. Most commercially available UV lamps used for germicidal purposes are low-pressure mercury vapor lamps that emit radiant energy predominantly at a wave-length of 253.7 nm.[229, 230] Two systems of UVGI have been used in health-care settings – duct irradiation and upper-room air irradiation. In duct irradiation systems, UV lamps are placed inside ducts that remove air from rooms to disinfect the air before it is recirculated. When properly designed, installed, and maintained, high levels of UVGI can be attained in the ducts with little or no exposure of persons in the rooms.[231, 232] In upper-room air irradiation, UV lamps are either suspended from the ceiling or mounted on the wall.[4] Upper air UVGI units have two basic designs: a) a "pan" fixture with UVGI unshielded above the unit to direct the irradiation upward and b) a fixture with a series of parallel plates to columnize the irradiation outward while preventing the light from getting to the eyes of the room's occupants. The germicidal effect is dependent on air mixing via convection between the room's irradiated upper zone and the lower patient-care zones.[233, 234]

Bacterial inactivation studies using BCG mycobacteria and *Serratia marcescens* have estimated the effect of UVGI as equivalent to 10 ACH–39 ACH.[235, 236] Another study, however, suggests that UVGI may result in fewer equivalent ACH in the patient-care zone, especially if the mixing of air between zones is insufficient.[234] The use of fans or HVAC systems to generate air movement may increase the effectiveness of UVGI if airborne microorganisms are exposed to the light energy for a sufficient length

of time.[233, 235, 237–239] The optimal relationship between ventilation and UVGI is not known.

Because the clinical effectiveness of UV systems may vary, UVGI is not recommended for air management prior to air recirculation from airborne isolation rooms. It is also not recommended as a substitute for HEPA filtration, local exhaust of air to the outside, or negative pressure.[4] The use of UV lamps and HEPA filtration in a single unit offers only minimal infection-control benefits over those provided by the use of a HEPA filter alone.[240] Duct systems with UVGI are not recommended as a substitute for HEPA filters if the air from isolation rooms must be recirculated to other areas of the facility.[4] Regular maintenance of UVGI systems is crucial and usually consists of keeping the bulbs free of dust and replacing old bulbs as necessary. Safety issues associated with the use of UVGI systems are described in other guidelines.[4]

d. Conditioned Air in Occupied Spaces

Temperature and humidity are two essential components of conditioned air. After outside air passes through a low- or medium-efficiency filter, the air undergoes conditioning for temperature and humidity control before it passes through high-efficiency or HEPA filtration.

i. Temperature

HVAC systems in health-care facilities are often single-duct or dual-duct systems.[35, 241] A single-duct system distributes cooled air (55°F [12.8°C]) throughout the building and uses thermostatically controlled reheat boxes located in the terminal ductwork to warm the air for individual or multiple rooms. The dual-duct system consists of parallel ducts, one with a cold air stream and the other with a hot air stream. A mixing box in each room or group of rooms mixes the two air streams to achieve the desired temperature. Temperature standards are given as either a single temperature or a range, depending on the specific health-care zone. Cool temperature standards (68°F–73°F [20°C–23°C]) usually are associated with operating rooms, clean workrooms, and endoscopy suites.[120] A warmer temperature (75°F [24°C]) is needed in areas requiring greater degrees of patient comfort. Most other zones use a temperature range of 70°F–75°F (21°C–24°C).[120] Temperatures outside of these ranges may be needed occasionally in limited areas depending on individual circumstances during patient care (e.g., cooler temperatures in operating rooms during specialized operations).

ii. Humidity

Four measures of humidity are used to quantify different physical properties of the mixture of water vapor and air. The most common of these is relative humidity, which is the ratio of the amount of water vapor in the air to the amount of water vapor air can hold at that temperature.[242] The other measures of humidity are specific humidity, dew point, and vapor pressure.[242]

Relative humidity measures the percentage of saturation. At 100% relative humidity, the air is saturated. For most areas within health-care facilities, the designated comfort range is 30%–60% relative humidity.[120, 214] Relative humidity levels >60%, in addition to being perceived as uncomfortable, promote fungal growth.[243] Humidity levels can be manipulated by either of two mechanisms.[244] In a water-wash unit, water is sprayed and drops are taken up by the filtered air; additional heating or cooling of this air sets the humidity levels. The second mechanism is by means of water vapor created from steam and added to filtered air in humidifying boxes. Reservoir-type humidifiers are not allowed in health-care facilities as per AIA guidelines and many state codes.[120] Cool-mist humidifiers should be avoided, because they can disseminate aerosols containing allergens and microorganisms.[245] Additionally, the small, personal-use versions of this equipment can be difficult to clean.

iii. Ventilation

The control of air pollutants (e.g., microorganisms, dust, chemicals, and smoke) at the source is the most effective way to maintain clean air. The second most effective means of controlling indoor air pollution is through ventilation. Ventilation rates are voluntary unless a state or local government specifies a standard in health-care licensing or health department requirements. These standards typically apply to only the design of a facility, rather than its operation.[220, 246] Health-care facilities without specific ventilation standards should follow the AIA guideline specific to the year in which the building was built or the ANSI/ASHRAE Standard 62, *Ventilation for Acceptable Indoor Air Quality*.[120, 214, 241]

Ventilation guidelines are defined in terms of air volume per minute per occupant and are based on the assumption that occupants and their activities are responsible for most of the contaminants in the conditioned space.[215] Most ventilation rates for health-care facilities are expressed as room ACH. Peak efficiency for particle removal in the air space occurs between 12 ACH–15 ACH.[35, 247, 248] Ventilation rates vary among the different patient-care areas of a health-care facility (Appendix B).[120]

Health-care facilities generally use recirculated air.[35, 120, 241, 249, 250] Fans create sufficient positive pressure to force air through the building duct work and adequate negative pressure to evacuate air from the conditioned space into the return duct work and/or exhaust, thereby completing the circuit in a sealed system (Figure 1). However, because gaseous contaminants tend to accumulate as the air recirculates, a percentage of the recirculated air is exhausted to the outside and replaced by fresh outdoor air. In hospitals, the delivery of filtered air to an occupied space is an engineered system design issue, the full discussion of which is beyond the scope of this document.

Hospitals with areas not served by central HVAC systems often use through-the-wall or fan coil air conditioning units as the sole source of room ventilation. AIA guidelines for newly installed systems stipulate that through-the-wall fan-coil units be equipped with permanent (i.e., cleanable) or replaceable filters with a minimum efficiency of 68% weight arrestance.[120] These units may be used only as recirculating units; all outdoor air requirements must be met by a separate central air handling system with proper filtration, with a minimum of two outside air changes in general patient rooms (D. Erickson, ASHE, 2000).[120] If a patient room is equipped with an individual through-the-wall fan coil unit, the room should not be used as either AII or as PE.[120] These requirements, although directed to new HVAC installations also are appropriate for existing settings. Non-central air-handling systems are prone to problems associated with excess condensation accumulating in drip pans and improper filter maintenance; health-care facilities should clean or replace the filters in these units on a regular basis while the patient is out of the room.

Laminar airflow ventilation systems are designed to move air in a single pass, usually through a bank of HEPA filters either along a wall or in the ceiling, in a one-way direction through a clean zone with parallel streamlines. Laminar airflow can be directed vertically or horizontally; the unidirectional system optimizes airflow and minimizes air turbulence.[63, 241] Delivery of air at a rate of 0.5 meters per second (90 $\pm$ 20 ft/min) helps to minimize opportunities for microorganism proliferation.[63, 251, 252] Laminar airflow systems have been used in PE to help reduce the risk for health-care–associated airborne infections (e.g., aspergillosis) in high-risk patients.[63, 93, 253, 254] However, data that demonstrate a survival benefit for patients in PE with laminar airflow are lacking. Given the high cost of installation and apparent lack of benefit, the value of laminar airflow in this setting is questionable.[9, 37] Few data support the use of laminar airflow systems elsewhere in a hospital.[255]

iv. Pressurization

Positive and negative pressures refer to a pressure differential between two adjacent air spaces (e.g., rooms and hallways). Air flows away from areas or rooms with positive pressure (pressurized), while

air flows into areas with negative pressure (depressurized). AII rooms are set at negative pressure to prevent airborne microorganisms in the room from entering hallways and corridors. PE rooms housing severely neutropenic patients are set at positive pressure to keep airborne pathogens in adjacent spaces or corridors from coming into and contaminating the airspace occupied by such high-risk patients. Self-closing doors are mandatory for both of these areas to help maintain the correct pressure differential.[4, 6, 120] Older health-care facilities may have variable pressure rooms (i.e., rooms in which the ventilation can be manually switched between positive and negative pressure). These rooms are no longer permitted in the construction of new facilities or in renovated areas of the facility,[120] and their use in existing facilities has been discouraged because of difficulties in assuring the proper pressure differential, especially for the negative pressure setting, and because of the potential for error associated with switching the pressure differentials for the room. Continued use of existing variable pressure rooms depends on a partnership between engineering and infection control. Both positive- and negative-pressure rooms should be maintained according to specific engineering specifications (Table 6).

Table 6. Engineered specifications for positive- and negative pressure rooms*

	Positive pressure areas (e.g., protective environments [PE])	Negative pressure areas (e.g., airborne infection isolation [AII])
Pressure differentials	> +2.5 Pa§ (0.01" water gauge)	> -2.5 Pa (0.01" water gauge)
Air changes per hour (ACH)	>12	≥12 (for renovation or new construction)
Filtration efficiency	Supply: 99.97% @ 0.3 µm DOP¶ Return: none required**	Supply: 90% (dust spot test) Return: 99.97% @ 0.3 µm DOP¶ †
Room airflow direction	Out to the adjacent area	In to the room
Clean-to-dirty airflow in room	Away from the patient (high-risk patient, immunosuppressed patient)	Towards the patient (airborne disease patient)
Ideal pressure differential	> + 8 Pa	> - 2.5 Pa

* Material in this table was compiled from references 35 and 120. Table adapted from and used with permission of the publisher of reference 35 (Lippincott Williams and Wilkins).
§ Pa is the abbreviation for Pascal, a metric unit of measurement for pressure based on air velocity; 250 Pa equals 1.0 inch water gauge.
¶ DOP is the abbreviation for dioctylphthalate particles of 0.3 µm diameter.
** If the patient requires both PE and AII, return air should be HEPA-filtered or otherwise exhausted to the outside.
† HEPA filtration of exhaust air from AII rooms should not be required, providing that the exhaust is properly located to prevent re-entry into the building.

Health-care professionals (e.g., infection control, hospital epidemiologists) must perform a risk assessment to determine the appropriate number of AII rooms (negative pressure) and/or PE rooms (positive pressure) to serve the patient population. The AIA guidelines require a certain number of AII rooms as a minimum, and it is important to refer to the edition under which the building was built for appropriate guidance.[120]

In large health-care facilities with central HVAC systems, sealed windows help to ensure the efficient operation of the system, especially with respect to creating and maintaining pressure differentials. Sealing the windows in PE areas helps minimize the risk of airborne contamination from the outside. One outbreak of aspergillosis among immunosuppressed patients in a hospital was attributed in part to an open window in the unit during a time when both construction and a fire happened nearby; sealing the window prevented further entry of fungal spores into the unit from the outside air.[111] Additionally, all emergency exits (e.g., fire escapes and emergency doors) in PE wards should be kept closed (except during emergencies) and equipped with alarms.

e. Infection Control Impact of HVAC System Maintenance and Repair

A failure or malfunction of any component of the HVAC system may subject patients and staff to discomfort and exposure to airborne contaminants. Only limited information is available from formal

studies on the infection-control implications of a complete air-handling system failure or shutdown for maintenance. Most experience has been derived from infectious disease outbreaks and adverse outcomes among high-risk patients when HVAC systems are poorly maintained. (See Table 7 for potential ventilation hazards, consequences, and correction measures.)

AIA guidelines prohibit U.S. hospitals and surgical centers from shutting down their HVAC systems for purposes other than required maintenance, filter changes, and construction.[120] Airflow can be reduced; however, sufficient supply, return, and exhaust must be provided to maintain required pressure relationships when the space is not occupied. Maintaining these relationships can be accomplished with special drives on the air-handling units (i.e., a variable air ventilation [VAV] system).

Microorganisms proliferate in environments wherever air, dust, and water are present, and air-handling systems can be ideal environments for microbial growth.[35] Properly engineered HVAC systems require routine maintenance and monitoring to provide acceptable indoor air quality efficiently and to minimize conditions that favor the proliferation of health-care–associated pathogens.[35, 249] Performance monitoring of the system includes determining pressure differentials across filters, regular inspection of system filters, DOP testing of HEPA filters, testing of low- or medium efficiency filters, and manometer tests for positive- and negative-pressure areas in accordance with nationally recognized standards, guidelines, and manufacturers' recommendations. The use of hand-held, calibrated equipment that can provide a numerical reading on a daily basis is preferred for engineering purposes (A.Streifel, University of Minnesota, 2000).[256] Several methods that provide a visual, qualitative measure of pressure differentials (i.e., airflow direction) include smoke-tube tests or placing flutter strips, ping-pong balls, or tissue in the air stream.

Preventive filter and duct maintenance (e.g., cleaning ductwork vents, replacing filters as needed, and properly disposing spent filters into plastic bags immediately upon removal) is important to prevent potential exposures of patients and staff during HVAC system shut-down. The frequency of filter inspection and the parameters of this inspection are established by each facility to meet their unique needs. Ductwork in older health-care facilities may have insulation on the interior surfaces that can trap contaminants. This insulation material tends to break down over time to be discharged from the HVAC system. Additionally, a malfunction of the air-intake system can overburden the filtering system and permit aerosolization of fungal pathogens. Keeping the intakes free from bird droppings, especially those from pigeons, helps to minimize the concentration of fungal spores entering from the outside.[98]

Accumulation of dust and moisture within HVAC systems increases the risk for spread of health-care–associated environmental fungi and bacteria. Clusters of infections caused by *Aspergillus* spp., *P. aeruginosa, S. aureus,* and *Acinetobacter* spp. have been linked to poorly maintained and/or malfunctioning air conditioning systems.[68, 161, 257, 258] Efforts to limit excess humidity and moisture in the infrastructure and on air-stream surfaces in the HVAC system can minimize the proliferation and dispersion of fungal spores and waterborne bacteria throughout indoor air.[259–262] Within the HVAC system, water is present in water-wash units, humidifying boxes, or cooling units. The dual-duct system may also create conditions of high humidity and excess moisture that favor fungal growth in drain pans as well as in fibrous insulation material that becomes damp as a result of the humid air passing over the hot stream and condensing.

If moisture is present in the HVAC system, periods of stagnation should be avoided. Bursts of organisms can be released upon system start-up, increasing the risk of airborne infection.[206] Proper engineering of the HVAC system is critical to preventing dispersal of airborne organisms. In one hospital, endophthalmitis caused by *Acremonium kiliense* infection following cataract extraction in an ambulatory surgical center was traced to aerosols derived from the humidifier water in the ventilation system.[206] The organism proliferated because the ventilation system was turned off routinely when the

center was not in operation; the air was filtered before humidification, but not afterwards.

Most health-care facilities have contingency plans in case of disruption of HVAC services. These plans include back-up power generators that maintain the ventilation system in high-risk areas (e.g., operating rooms, intensive-care units, negative- and positive-pressure rooms, transplantation units, and oncology units). Alternative generators are required to engage within 10 seconds of a loss of main power. If the ventilation system is out of service, rendering indoor air stagnant, sufficient time must be allowed to clean the air and re-establish the appropriate number of ACH once the HVAC system begins to function again. Air filters may also need to be changed, because reactivation of the system can dislodge substantial amounts of dust and create a transient burst of fungal spores.

Duct cleaning in health-care facilities has benefits in terms of system performance, but its usefulness for infection control has not been conclusively determined. Duct cleaning typically involves using specialized tools to dislodge dirt and a high-powered vacuum cleaner to clean out debris.[263] Some duct-cleaning services also apply chemical biocides or sealants to the inside surfaces of ducts to minimize fungal growth and prevent the release of particulate matter. The U.S. Environmental Protection Agency (EPA), however, has concerns with the use of sanitizers and/or disinfectants to treat the surfaces of ductwork, because the label indications for most of these products may not specifically include the use of the product in HVAC systems.[264] Further, EPA has not evaluated the potency of disinfectants in such applications, nor has the agency examined the potential attendant health and safety risks. The EPA recommends that companies use only those chemical biocides that are registered for use in HVAC systems.[264] Although infrequent cleaning of the exhaust ducts in AII areas has been documented as a cause of diminishing negative pressure and a decrease in the air exchange rates,[214] no data indicate that duct cleaning, beyond what is recommended for optimal performance, improves indoor air quality or reduces the risk of infection. Exhaust return systems should be cleaned as part of routine system maintenance. Duct cleaning has not been shown to prevent any health problems,[265] and EPA studies indicate that airborne particulate levels do not increase as a result of dirty air ducts, nor do they diminish after cleaning, presumably because much of the dirt inside air ducts adheres to duct surfaces and does not enter the conditioned space.[265] Additional research is needed to determine if air-duct contamination can significantly increase the airborne infection risk in general areas of health-care facilities.

4. Construction, Renovation, Remediation, Repair, and Demolition

a. General Information

Environmental disturbances caused by construction and/or renovation and repair activities (e.g., disruption of the above-ceiling area, running cables through the ceiling, and structural repairs) in and near health-care facilities markedly increase the airborne *Aspergillus* spp. spore counts in the indoor air of such facilities, thereby increasing the risk for health-care–associated aspergillosis among high-risk patients. Although one case of health-care–associated aspergillosis is often difficult to link to a specific environmental exposure, the occurrence of temporarily clustered cases increase the likelihood that an environmental source within the facility may be identified and corrected.

approaches to minimize the growth of *Legionella* spp. include a) periodically increasing the temperature to at least 150°F [66°C] at the point of use [i.e., faucets] and b) adding additional chlorine and flushing the water.[661, 710, 711] Systems should be inspected annually to ensure that thermostats are functioning properly.

Adequate water pressure ensures sufficient water supplies for a) direct patient care; b) operation of water-cooled instruments and equipment [e.g., lasers, computer systems, telecommunications systems, and automated endoscope reprocessors[712]]; c) proper function of vacuum suctioning systems; d) indoor climate control; and e) fire-protection systems. Maintaining adequate pressure also helps to ensure the integrity of the piping system.

c. Infection-Control Impact of Water System Maintenance and Repair

Corrective measures for water-system failures have not been studied in well-designed experiments; these measures are instead based on empiric engineering and infection-control principles. Health-care facilities can occasionally sustain both intentional cut-offs by the municipal water authority to permit new construction project tie-ins and unintentional disruptions in service when a water main breaks as a result of aging infrastructure or a construction accident. Vacuum breakers or other similar devices can prevent backflow of water in the facility's distribution system during water-disruption emergencies.[11] To be prepared for such an emergency, all health-care facilities need contingency plans that identify a) the total demand for potable water, b) the quantity of replacement water [e.g., bottled water] required for a minimum of 24 hours when the water system is down, c) mechanisms for emergency water distribution, and 4) procedures for correcting drops in water pressure that affect operation of essential devices and equipment that are driven or cooled by a water system [Table 16].[713]

Table 16. Water demand in health-care facilities during water disruption emergencies

	Potable water	Bottled, sterile water
Water use needs	Drinking water Handwashing Cafeteria services Ice Manual flushing of toilets Patient baths, hygiene Hemodialysis Hydrotherapy Fire prevention (e.g., sprinkler systems) Surgery and critical care areas Laboratory services Laundry and central sterile services* Cooling towers+ Steam generation	Surgical scrub Emergency surgical procedures Pharmaceutical preparations Patient-care equipment (e.g., ventilators)§

* Arrange to have a contingency provision of these services from another resource, if possible (e.g., another health-care facility or contractor).
\+ Some cooling towers may use a potable water source, but most units use non-potable water.
§ This item is included in the table under the assumption that electrical power is available during the water emergency.

Detailed, up-to-date plans for hot and cold water piping systems should be readily available for maintenance and repair purposes in case of system problems. Opening potable water systems for repair or construction and subjecting systems to water-pressure changes can result in water discoloration and dramatic increases in the concentrations of *Legionella* spp. and other gram-negative bacteria. The maintenance of a chlorine residual at all points within the piping system also offers some protection from entry of contamination to the pipes in the event of inadvertent cross-connection between potable and non-potable water lines. As a minimum preventive measure, ASHRAE recommends a thorough flushing of the system.[661] High-temperature flushing or hyperchlorination may also be appropriate

strategies to decrease potentially high concentrations of waterborne organisms. The decision to pursue either of these remediation strategies, however, should be made on a case-by-case basis. If only a portion of the system is involved, high temperature flushing or chlorination can be used on only that portion of the system.[661]

When shock decontamination of hot water systems is necessary (e.g., after disruption caused by construction and after cross-connections), the hot water temperature should be raised to 160°F–170°F (71°C–77°C) and maintained at that level while each outlet around the system is progressively flushed. A minimum flush time of 5 minutes has been recommended;[3] the optimal flush time is not known, however, and longer flush times may be necessary.[714] The number of outlets that can be flushed simultaneously depends on the capacity of the water heater and the flow capability of the system. Appropriate safety procedures to prevent scalding are essential. When possible, flushing should be performed when the fewest building occupants are present (e.g., during nights and weekends).

When thermal shock treatment is not possible, shock chlorination may serve as an alternative method.[661] Experience with this method of decontamination is limited, however, and high levels of free chlorine can corrode metals. Chlorine should be added, preferably overnight, to achieve a free chlorine residual of at least 2 mg/L (2 ppm) throughout the system.[661] This may require chlorination of the water heater or tank to levels of 20–50 mg/L (20–50 ppm). The pH of the water should be maintained at 7.0–8.0.[661] After completion of the decontamination, recolonization of the hot water system is likely to occur unless proper temperatures are maintained or a procedure such as continuous supplemental chlorination is continued.

Interruptions of the water supply and sewage spills are situations that require immediate recovery and remediation measures to ensure the health and safety of patients and staff.[715] When delivery of potable water through the municipal distribution system has been disrupted, the public water supplier must issue a "boil water" advisory if microbial contamination presents an immediate public health risk to customers. The hospital engineer should oversee the restoration of the water system in the facility and clear it for use when appropriate. Hospitals must maintain a high level of surveillance for waterborne disease among patients and staff after the advisory is lifted.[642]

Flooding from either external (e.g., from a hurricane) or internal sources (e.g., a water system break) usually results in property damage and a temporary loss of water and sanitation.[716–718] JCAHO requires all hospitals to have plans that address facility response for recovery from both internal and external disasters.[713, 719] The plans are required to discuss a) general emergency preparedness, b) staffing, c) regional planning among area hospitals, d) emergency supply of potable water, e) infection control and medical services needs, f) climate control, and g) remediation. The basic principles of structural recovery from flooding are similar to those for recovery from sewage contamination (Box 9 and 10). Following a major event (e.g., flooding), facilities may elect to conduct microbial sampling of water after the system is restored to verify that water quality has been returned to safe levels (<500 CFU/mL, heterotrophic plate count). This approach may help identify point-of-use fixtures that may harbor contamination as a result of design or engineering features.[720] Medical records should be allowed to dry and then either photocopied or placed in plastic covers before returning them to the record.

Moisture meters can be used to assess water-damaged structural materials. If porous structural materials for walls have a moisture content of >20% after 72 hours, the affected material should be removed.[266, 278, 313] The management of water-damaged structural materials is not strictly limited to major water catastrophes (e.g., flooding and sewage intrusions); the same principles are used to evaluate the damage from leaking roofs, point-of-use fixtures, and equipment. Additional sources of moisture include condensate on walls from boilers and poorly engineered humidification in HVAC systems.

ASHRAE Standing Standard Project Committee 170 (SSPC 170) Ventilation of Health Care Facilities

HOME

This project committee is responsible for maintaining ANSI/ASHRAE/ASHE Standard 170, Ventilation of Health Care Facilities

FOREWORD

ANSI/ASHRAE/ASHE Standard 170, Ventilation of Health Care Facilities, is one of a family of documents that offers guidance, regulation, and mandates to designers of health care facilities. It is first and foremost a mandatory minimum requirement and, as such, may not always offer the state-of-the-art best practice for health care ventilation design. Other publications, such as the ASHRAE HVAC Design Manual for Hospitals and Clinics, complement the standard, providing additional depth and detail for the designer. In addition, the health care designer must refer to any design requirements from the appropriate jurisdiction that has authority. Many jurisdictions use or refer to Guidelines for Design and Construction of Health Care Facilities, published by the Facility Guidelines Institute (FGI). Where practical, the committee was cognizant of these other documents in the development of this standard.

Ventilation design for health care spaces is a combination of tasks that leads to a set of documents used in construction. One such task requires medical planners to develop departmental programs of spaces. These programs include space names that suggest the use for which the space is intended, and health care ventilation designers depend upon these names to determine the ventilation parameters for their designs. This standard provides these ventilation parameters.

Ventilation systems and designs for health care facilities are intended to provide a comfortable environment for patients, health care workers, and visitors while diluting, capturing and exhausting airborne contaminants including potentially infectious airborne agents such as M. tuberculosis. Without high-quality ventilation in health care facilities, patients, health care workers, and visitors can become exposed to contaminants through normal respiration of particles in the air. Poorly ventilated health care facilities may increase the concentration of airborne contaminants including fungi or mold, which may cause allergic responses in even healthy workers and occupants. Some patients are profoundly immunosuppressed for prolonged periods and if exposed, are highly susceptible to infection from fungi. For such patients, fungal spores become invasive pathogens and lead to high rates of severe morbidity and mortality. For all these reasons, and considering the various occupancies and patient populations, great care must be taken in the design of health care ventilation systems.

(Standard 170 -2008—including all issued addenda—is incorporated into the 2010 edition of the Guidelines for Design and Construction of Health Care Facilities with the exception of Section 4.1 and Section 4.2.)

