American Council for Accredited Certification

Council-certified Environmental Infection Control Consultant/Investigator (CEICC/CEICI)

and

Council-certified Environmental Infection Control Supervisor/Remediator (CEICS/CEICR)

Optional
Examination Study Guide

Certification Exam Study Guide

Contents

Introduction: Preparing for the CEICC/CEICI and CEICS/CEICR Examinations

Purpose of this Document

This optional study guide provides an overview of topics covered by the CEICC/CEICI and CEICS/CEICR examinations. It is not intended to provide an exhaustive treatment of these topics, nor is this guide the source for any examination item. Exam items are drawn directly from the listed reference texts for this examination, which contain in-depth discussions of each exam topic. Candidates are encouraged to read each reference text in its entirety in preparation for the examination.

Examination Reference Texts

The CEICC/CEICI and CEICS/CEICR examinations are based not upon course curricula, but upon standard industry reference texts such as the following:

- American Council for Accredited Certification, *Code of Conduct* (www.acac.org)
- Centers for Disease Control, *Guidelines for Environmental Infection Control in Health-Care Facilities* (Atlanta: CDC, 2003, updated 2019), (https://www.cdc.gov/infectioncontrol/pdf/guidelines/environmental-guidelines-P.pdf)
- US Code of Federal Regulations, *29 CFR 1910.1030, Bloodborne Pathogens* (https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1030)
- Nancy Bollinger, *NIOSH Respirator Selection Logic 2004* (Cincinnati: NIOSH, 2004) (https://www.acac.org/forms/rclibrary/nioshresp2004.pdf)

Examination Topics

The closed-book CEICC/CEICI and CEICS/CEICR examinations cover **four topic areas** relevant to environmental infection control consulting and remediation:

1 Infectious diseases and their modes of transmission

1.1 Apply scientific knowledge of infectious diseases and their modes of transmission to infection control activities.

2 Principles of Infection Control During Construction, Demolition and Renovation

2.1 Understand the impact of HVAC systems on infection control during construction, demolition and renovation activities.

2.2 Understand the impact of filtration systems on infection control during construction, demolition and renovation activities.

2.3 Understand the impact of UV air cleaning systems on infection control during construction, demolition and renovation activities.

2.4 Understand the behavior of conditioned air in occupied spaces and its impact on infection control during construction, demolition and renovation activities.

2.5 Understand the impact of water systems on infection control during construction, demolition and renovation activities.

3 Infection Control Project Management (CEICC exam only)

3.1 Assemble an interdisciplinary project management team for purposes of infection control during construction, renovation and demolition.

3.2 Assemble an Infection Control Risk Assessment (ICRA) panel

3.3 Perform an Infection Control Risk Assessment (ICRA) for use during construction, renovation and demolition activities.

4 Effective Infection Control Practices

4.1 Conduct appropriate and effective containment engineering during construction, renovation and demolition activities.

4.2 Implement appropriate infection control practices for air handling systems during construction, renovation and demolition activities.

4.3 Conduct appropriate and effective environmental sampling during construction, renovation and demolition activities.

4.4 Implement appropriate infection control practices in Protective Environment (PE) rooms, Airborne Infection Isolation (AII) rooms and Operating Rooms (OR) rooms during construction, renovation and demolition activities.

4.5 Implement effective infection control practices for water handling systems during construction, renovation and demolition activities.

4.6 Employ effective infection control measures during cleanup activities.

Recommended Study Procedures

To prepare for the CEICC/CEICI or CEICS/CEICR examinations, first read the reference texts listed above, using this document as a guide. Then review the following sections from each text in more detail:

WARNING: Limiting your study to only the following pages will put you in danger of failing the exam. The following references are EXAMPLES of pages where exam topics are discussed. Exam items may be drawn from these or other pages. The exam assumes a comprehensive knowledge of each reference text.

1. **CDC, *Guidelines for Environmental Infection Control in Health-Care Facilities* (2003, revised 2019)**

   Pages 17, 19, 20, 23, 24, 27, 28, 29, 30, 31, 32, 33, 35, 37, 38, 39, 40, 44, 45, 48, 49, 50, 51, 54, 55, 56, 60, 61, 63, 64, 65, 73, 86, 101, 133, 134, 135, 136, 137, 138, 139, 147, 148, 152, 224, 225, and 226.

   Boxes 4 and 7.

   Tables 1, 3, 6, 7, 8, 9, 10, 15, and B.2.

2. **ACAC, Code of Conduct**

   https://acac.org/about/code_of_conduct.aspx

3. **29 CFR 1910.1030, *Bloodborne Pathogens***

   Sections (b), (c), (d), (e), (f), (g), and (h).

4. **NIOSH, *Respirator Selection Logic* (2004)**

   Pages 1, 4, 5, 8, 13, 17, 19, 20, and 22

Topic 1: Infectious Diseases & Their Modes of Transmission

Successful certification candidates can apply scientific knowledge of infectious diseases and their modes of transmission to infection control activities.

There are several categories of infectious diseases associated with healthcare and other institutional settings:

- Aspergillosis and Other Airborne Fungal Diseases
- Tuberculosis and Other Airborne Bacterial Diseases
- Airborne Viral Diseases
- Legionellosis and Other Waterborne Bacterial Diseases

Aspergillosis and Other Fungal Diseases

Aspergillosis is caused by molds belonging to the genus *Aspergillus*. *Aspergillus* species are pathogens associated with dusty or moist environmental conditions and are ubiquitous, occurring in soil, water and decaying vegetation. Aspergillosis spreads primarily through airborne transmission of fungal spores, direct inhalation and/or direct inoculation from environmental sources.

Aspergillosis and other fungal-related infections can occur during construction, renovation, remodeling, repair and/or demolition activities. Containment of aerosols at the source is thus the most important engineering control for preventing the spread of these pathogens. Aspergillosis infection can cause pneumonia; ulcerative tracheal bronchitis; abscesses of the lungs, brain, liver, spleen and kidneys; thrombosis of the blood vessels; sinusitis and chronic pneumonitis.

Other fungal pathogens that may be encountered in the healthcare and institutional settings include *Mucorales/Rhizopus* species, *Scedosporium* species, *Pennicilium* species, *Acremonium* species, *Cladosporium* species, *Sporothrix*, *Cryptococcus neoformans*, *Histoplasma* capsulatum and *Pneumocystis carinii*.

Tuberculosis and Other Bacterial Diseases

Tuberculosis is most commonly associated with airborne transmission of *Mycobacterium tuberculosis* via "droplet nuclei", the residuals of droplets that contain the pathogen and can remain suspended indefinitely in the air.

Pulmonary tuberculosis is a disease of the lungs, airways, or larynx. Extra pulmonary tuberculosis can affect any organ system or tissue. Tuberculosis is highly contagious. Populations at greatest risk for tuberculosis include immunocompromised persons, medically underserved persons, substance abusers, foreign-born persons from areas with high prevalence of TB and healthcare workers.

Other bacterial pathogens associated with healthcare-related infections include Gram-positive cocci such as *Staphylococcus aureus* and *Bacillus* species, and the Gram -negative *Acinetobacter* species.

Few other Gram-negative bacteria are associated with episodes of airborne transmission because they generally require moist environments for persistence and growth. However, aerosols generated from showers, faucets, cooling towers and decorative fountains may potentially contain *Legionellae* and other gram-negative waterborne bacteria such as *Pseudomonas aeruginosa*. Direct contact with water is the most common mode of transmission of infections related to these bacteria; thus, infection control measures for these pathogens center on the quality of water.

For more information, see the CDC publication *Guidelines for Preventing the Transmission of M. tuberculosis in Healthcare Settings* (2005) at https://www.cdc.gov/mmwr/pdf/rr/rr5417.pdf.

Viral Diseases

While some human viruses can be transmitted via droplet nuclei, very few viruses are consistently airborne. As a result, healthcare-associated outbreaks of airborne viral disease are limited to a few agents, such as measles (rubeola) and Varicella-zoster (VZV).

Other viral pathogens that are associated with healthcare-related exposure are more often spread via droplet nuclei, and include influenza, respiratory syncytial virus (RSV), smallpox and adenoviruses.

Legionellosis and Other Waterborne Bacterial Diseases

Legionellosis is the term describing the infection produced by *Legionella* species. Legionellosis can produce two clinical syndromes/diseases: Pontiac fever, which is a milder influenza-like illness, and Legionnaires disease, a progressive pneumonia that may be accompanied by cardiac, renal and gastrointestinal involvement.

Legionella species are commonly found in various natural and man-made aquatic environments. Legionellosis is transmitted by aspiration of water, direct inhalation or water aerosols. Cooling towers, evaporative condensers, heated potable water distribution systems and locally produced distilled water can provide environments for the multiplication of legionellae. Infection can occur through exposure to contaminated aerosols generated by showers, faucets, respiratory therapy equipment and room air humidifiers. Temperatures above 77°F, stagnation, and the presence of certain free living aquatic amoeba that can support intracellular growth of legionellae are all factors in the colonization in amplification of the pathogen.

In addition to *Legionella* species, *Pseudomonas* aeruginosa and *Pseudomonas* species are among the most clinically relevant, gram-negative, healthcare-associated pathogens identified from water. These pathogens have minimal nutritional requirements and can tolerate a wide variety of physical conditions. They are transmitted by direct contact with water and/or inhalation of water aerosols. They can also be transmitted by indirect transfer from moist environmental services in the hands of healthcare workers.

Other gram-negative bacteria associated with water and moist environments include *Acinetobacter* species, *Burkholderia cepacia*, *Stenotrophomonas maltophlia*, *Ralstonia pickettii*, *Serratia marcescens and Enterobacter spp*.

Topic 2: Principles of Infection Control

Successful certification candidates have mastered the following examination topics:

2.1 Understand the impact of HVAC systems on infection control during construction, demolition and renovation activities.

2.2 Understand the impact of filtration systems on infection control during construction, demolition and renovation activities.

2.3 Understand the impact of UV air cleaning systems on infection control during construction, demolition and renovation activities.

2.4 Understand the behavior of conditioned air in occupied spaces and its impact on infection control during construction, demolition and renovation activities.

2.5 Understand the impact of water systems on infection control during construction, demolition and renovation activities.