To view the title, purpose and scope (TPS) of this standard Click Here

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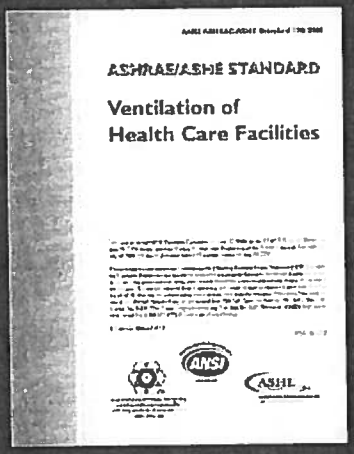

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ASSOCIATION FOR PROFESSIONALS IN INFECTION CONTROL AND EPIDEMIOLOGY, INC.

Infection Control in Ambulatory Care

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Kathleen H. Petersen

Table of Contents

Preface xiii

Acknowledgements xv

Chapter 1—Infection Control and Ambulatory Care 1
- Historical Perspective 1
- Ambulatory Care Settings 1
- IC in Ambulatory Care 1
- IC Programs 1
- IC Resources 2
- References 2

Chapter 2—The Infectious Disease Process 5
- Agent, Host, Environment 5
- Types of Infections 5
- Transmission of Infectious Agents 5
  - Contact Transmission 6
  - Droplet Transmission 6
  - Airborne Transmission 6
  - Common Vehicle Transmission 6
- Infection Risks 7
- Reducing the Risk of Infection 8
- References 8

Chapter 3—Cleaning, Disinfecting, and Sterilizing Patient Care Equipment 9
- Introduction 9
- Definition of Terms 9
- Reuse of Single-Use Devices 10
- Patients with Infectious Diseases 10
- Reprocessing Principles 11
- Guidelines and Procedures 11
- Cleaning 13
- Disinfection 13
  - Types of Disinfectants 13
  - Environmental Surface Disinfection 15
  - Effective Use of High-Level Disinfectants 17
  - Safe Use of Disinfectants 18
  - Pasteurization 18
- Sterilization 19
  - Background 19
  - Parameters 19
  - Cleaning and Wrapping 19
  - Preventive Maintenance 20
  - Sterilization Monitors 20
  - Failure and Recall Policy 20
  - Shelf Life and Event-Related Sterility 20
  - Flash Sterilization 20
- Other Reprocessing Methods 21
- Special Situations 21
- Workplace Design 22
- Storage 22
- Staff Education and Quality Improvement 23
- Further Information 23
- References 23

Chapter 4—Personal Protective Equipment 25
- Background 25
- Use of Personal Protective Equipment 25
  - Gloves 26
  - Other Garb 27
- PPE and Chemicals 27

Exposure Prevention 27
Access to and Location of PPE 28
Training 28
Exposures 28
References 28

Chapter 5—Hand Hygiene 31
Background 31
Definitions 31
Indications for Handwashing and Hand Antisepsis 31
Hand Hygiene Techniques 32
Selection of Hand Hygiene Agents 32
Alcohol-Based Hand Rubs 32
Other Products 35
Surgical Hand Antisepsis 35
Artificial Fingernails and Nail Polish 36
Skin Care 36
Sinks and Dispensers 37
Education and Motivation 37
Performance Improvement 37
References 38

Chapter 6—Isolation Precautions 39
Background 39
General Categories 40
Standard Precautions 40
Contact Precautions 40
Droplet Precautions 41
Airborne Precautions 41
Antibiotic Resistance 42
Special Application of Isolation Precautions in Ambulatory Settings 43
Waiting Rooms 43
Scheduling Patients 46
Triaging Patients 44
Immunization 44
Design of Area 44
Informing Others of Isolation Precautions 45
Transfer of Patients 45
Patient and Family Education 45
References 45

Chapter 7—Physician Offices and Clinics 47
Background 47
Environmental Issues 47
Housecleaning 47
Supplies 49
Trash Handling 51
Refrigerators 51
Toys and Computers 52
Construction 53
Renovation 54
Remediation 54
Patient Care Issues 55
Examination of the Patient 55
Infectious Patients 55
Minor Surgery in Exam Rooms 56
Patient Education 56
References 57

Chapter 8—Ambulatory Surgery 59
Background 59
Surgical Asepsis 60
Hand Hygiene 60
Patient Preparation 61
Surgical Attire 61
Sterile Field 61
Personal Protective Equipment 62
Traffic Patterns and Control 62
Equipment and Supplies 62
Medications and Multiple-Dose Vials (MDV) 62
Antimicrobial Prophylaxis 62
General Requirements 63
Sharps 63
Instruments 63
Lasers 63
Waste 64
Environmental Controls 64
Cleaning 64
Ventilation 64
Surveillance 64
Communicable Diseases in Patients 64
Antibiotic-Resistant Microbes 64
Tuberculosis 64
Minor Office Procedures 65
References 65

Chapter 9—Endoscopy 69
Background 69
Reprocessing Procedures 71

Protection from Exposure to Disinfectant 73
Standard Precautions 73
Protection from Exposure to Tuberculosis 74
Quality Assurance and Improvement Program 74
Resources 74
References 74

Chapter 10—Infusion Therapy 77
Background 77
Causes of Infection 77
Devices 77
Risks 77
Prevention 78
Physical Space 78
Catheter Insertion 78
Care and Maintenance of Infusive Systems 79
Care of the Site 79
Prevention Procedures 79
Waste Management 80
Isolation Precautions 80
Education 81
Surveillance 81
References 82

Chapter 11—Invasive Cardiology 83
Background 83
Causes of Infection 83
Risks 83
Prevention 84
Procedures 84
Physical Space 85
Decontamination of Equipment 86
Communicable Diseases in Patients 86
References 86

Chapter 12—Dentistry 89
Background 89
Causes of Infection 89
Devices 90
Risks 90
Prevention 90
Procedures 90
Physical Space 93
Waste Management 93
Evaluation and Management of Communicable Diseases 93
Employee-Focused Prevention Techniques—Vaccination and Education 94
Surveillance 94
References 94

Chapter 13—Dialysis 97
Background 97
Causes of Infection 98
Devices 98
Risks 98
Prevention 99
Care and Maintenance of Dialysis Systems 99
Treated Water and Dialysate 99
Dialyzer Reprocessing 100
Insertion of Hemodialysis Catheters 100
Care of the Access Site 101
Aseptic Procedures 101
Waste and Specimen Management 103
Evaluation and Management of Communicable Diseases 103
Isolation Precautions 104
Employee-Focused Prevention Techniques—Vaccination and Education 105
Surveillance 106
References 106

Chapter 14—Ophthalmology/Optometry 109
Background 109
Causes and Risks 109
Infection Prevention and Control Measures 110
Hand Hygiene and Gloving 110
Instrument Disinfection 110
Environmental Surfaces 111
Medications 112
Employee Health 112
Epidemic Keratoconjunctivitis (EKC) Prevention and Outbreak Control 112
Ophthalmologic Surgery 112
Professional Resources 113
References 113

Chapter 15—Physical Medicine and Rehabilitation 117
Background 117
Causes of Infection 117
Risks 117

Prevention 118
Procedures 118
Physical Space 118
Decontamination of Equipment 119
Communicable Diseases in Patients 120
References 120

Chapter 16—Radiology 123
Background 123
Causes of Infection 123
Risks 123
Prevention 124
Procedures 124
Physical Space 126
Decontamination of Equipment 126
Communicable Diseases in Patients 127
References 127

Chapter 17—Urgent/Emergency Care Centers 129
Background 129
Devices 129
Risks 129
Prevention 130
Use of Barrier Precautions and Hand Hygiene 130
Patient-Care Equipment 130
Intravascular Devices 130
Use of Medications and Multiple-Dose Vials 131
Cleaning Environmental Surfaces 131
Physical Space 131
Waste Management 131
Evaluation and Management of Communicable Diseases 131
Employee Focused Prevention Techniques 132
Surveillance and Public Health 132
References 133

Chapter 18—Laboratory Practices 135
Clinical Laboratory Improvement Amendments 135
U.S. Food and Drug Administration 135
Commission on Office Laboratory Accreditation 135
American Association of Blood Banks 137
College of American Pathologists 137
NCCLS 137
Joint Commission on Accreditation of Healthcare Organizations 137
Occupational Safety and Health Administration 137
Department of Transportation 138
General Laboratory Practices 138
Standard Precautions 138
Specimens 138
Blood Collection 139
Blood Banks 139
Quality Control 139
References 139

Chapter 19—Occupational Health 141
Recordkeeping 142
Health Assessments 142
Immunization 143
Hepatitis B Virus 143
Measles, Mumps, and Rubella 144
Influenza 144
Varicella 144
Other Vaccine Preventable Diseases 145
Tuberculosis Assessment and Control 145
TB Skin Testing 145
Two-Step Skin Testing 146
Periodic Testing 146
Skin Test Conversions and Treatment for LTBI 147
Medical Evaluation for TB Respirator Use 147
Exposure to Bloodborne Pathogens 147
Post Exposure Evaluation and Management 147
Exposures to Other Infectious Diseases 149
Work Restrictions 150
Occupational Health Concerns of Pregnant HCWs 150
Chemical Hazards 153
Latex Allergy and Hand Dermatitis 153
Disinfectants 154
References 155

Chapter 20—Data Management 157
Background 157
Surveillance or Data Management Plan 157
Assessment of the Population 158
Definition of the Population at Risk 158

Identification and Description of the Outcome or Process to Be Studied 158
Use of Standard Definitions 159
Identification and Description of Data Sources and Case-Finding Methods 159
Determination of Data Collection Methods 159
Selection of Appropriate Methods of Measurement and Performance of Data Analysis 160
Application of Risk Stratification Methodology 161
Reporting and Using Surveillance Information 161
Indicators: Outcomes and Processes 161
References 162

Chapter 21—Outbreak Investigation 165
Step 1: Confirm That an Outbreak Exists 165
Step 2: Characterize the Cases by Person, Place, and Time 166
Step 3: Formulate Tentative Hypotheses 166
Step 4: Test the Hypotheses 168
Step 5: Institute Appropriate Control Measures 168
Step 6: Evaluate the Control Measures 168
Step 7: Communicate Findings 168
Summary of Patient Outbreaks Identified in Ambulatory Care Settings 169
References 170

Chapter 22—Public Health, Accrediting & Regulatory Agencies 173
State Health Departments 173
Communicable Diseases 173
Other Health Department Responsibilities 173
Centers for Disease Control and Prevention 174
Healthcare Infection Control Practices Advisory Committee 174
National Institute for Occupational Safety and Health 174
Other CDC Guidelines 175
Occupational Safety and Health Administration 175
Bloodborne Pathogens 175
Tuberculosis 176
Accrediting Agencies 176
Joint Commission on Accreditation of Healthcare Organizations 176
Accreditation Association for Ambulatory Health Care 177
National Committee for Quality Assurance 178
Regulatory Agencies 178
Food and Drug Administration 178
Environmental Protection Agency 179
Clinical Laboratory Improvement Amendments 179
Centers for Medicare & Medicaid Services 179
Professional Organizations 179
Association for Professionals in Infection Control and Epidemiology 179
Society for Healthcare Epidemiology of America 180
Society for Gastroenterology Nurses and Associates 180
Association of periOperative Registered Nurses 180
American Institute of Architects 180
Association for the Advancement of Medical Instrumentation 180
References 181

Chapter 23—Bioterrorism 183
Background 183
Agents 183
Issues 183
Early Recognition 183
Patient Placement 184
Hand Hygiene 184
Personal Protective Equipment 184
Isolation Precautions 185
Laboratory 185
Transporting Patients 185
Waste Handling 185
Disinfection and Sterilization 185
Occupational Health 185
Education 185
References 187

Chapter 24—Organizing for Infection Prevention, Surveillance, and Control 189
Background 189
Organizational Structure 189
Infection Control Professional 189
Staff Member Liaison 190
Infection Control Committee 190
Resources 190
Training and Competencies 190
References 191

Appendices
A. Friedman C, Barnette M, Buck AS, Haas R, Harris J, Hoffman P, et al. Requirements for infrastructure and essential activities of infection control and epidemiology in out-of-hospital settings: A Consensus Panel Report. *Am J Infect Control* 1999;27:418-30. 193
B. Friedman C. Infection Control Program. In: *APIC Text of Infection Control and Epidemiology*. Washington, DC: Association for Professionals in Infection Control and Epidemiology; 2000:1:1-9. 207
C. Triage Screening Tools 217
Sample Triage Policy 218
Triage Screening Protocol 219
Tuberculosis Screening Tool 220
D. Isolation Tools 221
Contact Precautions Sign 222
Droplet Precautions Sign 223
Airborne Precautions Signs 224
Isolation Precautions Table 226
E. Education Tools 227
Antibiotic Resistance Precautions—A Patient's Guide 228
Sample Handout for Patients in Isolation/Precautions 230
F. Disinfection/Sterilization Tools 231
Sample Procedure for Disinfection 232
Sample Procedure for Sterilization 233
Steam Autoclave Spore Test Log 234
Endoscopy Competency 235
Autoclave Competency 237
High Level Disinfectant Competency 240
Temperature Log for Medication Refrigerator 242
Patient Food Refrigerator/Freezer Log 243
G. Surveillance Tools 245
Sample Surveillance Plan 1 246
Sample Surveillance Plan 2 246
Data Analysis 247
Line Listing 247
Rates 248
Outcome Measures 248
Process Measures 248
Tables, Graphs, and Charts 248
Table 248
Graph 249
Run Chart 250
Chart 250
Control Chart 250
Statistical Techniques 253
Descriptive Statistics 253
Inferential Statistics 253
Forms 256
Ambulatory Surgery Form 256
Site Review Form 257
Surveillance Data Entry Form 262
H. Outbreak Investigation Tools 263
Outbreak Investigation Protocol and Example 264
Definition of Terms 266
Information on Epi Info 267
I. Exposure Control Plan 269
Bloodborne Pathogens Exposure Control Plan Example 270
J. Occupational Health Tools 275
Latex Questionnaire for Health Care Workers 276
HIV Post-Exposure Prophylaxis (PEP) Algorithm 277
Immunization Inventory 278
Hepatitis B Vaccine Declination Form 279
K. Bioterrorism Tools 281
Sample Policy 282
Educational Material 284
Anthrax 284
Smallpox 284
Viral Hemorrhagic Fever 285

Index 287

Preface

An increasing number of patients with a variety of illnesses are cared for in ambulatory care settings. These patients are often immunocompromised due to underlying illness or treatment practices. In addition, many diagnostic and treatment modalities, including invasive and surgical procedures, are now performed in ambulatory settings. The combination of immunocompromised patients and complexity of care in ambulatory settings results in a need to focus on prevention of infection.

We wrote this book to assist all individuals who practice infection prevention and control and health care epidemiology in ambulatory settings. There are few comprehensive references outlining appropriate practices in these areas. It was our intent to glean information from various resources in order to compile as complete a reference as possible.

Infection prevention and control issues are important across the continuum of care. The basic principles of prevention and control are similar in these areas; however, circumstances may influence specific practice issues. We attempted to provide background information, review basic principles, and describe recommended practices for various ambulatory care settings.

CHAPTER 1

Infection Control and Ambulatory Care

HISTORICAL PERSPECTIVE

The first infection prevention and control efforts in the United States began in the 1950s concurrent with the growth of intensive care and increasing staphylococcal infections in hospitals.[1] Formal infection prevention and control (IC) programs then became common in hospitals during the 1970s when IC professionals were hired by many facilities.

There were no governmental or private regulatory or standards for IC until 1976 when IC programs became a requirement for accreditation by the Joint Commission on Accreditation of Healthcare Organizations.[1] The Joint Commission's standards are used by many institutions to establish a general framework for infection prevention and control activities. A publication by the Association for Professionals in Infection Control and Epidemiology and the Society for Healthcare Epidemiology of America outlines the structure and function of these programs.[2]

AMBULATORY CARE SETTINGS

Ambulatory care can be defined as health care rendered for acute and chronic diseases and for surgical interventions performed in facilities in which patients reside for less than 24 hours.[3] This type of care is delivered in a variety of settings, such as physician and dental offices, clinics or practices administered by groups of physicians, health maintenance organizations, and facilities attached to hospitals. Other settings include emergency and urgent care centers, diagnostic treatment centers or procedure suites, radiology and imaging centers, dialysis centers, chemotherapy or infusion centers, and short-stay facilities (e.g., 23-hour clinics). Surgical procedures are also performed in surgery centers, whether freestanding, office-based, or part of a traditional healthcare facility.

The risk of infection has traditionally been considered to be low in ambulatory care. This is because most persons seen in these settings have relatively minor illnesses or injuries, or have chronic conditions that have not seriously compromised their host defenses.[4] In addition, ambulatory care visits are typically of limited duration and consist of primarily noninvasive procedures. Few investigators have systematically evaluated the rates of infection in ambulatory care populations. However, because more invasive diagnostic and surgical procedures are being performed in outpatient settings and patients with unrecognized infectious diseases are seen, there is increased focus on infection prevention and control programs.

IC IN AMBULATORY CARE

Infectious diseases account for 20 to 30% of physician office visits, with acute infection of the respiratory tract as the most common reason for consulting a physician.[5] There have been multiple outbreaks of measles,[6-7] tuberculosis,[8] and other infectious diseases[9] traced to physician offices or clinics. Most of these outbreaks were associated with noncompliance with IC procedures.

basic principles of transmission and prevention are the same in a hospital or a clinic.

Medical conditions that were once managed in the acute care hospital are now being treated in ambulatory care settings. These conditions require infusion therapy, dialysis, endoscopy, and other invasive procedures. In addition, an increasing number of surgical procedures have shifted from inpatient to ambulatory settings.[9-11] The range of procedures performed in ambulatory care settings is broadening; surgeons may even have an entire surgical suite incorporated into their office.[12] Immunocompromised and chronically ill patients as well as increasingly invasive procedures pose a risk for the development of infection in these patients. Outbreaks of health care-associated infections have occurred in these various ambulatory care settings.[13]

Thus, transmission of both community- and health care-associated infections poses a risk to patients in ambulatory care. There is also concern about the potential for occupational transmission of infection in these settings. However, scant published information or recommendations exist regarding the specific risk of infections and prevention strategies in the outpatient setting.

IC PROGRAMS

The Joint Commission's Surveillance, Prevention and Control of Infection Standards for Ambulatory Care[14] are almost identical to those focused on the hospital. In fact, its Shared Visions–New Pathways initiative likely will result in completely identical standards.[15] This seems appropriate, because the basic principles of disease transmission and prevention are the same in ambulatory care service areas as in traditional hospital settings. However, the prevention strategies will vary based on the patient population served and the specific setting,[16] and various practices may need to be adapted for application in some ambulatory care areas.

IC RESOURCES

Infection prevention and control program oversight should come from a group or an individual with infection control expertise and the authority to carry out the components of the program. However, the IC program itself should be the responsibility of one individual. Specific training relevant to IC knowledge and practice will make this individual more effective in managing an IC program.[17] In many facilities this individual may also have other assigned activities; that is, the IC component will be part-time.[3]

As more care is provided in ambulatory care settings, patients and healthcare workers alike are at risk for developing or transmitting infection. The IC community has an opportunity to apply the large body of knowledge related to health care-associated infections, risk factors, and prevention strategies learned from the hospital setting and to develop programs that meet the needs of ambulatory care.

none were involved by this

References

1. McDonald, L. L. Healthcare-associated and community-acquired surgical care. *Curr Clin Surg Clin* 1995; 8:727–738.
2. Friedland, G., Hewitt, M., Bach, A. S., Hoe, B., Harris, J., and Holman, P. et al. Requirements for infection control and environmental services of infection control and epidemiology in out-of-hospital settings: A Consensus Paper report. *Am J Infect Control*. 1993; 27:414–430.
3. Sartwright, D. A., Casiakova, T., Chatwin, G., and Mackenzie, K. M. Infection control in ambulatory care. *Infect Dis Clin North Am*. 1995; 11:285–295.
4. Jackson, M. M. Ambulatory Care Facilities. In: Abrams, B., Gelfand, H. A., Schechter, W. H., eds., *Complex Infection Control Hospital Services*. 2nd Ed. Philadelphia: W. B. Saunders Co. 2001: 139.
5. Fraser, R., Gildeson, I., and Pathen, H., eds. *Infection Control*. 1st Ed. U.K. Blackwell Scientific Publishing, Inc., 1996: 243.
6. Meek, A. B., Ormsbee, W. A., Baker, W. M., Grais, W. H., Stallones, R. F., Hermann, F. L., and Hiramoto, A. R. Measles outbreak in a pediatric practice: Airborne transmission in an office setting. *Pediatrics* 1985; 75:478–483.
7. Davis, P. M., Osterman, W. A., Frank, J. A., Sarkis, J. J., Baker, I. G., and Pickard, K. R., et al. Transmission of measles in medical settings 1980 through 1984. *JAMA*. 1986; 255:1293–1298.
8. Ashkar, G. C., Orelli, L., Holmes, H., Lampe, E., Pomerantz, H., and Wilmer, K., et al. Airborne tuberculosis: transmission from a pediatrician to patients. *Pediatrics*. 1997; 100:19–22.
9. Goodman, R. A., and Sebastian, S. L. Transmission of infectious diseases in outpatient health care settings. *JAMA*. 1991; 265:2117–2181.
10. Mason, E. A. Surveillance of surgical site infections in ambulatory settings: Exploring two central options. *Am J Infect Control*. 1997; 25:102–105.
11. Dorn, J. L. Ambulatory surgery—How far can we go? *Med Clin North Am*. 1993; 77:352–372.
12. Weber, H. H. Construction of Surgical Care Issues. In: Wenzel, R. P., ed., *Prevention and Control of Nosocomial Infections*. 3rd Ed. Baltimore: Williams & Wilkins, 1993: 293.
13. Herwaldt, L. A., Smith, S. H., and Carson, C. D. Infections caused in the outpatient setting. *Infect Control Hosp Epidemiol*. 1993; 14:21–24.
14. Joint Commission on Accreditation of Healthcare Organizations. *Standards for Ambulatory Care*. Oakbrook Terrace, IL: JCAHO, 2000: 181.
15. Shared Visions–New Pathways. *Perspectives*. 2002; 22:1–13.
16. Jennings, L., Dolecek, M., Clement, K., and Craig, C. Ambulatory care. *APIC Text of Infection Control and Epidemiology*. Washington DC: Association for Professionals in Infection Control and Epidemiology 2000; 38:1–29.
17. Goldrick, B. A., Hogue, D. A., Gilmore, G. K., Gaudet, K. M., Fraser, C. L., Ebbing, C. J., and the Certification Board for Infection Control and Epidemiology, Inc. 2001 Advisory Committee. *Am J Infect Control*. 2002; 30:413–418.

CHAPTER 2

The Infectious Disease Process

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AGENT, HOST, ENVIRONMENT

Human beings live in dynamic interaction with their environment and microorganisms. The human body is host to numerous bacteria, fungi, and some viruses that live in a commensal relationship. The term normal flora refers to microorganisms that inhabit various parts of the body and may have a protective role in preventing infection. As an example, in most people *Escherichia coli*, *Enterococcus faecalis*, and millions of anaerobic bacteria live in the intestinal tract as normal flora. The presence of these microorganisms is beneficial to the host because they provide nutrients for absorption and competitively inhibit the growth of pathogenic microorganisms. Colonization is a term that describes growth of microorganisms in the body without damage to tissues. Normal flora may be described as colonization; however, other microorganisms, which are not usual inhabitants, may colonize the human body as well. Examples of microorganisms not considered to be normal flora that may colonize human beings include methicillin-resistant *Staphylococcus aureus* or vancomycin-resistant enterococci (VRE).

The body has multiple immune defense mechanisms that prevent colonizing microorganisms from causing infection. Infection occurs when a microorganism evades the normal host immune defenses and causes tissue damage and disease. Host factors, including age, underlying illness, or compromised immune defenses such as those occurring with corticosteroid therapy, other immunosuppressive medications, or irradiation, result in increased risk of infection. In addition, medical procedures, including surgical operations, anesthesia, and indwelling catheters, break down the normal first line of defense and make patients more susceptible to infection.

TYPES OF INFECTIONS

An infection occurs when an infective agent establishes itself and multiplies in or on a suitable host. Individuals are susceptible to an infection if they do not have sufficient resistance against a microorganism to prevent the infection if exposed to the microbe. The host immune response to infection results in clinical signs and symptoms of inflammation. These consist of systemic signs and symptoms, including fever, muscle aches, and malaise, or local signs of inflammation, such as pain, redness or erythema, and swelling. Many infections occur with very few recognizable signs and symptoms; these are considered to be subclinical infections. Other infections are associated with obvious signs and symptoms and are recognized as an infection. For example, chicken pox may cause a subclinical infection if the symptoms are mild and there is no observable rash. Alternatively, chicken pox usually presents with fever, malaise, and a characteristic rash.

There are some infections agents that can cause a chronic infection that does not damage the host tissues and is not associated with any signs or symptoms. This is called a carrier state. An example of a carrier state occurs in 10% of patients who are infected with hepatitis B virus. These patients remain asymptomatic and never develop damage to the liver. They are considered

to be carriers because even though they lack symptoms and signs of infection, they may act as a reservoir or source of transmission of hepatitis B virus to other people.

TRANSMISSION OF INFECTIOUS AGENTS

The method by which a microorganism spreads from the environment or from person to person is critical for developing infection prevention and control strategies. There are five main methods for spread of microorganisms: contact transmission, droplet transmission, airborne transmission, common vehicle transmission, and vectorborne transmission (see Table 2.1).[1-3] Most pathogenic microorganisms are spread in the ambulatory care setting through contact, droplet, or airborne transmission. Vectorborne transmission occurs when vectors, such as mosquitoes or ticks, spread microorganisms; this is an uncommon method of infectious spread in a healthcare setting and will not be discussed further here.