2.1 HVAC Systems

HVAC systems in health-care and other facilities are designed to perform several functions:

- Maintain indoor air temperature and humidity at comfortable levels
- Control odors
- Remove contaminated air
- Facilitate air handling requirements in order to minimize the risk for transmission of airborne pathogens

HVAC systems typically include the following components:

- Outside air intakes.
- Filters.
- Humidity modification systems.
- Heating and cooling equipment.
- Fans.
- Ductwork.
- Air exhaust systems.
- Registers, diffusers and grilles for distribution of air.

In a typical HVAC system, outdoor air and recirculated air pass through air cleaners or filter banks, where the concentration of airborne contaminants is reduced. Air is then conditioned for temperature and humidity before it enters the occupied space as supply air. Return areas generally exhausted from the system, though a portion is recirculated with fresh incoming air. The occupied space is also subject to infiltration (air leakage inward) and exfiltration (air leakage outward) through cracks and interstitial spaces of walls, floors and ceilings.

HVAC systems can be used as engineering controls to contain or prevent the spread of airborne contaminants through local exhaust ventilation, commonly referred to as "source control." HVAC systems can also be used to contain or prevent the spread of airborne contaminants through general ventilation, which encompasses dilution and removal of contaminants via distribution of filtered air as well as manipulation of pressure relationships.

2.2 Filtration Systems

Filtration is the physical removal of particulates from air, and is the primary means of cleaning the air in healthcare and other institutional settings. Effective filtration is the first step in achieving acceptable indoor air quality.

There are five basic filtration methods (listed in ascending order of efficiency):

- Straining.
- Impingement.
- Interception.
- Diffusion.
- Electrostatic filtration.

In a typical HVAC system, outdoor air usually passes through two banks of filters. ASHRAE standad 170 recommends that the first filtration bank in a healthcare facility HVAC system carry a MERV 7 rating. The second filter bank usually consists of high-efficiency filters such as HEPA filters, which are at least 99.97% efficient for removing particles greater than or equal to 0.3 µm in diameter.

Since filters are a critical component of any HVAC system, filter maintenance is an important consideration for overall indoor air quality. All filters should be regularly monitored and replaced according to manufacturer's recommendations. Poorly maintained filters have been implicated in outbreaks of diseases such as aspergillosis in the institutional setting.

2.3 UV Air Cleaning Systems

Ultraviolet germicidal irradiation (UVGI) can be effective in reducing the transmission of airborne bacterial and viral infections in institutional setting. UVGI is most often used as a supplemental air cleaning measure. In a typical UVGI application, low pressure mercury vapor lamps that emit radiant energy are placed inside return air ducts were exposure to occupants is very low.

UVGI has only a minimal inactivating effect on fungal spores. It is not recommended as a substitute for HEPA filtration, local exhaust of air to the outside or negative pressure.

Research has demonstrated that UVGI is effective in killing or inactivating *M. tuberculosis* under experimental conditions and in reducing transmission of other infectious agents in hospitals, military housing, and classrooms. UVGI has been recommended as a supplement or adjunct to other TB infection-control and ventilation measures in settings in which the need to kill or inactivate M. tuberculosis is essential. UVGI alone does not provide outside air or circulate interior air, both of which are essential in achieving acceptable air quality in occupied spaces. For more information on the use of UVGI, see the CDC guidance at https://www.cdc.gov/mmwr/pdf/rr/rr5417.pdf, pp. 69-74.

2.4 Conditioned Air in Occupied Spaces

After outdoor air passes through the initial filter banks of an HVAC system, it is conditioned for temperature and humidity before passing through high-efficiency or HEPA filtration.

Temperature

Optimal air temperature in the institutional setting is usually achieved by a single duct or dual duct HVAC system. A single duct system distributes cold air throughout the building and then reheats it to the desired temperature by means of thermostatically controlled reheat boxes located in terminal ductwork. A dual duct system delivers cold and hot air to a mixing box in each room or group of rooms.

Humidity

There are several measures of humidity used to characterize the amount of water vapor in air, including:

- Relative humidity, defined as the ratio of the amount of water vapor in the air to the amount of water vapor the air can hold at a particular temperature.
- Specific humidity, defined as the ratio of the mass of water vapor in a quantity of moist air to the mass of the moist air.
- Dewpoint, defined as the temperature at which water vapor in a quantity of air condenses into liquid or solid form.

It is extremely important to control relative humidity levels in occupied spaces, since relative humidity levels above 60% can promote fungal growth. HVAC systems usually manipulate relative humidity levels by water wash mechanisms (where water is sprayed into filtered air) or steam humidifiers (where steam is added to filtered air in humidifying boxes). Reservoir type humidifiers and cool mist humidifiers should be avoided, because they can disseminate aerosols containing allergens and other microorganisms. The Centers for Disease Control suggests that refraining from cycling the HVAC system on and off can help prevent elevated humidity in health-care facilities and other buildings.

Ventilation

Next to source control, ventilation is the most effective way to control indoor air pollution. In healthcare facilities and other buildings, ventilation is often measured in terms of room air changes per hour (ACH). The most efficient particle removal in occupied spaces occurs at a ventilation rate of 12 ACH – 15 ACH, although optimal ventilation rates will vary according to room usage.

Healthcare facilities and other buildings generally use a combination of fresh and recirculated air. Though some hospitals not served by central HVAC systems use through the wall air-conditioning units for room ventilation, the Centers for Disease Control recommends the use of central air handling systems to meet outdoor air requirements.

Some facilities use laminar airflow ventilation systems, which are designed to move air in a single pass, usually through a bank of HEPA filters, in a one-way direction through a clean zone. These systems have been used in Protective Environment (PE) rooms to help protect high-risk patients from exposure to airborne contaminants. Laminar airflow ventilation systems are expensive to install, however, and data that demonstrate their benefits are lacking.

Pressurization

The terms "positive pressurization" and "negative pressurization" refer to the pressure relationships between adjacent air spaces. Air flows away from areas with positive pressure (pressurized) and toward areas with negative pressure (depressurized).

Maintaining proper pressure relationships between areas of a facility is crucial to controlling the flow of airborne contaminants and achieving optimum indoor air quality. For this reason, the Centers for Disease Control recommends the use of sealed windows in healthcare facilities and other buildings to ensure the efficient operation of central HVAC systems.

Airborne infection isolation (AII) rooms should be set at negative pressure relative to adjacent areas, so that the clean-to-dirty airflow direction is towards airborne disease patients. Protective environment (PE) rooms should be set at positive pressure relative to adjacent areas, so that the clean-to-dirty airflow direction is away from high risk or immunosuppressed patients. The Centers for Disease Control recommend that a risk assessment be performed in order to determine the appropriate number of airborne infection isolation rooms and/or protective environment rooms in a healthcare facility.

2.5 Water Systems

Water systems in healthcare facilities and other buildings often use treated municipal water, which enters the facility through water mains and is distributed via a network of galvanized iron, copper or PVC pipe. Each water service main, branch main, riser or branch should have a valve and a panel allowing access.

Cold water should be stored and distributed at temperatures below 60°F. Hot water should be maintained above 140°F. In case of water disruption emergencies, enough replacement water to satisfy demand for at least 24 hours should be kept on hand.

Water pressure throughout the system should also be carefully maintained. A significant drop in water pressure in a healthcare facility, for example, could affect such procedures as climate control systems, direct patient care activities and vacuum suctioning systems.

Point-of-use fixtures for water in healthcare facilities and other buildings (including sinks, faucets, aerators, showers and toilets, eye-wash stations, etc.) are common reservoirs for pathogenic microorganisms. Each of these fixtures carries a different level of risk for aerosol production. For example, while aerosols from showerheads and faucet aerators have been linked to gram-negative bacterial colonization and infections, such outbreaks are infrequent and consensus has not been reached regarding the disinfection or removal of these fixtures from general use. Again, while aerosols are produced with toilet flushing, no epidemiologic evidence suggests that these aerosols pose a direct infection hazard.

Decorative fountains can produce aerosols that have been associated with transmission of *Legionella pneumophilia*. Such fountains should not be placed in or near high-risk patient care areas.

Water disruption events in healthcare and other facilities could necessitate decontamination of water systems. High temperature flushing or hyper chlorination may be appropriate in these cases to decrease potentially high concentrations of waterborne organisms. When "shock decontamination" of hot water systems is necessary, the water temperature should be raised to between 150°F and 170°F while each outlet in the system is progressively flushed. Alternatively, if chlorine is used in "shock decontamination," chlorine should be added overnight to achieve a free chlorine residual of at least 2 ppm throughout the system.

Flooding from external or internal sources usually results in property damage and a temporary loss of water and sanitation. Porous materials with a moisture content of greater than 20% more than 72 hours after a water damage event should be discarded.

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Topic 3: Infection Control Project Management (CEICC Exam Only)

Successful CEICC candidates have mastered the following examination topics:

3.1 Assemble an interdisciplinary project management team for purposes of infection control during construction, renovation and demolition activities in the healthcare or institutional setting.

3.2 Assemble an Infection Control Risk Assessment (ICRA) panel

3.3 Perform an Infection Control Risk Assessment (ICRA) for use during construction, renovation and demolition activities in the healthcare or institutional setting.

3.1 The Project Management Team

Construction, renovation repair and demolition activities require substantial planning and coordination to minimize the risk for airborne infection during and after the project. In the first place, facility owners and managers should prepare a detailed program describing specific needs for temperature, humidity and pressure control for each occupied space. Additionally, a multidisciplinary team approach to coordinating the various stages of construction activities is recommended. Construction planning and design meetings should be convened with architects and engineers. In addition, environmental services, employee health, engineering and infection control disciplines should be represented. The number of members and disciplines represented on the team should reflect the complexity of the project.

Suggested members of a multidisciplinary project management team for include:

- Infection control personnel.
- Laboratory personnel.
- Facility administrators or their designated representatives.
- Facility managers.
- Directors of engineering.
- Risk management personnel.
- Employee safety personnel.
- Industrial hygienists.
- Regulatory affairs personnel.
- Information systems personnel.
- Construction administrators and their designated representatives.
- Architects, design engineers, project managers and contractors.

A multidisciplinary project management team should be able to perform the following functions:

- Develop a comprehensive project management plan by coordinating members' input.
- Conduct a risk assessment of the project to determine potential hazards to susceptible building occupants.
- Prevent unnecessary exposure of building occupants to infectious agents.