Contact Transmission

Contact transmission is the most important mode of spread of microorganisms in the healthcare setting. Direct contact transmission occurs when person-to-person contact results in the transfer of microorganisms from an infected or colonized person to a susceptible host. Direct contact transmission occurs, for example, when a nurse with herpetic whitlow transfers herpes virus to a patient. Indirect contact transmission occurs when an intermediate object, such as a contaminated needle, instrument, or hands of a healthcare provider, transfers microorganisms to a susceptible host. A primary example of indirect contact transmission is when a healthcare provider performs a patient care activity and spreads a resistant microorganism, such as VRE, to the patient from unwashed hands, thus acting as an intermediary in patient-to-patient spread.

Table 2.1 Examples of Modes of Transmission of Common Pathogenic Agents

Mode of Transmission	*Agent*
Airborne	Chicken pox Measles (rubeola virus) Tuberculosis
Contact	Enteric pathogens Vancomycin-resistant enterococci
Respiratory droplet	Influenza Respiratory syncytial virus Rubella (German measles)
Common vehicle	Contaminated multidose vials
Vector	Lyme disease

Droplet Transmission

Droplet transmission occurs primarily from persons infected with upper respiratory viruses. Infectious droplets are generated from the infected person during coughing, sneezing, and talking. Certain medical procedures, including sputum induction and bronchoscopy, may generate droplets as well. These droplets are propelled through the air for a short distance (approximately three feet) and then fall to the floor or other environmental surfaces. Transmission occurs when infectious droplets contact the mucous membranes or conjunctiva of a susceptible host. An example of droplet transmission is when influenza virus is spread from a coughing infected child to a susceptible child while playing in the waiting room of an ambulatory clinic.

Airborne Transmission

Airborne transmission occurs when airborne droplet nuclei are carried through the air from an infected person and inhaled by a susceptible host. Droplet nuclei are tiny evaporated respiratory droplets that can float in the air for long periods of time and can be disseminated in air currents or ventilation systems. Important examples of microorganisms spread via airborne transmission are *Mycobacterium tuberculosis*, chicken pox, and measles virus (rubeola).

Common Vehicle Transmission

Common vehicle transmission occurs when microorganisms are spread from contaminated food, water, medications, or equipment. In the ambulatory setting, this type of transmission may occur from contaminated multi-dose medication vials or from contaminated facial lotions.

INFECTION RISKS

Several host factors may increase the risk of acquiring infections in the ambulatory setting. One important factor is age, as the very young and the very old are more susceptible to a variety of infections. Infants, especially in the neonatal period, have not developed an adequate immune response to many common pathogens. The infant immune system may take several months to mature to a fully functioning system. *Listeria monocytogenes* is an example of a pathogenic microorganism that is more likely to infect a neonate than an older person.

Pediatric patients, including infants, toddlers, and preschool children, are also at risk of acquiring infections in the ambulatory setting. At this age, children will begin attending day care and preschool facilities, where viruses are spread easily from child to child.[5] These children usually have not learned proper hygienic practices to prevent the spread of enteric and respiratory infections. Symptomatic children in the ambulatory care waiting area may inadvertently spread viruses while playing with other children through direct contact with infectious secretions or indirect contact with contaminated toys.

Unvaccinated children are also susceptible to a number of childhood viruses that cause a rash and can be spread through the airborne route. Chicken pox and measles (rubeola) are examples of childhood infections that can be spread through the air of a clinic.[4] These diseases are seen less frequently with the advent of vaccines. However, sporadic cases, especially chicken pox, still occur. Children are infectious in the early stages of their rash in chicken pox, until their lesions crust. Unfortunately, children may be infectious for up to 24 hours before their chicken pox rash becomes apparent. Measles is contagious from the beginning of prodromal symptoms until about four days after onset of rash. Because these infections are transmittable in ambulatory care settings, procedures for identifying patients with rash and those who are in the incubation period for these diseases and reaching their contagious period must be developed for ambulatory sites that may encounter pediatric patients.

Elderly persons are also at risk of developing infections. As a person ages, the immune system function wanes, increasing the risk of acquiring an infection and increasing the risk of death from infection.[3] In addition to a weaker immune system, elderly patients frequently have more chronic medical illnesses, such as diabetes, chronic lung disease, malignancy, dementia, or malnutrition, which complicate their course of disease and increase the risk of infection. Finally, elderly patients residing in long-term care facilities are at risk of acquiring infections with microorganisms that are endemic to nursing homes (e.g., methicillin-resistant staphylococcus) and infections related to treatments used in nursing homes (e.g., catheter-related urinary tract infections).

Patients with one or more defects in normal human defense mechanisms may be predisposed to common infectious agents and microorganisms that would not normally cause infection in humans (opportunistic pathogens).[6] Patients may have increased risk of infection due to immunosuppressive therapy (including corticosteroid therapy), the absence of a functioning spleen, or breakdown in normal protective mucosal barriers. Underlying diseases, such as infection with human immunodeficiency virus or hematological malignancies, alter the human immune system. Metabolic factors, such as malnutrition, uremia, or hyperglycemia, may also decrease the function of immune cells, putting the patient at increased risk of infection. As noted, a patient may have several factors simultaneously, which work together to increase the risk of infection.

Medical procedures performed in the ambulatory setting may also put patients at risk of infection. Intravascular devices are used to administer intravenous fluids, medications, blood products, and parenteral nutrition. The use of these catheters, however, may put the patient at risk of infectious complications, including catheter site infection, bloodstream infection, septic thrombophlebitis, or endocarditis.[7,8] Long-term intravascular catheters are also used frequently for chronic dialysis in the ambulatory setting. These patients are at high risk for the development of catheter-related bloodstream infection. Other invasive procedures, including surgical procedures, endoscopies, bronchoscopies, and cystoscopies, are associated with an increased risk of infection due to disruption of normal host barriers. All healthcare

providers should know the risks of infections associated with medical procedures and the necessary measures for preventing these infections.

REDUCING THE RISK OF INFECTION

Patients and staff in the ambulatory setting have risks for the development of various infections. Many of these infections are preventable through standard infection prevention and control measures. Correction of underlying diseases, such as diabetes or malnutrition, can improve the patient's ability to fight infection. Immunosuppressive medications and antibiotics must be used judiciously. Healthcare providers can improve patient and staff ability to resist infection through effective vaccine use.[9]

Standard infection prevention and control practices are the most effective means for reducing the risk of infection in the ambulatory setting. Handwashing remains the most important intervention for the prevention of infection in any healthcare setting.[10-12] Isolation precautions are necessary to prevent transmission of infection from patient to patient, patient to staff, or staff to patient[1] (see Chapter 6). In addition, procedures for the prevention of infections due to medical procedures are important for the prevention of health care-associated infections.[8,9,13]

References

1. Garner, J. S. and The Hospital Infection Control Practices Advisory Committee. Guidelines for isolation precautions in hospitals. *Am J Infect Control*. 1996; 24:24–52.
2. Aitken C. and Jeffries, D. J. Nosocomial spread of viral disease. *Clin Microbiol Rev*. 2001; 14:528–546.
3. Butz, A. M., Larson, E., Fosarelli, P., and Yolken, R. Occurrence of infection symptoms in children in day care homes. *Am J Infect Control*. 1990; 18:347–353.
4. Cole, J. ed. *Control of Communicable Diseases Manual*. 17th Ed. Washington, DC: American Public Health Association. 2000.
5. Crossley, K. B., and Peterson, P. K. Infections in the elderly. *Clin Infect Dis*. 1996; 22:209–215.
6. Hill, G. F., and Tomasulo, V. Prevention of infection in the immunocompromised host. *Am J Infect Control*. 1998; 26:594–618.
7. Mermel, L. A., Eber, G. M., Sherertz, R. J., Raad, I. I., O'Grady, N., Harris, J. S., and Craven, D. E. Guidelines for the management of intravascular catheter-related infections. *Infect Control Hosp Epidemiol*. 2001; 22:222–242.
8. Centers for Disease Control and Prevention. Guidelines for the Prevention of Intravascular Catheter Related Infections. *MMWR*. 2002; 51(RR-10):1–31.
9. Bolyard, E. A., Tablan, O. C., Williams, W. W., Pearson, M. L., Shapiro, C. N., Deitchman, S. D., and The Hospital Infection Control Practices Advisory Committee. Guidelines for infection control in healthcare personnel, 1998. *Am J Infect Control*. 1998; 26:289–354.
10. Larson, E. Skin hygiene and infection prevention: More of the same or different approaches. *Clin Infect Dis*. 1999; 29:1287–1294.
11. Centers for Disease Control and Prevention. Guideline for Hand Hygiene in Health-Care Settings: Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. *MMWR*. 2002; 51(RR-16):1–44.
12. Mangram, A. J., Horan, T. C., Pearson, M. L., Silver, L. C., Jarvis, W. R., and The Hospital Infection Control Practices Advisory Committee. Guideline for prevention of surgical site infection, 1999. *Am J Infect Control*. 1999; 27:97–132.

CHAPTER 3

Cleaning, Disinfecting, and Sterilizing Patient Care Equipment

INTRODUCTION

Effective reprocessing of patient care equipment and devices is one of the most challenging aspects of infection prevention and control in ambulatory care. Numerous occurrences and outbreaks of infections linked to devices have been reported, as described in the background sections of other chapters. Many disinfectants are toxic and require special handling. Developing and following standard protocols will prevent cross-contamination and minimize exposure of staff to chemicals or biohazardous material. Standard practices are also cost-effective, prolong the life of instruments, provide adequate documentation for regulatory agencies or managed care surveyors, provide for consistent reprocessing after each patient use, and can be flexible enough to accommodate the addition of new instruments.

DEFINITION OF TERMS

A precise use of terminology is crucial to informed decision making about reprocessing practices for instruments.[1-7]

Antiseptic. A chemical that either inhibits the growth of microorganisms or destroys them; this term refers to agents used on living tissue. Manufacturers develop germicides for specific uses; therefore, it is not advisable to use antiseptics on inanimate objects or, conversely, to use disinfectants on living tissue.

-cidal, -cide. Suffix meaning "to kill"; thus a germicide is an agent that destroys microorganisms, particularly pathogenic microorganisms ("germs"), and a bactericide is an agent that kills bacteria.

Cleaning. The removal of all visible dust, soil, and other foreign material, usually done using water with soaps, detergents, or enzymatic products along with physical action such as brushing. Meticulous cleaning must precede disinfection or sterilization of medical instruments.

Decontamination. The process of removing disease-producing microorganisms and rendering an object safe for handling.

Disinfection. A process that kills or destroys nearly all disease-producing microorganisms. Disinfectants are used on inanimate objects. There are three levels of disinfection, defined by the hardiness of microorganisms that are to be killed or inactivated (see Figure 3.1).

- High-level disinfection kills vegetative bacteria, tubercle bacillus, fungi, lipid, and nonlipid viruses, but not necessarily high numbers of bacterial spores.
- Intermediate-level disinfection kills vegetative bacteria, most fungi, tubercle bacilli, and most viruses; it does not kill resistant bacterial spores.
- Low-level disinfection kills most vegetative bacteria, some fungi, and some viruses, but cannot be relied on to kill mycobacteria or bacterial spores.

14. O'Rourke, E. New isolation strategies: Is there a need? *Infect Control Hosp Epidemiol*. 1994; 15:301-302.
15. Wilfy, M. E. The Epidemiology and Control of Communicable Diseases in the Outpatient Setting. *Epidemiol in Primary Care Practice*. 1990; 1:82-92.
16. Occupational exposure to bloodborne pathogens. Final rule. *Fed Reg*. 1991; 56:64175-64182.
17. Larson, E., Cunningham, M. J., Roberts, P. L., Hussain, M. I., Yates, B., and Stamm, W. E. Implementing and evaluating a system to prevent infection: personnel: Hospital substance infections. *Am J Infect Control*. 1990; 18:1-12.
18. Jackson, M. M., and Lynch, P. An attempt to make an issue less touchy. A compendium of low systems for infection precautions. *Infect Control Hosp Epidemiol*. 1991; 12:444-450.
19. Centers for Disease Control and Prevention. Guideline for Hand Hygiene in Health Care Settings: Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. *MMWR*. 2002; 51(RR-16):1-44.
20. Centers for Disease Control and Prevention. Guidelines for preventing the transmission of *Mycobacterium tuberculosis* in health-care facilities, 1994. *MMWR*. 1994; 43(RR-13):1-132.
21. Murray, B. E. The life and times of the vancomycin. *Clin Microbiol Rev*. 1990; 3:46-65.
22. Recommendations for Preventing the Spread of Vancomycin Resistance. Recommendations of the Hospital Infection Control Practices Advisory Committee (HICPAC). *MMWR*. 1995; 44(RR-12):1-13.
23. Boyce, J. M. Methicillin-Resistant Staphylococcus aureus Infections. In: Abrutyn, E., Goldmann, D. A., Scheckler, W. E., eds., *Saunders Infection Control Reference Service*. 2nd Ed. Philadelphia: W.B. Saunders Co., 2001: 775-779.
24. Interim Guidelines for Prevention and Control of Staphylococcal Infection Associated with Reduced Susceptibility to Vancomycin. *MMWR*. 1997; 46(27):626-628, 633.
25. Staphylococcus aureus Resistant to Vancomycin—United States, 2002. *MMWR*. 2002; 51:565-567.
26. American Academy of Pediatrics. Infection control in physicians' offices. *Pediatrics*. 2000; 105:1361-1369.
27. Palmer, S., Giddens, J., and Palmer, G. *Infection Control*. El Paso, TX: Skidmore Roth Publishing, Inc., 1998: 245.
28. Jennings, J., and Wilkinson, J. *APIC Handbook of Infection Control*. 3rd Ed. Washington, DC: Association for Professionals in Infection Control and Epidemiology, Inc., 2002: 354.
29. Pickering, L. K., ed. *2000 Red Book: Report of the Committee on Infectious Diseases*. 25th Ed. Elk Grove Village, IL: American Academy of Pediatrics, 2000.
30. Hubbard, F. A., Tarlan, G. C., Wilkinson, W. W., Patrick, M. L., Shapiro, C. N., and Deinhouwer, S. D., et al. Guideline for infection control in health care personnel, 1998. *Am J Infect Control*. 1998; 26:349-354.
31. AIA. *Guidelines for Design and Construction of Hospital and Health Care Facilities*. Washington, DC: The American Institute of Architects and the Facilities Guidelines Institute, 2001.

CHAPTER 7

Physician Offices and Clinics

BACKGROUND

Risk of infection transmission in primary care offices and clinics is generally considered lower than for hospitalized patients (see Chapter 1). However, infection prevention strategies need to be in place for both patient-care practices and the environment in order to ensure a low risk. Management of infectious patients and the ability to offer patient education may differ significantly from an in-patient setting due to the high number of patients seen in a short time and the brief encounter. Many environmental issues in these areas have overlapping infection control, safety, and aesthetic concerns. The expectation from the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) is for a "safe, functional, and effective environment for patients, staff members, and other individuals in the ambulatory care organization."[1] This section will review infection prevention and control, and environmental and general patient care considerations to help meet this expectation.

ENVIRONMENTAL ISSUES

Housecleaning

A clean environment theoretically may contribute to prevention of infection both to staff and patients; however, there are few references linking the spread of infection from common surfaces in any healthcare setting.[2] Various microorganisms can survive for extended periods on environmental surfaces; however, the importance of environmental contamination with health care-associated pathogens (e.g., methicillin-resistant *S. aureus*, vancomycin-resistant enterococcus, *C. difficile*) in ambulatory care has not been well defined.[3] During outbreaks in specific settings (e.g., ophthalmology [see Chapter 14]), the environment may contribute to the spread of microorganisms. However, for routine cleaning the following recommendations are based on common sense and aesthetics.

Frequency of Cleaning

Surfaces such as examination tables, countertops, floors, and public areas of the facility, such as waiting rooms and rest rooms need to be cleaned immediately after soiling with blood or body fluids.[4] In addition, these surfaces need to be cleaned at regular intervals, depending on use and function. Occupational Safety and Health Administration standards[4] state that: "Cleaning schedules and methods will vary . . . routine cleaning and removal of soil are required."

General cleaning of examination, waiting, and rest rooms should be performed daily; however, if patient load is heavy, several times a day may be necessary. Treatment or procedure rooms are subject to increased soiling potential, and surfaces visibly soiled should be cleaned after each patient.

Surfaces in contact with intact skin of the patient or a staff member, such as examination tables, baby scales, blood pressure cuffs, stethoscopes, tympanograms equipment, glucometers, and examination lights, should be cleaned when soiled and on a routine

basis. If clean paper is used on the examination tables and baby scales between each patient, these surfaces can be cleaned daily and when visibly soiled. If the provider adjusts the exam light during pelvic or other examinations where there is potential of touching mucous membrane or non-intact skin, it should be cleaned after each such exam.

Cleaning Agents

Products used for surface cleaner-disinfectants should be evaluated for and exhibit as many ideal characteristics as outlined in Table 7.1 as possible.[3] Low-level disinfectants (see Chapter 3) are adequate for environmental surface cleaning. Among the most commonly used and best cleaners are quaternary ammonium compounds. Phenolics are sometimes used, but they may leave a film or residue and are not recommended for surfaces in contact with newborns.[3] Neither alcohol nor bleach is recommended as a general environmental cleaner. Alcohol (usually 70–90% isopropyl) is effective in decontaminating blood but contains no cleaning agent, is flammable, and evaporates rapidly. Alcohol as supplied in sealed, small pads contains enough to disinfect a very small area. Bleach is corrosive, harmful to clothing, and easily inactivated by organic material.[3]

Because of the importance of mechanical cleaning, a product containing detergents or surfactants should be selected. Most importantly, the cleaner-disinfectant must be diluted, used, and stored precisely according to the label instructions. If diluted into secondary containers, these containers must be labeled with the brand name of the product and any health or physical hazards as listed on the Material Safety Data Sheet (MSDS). Although convenient, aerosol products usually are more costly and may elicit complaints about odor.

Method of Cleaning

As a practical matter, cleaning should be performed going from the cleanest to the most soiled area. Usually this means that cleaning will start at the highest point in the room (e.g., any spot cleaning on the walls) and then proceed to counters, sinks, examination tables, and so on. Although contact time is usually less than or equal to 10 minutes[3] for cleaner-disinfectants, from a practical, in-use point of view, surfaces are usually wiped and product allowed to dry with no rinsing, so that actual contact time is quite variable. Cleaning solution for general daily cleaning is often made up in a bucket. Cloths soaked with solution are used for mechanical cleaning. Most solutions will not need to be rinsed off. Cloths and buckets of cleaner-disinfectant should be changed often to prevent overloading with soil and microorganisms.

If light soiling is encountered most often, dispensing product from a spray bottle directly on the surface and wiping with clean cloth is practical. If blood or body fluids are being cleaned up, the spill initially should be absorbed with a moistened cloth or paper towel, the area sprayed with cleaner-disinfectant, and then cleaned again with cloth or paper towel. Follow the product label instructions regarding the length of time the product should remain moist on the surface.[4] Disinfectant-impregnated wipes in "pop-up" containers may be useful for cleaning small areas; for blood, one should be used to clean up the spot and then another one used to disinfect the area.

For floors, cleaning should start with a clean mop head and fresh bucket of cleaner-disinfectant solution. A single bucket and mop head will be sufficient to clean all of the noncarpeted areas in most physician offices and smaller clinics. Used mop heads and buckets of cleaning solution should never be stored overnight or for use at a later time due to the growth potential of microorganisms. Physical removal of soil with friction and scrubbing is as important as the product used and should not be overlooked in maintaining a clean environment. Damp dusting is preferred; dry dusting can cause fungal spore-laden dust particles to become airborne and should be discouraged.[5]

Table 7.1 Properties of Cleaner-Disinfectants to Consider

Broad antimicrobial spectrum	Review product specifications and microbiological testing data.
Stability	Review shelf life information for concentrate and in-use dilution.
Toxicity	Review Material Safety Data Sheets for health hazards associated with product use.
Absence of odor	To reduce possible sensitivity, allergic, or asthmatic reactions.
Cost	Review cost of pre-diluted, ready to use product versus concentrate.
Water solubility	Important if concentrate is under consideration.
Cleaning ability	Evaluate for surfactants or other cleaners that are important for mechanical removal of soil and organic material.
Rinsing	If rinsing is needed, the entire cleaning procedure will take longer.
Contact time	Usually less than or equal to 10 minutes.

Written Procedures

Written procedures are needed and should describe in detail:

- what and how to clean, the cleaning products, and any instructions for dilution;
- who is responsible (including direct patient care providers for immediate clean-up of a blood or body fluid spill);
- where the cleaning products are stored; and
- when and how often to clean.

All areas need to be included specifically in the written protocols: waiting room, patient examination and treatment/procedure rooms, laboratory, employee lounges, and restrooms. All surfaces should be included, from floors to walls to medical equipment to examination tables to countertops to doorknobs. Frequency of changing cleaning cloths, mop heads, and buckets of cleaner-disinfectant should be specified. Written protocols are important to avoid confusion about housecleaning expectations and should be used for training new staff and for verification that tasks are performed. If janitorial services are contracted, performance should be monitored and accountability established in the contract. Products used by the contract service should be reviewed for active ingredients and the other properties listed in Table 7.1, and they should be approved by administration and infection control staff.

Carpet

Carpet has not been shown to increase infection rates[7,9] in hospitals and is widely used in physician offices and clinics. Carpeting should be vacuumed and shampooed regularly.[10] Except during construction, high-efficiency particulate air filter (HEPA) vacuums have not been shown to be necessary.[10] As with other surfaces, blood and body fluid spills should be cleaned up immediately with a disinfectant; carpet choice should be based in part on the manufacturer providing adequate cleaning and disinfecting protocols. In areas where blood or body fluid spills may occur routinely (e.g., laboratories, procedure rooms, and soiled utility rooms), carpeting is not recommended because of aesthetics and odor control.

Supplies

Lack of storage space is chronic in many ambulatory settings. The ideal is to have clean storage and handling of soiled items done in separate rooms. However, because space and design may not permit this complete separation, there are flexible ways to organize the available space to keep supplies clean. However, it is important to review state or local regulations for requirements related to storage and separation of supplies. Codes may specify room function based on whether the facility is located in a hospital, medical professional building, or business occupancy. The American Institute of Architects (AIA) recommends that for outpatient centers a separate room or closet be provided for clean storage. For small, primary outpatient facilities, clean supplies may be stored in a separate room or in an isolated area of a room used for another purpose.[11]

Clean Storage

Guidelines for clean storage areas follows:

- Coordination should be made with delivery services so that clean supplies, such as linen, are not placed on the floor or on soiled shelving. If services also pick up soiled supplies, separate containers must be used for clean versus soiled supplies.
- Open shelves are acceptable in designated clean storage rooms, including linen storage. However, if mesh-type shelving is used, the bottom shelf should be covered or items stored in clean bins on the shelf to protect items from damage or soiling during cleaning of the floor under the shelves.
- Clean storage areas should have limited access and should not be located in a thoroughfare.
- Cleaning should be performed on a regular schedule to remove dust from floors and shelves. It should be performed carefully to avoid damage to or contamination of supplies.
- Supplies should be rotated "first in, first out" so that the oldest supplies are used first.
- In examination and treatment rooms, drawers and closed cabinets should be used for storage.
- To prevent water damage, no patient items should be placed under sinks, the ice machine, or other areas with water pipes.
- Cleaning supplies and disinfectants may be placed under sinks; however, unless the cabinet is locked, they should be kept only in rooms inaccessible to children or developmentally disabled individuals. Cleaner-disinfectant may be kept in treatment and procedure rooms for easy access for surface cleaning after procedures. It can be stored on an upper shelf or cabinet. It is common and generally acceptable for cleaning supplies to be stored under the sink in the soiled utility room.
- Items should be removed from shipping boxes before storage to prevent contamination with soil/debris that might be on the packing container.
- Although it is preferable to store linen in a clean room or in drawers or closed cabinets in exam rooms, it is acceptable to store linen on shelves in designated alcoves or other open areas. In these areas, the linen must be covered at all times to prevent potential soiling from traffic and to reduce the possibility of linen falling on the floor.
- In general, clean linen should not be stored in restrooms. However, in areas where the patient restroom adjoining a procedure room doubles as a locker room, it may be practical to keep a limited supply of patient gowns as long as they are covered and away from water contamination from the sink or toilet.
- Paper products (e.g., paper towels) stored in the janitor closet must not be stored on the floor.
- Clean items, including examination gloves, should be stored away from the "splash zone" around the sink to avoid contamination from microorganisms found in tap water. The precise distance will depend on the size and shape of the sink and water pressure. These items should also not be stored under the soap dispenser to prevent damage from dripping soap.
- It is safe to store clean items in closed cabinets, covered shelves, or drawers in a soiled utility room, but specific state health department regulations should be checked before implementing this practice. The area for storage of clean supplies should be labeled. If there is an autoclave in the utility room, supplies such as autoclave wrap, tape, peel pouches, and towels to be included in sterile packs may be stored in this room.
- If clean supplies will be held in the utility room after reprocessing until they can be delivered to a storage room or patient care areas, the holding space should be labeled to indicate that these items are "clean, patient ready."

Soiled Supplies and Linen

The underlying principle for managing soiled supplies, linen, and trash is to prevent contamination of clean items and to avoid exposure of patients or staff. After use, reusable medical devices should be taken directly to a soiled utility room. If this is not practical, they may be placed in a labeled, covered container in the examination or treatment room so that there is no chance of confusion with clean supplies. However, if there is opportunity for patients to unwittingly touch soiled items, they must be removed before another patient enters the room.

Soiled linen containers should be well defined and obvious, such as closed hampers in examination rooms or large hampers in the utility room. If drawers for soiled linen are provided in the examination table, they should be clearly labeled to avoid confusion with clean linen also found in examination table drawers. Drawers used for soiled linen should be decontaminated on a regular basis with an approved cleaner-disinfectant. Soiled linen should be collected at the point of use and handled minimally to prevent aerosolization of microorganisms. Linen should not be handled differently based on patient diagnosis. If linen is contaminated with blood or body fluid, wear barriers during handling of the items according to Standard Precautions[4,12] (see Chapter 6). Either plastic or cloth laundry bags are acceptable for managing soiled linen. Blood-saturated linen should be placed in plastic bags to prevent leakage.[12] Soiled and clean linen must be transported and stored separately.

Laundering patient linen on-site is uncommon. To maintain the highest quality and for cost efficiencies, it is rarely recommended that linen be washed on-site.[12] Although linen can harbor many microorganisms, risk of disease spread has been shown to be negligible and linen in these settings is rarely heavily soiled.[6,12] However, if washing machines are in use for cleaning patient sheets, towels, gowns, and so forth, state regulations must be consulted for proper water temperature, monitoring and record keeping, location of washing machines, and storage of soiled linen prior to washing. Recent guidelines indicate that ≥160°F (71°C) for 25 minutes or a lower temperature (71.6–122°F, i.e., 22–50°C) when bleach is added are effective.[12] The soiled laundry processing area should be physically separated from clean linen storage, patient care areas, food preparation areas, and clean supply and equipment storage areas.[13]

Trash Handling

Regulated medical (infectious) waste and regular trash must be separated for disposal; each state has specific definitions for regulated/medical/infectious waste (see Chapter 22). Approved sharps containers must be located at the point of use;[4] they should be placed in all examination, treatment, and procedure rooms, phlebotomy stations and utility rooms, at heights convenient for all staff (not so high that staff will have difficulty reaching them). Special safety considerations need to be addressed for their placement in pediatrics areas to avoid potential accidental patient injury and access. In these areas they should be placed high enough from the floor to be inaccessible. If there is great concern or history of injury, portable sharps containers may be taken into the room as needed and stored in an inaccessible area between uses.

Space constraints, infrequency of generating regulated medical waste, lack of understanding about items that are classified as regulated medical waste, and ineffective separation of trash and regulated waste often hamper efforts at efficient waste disposal. Red bags, biohazard buckets, or other containers as required by specific state regulations should be placed judiciously. It is often practical and sufficient to place one container for regulated waste in the lab area or utility room and one in each procedure or treatment room that generates regulated waste on a regular basis. Regular reminders to staff via in-service education and posted lists or posters may also help ensure adequate separation.

If there is an unplanned generation of regulated waste, a plastic bag can be used to collect the waste. Then it can carefully be transported to where the regulated waste container is located, or the regulated container can be taken where needed. Accurate sorting of trash and regulated waste is cost-effective due to the expense of disposing of regulated waste.

Refrigerators

Refrigerators should be clean and well maintained. There have been no outbreaks or reports of cross-infection due to refrigeration failure in ambulatory care. However, there have been recalls of immunization products, specifically hepatitis B vaccine in early 2001, due to storage temperatures not being maintained.[14] During the 1970s, articles were published on the impotency of vaccines as a result of improper handling.[15]

State regulations should be consulted for any specific temperature monitoring and record-keeping requirements of refrigerators and freezers. General guidelines include:

- Store patient food, medications, and specimens in separate, labeled refrigerators. Glucose beverages may be stored in the medication or the patient food refrigerator, but never in the specimen refrigerator.
- Store all medications at the temperatures indicated by the product labels or package inserts.

- Label the specimen refrigerator with a biohazard label to comply with OSHA regulations.[4]
- Comply with safe temperature ranges for specimen,[16] food,[17] and medication[18] refrigerators and freezers (see Table 7.2).
- Use a thermometer inside each refrigerator and freezer.
- Monitor and chart temperatures at regular intervals, such as each day the clinic is open. Note on the chart the acceptable temperature range. (See Appendix E for sample temperature recording chart.) If the clinic is part of the Vaccines for Children Program administered through state health departments, there may be additional monitoring requirements (http://www.cdc.gov/nip/vfc/default.htm).
- Develop a procedure to follow should the temperatures fall outside the acceptable range. Describe steps to take and who to contact on the temperature log. Consult with drug manufacturing companies or an affiliated pharmacy for how long medications will be safe if outside the acceptable temperature range. Develop alternative storage methods during power or refrigerator failure and post the written procedure for easy access.
- Clean and defrost refrigerators, including staff refrigerators, at regular, defined intervals and when soiled or if a spill occurs. The procedure should be written and include the responsible staff and the cleaning product to use.
- Date patient food and beverages and discard at reasonable time intervals, such as 48 hours after opening. Check for state or local regulations.
- A full refrigerator will retain a constant temperature better than an empty one. Therefore, it may be helpful to place containers of water in refrigerators with extra space. For infection control purposes, label containers with "Water. Not for drinking. Do not remove from the refrigerator. The water needs to stay in the refrigerator to help maintain a constant temperature."

Because many ambulatory sites are not open every day and it may be impractical and cost-prohibitive to install refrigerators with alarms, questions often arise about how to identify power failures. One method is to place a small, water-filled container, such as a paper cup, in the freezer. After the water has frozen, place a coin on the ice. If the refrigerator fails while the clinic is closed, the ice will melt and the coin will stick. Someone must be assigned the duty of checking on the coin the morning after a weekend or holiday closure.

There are no regulations or specific JCAHO standards on staff refrigerators, so common sense should prevail for their cleaning and maintenance.

Toys and Computers

There are many concerns about the risk of cross-infection from toys. Although actual incidence of disease transmission directly linked to toys has been rare, it is known that microorganisms can survive for extended periods of time on environmental surfaces. After a busy morning in a physician's office, one study found that toys appeared unclean, that 10% were contaminated with potential pathogens, and that bacteria were cultured more frequently from soft toys than from hard toys.[19] Another study found higher contamination levels on soft toys, that neither machine washing and drying nor autoclaving were adequate to totally reduce microorganisms on soft toys, and that soft toys in waiting rooms became contaminated much more quickly than hard toys. This study also found that in waiting rooms hard toys that were cleaned weekly or every other week had low total bacterial counts compared with toys cleaned infrequently or not at all.[20]

Professional organizations and publications have made various recommendations; however, there are no definitive standards for toy cleaning. The American Academy of Pediatrics recommends that toys used in day-care settings that are mouthed or contaminated with body secretions should be cleaned, disinfected, and rinsed. Toys frequently touched by infants or toddlers should be cleaned and disinfected daily, and toys used by nondiapered children should be cleaned at least weekly. Soft, nonwashable toys should be discouraged.[21] The Association for Professionals in Infection Control and Epidemiology (APIC) states that in day-care centers only washable toys should be shared, and they should be washed as frequently as possible and at the end of the day.[22] The value of disinfection for toy cleaning has not been proven. Thorough washing with detergent or in a dishwasher will clean and adequately decrease the microbial load on items.[23]

The procedure and frequency for cleaning toys should be practical and based on the patient population. Toys in a very active pediatric practice with many toddlers will need more frequent cleaning than in practices with fewer young children. Safe disinfectants include dilute bleach (1:100), quaternary ammonium hospital-grade disinfectants, and 70% isopropyl alcohol. Phenolics should never be used (see Chapter 3). Small toys should be thoroughly rinsed; if alcohol is used, toys can air dry and need not be rinsed with water. Alternately, small toys can be placed in a mesh bag and run through a dishwasher with standard dishwashing detergent. Large items, such as wall-mounted toys, tables, or playhouses, can be wiped with a disinfectant cleaner on a regular basis.

Written toy-cleaning policies should be developed and include:

- Frequency of routine toy cleaning. May be daily to weekly, depending on intensity of use.
- Types of toys. Soft toys should not be provided; toys should be restricted to those easily cleaned. New soft toys may be given to patients to take home. Books and puzzles are generally seen to pose very little risk and need not be cleaned unless visibly soiled.
- Toy circulation: Moulded and visibly soiled toys should be removed from circulation until cleaned.
- Training: Staff training should be clearly documented.
- Toy cleaning procedure: Should include washing, disinfection or sanitization, and rinsing.
- Cleaning agent to be used: Substance(s) must be nontoxic for children.

Computers are now common in exam rooms and in some waiting rooms. Computer surfaces cultured in intensive care units in hospitals have harbored bacteria that can cause outbreaks, and some types of bacteria can survive for many days on plastic.[24] The risk for actual disease transmission from computers in ambulatory care is presumed to be very low. However, protocols should be developed to include cleaning the keyboard or keyboard cover and mouse with disinfectant cleaner on a regular basis and when soiled. The computer should be located away from potential splashing from the sink. The computer manufacturer should supply information on types of disinfectants that are safe to use on the hardware. Handwashing by staff before and after patient contact can reduce risk further.[25]

Construction

Plans for a new building or renovation of existing areas should be reviewed for infection prevention and control issues. The AIA's "Guidelines for Design and Construction of Hospital and Health Care Facilities" contains broadly applicable standards;[11] however, local and state health department ordinances should also be consulted. Infection control professionals should identify who in the institution is responsible for construction and renovation and should request to review all building plans for ambulatory care sites. Plans need to be reviewed early enough to effect change.

Whether planning for a new building or renovating an existing site, plans should be reviewed to ensure that the following infection control questions are addressed:

1. Are clean storage and soiled utility rooms large enough to accommodate expansion?
2. Will the utility room be close to treatment/procedure rooms for safe, expedient transport of contaminated, used equipment?
3. Are instrument reprocessing activities planned for a separate room rather than in a clean room or in a patient care room?
4. Are soiled utility rooms and instrument reprocessing rooms fitted with adequate ventilation? Do they have a negative pressure relationship to the adjacent corridor? If glutaraldehyde disinfectant will be used, does the room have 15 air changes per hour with negative pressure?[11]
5. Do instrument processing rooms have adequate counter space to accommodate containers of disinfectant and/or a table-top autoclave? Are areas large enough to accommodate mixing of instruments?

Table 7.2 Recommended Storage Temperatures for Refrigerators/Freezers

Type	Refrigerator	Freezer
Specimen	36 to 46°F (2 to 8°C)	−4 to 14°F (−20 to −8°C)
Food	≤ 41°F (≤ 5°C)	≤ 0°F (≤ −17.8°C)
Medication	36 to 46°F (2 to 8°C)	−4 to 14°F (−20 to −10°C) ≤ 57°F (≤ 15°C)

6. Are handwashing sinks located in each examination/treatment/procedure room, all restrooms, the laboratory area, the medication preparation area, and all soiled utility/workrooms?
7. Will hand soap and paper towel dispensers be conveniently located?
8. Will sharps disposal containers be conveniently located?
9. What areas will be carpeted? Carpet is not recommended in laboratory areas or procedure/treatment rooms because it cannot be cleaned effectively.
10. Are environmental surfaces, such as walls, cabinetry, and horizontal surfaces, easy to clean?
11. Is there a lounge area so that staff will not be tempted to eat in patient-care, laboratory, utility, or clean areas?
12. Is there a housekeeping room supplied with a service sink and storage for housekeeping supplies and equipment?
13. If bronchoscopies or other aerosol generating procedures are expected to be performed or if a tuberculosis (TB) patient is likely to be seen (e.g., a pulmonary clinic), are there plans for a negative pressure room? (See Chapter 9.)
14. Are doors and windows secured to prevent entrance of insects, rodents, or other pests?

Renovation

For renovation projects, Dust abatement[11, 26] must be addressed to prevent exposure to airborne mold spores such as *Aspergillus* and *Penicillium*. Infection prevention and control activities during renovation are outlined by APIC.[26] Regardless of the size of the project, overall planning should include at least the following:

- Evaluate whether and how much dust is likely to be generated.
- Arrange for the area undergoing renovation to be contained within plastic sheeting.
- Arrange for air flow and/or filtration to prevent dust from blowing into adjacent areas.
- Arrange for monitoring the area under construction to determine that barriers are in use.
- Arrange for thorough damp mopping or HEPA vacuuming daily, or as needed.
- Outline traffic flow and worksite gaub for contractors.
- Determine whether there are any immunocompromised patients who will need to be rerouted away from the area to avoid potential exposure.

Construction companies accustomed to working with healthcare facilities are often aware of these special needs and include costs for dust abatement.

Remediation

Water damage requires drastic action if not handled expediently.[26] It can occur following heavy rains, plumbing leaks, or excessive condensation. If water is not swiftly removed and damaged items completely dried, microorganisms, especially mold such as *Stachybotrys*, *Aspergillus*, and *Penicillium*, can quickly multiply. Spore numbers increase exponentially and are released into the air. Inhaling these spores in high quantities can cause allergic reactions, dubbed "sick building syndrome," and/or respiratory infections.

As soon as water damage is detected, intervention should begin. Porous materials must be dried within 48 hours to prevent an exponential increase in fungal spores. If this is not possible, often the only way to mitigate the problem is to completely remove all of the flooring, carpeting, wall covering, ceiling tiles, plaster, or wallboard affected. Any paper, such as medical records or office products, must also be inspected for water damage. Because intervention must begin immediately, it is best to develop a plan, including a list of remediation contractors with emergency, non-business-hour contact numbers, before any such occurrence. After water damage, the immediate (within 24 to 48 hours) response should be to:

- Remove wet carpeting, ceiling tiles, dry wall, baseboard, or vinyl wall covering;
- Remove contents and furniture;
- Damp-wipe books and papers exposed to water with sanitizer;
- Damp-wipe smooth surfaces with sanitizer, such as diluted bleach; and
- Provide dehumidification to maintain relative humidity between 30 and 60%. Use dehumidifiers rather than fans, which can aerosolize any fungal spores to an even greater extent.

The type and extent of protective barriers remediation workers will need to wear during the clean-up will depend on whether the water is from rain, clean water lines, or sanitary sewerage lines.

PATIENT CARE ISSUES

Examination of the Patient

- Before physical examination of the patient, the healthcare provider should wash hands[27] or use alcohol-based hand rubs if hands are not visibly soiled. (Review Chapter 5 for additional details.) During a physical examination, Standard Precautions should be followed; Gloves should be worn for contact with mucous membranes or non-intact skin, and hands should be washed immediately after glove removal. Gloves must also be worn for vascular access and phlebotomy procedures[4] (see Chapter 4).
- Depending on symptoms, the patient should be assessed for risk of contagious disease, travel history, or occupational exposure. Clear procedures should be in place to report any suspected outbreaks or reportable diseases to the health department. Unusual and rare infections should also be reported (see Chapter 22).
- Depending on age, underlying illness, or occupation, immunization status should be assessed and immunizations advised when necessary.
- If the patient presents with an infection of a recent surgical site, the surgeon and infection control department where the surgery was performed should be notified and the site cultured for causative microorganism and antibiotic susceptibility. Reporting will assist in surgical site infection surveillance and control.
- If multidose vials (MDVs), such as local anesthetics, are used, the access diaphragm should be wiped with alcohol prior to puncture. A new sterile device should be used for any access to the medication vial. MDVs should be stored at the temperature recommended by the manufacturer. MDVs must be discarded by the manufacturer's expiration date or according to the policies of the institution.
- Medication should be drawn up into syringes immediately before use on individual patients and not batched. Syringes must be labeled with the contents. Medications and immunizations should be prepared in a designated clean area, away from the splash zone around the sink.

There are no published studies linking stethoscopes or other devices, such as otoscope handles or thermometer cassettes, to cross-infection in the ambulatory care setting. However, there is enough evidence to show that stethoscopes become contaminated in use.[28–30] Thus the American Medical Association passed a resolution recommending cleaning of stethoscopes and other handheld instruments, such as otoscopes, between each patient in all healthcare settings[31] or minimally on a "regular basis."[28–30] In a clinic setting, one study showed that 100% of stethoscopes (and 90% of otoscope handles) were contaminated by skin bacteria in a pediatric clinic and that alcohol swabs were effective in reducing bacterial counts.[30] Prepackaged alcohol wipes or pads were determined to be economical and convenient, as well as effective, to wipe these small areas.[28–30]

Infectious Patients

Triage

To prevent spread of airborne infections (e.g., chicken pox, measles, and TB) the clinic or office needs to develop a triage system to assist in recognizing these diseases and then in managing the patients. Information to consider includes:

- How patients make appointments with the clinic: phone calls versus urgent care walk-ins
- Initial encounter with the clinic: where, how, and who assesses the patient
- The most common types of airborne infection (e.g., chicken pox) in a pediatric practice
- Maintaining an up-to date list of staff who are immune to childhood diseases, such as chicken pox, measles, mumps, and rubella
- The risk of seeing a patient with TB; for example, it is higher at clinics caring for the medically underserved, low-income populations, alcoholics, foreign-born, and intravenous drug abusers[32]
- Maintaining confidentiality of the patient's diagnosis

- Whether the practice sees patients where there is a likelihood of children accompanying the patient who might be contagious
- How the information will be communicated to facilitate immediate placement of the patient into isolation precautions

Using the previous criteria, a triage procedure should be developed that can be posted for use by admitting clerks, nurses, or other assigned staff who have initial patient contact. Staff with direct responsibility for administering the procedure should be involved in its development. The triage procedure:

- Should begin at the time the office visit is scheduled.[24] If possible, the office visit should be postponed
- Should be simple enough to administer quickly and unobtrusively to patients.
- Should be posted for easy referral at both intake areas and by phones used to make the appointments.
- Should include key symptoms indicative of airborne infection (rather than diagnoses)
- Should include where to access information on noncontagious rashes (e.g., poison ivy)
- For an exclusively pediatric population, may include whether the patient (or any child accompanying the patient) has had exposure to chicken pox during the past three weeks
- Should be reviewed periodically to ensure procedure is applied consistently and continues to contain relevant information.
- Should be reviewed with clerical intake staff on a regular basis.
- To aid clerical staff, it may be useful to have tissue available at the intake or check-out desks for patients who are coughing and sneezing.

Examples of triage procedure formats include flow sheets, scripts with questions to ask the patients (or their parents or guardians), or information directly on the patient intake form as part of the patient record (see examples in Appendix C).

After a patient is recognized to potentially have an airborne infection, the patient will need to be isolated promptly.[25] The patient should be admitted directly to an examination room through an alternate entrance, if available, and placed into Airborne Precautions (see Chapter 6).

airborne infection spread is highest in primary care clinic setting.

Some general pediatric clinics maintain a separate waiting room for "infectious" cases. Although there has been spread of airborne diseases (measles and TB) in ambulatory care settings[11], there has been no published information on the efficacy in preventing spread by this method.

Diseases that are spread by direct contact (including scabies, lice, impetigo, and diarrheal infections) pose less of a threat for cross-infection in the clinic setting. In most cases, using Standard Precautions and cleaning the environment will be effective in preventing spread.

Development of antibiotic resistant bacteria poses another threat facing health care across the continuum. Vancomycin-resistant enterococci (VRE) have been shown to survive in the environment for an extended time.[26] In the hospital setting, there are recommendations from the Centers for Disease Control and Prevention (CDC) to prevent nosocomial spread.[16] In physician office and clinic settings, spread has not been shown to be an issue; short length of exposure times, lack of invasive procedures, and generally healthier states probably explain why transmission has not been observed. The first case of vancomycin-resistant *Staphylococcus aureus* (VRSA) was confirmed in 2002 in a dialysis patient with a complicated medical history and many healthcare encounters.[27] The consequences of spread of this microorganism are great, the CDC recommends that "in the health-care setting, a patient with VRSA should be placed in a private room and have dedicated patient-care items. Health-care workers providing care should wear gowns, masks, and gloves and use antibacterial soap for handwashing."[21]

Minor Surgery in Examination Rooms

This topic is covered in Chapter 8, including types of procedures, hand antisepsis, and patient preparation. Any equipment or medications should be prepared immediately before the procedure to avoid contamination of the sterile field.

Patient Education

Overall goal of patient education in infection prevention and control are to promote personal health and improve overall public health. As ambulatory care settings provide increasingly complex services, more patient education is needed.[28] Patients should be encouraged to ask health professionals questions about protecting themselves from infections.

There are many passive and interactive means of patient education for general and specific topics, including:

- Handwashing: reminder signs or posters placed in public rest rooms, phlebotomy stations, laboratories, examination, procedure, and toilet utility rooms
- Immunizations for children and adults: posters, brochures
- Influenza: posters, brochures
- Antibiotic resistance: brochures explaining judicious use of antimicrobials and for what conditions antibiotics are ineffective.[13,39,40] A number of organizations publish handouts on this topic; the CDC has extensive information available online, both for the public and for healthcare providers.[41] Antibiotic resistance is increasingly a problem, so it is important to provide pertinent information to patients.
- Human Immunodeficiency virus/Acquired Immunodeficiency syndrome (HIV/AIDS), hepatitis, TB, *Burkholderia cepacia*, sexually transmitted diseases, urinary tract infections, Lyme disease and other infections depending on the demographics of the population served
- Food poisoning: brochures on safe food handling and storage
- Infection potential in popular travel destinations
- Prevention of infection in specific at-risk populations (e.g., diabetics, HIV/AIDS patients, asplenic individuals, and individuals with cystic fibrosis)
- Infection during pregnancy

For specific infections, it is important to assess the overall patient population to determine the most common infectious diseases so that educational resources can be acquired. When patients are diagnosed with an infectious disease or have a procedure that involves post-discharge care, printed information should be reviewed with the patient and phone numbers or Web site addresses provided for concerns that may arise after the patient has left. Many infectious diseases require work restrictions; information provided for healthcare professionals can often be applied to the general population (see Chapter 19).

Resources are published by various public health and private agencies. Web sites as well as printed and audiovisual material from the CDC and from local and state health departments have been reviewed for accuracy and credibility. When consulted, infection control professionals can provide expertise in reviewing educational materials.

Resources for patient education include:

- CDC (*http://www.cdc.gov/health/*)
- State and local Departments of Health
- Infection control departments of hospitals or affiliated medical care facilities
- Food and Drug Administration (*http://www.fda.gov/oc/opacom/hottopics/anti_resist.html*)—for antibiotic resistance
- Food and Drug Administration (*http://www.nal.usda.gov/foodborne/index.html*)—for foodborne infections
- Association for Professionals in Infection Control and Epidemiology (*http://www.apic.org/cons/*)

References

1. HANDI, Handbook for Ambulatory Care. Hallmark Texas, IL: Joint Commission on Accreditation of Healthcare Organizations, 2000-2001.
2. Rinaldi, P. The intensive environment. In: Bennett, J. V., and Brachman, P. S., eds. In: *Hospital Infections*. 4th Ed. Philadelphia, PA: Lippincott-Raven Publishers, 1998: 295-314
3. Weber, D. J., and Rutala, W. Environmental issues and nosocomial infections. Wenzel, R. P., ed. In: *Prevention and Control of Nosocomial Infections*. 3rd Ed. Baltimore, MD: Williams & Wilkins, 1997: 491-514.
4. Occupational Exposure to Bloodborne Pathogens; Needlestick and Other Sharps Injuries; Final Rule. *Fed Reg*. 2001; 66:5317-5325 http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=FEDERAL_REGISTER&p_id=16203.
5. Rutala, W. Disinfection, sterilization, and waste disposal. Wenzel R. P., ed. In: *Prevention and Control of Nosocomial Infections*. 3rd Ed. Baltimore, MD: Williams & Wilkins, 1997: 539-573.
6. Chin, J. Environmental Services. In: *APIC Text of Infection Control and Epidemiology*. Washington, DC: Association for Professionals in Infection Control and Epidemiology, 2000, 72-1-8.
7. Fraser-Bach, C. L., and Jacobs, J. W. Bacterial applications in infection control. Rutala, S. S., ed. In: *Sterilization, Disinfection and Preservation*. 5th Ed. Malvern, PA: Lea & Febiger, 2000: 935-944.