- Oversee all infection control aspects of construction activities.
- Provide education about the infection control impact of construction staff and construction workers. Visual and printed educational materials should be provided in the language spoken by staff and construction workers.
- Establish site-specific infection control protocols for specialized areas.
- Insure compliance with technical standards, contract provisions and regulations.
- Establish a mechanism for addressing and correcting problems quickly. In particular, specific lines of communication are important to addressing problems, resolving complaints and keeping projects moving toward completion.
- Develop contingency plans for emergency response to power failures, water supply disruptions and fires.
- Provide a water damage management plan (including drying protocols) for handling water intrusion from floods, leaks and condensation.
- Develop a plan for structural maintenance.

Before any construction or repair activity is undertaken, several considerations should be addressed by the project management team, including:

- The design and function of the new structure or area.
- The environmental risks for airborne disease and opportunities for prevention.
- Available measures to contain dust and moisture during construction or repairs. These should be appropriate to the location of the construction site. For example, outdoor demolition and construction require actions to keep dust and moisture out of the facility (sealing windows and vents, etc.). Indoor demolition and construction, on the other hand, require barrier structures and engineering controls to clean the air in and around the construction site.

In particular, the following construction design and function considerations are important for environmental infection control:

- Location of sinks.
- Types of faucets (aerated versus non-aerated).
- Air handling systems.
- ACH and pressure differentials.
- Location of fixed sharps containers.
- Types of surface finishes (porous, versus nonporous).
- Well called walls with minimal scenes.
- Location and size of storage and supply areas.
- Types of materials used in sinks and wall coverings.
- Traffic flow patterns.
- Types of flooring materials.
- Location of carpeted areas.
- Location of soiled utility areas.
- Design of solid waste management systems.
- Location of main generator.

- Proper installation of sheet rock.

In each of these areas, proactive strategies can help prevent environmentally mediated airborne infections during construction, demolition and renovation. Early in the planning stage of any construction project, the project management team should consider the potential presence of dust and moisture and critically evaluate their contribution to healthcare-associated infections.

3.2 The ICRA Panel

See section 3.1, "Project Management Team"

3.3 The Infection Control Risk Assessment (ICRA)

When conducted before initiating repairs, demolition, construction or renovation activities, an infection control risk assessment (ICRA) can identify potential exposures of building occupants to dust and moisture resulting from these activities. Additionally, the ICRA can determine if patients in a healthcare facility or other building may be at risk for exposure to fungal spores during a construction project.

The ICRA panel can use this information to recommend dust and moisture containment measures and to develop a contingency plan to prevent patient exposures to fungal spores. An ICRA normally centers on the type and extent of construction or repairs in the work area, but may also deal with adjacent areas such as patient care rooms, supply storage rooms and rooms located on floors above and below the proposed project.

Other considerations addressed by an ICRA may include:

- Determining baseline levels of environmentally acquired airborne and waterborne infections in order to monitor changes in infection rates and patterns during construction activities.
- Defining the types of barrier systems necessary for the scope of construction projects.
- Relocating building occupants to other areas of the facility not affected by construction activities.
- Providing respiratory protection for building occupants. (The routine use of N95 respirators by patients in healthcare facilities has not been evaluated for preventing exposure to fungal spores during periods of non-construction)
- Determining whether microbiologic and/or particle sampling during and after construction activities is warranted to determine indoor air quality and the efficacy of dust control measures.

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Topic 4: Effective Infection Control Practices

Successful candidates have mastered the following examination topics:

- 4.1 Conduct appropriate and effective containment engineering during construction, renovation and demolition activities.
- 4.2 Implement appropriate infection control practices for air handling systems during construction, renovation and demolition activities.
- 4.3 Conduct appropriate and effective environmental sampling during construction, renovation and demolition activities.
- 4.4 Implement appropriate infection control practices in Protective Environment (PE) rooms, Airborne Infection Isolation (AII) rooms and Operating Rooms (OR) rooms during construction, renovation and demolition activities.
- 4.5 Employ effective cleaning practices for environmental surfaces during construction, renovation and repair activities.
- 4.6 Implement effective infection control practices for water handling systems during construction, renovation and demolition activities.

4.1 Containment Engineering

The proper use of containment to prevent the spread of airborne contaminants is of primary importance during construction, repair or renovation projects. Infection control professionals should be prepared to recommend a variety of strategies to reduce dust and moisture intrusion during these activities.

For demolition and construction projects outside the facility, the following strategies should be considered:

- Shroud demolition sites, if possible.
- Carefully evaluate proposed location for dust generating equipment to ensure that the dust produced by such equipment cannot enter the building.
- Locate construction materials storage areas away from ventilation air intakes.
- Seal off air intakes located adjacent to construction areas.
- Consult with facility managers about HVAC system and air recirculation options.
- Use HVAC system to keep facility air pressure positive relative to outside air.
- Maximize the use of recirculated air in the HVAC system while outdoor air intakes are shut down.
- Monitor proper installation of filters. Protect high-efficiency filters by changing roughing filters frequently.
- Seal and caulk windows to prevent entry of airborne fungal spores.
- Keep doors closed as much as possible. Seal and caulk unused doors.
- Use mats with tacky surfaces at outside entrances.

- Note location of water utilities relative to construction areas to prevent intrusion of dust into water systems.
- Temporarily close off rooftops that are normally open to the public during active demolition and construction activities.
- Provide methods to minimize dust, such as misting construction areas with water.
- Protect immunocompromised patients in healthcare facilities by providing designated walkways protected from demolition and construction sites.
- Control pedestrian traffic through the facility by closing off entryways as needed to minimize dust intrusion. Direct pedestrian traffic away from patient care areas in healthcare facilities.
- Reroute truck traffic near the construction site if possible, or arrange for frequent street cleaning.
- Encourage the reporting of hazardous or unsafe incidents associated with construction to maintain awareness.

During construction and repair projects inside the facility, the following steps should be taken to ensure that containment measures are as effective as possible:

- Educate construction workers about the importance of containment measures.
- Prepare the site properly (see below).
- Notify and issue advisories for staff building occupants and visitors.
- Relocate staff and building occupants as needed.
- Issue standards of practice and precautions during construction activities and maintenance.
- Monitor adherence to containment measures during construction.
- Provide prompt feedback about lapses in control.
- Monitor HVAC performance.
- Implement daily cleanup, terminal cleaning and removal of debris upon completion.
- Ensure the integrity of the water system during and after construction activities.

Though the specific type of physical barrier required for each project depends upon the project's scope and duration, many projects require barrier structures of some type, including:

- Demolition of walls, wallboard, plaster, ceramic tile, ceiling tiles and ceilings.
- Removal of flooring and carpeting, windows and doors, and casework.
- Demolition and/or repairs to sinks and plumbing that could result in aerosolization of water.
- Exposure of ceiling spaces.
- Crawling into ceiling spaces for inspection.
- Demolition, repair, or construction of elevator shafts.
- Repairing water damage.

Infection control measures for internal construction and repair projects may encompass the following 11 steps:

1. Prepare for the Project

    a. Incorporate infection control into the project using a multidisciplinary team approach.
    b. Conduct a risk assessment and preliminary walk-through with project managers and staff.
2. Educate staff and construction workers.
    a. Emphasize the importance of adhering to infection control measures during the project.
    b. Provide educational materials in the language of workers.
    c. Include language in the construction contract requiring contractors and subcontractors to participate in infection control training.
3. Issue hazard and warning notices.
    a. Post signs to identify construction areas and potential hazards.
    b. Mark detours requiring pedestrians to avoid the work area.
4. Relocate high risk building occupants as needed.
    a. Identify target occupant populations for relocation based on a risk assessment.
    b. Arrange for the transfer in advance to avoid delays.
    c. At-risk building occupants should wear protective respiratory equipment when outside Protective Environment rooms.
5. Establish alternative traffic patterns for staff, hospital patients and visitors and construction workers.
    a. Determine appropriate alternate routes based on the risk assessment.
    b. Designate areas for construction worker use, including separate entrances, if possible.
    c. Do not transport healthcare patients on the same elevator with construction materials and debris.
6. Conduct an environmental assessment to determine and eliminate the source of fungal contamination, if epidemiologic evidence suggests the ongoing transmission of fungal disease.
7. Erect appropriate barrier containment.
    a. Use barriers to prevent dust from construction areas from entering patient care areas in healthcare facilities.
    b. Use prefabricated plastic units or plastic sheeting for short-term projects that will generate minimal dust, or for projects that include removal of ceiling tiles and disruption of the space above a false ceiling.
    c. Use durable rigid barriers for ongoing, long-term projects. Block and seal off return air vents if rigid barriers are used for containment. Ensure that containment for ongoing, long-term projects includes floor to floor barriers which take into account the space above the finished ceiling.
8. Establish proper ventilation.
    a. Shut off return air vents in the construction zone, if possible, and seal around grilles.
    b. Exhaust air and dust to the outside, if possible.

   c. If recirculated air from the construction zone is unavoidable, use a pre-filter and a HEPA filter before air returns to the HVAC system.
   d. When vibration-related work is being done that may dislodge dust in the ventilation system or when modifications are made to ductwork serving occupied spaces, install filters on the supply air grilles temporarily.
   e. Set pressure differentials so that the contained work area is under negative pressure. Ensure proper operation of the air handling system in the affected area after erection of containment barriers and before the room or area is set to negative pressure.
   f. Use airflow monitoring devices to verify the direction of the air pattern.
   g. Monitor temperature, air changes per hour, and humidity levels. Humidity levels should be less than 65%.
   h. Use portable industrial grade HEPA filters in the adjacent area and/or the construction zone for additional air changes per hour.
   i. Keep windows closed, if possible.
9. Control solid debris.
   a. When replacing filters, place the old filter in a bag prior to transport and dispose as a routine solid waste.
   b. Clean the construction zone daily or more often as needed.
   c. Designate a removal route for small quantities of solid debris.
   d. Mist debris and cover disposal cart for transport.
   e. Designated elevator for construction crew use.
   f. Use window chutes and negative pressure equipment for removal of larger pieces of debris while maintaining pressure differentials in the construction zone.
   g. Scheduled debris removal during periods when building occupant exposure to dust is minimal.
10. Control water damage.
   a. Make provisions for dry storage of building materials.
   b. Do not install wet, porous building materials (i.e., sheet rock).
   c. Replace water damage to porous building materials if they cannot be completely dried out within 72 hours.
11. Control dust in air and on surfaces.
   a. Monitor the construction area daily for compliance with the infection control plan.
   b. Protective outer clothing for construction workers should be removed before entering clean areas.
   c. Use mats with tacky surfaces within the construction zone at the entry; cover sufficient area so that both feet make contact with the mat while walking through the entry.
   d. Construct an anteroom as needed work coveralls can be dawned and removed.
   e. Clean the construction zone in all areas used by construction workers with a wet mop.
   f. If the area is carpeted, attacking daily with a HEPA filter equipped vacuum.