8. Anderson, R. L., Mackel, D. C., Stiles, H. S., and Mallison, G. F. Cleaning in hospitals: An epidemiological evaluation. *J Clin Microbiol*. 1982; 15:408–415.
9. Cassidy, R. M. Gagging is hazardous: An infection control problem? *JAMA*, 1989; 261:2421.
10. Dudley, J. Contamination and Renovation. In: *APIC Text of Infection Control and Epidemiology*. Washington, DC: Association for Professionals in Infection Control and Epidemiology, 2000: 72:1–11.
11. AIA. Guidelines for Design and Construction of Hospital and Health Care Facilities. Washington, DC: The American Institute of Architects and the Facilities Guidelines Institute, 2001: 17, 103–171.
12. Pugliese, G., and Hubbard, G. A. Central services, linens and laundry. Bennett, J. V., and Brachman, P. S., eds. In: *Hospital Infections*. 4th Ed. Philadelphia, PA: Lippincott Raven, 1998: 325–332.
13. McDonald, L. L., Linen Services. In: *APIC Text of Infection Control and Epidemiology*. Washington, DC: Association for Professionals in Infection Control and Epidemiology, 2000: 75:1–4.
14. U.S. Food and Drug Administration. Recalls / Withdrawals. *http://www.fda.gov/cber/recalls.htm*; U.S. Food and Drug Administration. Voluntary Recall of Hepatitis B Vaccine (Recombinant). Engerix-B #122801. *http://www.fda.gov/cber/recalls/gskhep122801.htm*.
15. Krugman, R. D., Meyer, H. C., Doerhoff, R. C., Parkman, P. D., White, J. J., and Meyer, H. M. Longevity of live virus vaccines as a result of improper handling in clinical practice. *J Pediatr*. 1974; 85:817–814.
16. Miller, J. M., and Holmes, H. T. Specimen Collection, Transport and Storage. In: Murray, P. R., ed. *Manual of Clinical Microbiology*. 7th Ed. Washington, DC: ASM Press, 1999: 33–63.
17. Recommendations of the United States Public Health Service Food and Drug Administration. *Food Code*. Section 3-301.16. Springfield, VA: National Technical Information Service, 2001. *http://www.cfsan.fda.gov/dms/fc-2001.html#3-1*.
18. Committee on Infectious Diseases. In: *2003 Red Book*. Elk Grove Village, IL: American Academy of Pediatrics, 2000: 9–16.
19. McKay, T., and Gillespie, T. A. Bacterial contamination of children's toys used in a general practitioner's surgery. *Scottish Med J*. 1991; 43:12–13.
20. Morrison, L., Cookson, P., and Davis, R. Toys are a potential source of cross infection in general practitioners' waiting rooms. *Brit J Gen Practice*. 2002; 52:139–140.
21. Committee on Infectious Diseases. In: *2003 Red Book*. Elk Grove Village, IL: American Academy of Pediatrics, 2003: 116–119.
22. McFarland, L., and Kalra, K. Y. Child Care. In: *APIC Text of Infection Control and Epidemiology*. Washington, DC: Association for Professionals in Infection Control and Epidemiology, 2000: 40–47.
23. Committee on Infectious Diseases and Committee on Practice and Ambulatory Medicine, American Academy of Pediatrics. Infection control in physicians' offices. *Pediatrics*. 2000; 1361–1364.
24. Neely, A. N., and Seng, D. F. Hand microbiology and infection control behaviors to reduce the potential transmission of pathogens to patients via computer keyboards. *J Am Med Informatics Assoc*. 2002; 9:500–508.
25. Dunne, J., Cuder, R. P. D., and Wright, C. P. Methicillin resistant *Staphylococcus aureus* (MRSA) contamination of ward based computer keyboards a surrogate marker for nosocomial MRSA transmission and hands asking compliance? *J Hosp Infect*. 2001; 48:52–53.
26. Barlow, J. APIC State of the art report: The role of infection control during construction in health care facilities. *Am J Infect Control*. 2000; 28:158–169.
27. Boyce, J. M., and Pittet, D. Recommendations of the Healthcare Infection Control Practices Advisory Committee. Guideline for hand hygiene in health care settings. *MMWR*. 2002; 51(RR-16):1–45. *http://www.cdc.gov/mmwr/PDF/rr/rr5116.pdf*.
28. Sandle, M., Mahoney, J. J., Ward, T. A., Bergella, R. C., and Greenson, C. D. Contaminated gastroscopes revisited. *Arch Int Med*. 1996; 156:82–84.
29. Marinella, M., Pierson, C., and Chenoweth, C. The stethoscope: A potential source of nosocomial infection? *Arch Int Med*. 1993; 153:786–790.
30. Wurtz, R., and Wolinsky, R. Microbiologic contamination and cleaning personal medical equipment. *JAMA*. 1998; 280:549–550.
31. Cohen, H. A., Amir, J., Matalon, A., Marzan, R., Hoss, S., and Barzilai, A. Stethoscopes and otoscopes – a potential vector of infection? *Family Practice*. 1997; 14:449–449.
32. Division of Tuberculosis Elimination, Centers for Prevention Services, Centers for Disease Control and Prevention. *National Tuberculosis Training Initiative Core Curriculum on Tuberculosis*. Washington, DC: U.S. Department of Health and Human Services, 1994: 7–8.
33. Committee on Infectious Diseases. In: *2003 Red Book*. Elk Grove Village, IL: American Academy of Pediatrics, 2000: 137.
34. Arias, K. M. Outbreaks Reported in the Ambulatory Care Setting. In: Arias, K. M., ed. *Quick Reference to Outbreak Investigation and Control in Health Care Facilities*. Gaithersburg, MD: Aspen Publishers, Inc., 2000: 105–118.
35. Nathan, G. A., Simon, V., Cooper, I., and Pierson, L. K. Recovery of vancomycin resistant enterococci on fingertips and environmental surfaces. *Infect Control Hosp Epidemiol*. 1995; 16:577–581.
36. Recommendations for preventing the spread of vancomycin resistance. Recommendations of the Hospital Infection Control Practices Advisory Committee (HICPAC). *Am J Infect Control*. 1995; 23:87–94.
37. Influenza-associated deaths among children – United States, 2002. *MMWR*. 2002; 51:365–367.
38. Friedman, C., Hannan, M., Buck, A. S., Hunt, R., Harris, J., and Hoffman, P., et al. Requirements for infrastructure and essential activities of infection control and epidemiology in out of hospital settings: A consensus panel report. *Am J Infect Control*. 1999; 27:418–430.
39. Gonzales, R., Bartlett, J. G., Besser, R. E., and Cooper, R. J. Principles of appropriate antibiotic use for treatment of acute respiratory tract infections in adults: Background, specific aims, and methods. *Ann Intern Med*. 2001; 134:479–486.
40. Gonzales, R., Steiner, J. G., Lum, A., and Barrett, P. H. Decreasing antibiotic use in ambulatory practice: Impact of a multidimensional intervention on the treatment of uncomplicated acute bronchitis in adults. *JAMA*. 1999; 281:1512–1519.
41. Centers for Disease Control and Prevention (CDC). Promoting appropriate antibiotic use in the community. *http://www.cdc.gov/drugresistance/community/*.

CHAPTER 8

Ambulatory Surgery

BACKGROUND

The first surgicenter was opened in 1970. The number of centers and the number of procedures routinely performed in an ambulatory setting have risen dramatically since then.[1] In 1996, 31.5 million ambulatory surgery procedures were performed in the United States.[2] The types of ambulatory surgery sites include laser surgery clinics, plastic surgery centers, surgicenters, physician offices, and oral surgery centers.

An increasing number of "not so minor" surgical procedures have shifted from inpatient to ambulatory care settings. Along with the provision of more intensive ambulatory surgery procedures has come an increase in the risk of health care-associated infections. Types of surgical procedures often performed in the ambulatory setting include ophthalmology procedures, excision of lesions or tissue, muscle/tendon procedures, reduction of fractures, cholecystectomy, and minor procedures in offices.[3]

Adverse infectious events following surgery (for example, surgical site infections (SSI), bacteremia, and pneumonia) result in increased morbidity and increased use of antibiotics. Various studies have been published outlining the risk of site infection associated with ambulatory surgery. These studies focused on various procedures and used different techniques to determine which patients developed SSIs. Infection rates from these studies are summarized in Table 8.1.

Most SSIs result from microbial contamination of the wound during surgery. The microorganisms typically come from endogenous sites, that is, within the patient. Exogenous contamination can result from the operating room environment or surgical personnel. Prevention techniques are aimed at both endogenous and exogenous microbes.

It is suggested that SSI rates for ambulatory procedures are lower than those conducted in hospitals because:[4]

1. Most procedures are either clean or clean-contaminated.[11] These procedures have the lowest risk of infection.
2. Exposure to multidrug-resistant microorganisms is reduced. Patients are not exposed to microbes of other patients as in hospitals.
3. Patients undergoing contaminated or dirty procedures as outpatients are generally at lower risk. Patients who have more risk factors are generally hospitalized.

Reports of outbreaks related to ambulatory surgery procedures are rare (see Table 8.2).

Staff members involved in ambulatory surgery procedures are also at risk for infection due to the potential for blood and body fluid contamination and injuries from sharp items. In one study[16] at least one person was contaminated with blood in half of the procedures. Cuts or needlestick injuries occurred in 15% of the operations. It was noted that longer operations and use of more needles in an operation lead to increased risk for staff.

There are various requirements for practices in ambulatory surgery centers. The Joint Commission on Accreditation of Healthcare Organizations has special standards for ambulatory surgery.[17] The standards focus on patient care, quality, and safety, and they

Diabetes in California Counties

Date Activated: 05/15/2009 (*Last Updated 07/09/2012*)
Contributed By: California Diabetes Program
Author: Guozhong He, PhD, Karen Black, MSIS, Susan Lopez-Payan, Karin Omark, MPH, EdM, and Dean Schillinger, MD

Attached Files (4)

Introduction by Dean Schillinger, MD

As a primary care physician in a safety net hospital, I see patients every day who either have diabetes or are at high risk of developing diabetes. Our patients are the uninsured and the underinsured, the old and the young. Many are poor and their needs are great. I see how diabetes, for many people, can be a devastating disease that can alter their life's trajectory and present a challenge to family caregivers. Over the last 15 years, I have been working with a multidisciplinary team of clinical staff, researchers, and public health experts to develop ways to improve communication about diabetes and improve health outcomes. In 2008, I was able to join the wonderful team of the California Diabetes Program to try and bridge the gap between research and practice and to find ways to scale-up and disseminate successful interventions into population-based solutions.

Diabetes is a complex disease that is sweeping the country. Its prevalence is strongly influenced by social circumstances and social policy and its management by health policy. California has nearly three million people with diabetes, meaning that more than 1 out of 10 adult Californians has diabetes. From 1998 to 2007, the prevalence of diagnosed diabetes rose from 5.5 to 7.6 percent, representing a 38 percent increase in one decade. California has the greatest number of people in the US who are newly diagnosed with diabetes. In 2007, about 7.9 million (29 percent, or nearly 1 in 3) adults in California had prediabetes, a condition that often precedes type 2 diabetes. Prevalence of gestational diabetes (diabetes that occurs in the context of pregnancy) has increased 60 percent in California in just seven years, from 3.3 percent of hospital deliveries in 1998 to 5.3 percent in 2005. In addition, small studies suggest a consistent increase in diabetes among children and youth. California's ethnically diverse population has a higher risk and prevalence of type 2 diabetes. Total health care and related costs for the treatment of diabetes in California alone is about $24.5 billion each year. As such, diabetes in California represents a significant and growing economic drain for families, employers, and communities, especially during these difficult economic times.

This document presents some key diabetes statistics in California counties. Its purpose is to provide background information and facts about diabetes. In California, diabetes data are not captured in one statewide registry. Therefore, we have used data collected from the 2005 California Health Interview Survey (CHIS) and compiled a summary of information for each county. CHIS is the nation's largest state health survey. A randomdial telephone survey conducted every two years on a wide range of health topics, CHIS data give a detailed picture of the health and health care needs of California's large and diverse

population. CHIS 2005 is currently the best data source in terms of county-level information, sub-population analyses, and diabetes indicators. More than 50,000 Californians are surveyed by CHIS. Participants in the CHIS survey are chosen at random and the sample is extensive enough to be statistically representative of California's diverse population. CHIS is especially known for its hard-to-find data on ethnic subgroups.

The information herein can be used by county health departments, community-based organizations, and those providing clinical services to make strategic decisions about their current and future activities. Environmental planners, industry partners, the media, restaurants, schools, parks and recreation services, and many other groups also need to engage with these data to inform their work and modify their activities to help create the conditions in which people can make healthy choices.

Compared to prior years, there are a number of new components to this report and some striking findings worthy of special comment. For this report, we have added annual cholesterol tests, annual eye exams, and annual flu shots received by people with diabetes under the Diabetes and Related Services section; current smoking in the Diabetes Risk Factors section; and a new section, Health Status and Access to Care, which includes history of high blood pressure, high cholesterol, heart disease, type of insurance (Medicare, Medi-Cal, uninsured), and no usual source of care. All data are reported by county demographics in the general adults population and for adults with diabetes, when applicable. All data are reported in percentage rates. The county adult population total and adults with diagnosed diabetes total are provided at the top of each county table. Unlike the previous report, total numbers for each health condition/status are not provided in this report. Readers can easily calculate the total number by simply multiplying the rate with either the county adult population or the diagnosed diabetes population.

Notable findings include:

- especially high rates of diabetes in California's Central Valley;
- high prevalence of being uninsured and having diabetes (especially among the Hispanic/Latino population), and the tremendous county-by-county variation in coverage of uninsured people with diabetes; and
- growing prevalence of diabetes in young adults (ages 18-44) and the behavioral and health access risk profiles that make them particularly vulnerable to developing complications in the prime of their lives. These include especially high rates of con-current tobacco use (20%) and heart disease (8%), high rates of un-insurance (30%), and low rates of receipt of recommended services such as eye exams and influenza vaccination.

The California Diabetes Program serves as a coordinating leader for organizations working to prevent diabetes and its complications in California's diverse communities. We hope you will find these data useful and seek additional resources on our Diabetes Information Resource Center (DIRC) at www.caldiabetes.org.

Download Files:

Click on a link below to save the file to your hard drive.

- Diabetes in California Counties, 2009 *(4.42 MB)*
- Diabetes in California Counties, 2005 *(25.2 MB)*
- Diabetes in California Counties, 2001 *(166 KB)*
- The Burdens of Diabetes in California Counties 2000 *(606 KB)*

California Department of Public Health | Diabetes Coalition of California | University of California, San Frar

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CALIFORNIA WATCH

HEALTH & WELFARE | DAILY REPORT

Californians growing heavier, more obese and diabetic

September 1, 2010 | Joanna Lin, California Watch

Tony Alter/Flickr

Californians are increasingly overweight, obese and diabetic, a study by UCLA researchers found. The epidemics are worsening throughout the state and disproportionately affect ethnic minorities, the poor and the least educated.

More than half of the adults in the state – 15.3 million – are overweight or obese, and more than 2 million are diabetic, according to the report released yesterday [1] by the UCLA Center for Health Policy Research.

In 2001, 19.3 percent of California adults were obese and 6.2 percent were diabetic. By 2007, 22.7 percent were obese and 7.8 were diabetic, the study found.

American Indians, blacks and Latinos have the highest rates of obesity and diabetes, but the rates have increased significantly among whites and Asians as well.

Obesity and Diabetes Prevalence by Race and Ethnicity, Adults Age 18 and Over, California, 2001 and 2007

	Obesity Prevalence			Diabetes Prevalence		
Race/Ethnicity	2001 %	2007 %	Percentage Point Change 2001 to 2007	2001 %	2007 %	Percentage Point Change 2001 to 2007
White	17.5	20.4	+2.9**	5.5	6.7	+1.2**
Latino	25.4*	30.1*	+4.7**	7.1*	9.2*	+2.1**
Asian	5.3*	6.7*	+1.4	5.0	6.4	+1.4**
African American	31.0*	35.0*	+4.0	10.5*	11.5*	+1.0
American Indian	31.0*	32.4*	+1.4	9.6*	14.2*	+4.6
All Adults	19.3	22.7	+3.4**	6.2	7.8	+1.6**

* Indicates significantly different from White, $p<0.05$.

** Indicates significantly different from 2001, $p<0.05$.

Source: 2001 and 2007 California Health Interview Surveys

UCLA Center for Health Policy Research

Lower income and less educated Californians have higher rates of obesity and diabetes, the report said. Nearly 28 percent of adults living below the poverty line are obese, compared to about 20 percent of those with higher incomes. Adults without high school education were twice as likely to be obese and three times more likely to be diabetic than those with college degrees.

Obesity and diabetes were most prevalent in some of California's poorest areas. The rate of obesity is highest in Imperial County, where 39.6 percent of adults are obese. San Francisco had the lowest obesity rate, at 11.8 percent of adults. Diabetes is most prevalent in Tulare, affecting 12.1 percent of adults, and lowest in San Luis Obispo, with 3.1 percent of adults diagnosed as diabetic.

Because of its large population, Los Angeles County has by far the most residents who are obese (1.7 million) and diabetic (642,000). But the prevalence of the conditions vary greatly among the county's communities. Obesity rates range from as low as

12 percent in West LA to as high as 34 percent in South LA, and diabetes rates range from 6.2 percent in West LA to 10 percent in East LA.

The risk of diabetes increases with age, a factor that researchers adjusted for in their report. Even so, the report suggests living in the United States could increase the risk: Immigrants who live in the country 15 years or more have diabetes rates more than three times higher than those who have lived here less than 10 years.

Teens in California are heavier and fatter too: 970,000 adolescents – 27 percent – are obese or overweight.

Obesity and diabetes are closely related conditions that significantly increase the risk for heart disease and other serious medical problems.

California and local governments have enacted a number of policies in recent years to address the obesity epidemic, which comes with a hefty price tag: Researchers estimate that diabetes costs the state $24 billion a year.

The state requires chain restaurants to display calorie information on menus. Nationwide, many restaurants and vending machines [2] will soon have to post calorie counts under new federal health care laws. Sodas and sugary drinks are banned from school campuses [3] in California.

But researchers said their findings underscore the need for more policy and environmental changes that promote physical activity and healthy eating.

The study recommends that school facilities for physical activity be available after school and on weekends, and that communities increase the availability of parks and improve recreational spaces. It also says neighborhoods with low-income residents and ethnic minorities need better access to healthy food options, such as farmers markets and community gardens.

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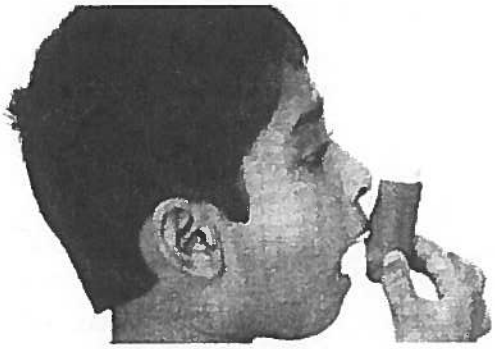
CALIFORNIA WATCH

HEALTH & WELFARE | DAILY REPORT

Asthma hits state's poor the hardest

December 17, 2010 | Christina Jewett, California Watch



Arvind Balaraman/freedigitalphotos.net

Asthma is on the rise in California, and the low-income tend to bear the greatest burden from the condition, according to a report by the UCLA Center for Health Policy Research.

Since 2001, the percent of Californians diagnosed with asthma has increased from 11.3 percent to 13 percent, the study shows [PDF] [1]. Asthma is most common in Central Valley and in Northern California counties, and least common in wealthy and coastal San Francisco.

The report found that asthma tends to be harder on people whose family income fell under about $41,300 for a family of four. Specifically:

- Low-income people went to the emergency room or urgent care twice as often as wealthier people.
- Hospitalization rates for low-income kids and adults was five times higher than for the more affluent.
- Second-hand smoke exposure – which can worsen asthma symptoms – is more than three times more common in low-income homes.

Complicating matters, low-income families were also far more likely to be uninsured and to have no consistent source of medical care.

To address these problems, the study's authors suggest an expansion of health coverage to low-income Californians.

They also suggest that asthma might be better stabilized with high-quality care that involves disease management programs or a "medical home" model [2]. Authors also urged improvement of the housing conditions of low-income people, which can include mold, roaches, second-hand smoke or other irritants.

The study also found [3] that Central Valley counties including Fresno, Merced and Sacramento have higher levels of asthma than coastal counties including Ventura and Monterey.

The UCLA study, based on information from the California Health Information Survey [4], builds on work that the Department of Public Health has done around asthma.

The California Breathing [5] website includes information about asthma triggers and treatment, as well as county-level data about incidence of the condition.

That group issued a report in 2007 about the burden of asthma in California. There was some good news in that report [PDF] [6]: Asthma mortality rates have fallen markedly, from 19.3 deaths per million in 1999 to 13 per million in 2004.

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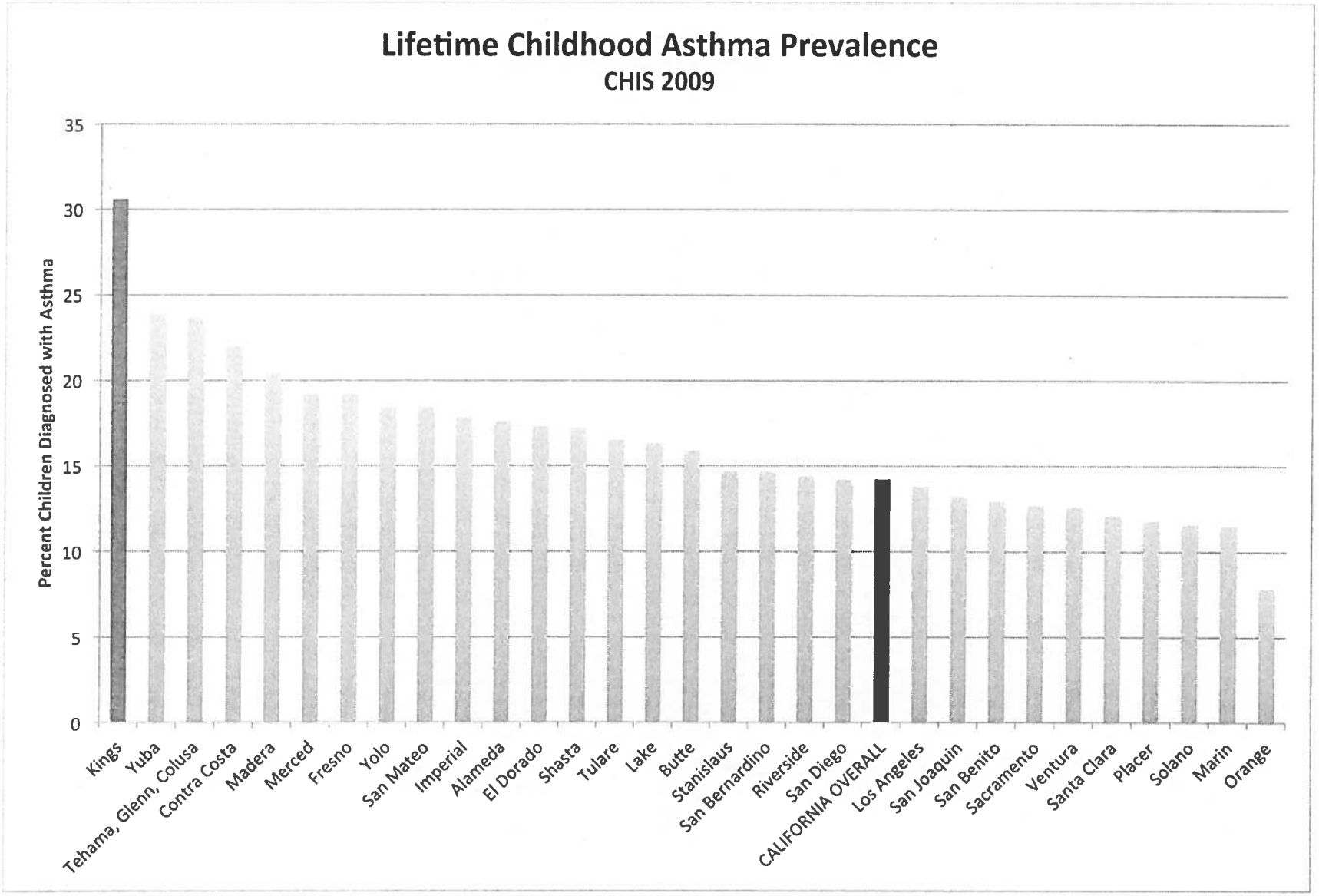
[4] http://www.askchis.org/
[5] http://www.californiabreathing.org/
[6] http://www.californiabreathing.org/phocadownload/asthmaburdenreport.pdf


Lifetime Childhood Asthma Prevalence
CHIS 2009
Percent Children Diagnosed with Asthma
35
30
25
20
15
10
5
0
Kings
Yuba
Tehama, Glenn, Colusa
Contra Costa
Madera
Merced
Fresno
Yolo
San Mateo
Imperial
Alameda
El Dorado
Shasta
Tulare
Lake
Butte
Stanislaus
San Bernardino
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This project committee is responsible for maintaining ANSI/ASHRAE/ASHE Standard 170, Ventilation of Health Care Facilities

FOREWORD

ANSI/ASHRAE/ASHE Standard 170, Ventilation of Health Care Facilities, is one of a family of documents that offers guidance, regulation, and mandates to designers of health care facilities. It is first and foremost a mandatory minimum requirement and, as such, may not always offer the state-of-the-art best practice for health care ventilation design. Other publications, such as the ASHRAE HVAC Design Manual for Hospitals and Clinics, complement the standard, providing additional depth and detail for the designer. In addition, the health care designer must refer to any design requirements from the appropriate jurisdiction that has authority. Many jurisdictions use or refer to Guidelines for Design and Construction of Health Care Facilities, published by the Facility Guidelines Institute (FGI). Where practical, the committee was cognizant of these other documents in the development of this standard.

Ventilation design for health care spaces is a combination of tasks that leads to a set of documents used in construction. One such task requires medical planners to develop departmental programs of spaces. These programs include space names that suggest the use for which the space is intended, and health care ventilation designers depend upon these names to determine the ventilation parameters for their designs. This standard provides these ventilation parameters.

Ventilation systems and designs for health care facilities are intended to provide a comfortable environment for patients, health care workers, and visitors while diluting, capturing and exhausting airborne contaminants including potentially infectious airborne agents such as M. tuberculosis. Without high-quality ventilation in health care facilities, patients, health care workers, and visitors can become exposed to contaminants through normal respiration of particles in the air. Poorly ventilated health care facilities may increase the concentration of airborne contaminants including fungi or mold, which may cause allergic responses in even healthy workers and occupants. Some patients are profoundly immunosuppressed for prolonged periods and if exposed, are highly susceptible to infection from fungi. For such patients, fungal spores become invasive pathogens and lead to high rates of severe morbidity and mortality. For all these reasons, and considering the various occupancies and patient populations, great care must be taken in the design of health care ventilation systems.

(Standard 170 -2008—including all issued addenda—is incorporated into the 2010 edition of the Guidelines for Design and Construction of Health Care Facilities with the exception of Section 4.1 and Section 4.2.)

To view the title, purpose and scope (TPS) of this standard Click Here

This standard is jointly sponsored with ASHE

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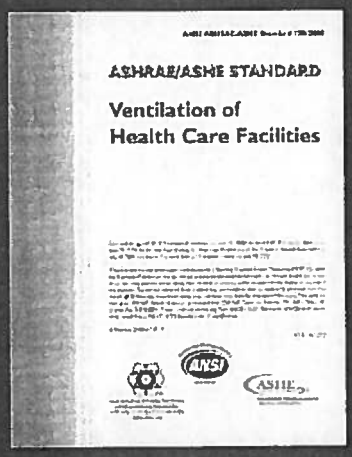

ANSI/ASHRAE/ASHE Standard 170 is under continuous maintenance by SSPC 170 for which the Standards Committee has established a documented program for regular publication of addenda or revisions.

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May 28, 2011

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This web site describes the activities of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) Standing Standard Project Commitee 170 (SSPC 170), Ventilation of Health Care Facilities. It does not present official positions of the Society nor reflect Society policy. ASHRAE is not responsible for this site's content. To learn more about ASHRAE activities on an international level, contact the ASHRAE home page at http://www.ashrae.org. Comments? Contact us at Contact E-mail Address (c)2009, ASHRAE SSPC 170

Airborne Respiratory Diseases and Mechanical Systems for CONTROL OF MICROBES

Airborne respiratory pathogens and diseases in health care facilities are numerous and dangerous. HVAC systems are critical in controlling them.

By W. J. Kowalski, PE, Graduate Researcher, and William Bahnfleth, PhD, PE, Assistant Professor, The Pennsylvania State University, Architectural Engineering Dept., University Park, Pa.

1 Airborne transmission of respiratory diseases in indoor environments remains a problem of indoor air quality (IAQ) with few engineering alternatives and for which performance goals and design parameters are unclear. The engineer who attempts to deal with microbial IAQ finds that pertinent microbiological information exists in abundance but not in easily digestible forms. This article summarizes the relevant literature of medical microbiology and aerobiology in a manner that engineers may find useful and informative and that will facilitate the design of HVAC systems intended to reduce the threat. The general principles presented here can be applied to any indoor environment, including office buildings, schools, residences, hospitals, and isolation wards.

Origin of respiratory diseases

The first indoor environments, built by man over half a million years ago, included caves with leather-draped interiors, fur-carpeted tents, and huts covered with animal hides. Microbial predators existed from time immemorial, but transmission had always required direct contact because they could not tolerate the sunlight and temperature extremes outdoors. Man's cozy new habitats made it possible for these ancient parasites to survive short airborne trips between hosts.

Animal husbandry seems to have resulted in a number of pathogens jumping species and then becoming adapted to indoor transmission to the exclusion of outdoor transmission. These include rhinoviruses, diphtheria, TB, smallpox, measles, and influenza, which appear to have come variously from horses, cows, dogs, pigs, and chickens. Most contagious human pathogens have evolved to such dependence on man's habitats for transmission that they lack any ability to survive outdoors for long.[1]

In contrast, the non-contagious pathogens, including the fungi, environmental bacteria, and some animal pathogens, have maintained the ability to survive in the environment. Even so, direct sunlight is rapidly fatal to almost anything but spores.[1]

Classification of pathogens

Pathogens are any disease-causing microorganism, but the term applies to any microbial agent of respiratory irritation, including allergens or toxigenic fungi. Respiratory pathogens fall into three major taxonomic groups: viruses, bacteria, and fungi. The fungi and some bacteria, most notably the actinomycetes, form spores. Since spores are characteristically larger and more resistant to factors that will destroy viruses and bacteria, the engineer may find it more convenient to consider spores a definitive and separate category.

The single most important physical characteristic by which to classify airborne pathogens is size since it directly impacts filtration efficiency.[2] Fig. 1 presents a graphic comparison of airborne respiratory pathogens in which the spores, bacteria, and viruses can be observed to differentiate well, based on size alone. The left axis indicates the "average" or typical diameter or width. The areas of the circles do not represent the actual sizes of the microbes, but each represents the diameter in proportion to one another. The span of diameters is seen to be almost four orders of magnitude. Some microbes are oval or rod-shaped, and for these only, the smaller dimension is indicated.

[1]*Superscript numerals indicate references listed at end of article.*

This article originally was published in HPAC Engineering in July 1998. Some corrections and slight modifications were made in collaboration with the authors during the republication process.

Perhaps the most important classification is that of communicable versus non-communicable, a distinction that has both medical and engineering relevance. The term *communicable* is synonymous with the term *contagious*. Communicable diseases come mainly from humans, while non-communicable diseases hail mostly from the environment. However, many microbes that are endogenous to humans or are environmentally common may cause opportunistic infections in those whose health has been compromised. These occur primarily as nosocomial, or hospital-acquired, infections. These three categories then define all airborne pathogens:

- Communicable
- Non-communicable
- Primarily nosocomial

Table 1 lists all respiratory pathogens under these three categories, along with major diseases, common sources, and average diameters. In the column identifying microbial group, the term *actinomycetes* refers only to the spore-forming actinomycetes. Some general observations can be made from these charts such as the fact that most contagious pathogens come from humans, most non-contagious pathogens come from the environment, and most primarily nosocomial infections tend to be endogenous. These tables are not necessarily inclusive since a number of pathogens, such as *E. coli*, *Bacillus subtilis*, and some other strains of *Legionella*, can, on rare occasions, cause respiratory disease or allergic reactions.[3] The abbreviation "spp." denotes that infections may be caused by more than one species of the genera but does not imply that all species are pathogenic.

Table 1 lists only respiratory pathogens, although non-respiratory pathogens can also be airborne. Certain infections of the skin or eyes, nosocomial infections of open wounds and burns, and contamination of medical equipment may occur by the airborne route. Although these types of infections have not been well studied, any pathogen that transmits by the airborne route will be subject to the same principles and removal processes described in this article.

Communicable diseases

Table 1 lists all the main respiratory diseases that can transmit between human hosts via the airborne route. Humans are the natural reservoir for most contagious pathogens but some notable exceptions exist. Pneumonic plague and Arenavirus epidemics originate with rodents or other mammals.[1] In regards to the mysterious origin of *Influenza*, humans apparently share the function of natural reservoir with birds and pigs, as strains of this virus periodically jump between species.[3]

continued on page 37

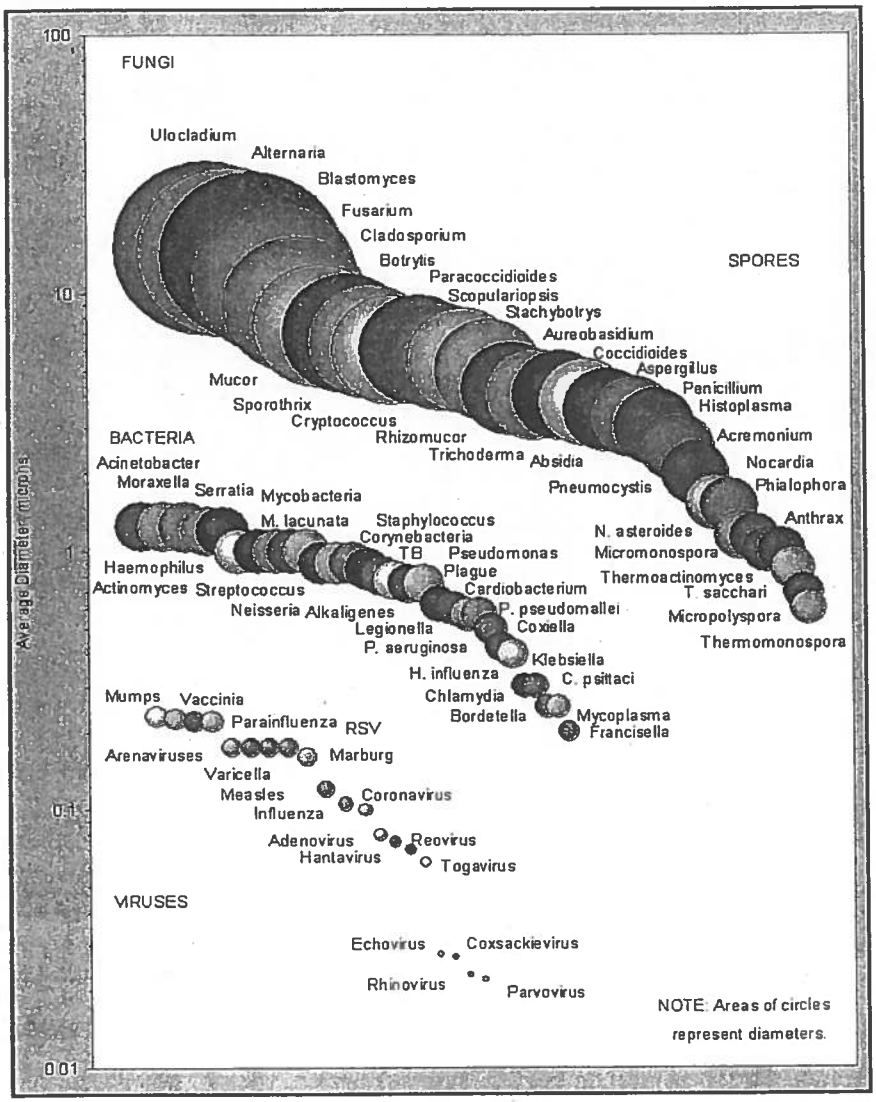

Figure 1. Relative size of airborne respiratory pathogens.

	GROUP			microns	
Adenovirus	VIRUS	colds	Humans	0.06-0.09	
Arenavirus	VIRUS	hemorrhagic fever	Rodents	0.13	F
Coronavirus	VIRUS	colds	Humans	0.08-0.16	
Coxsackievirus	VIRUS	colds	Humans	0.022	
Echovirus	VIRUS	colds	Humans	0.028	
Morbillivirus	VIRUS	measles (rubeola)	Humans	0.12	E, N
Influenza	VIRUS	flu	Humans, birds	0.11	E, N
Parainfluenza	VIRUS	flu	Humans	0.22	E, N
Paramyxovirus	VIRUS	mumps	Humans	0.23	E, N
Parvovirus B19	VIRUS	fifth disease, anemia	Humans	0.022	F
Reovirus	VIRUS	colds	Humans	0.075	
Respiratory Syncytial Virus	VIRUS	pneumonia	Humans	0.22	E, N
Rhinovirus	VIRUS	colds	Humans	0.023	
Togavirus	VIRUS	rubella (German measles)	Humans	0.063	N
Varicella-zoster	VIRUS	chickenpox	Humans	0.16	N
Chlamydia pneumoniae	BACTERIA	pneumonia, bronchitis	Humans	0.3-0.5	N
Mycobacterium tuberculosis	BACTERIA	TB	Humans	0.35	E, N
Yersinia pestis	BACTERIA	pneumonic plague	Rodents	0.75	F

Table 1: Primarily Nosocomial Respiratory Pathogens

AIRBORNE PATHOGEN	MICROBIAL GROUP	DISEASE	SOURCE	Diameter microns	NOTES
Acinetobacter	BACTERIA	opportunistic infections	Environmental	1-3	E, N
Actinomyces israelii	BACTERIA	actinomycosis	Humans	1.0	E, N
Alkaligenes	BACTERIA	opportunistic infections	Humans	0.75	E, N
Bordetella pertussis	BACTERIA	whooping cough	Humans	0.25	E, N
Cardiobacterium	BACTERIA	opportunistic infections	Humans	0.75	E, N
Corynebacteria diphtheria	BACTERIA	diptheria	Humans	1.0	E, N
Haemophilus influenzae	BACTERIA	meningitis, pneumonia	Humans	0.25	E, N
Haemophilus parainfluenzae	BACTERIA	opportunistic infections	Humans	1	E, N
Klebsiella pneumoniae	BACTERIA	opportunistic infections	Environmental	0.4	E, N
Moraxella catarrhalis	BACTERIA	opportunistic infections	Humans	1-3	E, N
Moraxella lacunata	BACTERIA	opportunistic infections	Humans	1	E, N
Mycobacterium avium	BACTERIA	cavitary pulmonary dis.	Environmental	0.2	N
Mycoplasma pneumoniae	BACTERIA	pneumonia	Humans	0.25	E, N
Neisseria meningitidis	BACTERIA	meningitis	Humans	0.8	E, N
Pseudomonas aeruginosa	BACTERIA	opportunistic infections	Environmental	0.5-7	N
Pseudomonas mallei	BACTERIA	opportunistic infections	Environmental	0.7-7	N
Pseudomonas pseudomallei	BACTERIA	opportunistic infections	Environmental	0.5-7	N
Serratia marcescens	BACTERIA	opportunistic infections	Environmental	0.3-1	E, N
Staphylococcus aureus	BACTERIA	opportunistic infections	Humans	1	E, N
Streptococcus pneumoniae	BACTERIA	pneumonia, otitis media	Humans	0.9	E, N, F
Streptococcus pyogenes	BACTERIA	scarlet fever, pharyngitis	Humans	0.9	N
Pneumocystis carinii	Protozoa / Fungi	pneumocystosis	Environmental	2	E, N
Cryptococcus neoformans	FUNGI	cryptococcosis	Environmental	5-7.5	E, N

NOTES:
E = Endogenous, common as human flora
F = Fatalities occur (excluding nosocomial)
HP = Hypersensitivity Pneumonitis
N = Nosocomial, common as (purple blocks)
EAA = Extrinsic Allergic Alveolitis
S = Spores
VOC = Volatile Organic Compounds produced
References: 1, 3, 4, 5, 8

Table 1: Non-Communicable Respiratory Pathogens

AIRBORNE PATHOGEN	MICROBIAL GROUP	DISEASE common (potential)	SOURCE	Diameter microns	NOTES
Hantavirus	VIRUS	hantavirus	Rodents	0.07	F
Poxvirus - Vaccinia	VIRUS	cowpox	Agricultural	0.2-1	
Bacillus anthracis	BACTERIA	anthrax	Cattle, sheep	1-4	S, F
Chlamydia psittaci	BACTERIA	psittacosis	Birds	0.3	
Coxiella burnetii	BACTERIA	Q fever	Cattle, sheep	0.5	
Francisella tularensis	BACTERIA	tularemia	wild animals	0.2	F
Legionella pneumophila	BACTERIA	LD, Pontiac fever	Environmental	0.5-1	E, N
Mycobacterium intracellulare	BACTERIA	cavitary pulmonary dis.	Environmental	0.2	
Mycobacterium kansasii	BACTERIA	cavitary pulmonary dis.	Unknown	0.35	
Micromonospora faeni	ACTINOMYCETES	Farmer's Lung, HP	Agricultural	3	S
Micropolyspora faeni	ACTINOMYCETES	Farmer's Lung, HP	Agricultural	0.75-3	S
Nocardia asteroides	ACTINOMYCETES	nocardiosis	Environmental	0.1-1	E, N
Nocardia brasiliensis	ACTINOMYCETES	pulmonary mycetoma	Environmental	0.5-1	E, N
Nocardia caviae	ACTINOMYCETES	nocardiosis	Environmental	0.5-1	E, N
Thermoactinomyces sacchari	ACTINOMYCETES	bagassosis, HP	Agricultural	0.75-1	S
Thermoactinomyces vulgaris	ACTINOMYCETES	Farmer's Lung, HP	Agricultural	1	S
Thermomonospora viridis	ACTINOMYCETES	Farmer's Lung, HP	Agricultural	0.8	S
Absidia corymbifera	FUNGI	zygomycosis	Environmental	3-8	S
Acremonium spp.	FUNGI	(EAA)	Environmental	2-5	S
Alternaria alternata	FUNGI	mycotoxicosis	Environmental	14-14	S
Aspergillus spp.	FUNGI	aspergillosis, VOC	Environmental	3-5	E, N
Aureobasidium pullulans	FUNGI	chromomycosis, EAA	Environmental	6	S
Blastomyces dermatitidis	FUNGI	blastomycosis	Environmental	14	S
Botrytis cinera	FUNGI	EAA	Environmental	7	S
Chaetomium globosum	FUNGI	chromomycosis, VOC	Environmental	4-5	S
Cladosporium spp.	FUNGI	chromoblastomycosis	Environmental	3	S
Coccidioides immitis	FUNGI	coccidioidomycosis	Environmental	4	E, N
Emericella nidulans	FUNGI	(mycotoxicosis)	Environmental	3-5	S
Epicoccum nigrum	FUNGI	(EAA)	Environmental	20	S
Eurotium spp.	FUNGI	EAA	Environmental	5-7	S
Exophiala jeanselmei	FUNGI	chromomycosis	Environmental	2-6	S
Fusarium spp.	FUNGI	mycotoxicosis, VOC	Environmental	10-15	S
Geomyces pannorum	FUNGI	EAA	Environmental	3	S
Helminthosporium	FUNGI	EAA	Environmental	12-15	S
Histoplasma capsulatum	FUNGI	histoplasmosis	Environmental	3	E, N
Mucor plumbeus	FUNGI	mucormycosis	Environmental	7-15	E, N
Paecilomyces variotii	FUNGI	mycotoxicosis	Environmental	3	S
Paracoccidioides brasiliensis	FUNGI	paracoccidioidomycosis	Environmental	2-3	S
Penicillium spp.	FUNGI	mycotoxicosis, VOC	Environmental	2-3	S
Phialophora spp.	FUNGI	chromomycosis	Environmental	1-15	S
Phoma spp.	FUNGI	mycotoxicosis	Environmental	3-8	S
Rhizomucor pusillus	FUNGI	zygomycosis	Environmental	4-9	S
Rhizopus stolonifer	FUNGI	zygomycosis	Environmental	3	E, N
Rhodotorula spp.	FUNGI	(EAA)	Environmental	14	S
Scopulariopsis spp.	FUNGI	onychomycosis	Environmental	4	S
Sporothrix schenckii	FUNGI	sporotrichosis	Environmental	3-15	S
Stachybotrys spp.	FUNGI	stachybotryotoxicosis	Environmental	5-7	E, N
Trichoderma spp.	FUNGI	mycotoxicosis, VOC	Environmental	4-7	S
Ulocladium spp.	FUNGI	EAA	Environmental	7-8	S
Wallemia sebi	FUNGI	EAA	Environmental	3	S

continued from page 35

Many contagious respiratory pathogens also transmit by direct contact through the exchange of infectious droplets or particles called fomites.[4] The eyes and nasal passages are vulnerable to fomite transmission. The predominance of these direct routes in comparison with the inhalation route has not been well established but can be very species-dependent.[5] Infectivity is also lost upon drying, and therefore hand or surface contact may require the exchange of moisture as well as an infectious dose.[1,6]

Barely 20 pathogens account for the overwhelming number of contagious respiratory infections. Table 2 lists the characteristics of these infections, while the typical course of these infections is depicted in Fig. 2. The infection rate refers to the fraction of those exposed to an infectious dose who contract the disease. This type of information can be useful to engineers attempting risk assessment or procedural control of infectious occupants or patients. Few infectious doses have been established, but for purposes of making rough or conservative estimations, as few as 1-10 TB bacilli can be infectious for humans—while a total of 200 Rhinovirus virions may be required to cause a cold.[4]

Most respiratory parasites induce their hosts to aerosolize large quantities of infectious bioaerosols by nasopharyngeal irritation, which causes coughing and sneezing.[4,5] Consider the profiles of the particle sizes shown in Fig. 3. A single sneeze can generate a hundred thousand floating bioaerosol particles, and many may contain viable microorganisms.[7] A single cough typically produces about one percent of this amount, but coughs occur about 10 times more frequently than sneezes.[7] Bioaerosols produced by talking are negligible, but extended shouting and singing can transmit infections.

Some limited data from Duguid[7] is available in generation rates stating that A TB infective can produce 1-249 bacilli per hr,[8] while a person in the infectious stage of a cold may produce 6200 droplet nuclei per hr containing viable viruses that remain airborne longer than 10 min. In one measles epidemic, 5480 virions were generated per hr.[8]

The dose received from an airborne concentration of microbes could be considered a factor under engineering control since it

TABLE 2: Communicable Respiratory Infection Characteristics

PATHOGEN	Common Disease	Annual Cases (U.S.)	Average Incubation (days)	Infectious Peak (days)	Maximum Duration (days)	Infection Rate (fraction)
VIRUS						
Adenovirus	colds	*	4	4-9	19	0.51-0.75
Coronavirus	colds	*	3	(3-4)	18	0.45-0.5
Coxsackievirus	colds	*	3	3-12	20	0.53-0.64
Echovirus	colds	*	3	(3-4)	18	0.43-0.80
Influenza	flu	200000	2	2-7	21	0.2-0.8
Morbillivirus	measles	25000	12	8-16	29	0.85
Parainfluenza	flu	*	3	3-12	21	0.2-0.75
Paramyxovirus	mumps	10000	17	10-26	39	0.6-0.85
Parvovirus B19	fifth disease	*	6	7-14	28	0.3-0.6
Respiratory Synctial Virus	pneumonia	*	2	5-7	14	0.5-0.9
Rhinovirus	colds	*	2	2-7	7	0.35-0.89
Togavirus	rubella	3000	17	24-31	31	0.3-0.8
Varicella-zoster	varicella	*	15	12-20	25	0.75-0.96
Bordetella pertussis	whpg cough	2000	8	15-22	42	high
Chlamydia pneumoniae	pharyngitis	-	7	7-21	28	0.5
Corynebacteria diptheria	diptheria	490000	3	2-10	10	varies
Haemophilus influenzae	meningitis	8000	3	3-4	(14)	0.2-0.5
Mycobacterium tuberculosis	TB	21000	28	varies	–	0.33
Neisseria meningitidis	meningitis	4500	3	3-4	(21)	high
Streptococcus pneumoniae	pneumonia	500000	2	(2-10)	21	0.1-0.3
Yersinia pestis	pn. plague	14	2	2-3	3	varies

References 3, 4, 5, 8, 13

*(Common respiratory infections are often not reported.)

depends on the local air change rate and degree of mixing as well as the generation rate. The successful transmission of an infection, however, depends on all of the following factors:

- Susceptibility of the individual (immunity).
- Duration of exposure.
- Concentration of infectious agent.
- Virulence of infectious agent.
- Breathing rate.
- Route of infection (inhalation, eyes, nasopharynx, etc.).

None of these factors is necessarily an absolute determinant. Health and degree of immunity can be as important as the dose received from prolonged exposure.

Computations of infectious airborne doses can be fraught with uncertainty. Epidemiological studies on colds avoid these problems by computing actual risks. Fig. 4 shows how duration and proximity to an infectious person can increase the likelihood of infection, based on data from Lidwell's studies of the common cold.[9] These data suggest that there may be a threshold distance beyond which risk decreases sharply. This risk may result from local airborne concentrations but may also include the risk of contact with fomites.

Non-communicable diseases

The list of non-communicable pathogens in Table 1 includes all known that cause respiratory infections, allergic reactions, and toxic reactions. Included among the diseases are EAA and HP (see notes),

continued on page 40

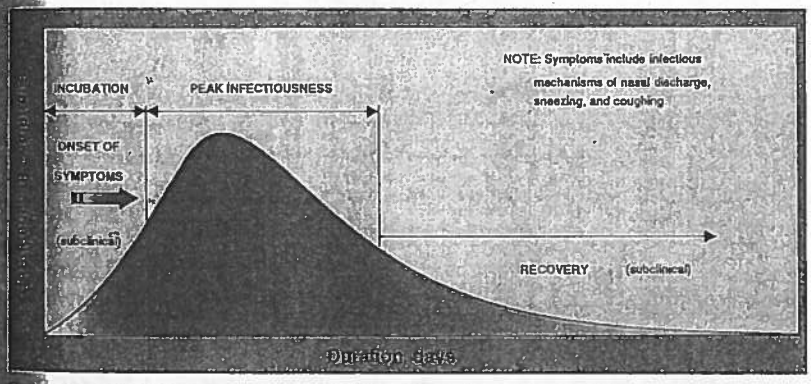

Figure 2. Generic curve for duration of symptoms of respiratory infections

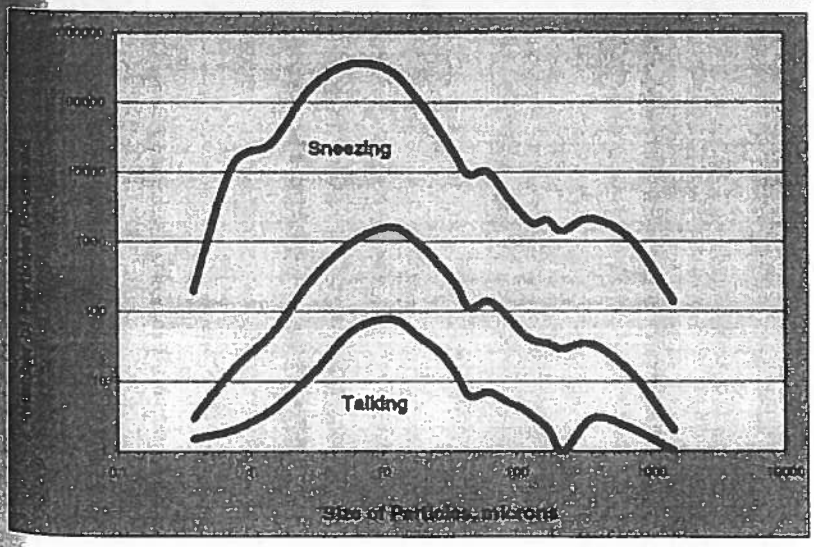

Figure 3. Profile of particle sizes produced by an infectious person.
Based on data from Duguid et al 1945.

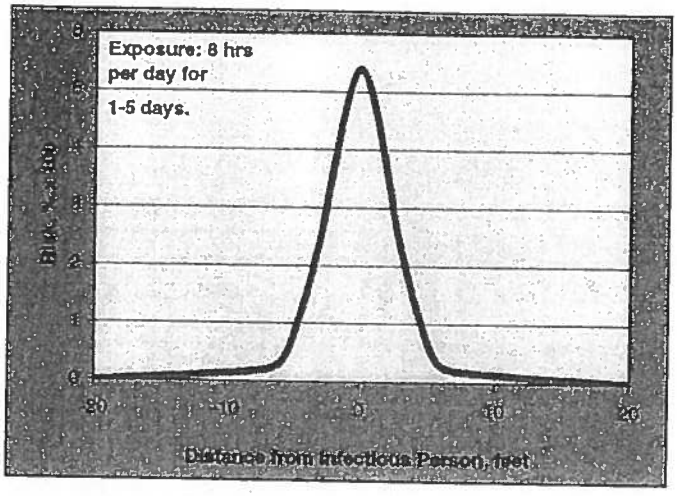

Figure 4. Risk of cold infection from proximity. Risk at zero represents intimate (husband-wife) contact. *Estimated per data from Lidwell.*[9]

continued from page 38

which are sometimes associated with sick building syndrome (SBS). Non-communicable infections are almost entirely due to fungal or actinomycete spores and environmental or agricultural bacteria.