    g. Provide temporary essential services (e.g., toilets) and worker conveniences in the construction zone as appropriate.
    h. Damp wipe tools if removed from the construction zone or left in area.
    i. Ensure the construction barriers remain well sealed; use particle sampling as needed.
    j. Ensure that clinical laboratories are free from dust contamination.
12. Complete the project.
    a. Flush the main water system to clear dust-contaminated lines.
    b. Terminally clean the construction zone before the construction barriers are removed.
    c. Check for visible mold and mildew and eliminate, if present.
    d. Verify appropriate ventilation parameters for the new area as needed.
    e. Do not except ventilation deficiencies, especially in special care areas.
    f. Clean or replace HVAC filters using proper dust-containment procedures.
    g. Remove the barriers and clean the area of any dust generated during this work.
    h. Ensure that the designated heir balances in operating rooms (OR) and protective environments (PE) are achieved before occupancy.
    i. Commission, the space as indicated, especially in OR and PE environments, ensuring that the room's required engineering specifications are met.

4.2 Air Handling Systems

Monitoring and maintaining proper function of air handling systems during construction, renovation and repair projects is an integral part of the infection control process. In particular, the Centers for Disease Control (CDC) recommends the following procedures:

1. Monitor ventilation systems in accordance with engineers' and manufacturers' recommendations to ensure preventive engineering, optimal performance for removal of particulates, and elimination of excess moisture.
    a. Ensure that HVAC filters are properly installed and maintained to prevent their leakages and dust overloads.
    b. Develop and implement a maintenance schedule for ACH, pressure differentials, and filtration efficiencies using facility specific data as part of a multidisciplinary risk assessment. Take into account the age and reliability of the system. Document these parameters.
        i. The following healthcare spaces should be maintained at positive pressure relative to adjacent areas: operating rooms, Cesarean delivery rooms, critical and intensive care areas, newborn intensive care areas, trauma rooms, protective environment rooms, pharmacies, clean linen storage areas, clean work rooms and sterile storage areas.

ii. The following healthcare spaces should be maintained at negative pressure relative to adjacent areas: ER waiting rooms, triage areas, toilet rooms, airborne infection isolation (AII) rooms, physical therapy rooms, dark rooms, laboratory areas, soiled linen storage rooms, janitor's closets and hazardous material storage areas.

c. Engineer humidity controls into the HVAC system and monitor the controls to ensure proper moisture removal.
d. Incorporate fresh water steam humidifiers if possible to reduce potential for microbial proliferation within the system. Avoid the use of cool mist humidifiers.
e. Ensure that air intakes and exhaust outlets are located properly. Locate exhaust outlets at least 25 feet from air intake systems. Locate outdoor air intakes at least 6 feet above ground or at least 3 feet above roof level. Locate exhaust outlets from contaminated areas above roof level to minimize recirculation of exhausted air.
f. Maintain air intakes and inspect filters periodically to ensure proper operation.
g. Bag dust-filled filters immediately upon removal to prevent dispersion of dust and fungal spores. Remove bird nests near air intakes to prevent mites and fungal spores from entering the ventilation system.
h. Prevent dust accumulation by cleaning air duct grilles in accordance with facility-specific procedures and schedules when rooms are unoccupied.
i. Periodically monitor HVAC system output to monitor system function.
j. Keep HVAC duct system free of construction debris.
k. Clean ventilation ducts as part of routine HVAC maintenance to ensure optimum performance. (The Centers for Disease Control states that the usefulness of HVAC duct cleaning for infection control purposes has not been conclusively determined.)

2. Use portable, industrial-grade HEPA filter units capable of filtration rates in the range of 300 -- 800 ft.^{3}/min. to augment removal of respirable particles as needed. Select portable HEPA filters that can recirculate all or nearly all of the room air and provide the equivalent of at least 12 ACH.
3. Follow appropriate procedures for use of areas with through-the-wall ventilation units. Do not use such areas as protective environment (PE) rooms.
4. Conduct an infection-control risk assessment (ICRA) and provide an adequate number of AII and PE rooms (if required) or other areas to meet the needs of the patient population.
5. Airborne Infection Isolation (AII) rooms:
    a. Exhaust all air directly to the outdoors.
    b. Maintain differential pressure between AII rooms and adjacent spaces at a minimum of -0.01 inches water column.
6. Protective Environment (PE) rooms:
    a. Locate supply diffusers above the patient bed.
    b. Locate return/exhaust grilles or registers near the patient room door.
    c. Maintain differential pressure between PE rooms and any dissimilar adjacent spaces at a minimum of 0.01 inches water column.
7. Operating Rooms (OR):

   a. Maintain downwards unidirectional airflow.
   b. Maintain average supply diffuser velocity of 25 to 35 $ft.^3$ per minute per square foot.
   c. Provide at least two lows sidewall return or exhaust grilles, installed approximately 8 inches above the floor.
8. Seal windows in buildings with centralized HVAC systems and especially with PE areas.
9. Keep emergency doors and exits from PE rooms closed except during an emergency; equip emergency doors and exits with alarms.
10. Develop a contingency plan for backup capacity in the event of a general power failure.
11. Do not shut down HVAC systems in patient-care areas of healthcare facilities except for maintenance, repair, testing of emergency backup capacity, or new construction.
12. Whenever possible, avoid in activating or shutting down the entire HVAC system at one time, especially in acute-care facilities.
13. Whenever feasible, design and install fixed backup ventilation systems for new or renovated construction for PE rooms, AII rooms, operating rooms, and other critical care areas identified by the ICRA.