Spores form the most important group of non-communicable diseases. Outdoor spore levels vary with season and climate and can reach very high levels when dry, windy conditions result in disturbance of the soil where fungi grow. Surprisingly, few cases of respiratory infection have ever been attributed to inhalation of outdoor air,[4,5] probably because most people, especially Americans and Europeans, spend over 90 percent of their time indoors.[10] A small proportion of actinomycete infections have occurred outdoors in agricultural facilities, although most tend to occur inside barns and worksheds.[11,12]

Indoor air spore levels can differ from outdoor air in both concentration and composition of spores. In normal, dry buildings, spore levels tend to be anywhere from 10 to 100 percent of outdoor spore levels[11] and are mostly less than 200 colony forming units (CFU) per cu meter. Problem-free, multi-story office buildings typically have levels that are 10 to 31 percent of the outdoor air[11] levels. The composition of fungal species indoors tends to reflect that of the outdoors.[13] Some fungal species, most notably *Aspergillus* and *Penicillium*, are often found to account for 80 percent of indoor spores.[10]

Spores will germinate and grow in the presence of moisture and nutrients[13] in locations such as basements, drain pans, and on refrigerator coils. As a result of such growth, spores can be generated internally in problem buildings, wet buildings, and certain agricultural facilities at a high enough rate to cause indoor spore levels to exceed outdoor levels. If spore concentrations indoors consistently exceed

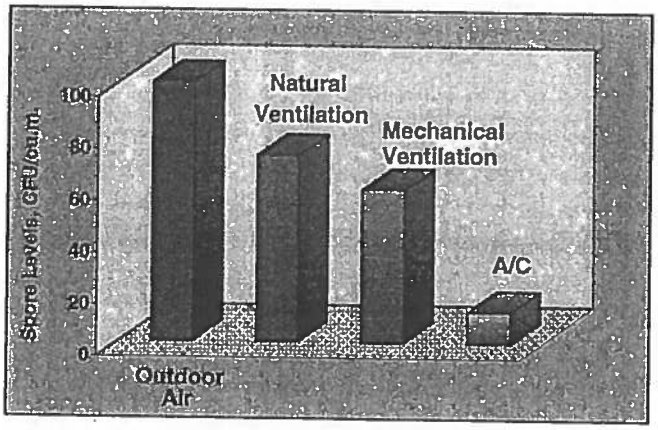

Figure 5. Indoor spore levels by ventilation system type. *From the California Healthy Buildings Study.*[11]

Table 3: Microbial Levels in Indoor and Outdoor Air
(Suggested Guidelines, Upper Limits, Average or Representative Levels)

Microbe	Lower Limit CFU/cu.m.	Average Range		Upper Limit	Qualification	I/O Ratio		Reference
		Low	High			Low	High	
Indoor Fungal Spores*	50	10	500	150		0.1	0.33	14, 12(ACGIH), 10(CG)
(summer)				500				10(CG)
Outdoor Fungal Spores	100	100	1000	-		-	-	11(CHBS), 10
Actinomycete Spores	0	0	150	240	normal homes	-	-	12(Nevalainen), 10
Outdoor Actino. Spores	0	4	-	-	farmhouses	-	-	12(Heineman)
Bacteria, non-pathogenic	50	0	500	50		0.26	1.1	10, 12, 10(ACGIH)
Outdoor Bacteria	-	179	1083	-		-	-	11(Brickus), 12
Pathogenic Bacteria	0		-	0				14(AIHA)
Viruses	0	-	-	0				14(AIHA)

*(when species mix reflects outdoor air)
CG: Canadian Guidelines
ACGIH: American Conference of Government Industrial Hygienists
AIHA: American Industrial Hygiene Association
CHBS: California Healthy Buildings Study

outdoor levels, the building can be inferred to contain an indoor amplifier.[14]

In the California Healthy Buildings Study,[11] naturally ventilated, mechanically ventilated, and air conditioned buildings all had lower indoor spore levels than the outdoors (Fig. 5). However, Fig. 5 may reflect favorable local conditions since many studies have measured much higher levels than these in non-problem buildings.

Table 3 lists the results of various studies that include measurements of outdoor spore levels and typical, average, or representative indoor levels. These levels do not necessarily pose a health threat. Measurements and guidelines vary almost as widely as outdoor levels vary seasonally and geographically.

Microorganisms will take advantage of any opportunity to establish themselves and multiply in a new environment.[4] Niches for microbial growth may be created inadvertently by engineered systems that generate moisture such as humidifiers, evaporative air coolers, cooling coil drain pans, and condensation on ductwork insulation. Amplification may result in airborne concentrations above the outdoors[10] and may reach unhealthy levels.[13] Legionnaire's Disease provides a sentinel example of pathogenic microbial amplification by an engineered system.

Amplifying factors can be controlled through various means, including preventive design through humidity and moisture control. Some other first and second line defensive measures include filtration, the removal of materials that provide nutrients, procedural cleaning and maintenance, and the use of biocidal equipment.

Table 4 identifies fungal pathogens that have been found to grow indoors on various surfaces or in HVAC equipment. Unidentified multiple species (spp.) may not necessarily be pathogenic. Many factors may dictate which pathogens will grow indoors such as climate, indoor materials, degree of human occupancy, hygiene, and moisture levels.[1,8]

Table 5 identifies some pathogenic environmental bacteria that have been found growing indoors or on HVAC equipment. Occasionally, some contagious bacteria disemminated from hu-

Table 4: Fungi That May Grow Indoors

Airborne Pathogen	Indoor Growth		HVAC Equipment Growth	
	Location	Reference	Location	Reference
Acremonium spp.			humidifier water	Heineman (12)
			HVAC fiberglass insulation	(24)
Alternaria spp.	indoors > outdoors	(2)	cooling systems	(22)
	paint mildew	(26)	refrigerator coils	(25)
	carpet dust	Gravesen (23)	filters	Shata (11), (17)
	floor dust	Hoekstra (23)	filters	Neumeister (10)
			dust in ductwork	Valbjorn (11)
Aspergillus spp.	indoors > outdoors	(2)	evaporative air cooler	(23)
	carpet dust	Gravesen (23)	HVAC fiberglass insulation	(24)
	floor dust	Hoekstra (23)	cooling systems, coils	(22)
			fans, filters	Heineman (12), (17)
			dust in ductwork	Sugawara (10)
Aureobasidium pullulans	moist building materials	Pasanen (23)	filters	Shata (11)
	latex painted surfaces	(26)		
Chaetomium spp.			HVAC fiberglass insulation	(24)
			filters	Heineman (12)
			dust in ductwork	Valbjorn (11)
Cladosporium spp.	wet carpet, wet walls	(21)	evaporative coolers	(22)
	moist building materials	Pasanen (23)	HVAC fiberglass insulation	(24)
	latex painted surfaces	(26)	filters	Shata (11)
	floor dust	Hoekstra (23)	HVAC metal surfaces	(19)
	carpet dust	Gravesen (23)	fans, filters	Heineman (12)
			ductwork dust	Sugawara (10)
Cryptococcus spp.	floor dust	Hoekstra (23)		
Epicoccum spp.	indoors > outdoors	Kemp (16)	fiberglass insulation	Morey (11)
Eurotium herbariorum	gypsum-based finishes	Adan (23)		
Exophiala spp.			humidifier water	Heineman (12)
Fusarium spp.	indoors > outdoors	Fouad (16)	filters	Neumeister (10)
	floor dust	Hoekstra (23)	humidifier water	Heineman (12)
Helminthosporium	indoors > outdoors	Kemp (16)		
Mucor spp.	indoors > outdoors	Kemp (16)	fans, filters	Heineman (12), (17)
	floor dust	Hoekstra (23)	dust in ductwork	Valbjorn (11)
Paecilomyces spp.			humidifier water	Heineman (12)
Penicillium spp.	indoors > outdoors	(2)	air conditioners	(22)
	latex painted surfaces	(26)	evaporative air cooler	(23)
	carpet dust	Gravesen (23)	HVAC ducts	(20)
			filters	Pasanen (12), (17)
			fans, humidifier water	Heineman (12)
Phialophora spp.			humidifier water	Heineman (12)
Phoma spp.	paint mildew	(26)	filters	Neumeister (10)
	floor dust	Hoekstra (23)	humidifier water	Heineman (12)
Rhizopus spp.	floor dust	Hoekstra (23)	fans	Heineman (12)
			filters	Neumeister (10)
			dust in ductwork	Valbjorn (11)
Rhodoturula spp.	wet carpet, wet walls	(21)		
	indoors > outdoors	Kemp (16)		
Scopulariopsis spp.	floor dust	Hoekstra (23)	filters	Heineman (12)
Stachybotris spp.	building materials	Scott (16)	fans, humidifier water	Heineman (12)
	moist building materials	Pasanen (23)		
Trichoderma spp.	indoors	(7)	fans	Heineman (12)
	moist building materials	Pasanen (23)	filters	Neumeister (10)
			ductwork dust	Sugawara (10)
Ulocladium spp.	floor dust	Hoekstra (23)	filters	Neumeister (10)
			humidifier water	Heineman (12)
Wallemia sebi	floor dust	Hoekstra (23)	filters	Shata (11)

mans can be found in water, equipment, or in dust, but these are transient occupants and unlikely to grow or survive long outside of human hosts.[1,5]

Nosocomial infections

All respiratory pathogens are potentially nosocomial, but those that occur almost exclusively as nonsocomial infections are listed in Table 1 such as primarily nosocomial respiratory pathogens.

Table 5: Bacteria That May Grow Indoors

Airborne Pathogen	Location of Growth	Reference
Acinetobacter	potable water	Highsmith (8)
Klebsiella pneumoniae	potable water	Highsmith (8)
Legionella pneumophila	potable water	(4)
	cooling towers	(8)
Micropolyspora faeni	home humidifiers	(21)
Pseudomonas aeruginosa	indoors	Strom (11)
	indoor dust	(1)
	potable water	Highsmith (8)
	evaporative air cooler	(23)
	humidifiers	(25)
Pseudomonas spp.	filters	Martikainen (11)
Serratia Marcescens	potable water	Highsmith (8)
Thermoactinomycetes vulgaris	air conditioners	(25)
	humidifier water	Heineman (12)

The other common nosocomial infections are identified with a purple boxed *N* in the notes column.

In intensive-care units, almost a third of nosocomial infections are respiratory, but not all of these are airborne since some are transmitted by contact or by intrusive medical equipment.[15] Nosocomial infections can also be airborne but non-respiratory such as when common microbes like *Staphylococcus* settle on open wounds, burns, or medical equipment.

Patients who succumb to nosocomial infections are often those whose natural defenses have been compromised either as a result of disease, medication, injury, or bypassed by intrusive procedures. In cases of immune system deficiency, even a patient's own endogenous flora could cause infection, while normally benign environmental microbes can become pathogenic.

The protection of patients from potential pathogens requires the reduction of microbial contaminants below normal or ambient levels. This is usually accomplished through the use of isolation rooms, HEPA filters, UVGI, and strict hygiene procedures.[15] In the health care environment, particular attention must be paid to the possibility of microbial growth indoors and in the air handling units, even if levels are not a threat to healthy people. Low-level indoor microbial amplification in health care settings may cause building-related illness (BRI) without actually representing SBS.

Technically, nosocomial infections relate to those who are hospitalized, but health care professionals themselves may be at risk. The Center for Disease Control(CDC) publishes guidelines for control of infections[15] among hospital employees, but appropriate engineering design and maintenance can play a significant role in reducing the risks for medical professionals as well as for patients.

Natural microbial decay

Various environmental factors destroy airborne microbes.[1] Direct sunlight contains lethal levels of ultraviolet radiation. Dehydration renders most microbes inactive, although many spores may survive indefinitely. High temperatures will inactivate all pathogens, some more rapidly than others. Freezing will destroy most pathogens; except that some, especially spores, may be preserved. Oxygen slowly kills most airborne microorganisms through oxidation. Pollution levels that we tolerate our entire lives can be fatal to microorganisms. Plate-out, or adsorption, occurs on all interior building surfaces, but this removal rate tends to be negligible.

Each of these environmental processes reduces pathogen populations according to the following general equation:[1,6]

$$N = N_o e^{-kt} \qquad (1)$$

where

N = population at time t
N_o = population at time $t=0$
k = rate constant for process
e = 2.718

The resulting exponential decay curve is known as a survival curve, or death curve. Often, a very small fraction of the microbial population, usually about 0.01 percent, resists chemical or physical inactivation for extended periods of exposure.[1,16]

This relation applies additively to all reduction processes—except that humidity levels will influence the effects of other factors such as ultraviolet germicidal irradiation (UVGI) and heat on a species-dependent basis. In the outdoors, sunlight, temperature extremes, and wind ensure that non-spore microbial populations decay and disperse rapidly, generally within minutes.[1,16] In the indoors, these factors

continued on page 44

continued from page 42

are controlled for human comfort, resulting in airborne microbes surviving longer, sometimes even days.[1,4]

After expulsion by sneezing or coughing, most large droplets will settle out of the air within a matter of minutes. Fig. 6 illustrates this process and is based on fitted data. Many of the micron-sized droplets will rapidly evaporate to droplet nuclei that approach the size of the individual microbe. Micron-sized particles can remain suspended for hours and spread by diffusion or air currents.[8]

Airborne microbes lose viability over time. In the absence of sunlight, the decay rates for each microbial group, based on rates measured in a variety of studies,[16] are shown in Fig. 7. Curiously, bacteria decay faster in air than viruses apparently because they depend more on moisture for their survival than do viruses.

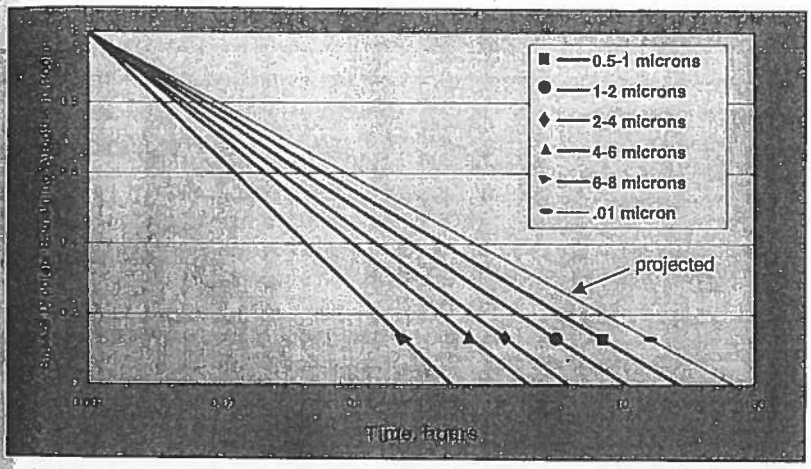

Figure 6. Disappearance of airborne sneeze droplets from room air by size. *Based on fitted, normalized data from Duguid.*[7]

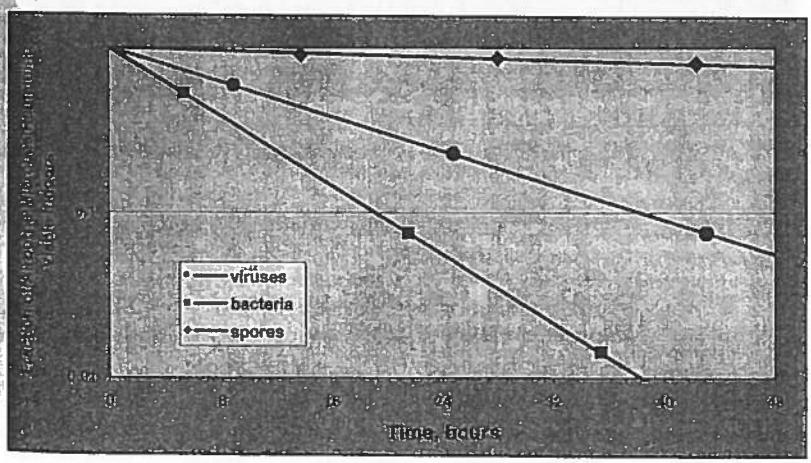

Figure 7. Viability of airborne microbes indoors in absence of sunlight. *Based on averages for each microbial group.*[1,16]

Pathways and dissemination

Fig. 8 illustrates some distinctions between airborne pathogens in relation to a typical air handling unit (AHU). Contagious viruses and bacteria come almost exclusively from humans, and they will appear only in the return air. Spores and environmental bacteria may enter from the outdoors, but once growth (amplification) occurs indoors, they may appear in the return air at higher levels than in the outdoor air. Environmental bacteria are rarely pathogenic for healthy people (Table 1), but they may provide a nutrient source for pathogenic fungi.

Spores can initially enter a building by various routes, including inlet air or infiltration, or they may be brought in with building materials, carpets, clothes, food, pets, or potting soil. In a normal, dry building, the return air will have lower levels of spores than the outdoor air,[11,12] except when snow covers the ground and outdoor spore levels approach zero. When indoor amplifiers are present, the return air could be expected to contain higher levels of spores than the outdoor air, except during dry, windy, summer conditions when outdoor levels of spores can become very high.

Once spores germinate and growth occurs in an AHU or anywhere inside the building, new spores may be generated and appear in the return air. Filters may intercept spores, but moisture may cause them to "grow through" the filter media. Cooling coils can have a pronounced filtering effect on spores,[11,12] but the presence of condensation may also cause microbial growth and amplification[10] downstream of the coils, negating the effect.

Boosting outside air flow may be an option only if the ventilation system is not the source of microbial contamination; in which case, increasing air flow may exacerbate the problem.[11] A fungus problem that is not caused by the ventilation system, such as a leaky roof or wall, requires separate remedial action such as removing the damaged material.[17]

Engineered alternatives

Natural decay mechanisms operate too slowly inside most buildings to prevent secondary infections.[16] Available engineering alternatives include purging with outside air, filtration, UVGI, and isolation through pressurization control. Each of these technologies has advantages and limitations, but optimization for any application is always possible if the microbial IAQ goals are clearly specified.

Pressurization control is commonly used in biohazard facilities and isolation rooms to prevent migration of microbes from one area to another, but inherent costs and operational instability at normal air flow rates limit feasibility for other applications.

Full outside air systems are often used in health care facilities and TB isolation rooms, subject to CDC guidelines.[15] Fig. 9 shows the effect of full purge air flow on the reduction of pathogens in a room with an initial concentration of 100 microbe CFU per cu meter. Comparing this with Fig. 10 shows the results of HEPA filtration at the same recirculation flow rates. The results are practically identical.

The use of HEPA recirculation, of course, carries a lower total energy penalty[2] in hot or cold climates. But in mild or dry climates, high percentages of outside air can prove economical, especially in applications involving evaporative coolers. Hospitals often have commitments to specific guidelines, but other facilities may select and size systems to suit their goals and budgets.

HEPA filters, for example, are not the only choice for controlling microbial IAQ. High or medium efficiency filters are capable of removing airborne pathogens, especially spores, without high operation or replacement costs.[2,16] Overall, particle removal efficiency might be improved by locating medium efficiency filters in the recirculation loop vs. the outside air intakes[16] or even downstream of the cooling coils. But, this choice will depend on each individual system's operating parameters.

Combining purge air with HEPA filtration results in performance that is essentially additive, and cost optimization becomes straightforward. Energy consumption, replacement costs, and microbial IAQ goals will dictate the economic choice for any particular installation.[16] The performance of medium efficiency filters in combination with purge air flow is not directly additive but depends on the filter efficiency vs. particle size curves, the sizes of the pathogens of concern, and the system operating parameters.

UVGI can be an efficient method to use in the right applications such as controlling microbial growth in cooling coils.[18] The continuous exposure appears to inhibit fungal growth and may kill the spores as well. In applications involving the disinfection of air streams, the effectiveness of UVGI depends on factors that include air velocity, local air flow patterns, degree of maintenance, characteristic resistance of the microbes, and humidity.[16] A single pass through a UVGI system may have a limited effect, but recirculation, either through stand-alone units or ventilation systems, will result in multiple exposures or chronic dosing.

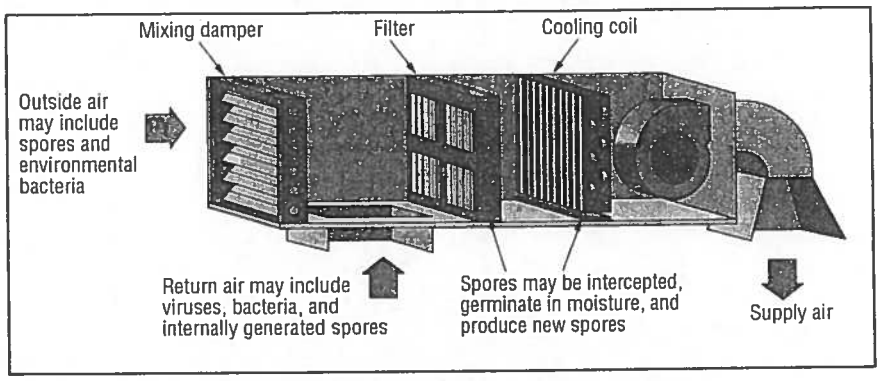

Figure 8. Sources and pathways of microbial contamination in a typical air handling unit.

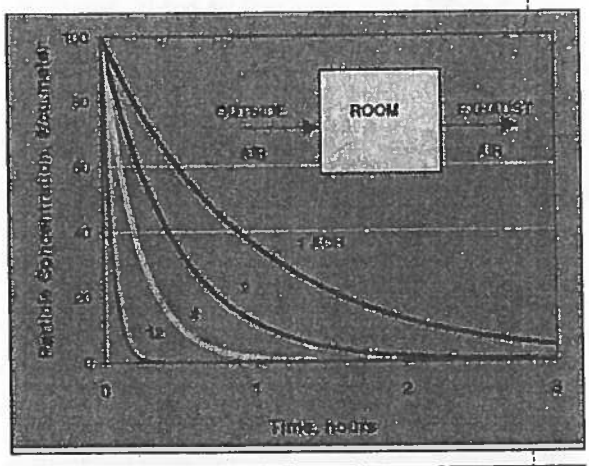

Figure 9. 100 percent outside air: effect of ach on reduction of initial level of room microbial contamination.

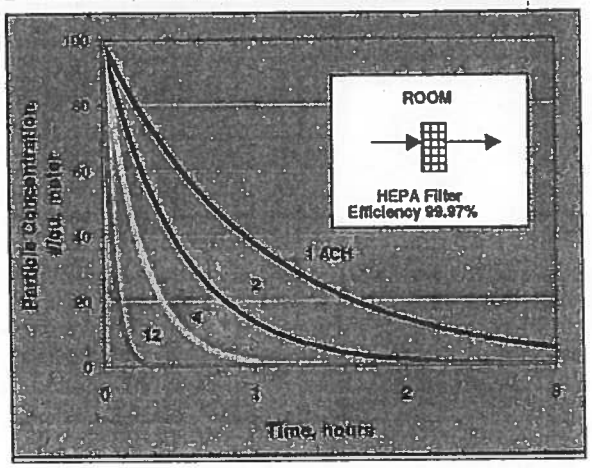

Figure 10. HEPA filter recirculation: effect of flowrate (in ach) on the reduction of initial level of room microbial contamination.

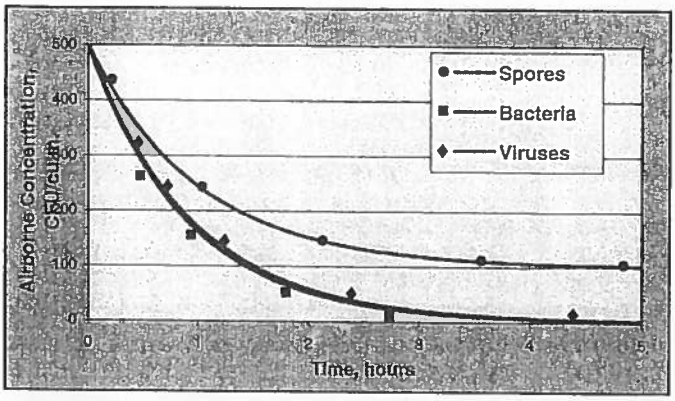

Figure 11. Effects of 25 percent outside air (1 ach) on indoor contaminant levels.[16] Outdoor spore level = 100 cfu per cu meter.

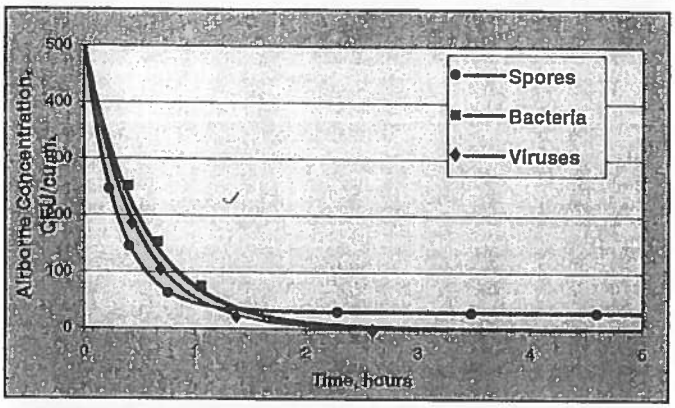

Figure 12. Effect of ASHRAE filter, 80 to 85 percent efficiency on indoor contaminant levels.[16] Recirculation with 25 percent outside air.

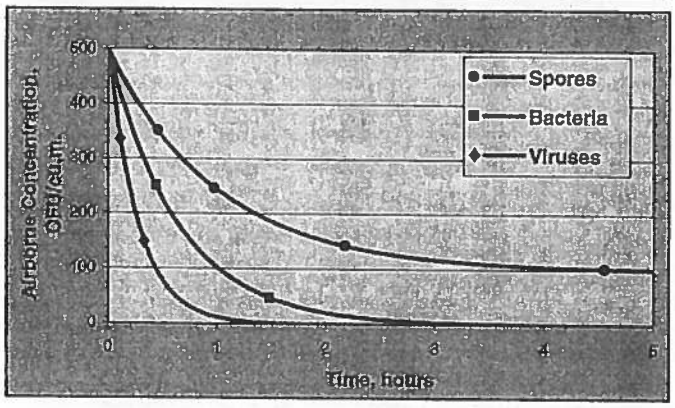

Figure 13. Effect of UVGI on indoor contaminant levels.[16] Recirculation with 25 percent OA. UVGI power mW (W=watt) per sq cm

Chronic dosing with UVGI can have a major impact on airborne viruses and bacteria.[16]

A graphic comparison of the relative effectiveness of the three main alternatives—outside air purge, filtration, and UVGI—is provided in Fig. 11 through 13. Fig. 11 shows the effect of 1 air changer per hr (ach) of outside air on reduction of room air contaminant concentrations from an initial value. Perfect mixing is assumed, along with 500 CFU per cu meter contamination of each microbial group initially, 100 CFU per cu meter of spores in the outside air, and no internal generation. Natural decay rates from Fig. 7 are incorporated in the model. The scenario of an initially contaminated room may not be realistic but provides dramatic differentiation of the effectiveness of pathogen removal.

Fig. 12 shows the effect of an ASHRAE medium efficiency filter (80 to 85 percent dust spot) to the supply air of the model building while maintaining 1 ach of outside air. The filter model describes filter efficiency vs. diameters in accordance with typical vendor performance curves.[16] Spore levels indoors are clearly reduced below outdoor ambient levels. Some reduction of bacteria and viruses can also be noted, but their removal is still dominated by the purging effect of the outside air. The filter used in this analysis provides a baseline for comparison. High efficiency filters, such as the 90 to 95 percent filters used in hospitals,[2] would result in even higher removal rates.

Fig. 13 shows the impact of a UVGI system with 25 μW (W=watt) per sq cm placed in the recirculation loop. The outside air is maintained at 1 ach, but no filters are included. Spores are relatively unaffected by the UVGI, but the viruses are markedly reduced. This model incorporates chronic dosing effects from recirculation with an exposure of 0.2 sec for each pass. The decay rate Equation 1 is applied with known rate constants[16] for a wide cross-section of the microbial species listed in Table 1.

The unusual performance characteristics of each technology have been highlighted in these examples. Inclusion of these characteristics in any evaluation, along with the IAQ design goals, ambient conditions, and internal generation rates, will dictate the choices for any given application—subject only to economic limitations.

Other alternatives

Various current or experimental technologies have the potential for reducing airborne disease transmission or indoor amplification. Biocidal filters can limit or prevent fungal growth on the filter media. Electrostatic filters (*i.e.*, electrets or electrically stimulated filters) are available but have not seen widespread

continued on page 48

continued from page 46

use. Carbon adsorbers have pore sizes too small to remove viruses, but they are effective at removing VOCs produced by some fungi and bacteria.

Other technologies currently under research include low-level ozonation, negative air ionization, and photocatalytic oxidation—a technology that may one day result in a type of light-powered, self-cleaning, microbial filter.

Conclusions

Perfect solutions to the problem of airborne disease transmission do not yet exist, but the available technologies—outside purge air, filtration, and UVGI—can be successfully implemented when their characteristic effects are understood and the goals clearly defined. Whether the application involves improvement of microbial IAQ in an office building or minimizing the risk of infection in an operating room, these technologies can be optimized individually or in combination from a cost or performance standpoint.

Finally, since microbes will never ignore opportunities provided to them, appropriate design, regular surveillance, and maintenance of these technologies in particular, and HVAC systems in general, should always be proactive. HPAC

References

1) Mitscherlich, E. and E. H. Marth. Microbial Survival in the Environment. Berlin: Springer-Verlag, 1984.

2) Burroughs, H. E. "Filtration: An investment in IAQ." HPAC Aug. 1997: 55-65.

3) Freeman, B. A. ed. Burrows Textbook of Microbiology. Philadelphia: W. B. Saunders Co., 1985.

4) Ryan, K. J. ed. Sherris Medical Microbiology. Norwalk: Appleton & Lange, 1994.

5) Mandell, G. L. ed. Principles and Practice of Infectious Diseases. New York: Wiley, 1985.

6) Hers, J. F. ed. Airborne Transmission and Airborne Infection. Proc. of VIth International Symposium on Aerobiology. Technical University at Enschede. The Netherlands: Oosthoek Publishing Company, 1973.

7) Duguid, J. P. "The size and the duration of air-carriage of respiratory droplets and droplet-nuclei." Journal of Hygiene 45: 471-479.

8) Kundsin, R. B., ed. (1980). Airborne Contagion, NYAS, New York.

9) Lidwell, O. M. and R. E. O. Williams. "The epidemiology of the common cold." Journal of Hygiene 59 (1961): 309-334.

10) Woods, J. E. ed. Healthy Buildings/IAQ '97. Proc. of ASHRAE Annual IAQ Conference. Washington, DC, 1997.

11) Godish, T. Sick Buildings: Definition, Diagnosis, and Mitigation. Boca Raton: Lewis Publishers, 1995.

12) Samson, R. A., ed. Health Implications of Fungi in Indoor Environments. Amsterdam: Elsevier, 1994.

13) Burge, H. "Bioaerosols: Prevalence and health effects in the indoor environment." Journal of Allerg. Clin. Immunol. May 1990: 687-781.

14) Rao, C. Y. and H. A. Burge. "Review of quantitative standards and guidelines for fungi in indoor air." Journal of Air & Waste Management. Assoc. Sep. 1996: 899-908.

15) Castle, M. and E. Ajemian. Hospital infection control. New York: John Wiley & Sons, 1987.

16) Kowalski, W. J. "Technologies for controlling respiratory disease transmission in indoor environments: Theoretical performance and economics." The Pennsylvania State University.

17) Kemp, S. J., et al. "Filter collection efficiency and growth of microorganisms on filters loaded with outdoor air." ASHRAE Transactions Jan. 1995: 228.

18) Scheir, R. and F. B. Fencl. "Using UVC Technology to Enhance IAQ." HPAC Feb. 1996: 28-29, 85, 87.

Bibliography

19) Ahearn, D. G., et al. "Colonization by Cladosporium spp. of painted metal surfaces associated with heating and air conditioning systems." Journal of Ind. Microbiol Aug. 1991: 277-280.

20) Chang, J. C. S., K. K. Foarde and D. W. VanOsdell. "Assessment of fungal (Penicillium chrysogenum) growth on three HVAC duct materials." Environment International Apr. 1996: 425.

21) Flanningan, et al. Allergenic and toxigenic micro-organisms in houses. Pathogens in the Environment. Oxford: Blackwell Scientific Publications, 1991.

22) Hyvarinen, et al. "Influence of cooling type on airborne viable fungi." Journal of Aerosol Science 26.S1 (1995): s887-s888.

23) Macher, J. M. and J. R. Girman. "Multiplication of microorganisms in an evaporative air cooler and possible indoor air contamination." Environment International 16 (1990): 203-211.

24) Price, D. L., et al. "Colonization of fiberglass insulation used in heating, ventilation, and air conditioning systems." Journal of Ind. Microbiol. 13 (1994): 154-158.

25) Reynolds, S. J., et al. "Elevated airborne concentrations of fungi in residential and office environments." Am. Ind. Hygiene Association Journal 51 (1990): 601-604.

26) Zabel, R. A. and F. Terracina. The role of Aureobasidium pullulans in the disfigurement of latex paint films. Developments in Industrial Microbiology, Society for Industrial Microbiology, Pittsburgh, 1980.

Guidelines

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(1) Duct linings exposed to air movement shall not be used in ducts serving operating rooms, delivery rooms, LDR rooms, nurseries, protective environment rooms, and critical care units. This requirement shall not apply to mixing boxes and sound attenuators that have special coverings over such lining.

(2) Duct lining shall not be installed within 15 feet (4.57 meters) downstream of humidifiers.

(3) Renovation. If existing lined ductwork is reworked in a renovation project, the liner seams and punctures shall be resealed.

3.1-8.2.4 HVAC Air Distribution

3.1-8.2.4.1 Return air systems. For patient care areas, return air shall be via ducted systems.

3.1-8.2.4.2 HVAC ductwork

(1) General. When smoke partitions are required, heating, ventilating, and air conditioning zones shall be coordinated with compartmentation insofar as practical to minimize the need to penetrate fire and smoke partitions.

*(2) Duct humidifiers

(a) If duct humidifiers are located upstream of the final filters, they shall be at least twice the rated distance for full moisture absorption upstream of the final filters.
(b) Ductwork with duct-mounted humidifiers shall have a means of water removal.
(c) Humidifiers shall be connected to airflow proving switches that prevent humidification unless the required volume of airflow is present or high-limit humidistats are provided.
(d) All duct takeoffs shall be sufficiently downstream of the humidifier to ensure complete moisture absorption.
(e) Steam humidifiers shall be used. Reservoir-type water spray or evaporative pan humidifiers shall not be used.

(3) Fire and smoke dampers

(a) Fire and smoke dampers shall be constructed, located, and installed in accordance with the requirements of NFPA 101, 90A, and the specific damper's listing requirements.
(b) Fans, dampers, and detectors shall be interconnected so that damper activation will not damage ducts.
(c) Maintenance access shall be provided at all dampers.
(d) All damper locations shall be shown on design drawings.
(e) Dampers shall be activated in accordance with NFPA 90A. Installation of switching systems for restarting fans shall be permitted for fire department use in venting smoke after a fire has been controlled. Provisions to avoid possible damage to the system due to closed dampers shall be permitted.

(4) Construction requirements. Ducts that penetrate construction intended to protect against x-ray, magnetic, RFI, or other radiation shall not impair the effectiveness of the protection.

3.1-8.2.4.3 Exhaust systems

(1) General

(a) To enhance the efficiency of recovery devices required for energy conservation, combined exhaust systems shall be permitted.
(b) Local exhaust systems shall be used whenever possible in place of dilution ventilation to reduce exposure to hazardous gases, vapors, fumes, or mists.
(c) Fans serving exhaust systems shall be located at the discharge end and shall be readily serviceable.

APPENDIX

3.1-8.2.4.2 (2) One way to achieve basic humidification may be by a steam-jacketed manifold-type humidifier with a condensate separator that delivers high-quality steam. Additional booster humidification (if required) should be provided by steam-jacketed humidifiers for each individually controlled area. Steam to be used for humidification may be generated in a separate steam generator. The steam generator feedwater may be supplied either from soft or reverse osmosis water. Provisions should be made for periodic cleaning.

3.1-8.2.4.3 (2) See *Industrial Ventilation: A Manual of Recommended Practice*, published by the American Conference of Governmental Industrial Hygienists (www.acgih.org), for additional information.

A History of Plenum Cable Fire Safety Issues

Heard on the Street

THE EVOLUTION OF PLENUM CABLE FIRE STANDARDS AND THE IMPACT OF THOSE STANDARDS ON MATERIAL SPECIFICATION

By Gary Stanitis and Fred Dohmann, Ausimont USA, Inc.

The evolution of building practices during the second half of the 20th century included many general trends. One was the proliferation of very tall "High-Rise" buildings in metropolitan areas. In addition, changes in construction materials, furnishings, and interior decorative finishes have made fire loadings and fire load distributions within buildings change with time. There has been a dramatic evolution of voice and data communications systems and an increase in the routing of voice/data cable air handling plenums. Air handling plenums (the space above the ceiling used for air management) have become more common with the advent of integrated heating ventilation and air-conditioning.

To understand the impact that these changes have had on fire safety, the City of New York can be viewed as a representative population of modern high-rise office buildings. For the first half of the 20th century, even into the late 1960s, lives lost in New York City high-rise fires were few. This changed in 1968 and 1969 with three well-publicized fires, the Time and Life building, the Chemical Bank building, and an architect's office. The architect office fire, which was in a building only five-stories tall, killed ten occupants. In 1970 there was a fire at One New York Plaza and 919 Third Avenue that killed five people. As a response New York City established "Local Law 5", which established a number of requirements for high-rise office buildings for greater fire protection.

In 1975 there was a large fire at One World Trade Center that luckily occurred in the middle of the night when the building was unoccupied. The One World Trade Center fire was analyzed in great detail and a report was issued by The New York Board of Fire Underwriters Bureau of Fire Prevention and Public Relations. The information gathered in this investigation was used to further develop New York City Local Law 5. The following are some of the observations/ conclusions of the report.

"The [exposed] polyethylene (PE) and polyvinyl chloride (PVC) cable insulation and plastic back panel blocks burned readily so that virtually all combustibles including the fire retardant wood paneling on the telephone closet walls of the 10th and 12th floors were destroyed".

"High temperatures in the plenum radiated enough heat into the offices to the north of the fire to melt plastic phones and char papers on desk tops, but ignition did not take place".

"Cables passing from one closet to another closet on the same floor pass through the plenum above the hung ceiling. The exposed cable [1975 PE and PVC compounds] is combustible and constitutes a hazard because fire will be drawn into the plenum and the insulation will intensify the fire at this point".

"The central air conditioning system of itself is not a fire hazard. It is of importance because of its ability to spread smoke throughout a building, to carry the fire from one section to another, and to intensify the fire. Smoke can carry through a system even when it is shut down and create intolerable conditions on other than the fire floor. It is because of this that no combustibles should be allowed in the plenum to create additional heat and additional problems".

"It should be noted, that the mass of cables to supply communications equipment in many office occupancies is sufficient to sustain a substantial fire. While an individual cable is extremely difficult to ignite, a group of cables lying parallel will burn intensely, similar to the situation that exists with a group of logs in a fire".

The quotes listed here, and the One World Trade Center Fire report clearly reinforce the following two

conclusions:

1. *Plenum fire safety must be strongly emphasized because the plenum is an excellent path for both flame and smoke transport throughout a building structure.*
2. *Even in 1975 it was clear that cables placed in plenums were potentially a serious fire risk and selection and installation practices must be developed to manage that risk properly.*

How to address these concerns, both in 1975 and today? Through the evolution of plenum cable fire safety practices.

The Evolution of Plenum Cable Fire Safety Practices

Prior to 1975, the National Electric Code (established by the National Fire Protection, NFPA, no. 70) required that all cables installed in building plenums be either encased in metal raceway or conduit, or have metal sheaths. Three types of metal sheaths were accepted - mineral-insulated metal, metal clad, and armored.

- Although the mandate to place all cables inside of metal protection made fire safety professionals feel comfortable, was it the overall best solution?
- Construction practices must be monitored closely to ensure compliance to the installation standard.
- With the dramatic proliferation of voice and data cables, a huge cost and installation time penalty was required.
- Inability to easily re configure installed voice and data cabling.
- And perhaps the most important issue - placing flammable cables inside conduit does not necessarily prevent their contribution to the fuel load. Most plastics break down into flammable gaseous by products at high temperatures, which can easily vent from joints and fittings in the conduit or sheath.

In 1975 The National Electric Code added the following wording to the cabling standard: "Exceptions to the conduit requirement are provided for communications, power-limited, and fire alarm cables that are listed as having "adequate" fire resistant and low smoke producing characteristics".

Unlike the previous code that identified specific construction details, the added wording specifies a performance requirement. But how does one test for "adequate fire resistance and low smoke producing characteristics" of cables?

To answer this question, in 1979/1980 Underwriters Laboratories, Bell Laboratories, and E.I. du Pont de Nemours cooperated in developing a suitable test method. The apparatus chosen was The Steiner Tunnel; a well recognized large-scale burn apparatus routinely used to evaluate construction material fire safety (ASTM E84). Conditions of the test were established to accommodate cables and their unique flame spread and fire characteristics. Careful attention was paid to establishing a smoke scale that was directly related to human visibility. Work published by R.G. Silversides "measurement and Control of Smoke in Building Fires" and Gross, Loftus and Robertson's "Method for Measuring Smoke from Burning Materials" was used to ensure that smoke obscuration measured in the test related to real room fires.

A variety of cables insulated with PE (polyethylene) and PVC (polyvinyl chloride) compounds were tested both within metal conduit or sheathing to reflect the code practices required at that time. Cables with fluoropolymer primary and jacket insulation were tested without conduit or metal sheathing. The fluoropolymer cables were chosen because fluoropolymers are known to have excellent fire performance (difficult to ignite, low smoke generation, low heat of combustion).

The results of the work had the following conclusions:

- A reproducible test was developed that can be used to quantify and to differentiate the fire and smoke performance of cables.
- The highest smoke-generation and flame spread was generated by PE/PVC cables within metal conduit of metal sheathing, confirming that conduit does not always effectively eliminate the contribution to smoke and flame of the enclosed cable.
- FEP (fluoropolymer) cables not in conduit showed flame spread and smoke generation characteristics comparable to, or less than, conventional PVC and PE cable in conduit, and have been classified by UL as to their fire resistance and smoke producing characteristics per the National Electrical Code.

Thus, from the Underwriters Laboratories/Bell Laboratories/DuPont cooperation came two significant achievements, an accepted test method to qualify cables for plenum service without metal protection, UL 910, and the first plenum rated cables.

THE ACCEPTANCE And EVOLUTION Of UL 910

In the early 1980s the National Fire Protection Agency (NFPA) recognized that the UL 910 test was appropriate and incorporated it into the 90A standard (Standard for the Installation of Air Conditioning and Ventilation Systems).

It is the 90A standard that identifies the fire and smoke properties required for materials to be used I

plenums. During the 1980s the NFPA chose to establish its own test standard identified as NFPA 262. NFPA 262 was written directly from UL 910 with the intent of copying it exactly. By writing a general standard, NFPA opened the door to laboratories other than UL to characterize cables for plenum use. During the 1980s fluoropolymer insulated voice, data, and fire alarm cables became the standard in the industry due to their cost effective installation and rerouting with no compromise of flame spread and smoke generation compared to PVC and PE cables in conduit.

When NFPA 262 was first drafted, exact equivalence to UL 910 was not established. The differences between the documents were not intentional. This issue became apparent in the codes and standards arena in 1997 as companies pushed for cheaper, highly compounded PVCs and polyolefins (polyethylene and polypropylene), to be used in plenums. Because even heavily compounded PVCs and polyolefins (POs) have more marginal flame spread and smoke generation performance than fluoropolymers, there was pressure on the codes groups to weaken plenum standards. Fortunately, rational thought prevailed and the NFPA 262 and UL 910 standards were redrafted to be identical in 1998, and now match the protocol first established in 1979/1980 to characterize plenum cables.

During the effort to harmonize the UL 910/NFPA 262 protocols, and based on other events occurring in the industry, it became apparent that proper installation, maintenance, and operation of the equipment is crucial to achieve high reliability in the UL 910/NFPA 262 test. To assure proper results, a research program was established by the Fire Protection Research Foundation (FPRF) in 1998 to harmonize laboratories performing UL 910/ NFPA 262.

The project, entitled "International UL 910/ NFPA 262 Fire test Harmonization Project", is harmonizing five laboratories globally:

- British Research Engineering, United Kingdom
- Loss Prevention council, United Kingdom
- Underwriters Laboratories, United States
- Intertek Testing Services, United States
- Japan Electric Cable technology Center, Inc., Japan

Additionally, FPRF started a Technical Advisory Council for tunnel operators to ensure continued consistency laboratory to laboratory by meeting regularly and providing a forum to discuss maintenance, calibration, and operational issues.

As recently as the mid-1990s, the validity of the UL 910/NFPA 262 protocol was further demonstrated. The Fluoropolymers Division of the Society of the Plastics Industry (SPI) sponsored a research program at British Research Engineering (BRE) in the UK. The objective was to compare the flame and smoke performance of a variety of cable constructions. Tests were performed both in the UL 910/NFPA 262 test, and also in a full room fire test constructed at BRE. At the completion of the program, DuPont carried out additional work in the same apparatus, and eventually the British Government sponsored a research project that is still ongoing. SPI was expected to publish a paper by the end of 1999. Dupont published results from this work that clearly demonstrate the following:

- "All [UL 910/NFPA 262] results are comparable to the full-scale [full room] results."
- "The fire performance of the exposed CMP [plenum rated] cable was comparable to CMX [non-plenum rated] cable in metal trunking in the BRE full-scale [full room] and Steiner tunnel [UL 910/NFPA 262] tests."

Establishing that even for newer cable designs with new compounds used for insulation, the UL 910/NFPA 262 test still has excellent correlation with a full room fire scenario.

Not All Plenum Rated Cables Are The Same

Despite the excellent fire history and cost effectiveness (compared with metal conduit) of fluoropolymer insulated cables, there has been an unfortunate evolution to lower quality PVC (polyvinylchloride) and PO (polyolefin) compounds for use as primary and jacket insulation on plenum cables. The motivation to use PVC and PO compounds is purely to reduce the cost of cable. No positive benefits ensue. In fact, there are many compromises, such as reduced physical properties, higher smoke generation, higher fuel load contribution, greater moisture permeation, and deterioration with age, that have led to several problems in the industry.

New York City Local Law 5, as mentioned earlier, is written to establish practices to ensure fire safety in commercial high-rise buildings in NYC. Part of this law requires fire monitoring and alarms. Although originally the cables used for fire monitoring required only plenum rating (as determined by UL 910/NFPA 262), a serious problem was encountered. Cables were being produced with highly compounded PVC that were able to pass the fire and smoke test. However, the physical properties of the PVC were so reduced due to large amounts of additives, that during installation the jacket and insulation was being torn, significantly deteriorating the performance of the cable.

To overcome this problem with PVC cables, in the mid 1990s, NYC Local Law 5 was re-written to require cables to have 150 C temperature rating as well as pass UL 910/NFPA 262. Only fluoropolymers are capable of meeting these requirements. Because fluoropolymers are not highly filled, the mechanical properties of

the insulation are much higher and eliminate the installation problems. This strategy has successfully eliminated the problem and remains in effect today.

When PVC compounds are analyzed, it is not hard to see why this problem occurs. PVC, as a material, cannot pass the UL 910/NFPA 262 due to the evolution of thick black smoke. A large quantity of additives must be added to the PVC. In 1996 three commercial PVC cable compounds were analyzed at Ausimont. Results are shown in Table 1. In each case less than 50%by weight of the compound is plastic. The rest is inorganic fillers, fire retardants, plasticizers, and stabilizers. This composition is the explanation for the poor mechanical properties.

Quantified evidence of the poor properties of PVC is given in Underwriters Laboratories UL 444 standard ("Standard for Communications Cable"). UL 444 identifies the physical requirements of plastic materials used in communications cables. PVC compounds are identified as requiring only 2000 psi tensile strength, while a typical fluoropolymer jacket material, ECTFE, has 5000 psi minimum tensile strength. An even more dramatic detail is that the PVC can lose 50% of its properties after only 7 days aging at 136 C. The ECTFE will retain 75% or more of its tensile properties even when aged at 180 C. Therefore, the concern with regard to installation damage is supported by information contained in UL 444. Implied in this same data is the conclusion that damage during re configuration is even greater with compounded PVCs given the fact that they exhibit a significant loss of mechanical properties with age.

A more dramatic consequence of increased use of PVC and PO compounds is the potential of greater flame spread and smoke developed values of cables where these compounds are used. Additionally, although not specifically tested for in UL 910/NFPA 262, PVC and PO have 3 to 6 times the heat of combustion (fire load) as do fluoropolymers. Underwriters Laboratories realized the consequence of gradual transition to more PVC and PO in late 1996. The normal procedure for UL to list a plenum cable is to perform approval testing, and then continue to re-sample and test production samples of the cable on a regular basis to ensure continued compliance. This second activity is called the Follow Up Service (FUS).

Analysis showed that for the 9 years starting in 1988 and ending in 1996, the percentage of cables failing the UL 910/NFPA 262 FUS test increased from 10% to over 50%. Although some failure rate can be expected because of testing variation and cable manufacturing variation, a FUS failure rate of 50% is clearly an indication of a chronic problem. Certainly it is not coincidental that this deterioration in flame and smoke performance occurred during a period when more PVCs and PO compounds were being designed into cable solely for economic reasons. UL responded to the FUS failure problem by convening an industry advisory panel referred to as TAPCOM (Technical Advisory Panel for Communications Cable). Some critical observations/ conclusions from the meetings have been:

- It was found that the UL 910 test apparatus (Steiner Tunnel) had a small leak due to corrosion in the exhaust duct. It is not known how long the leak was present, but certainly for some years. The impact of the leak was to reduce the smoke developed value. Again, it's most likely not a coincidence that the leak was occurring during a time when more PVC and Pos were being used. UL has fixed the leak and the test performance has returned to the more severe screening criteria that it was originally designed to be in 1979/1980.
- UL has hired a statistical process control consultant to help establish and maintain the reproducibility of the test. Conclusions by the consultant are that the test itself does not have an unusually high degree of variation. Never the less, UL has continued to make improvements to further increase reproducibility.
- It was discovered that in some cases cables jacketed with PVC compounds produced more variable smoke developed results depending on humidity (humid cables tended to generate more smoke). This was not true of the fluoropolymer-jacketed cables. Because of this, conditioning requirements have now been specified for cables prior to testing. Unfortunately, cable in a plenum cannot be conditioned before a real fire.
- Cables made with complex compounds are much more sensitive to the conditions by which they are made. Processing of the polymer compounds can cause variation in the chemical reaction that is required to keep PVC and PO from generating dark smoke. Variations in flame spread and smoke generation results from changes in manufacturing speed, location, and tooling. Again, this is not the case when fluoropolymers are used.
- Cables that are made with PVC and PO compounds may pass the requirements of the UL 910/NFPA test, but are typically closer to the failure point than "all" fluoropolymer cables. Because of this UL will be introducing a more severe FUS procedure for cables that perform marginally in smoke and flame. http://www.ausiusa.com/

TABLE 1 - Composition Analysis of Commercial PVC Plenum Compounds Performed in 1996

Weight%	Sample 5C	Sample 7A	Sample 1A
Molybdenum Oxide (MoO3)	2.6	3.2	-
Antimony Oxide (Sb2O3)	0.2	0.3	-
Zinc Oxide (ZnO)	2.1	5.2	-
Lead Oxide (PbO)	2.0	1.3	2.3
Iron Oxide (Fe2O3)	0.3	0.2	-
Magnesium Oxide (MgO)	3.7	-	2.4

Calcium Oxide (CaO)	0.3	0.1	-
Titanium Dioxide (TiO2)	-	-	0.4
Aluminum Oxide (Al2O3)	5.0	13.3	17.0
Plasticizers (aliphatic esters)	2.0	14.0	3.0
Halogen Flame Retardant (Tetrabromo benzene derivative)	7.0	7.0	14.0
Low-Smoke Plasticizer (Alkyl-aryl-phosphate)	8.0	2.0	3.0
Unknowns	23	5.4	8 to 13
Polymer (either PVC or PVC/EVA)	44	48	45 to 50

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