4.3 Environmental Sampling

Microbiologic sampling of air, water, and inanimate surfaces (i.e. environmental sampling) is an expensive and time-consuming process that is complicated by many variables in protocol, analysis and interpretation. Additionally, certain types of sampling are ill-suited to detecting and quantifying certain contaminants (air sampling, for example, is insensitive means of detecting the presence of *Legionella pneumophila*).

As a result, the Centers for Disease Control discourages the practice of random, undirected microbiologic sampling (formerly referred to as "routine sampling"). Microbiologic sampling is recommended in only four situations:

- To support an investigation of an outbreak of disease or infection when environmental reservoirs are implicated epidemiologically in disease transmission.
- To support well designed and controlled experimental research into the spread of environmentally associated diseases.
- To monitor a potentially hazardous environmental condition, confirm the presence of the hazardous chemical or biological agent, and validate the successful abatement of the hazard.
- To evaluate the effects of a change in infection control practice, or to ensure that equipment or systems (such as containment barriers) perform according to specifications and expected outcomes (quality assurance sampling).

The Centers for Disease Control (CDC) offers these recommendations when air, water, and environmental-surface sampling are indicated:

- Use a high-volume air sampling device if contaminant levels are expected to be low.

- Do not use settle plates to quantify the concentration of airborne fungal spores.
- When sampling water, choose growth media and incubation conditions that will facilitate the recovery of waterborne organisms.
- When using a sample/rinse method for sampling and environmental surface, develop and document the procedure for manipulating the swab, gauze or sponge in a reproducible manner so that results are comparable.
- When environmental samples and patient specimens are available for comparison, perform the laboratory analysis on the recovered microorganisms down to the species level at a minimum and beyond the species level if possible.

4.4 Special Environments

Healthcare facilities and other buildings may contain several special environments, which present challenges to the infection control professional. These include airborne infection isolation (AII) rooms, protective environment (PE) rooms, and operating rooms (OR). Such environments are defined by particular requirements for air pressure, room air changes, filtration supply and recirculation.

Airborne Infection Isolation (AII) room requirements:

- Negative pressure relative to adjacent spaces. Pressure should be monitored daily.
- At least six air changes per hour for existing rooms.
- At least 12 air changes per hour for renovation or new construction.
- Filter supply air at 90% efficiency.
- No recirculation - direct exhaust air to the outside.

Protective Environment (PE) room requirements:

- Positive pressure relative to adjacent spaces.
- At least 12 air changes per hour.
- Filter supply air at 99.97% (HEPA) efficiency.
- Recirculation permitted.
- Locate air supply and exhaust grilles so that clean, filtered air enters from one side of the room, flows across the patient's bed and exits from the opposite side of the room.
- Do not use laminar airflow systems in newly constructed PE rooms.

Operating Rooms (OR) requirements:

- Positive pressure relative to adjacent spaces.
- At least 15 air changes per hour, three of which should be fresh air.
- Filter supply air at 90% efficiency.
- Recirculation permitted.
- Introduce air at the ceiling and exhaust air near the floor.

4.5 Water Handling Systems

Many modern large facilities maintain indoor climate control during warm weather by means of cooling towers. Smaller buildings often employ evaporative condensers. Both of these systems provide ideal ecological niches for waterborne microorganisms such as *Legionella* spp. In fact, healthcare-associated Legionnaires disease has been linked to cooling tower aerosol exposure.

Infection control professionals should consider the following recommendations when dealing with cooling towers and evaporative condensers:

1. When planning construction of new healthcare facilities, locate cooling towers so that the drift is directed away from the air intake system, and designed the towers to minimize the volume of aerosol drift.
2. Implement infection control procedures for operational cooling towers:
    a. Install drift eliminators.
    b. Use an effective EPA-registered biocide on a regular basis.
    c. Maintain towers according to manufacture recommendations, and keep detailed maintenance and infection control records, including environmental test results from legionellosis outbreak investigations.
3. If cooling towers or evaporative condensers are implicated in legionellosis, decontaminate the cooling tower system.

4.6 Infection Control During Cleaning Activities

Microbiologically contaminated surfaces can serve as reservoirs of potential pathogens. In the healthcare field, the term "environmental surfaces" is used to refer to surfaces that generally do not come into direct contact with patients during care. Environmental surfaces carry less risk of disease transmission than medical instruments and devices, and can therefore be safely decontaminated using less rigorous methods. Importantly, these methods can also apply to cleanup activites outside the healthcare setting, and the term “environmental surfaces” as used below should be understood to apply to these activities as well.

Several factors may influence the choice of disinfection procedures for environmental surfaces and other cleanup activites, including the nature of the item or area to be disinfected or cleaned, the number and nature of microorganisms present, the amount of organic soil present, the type and amount of disinfectant being used, and the duration and temperature of disinfectant contact.

In general, however, the following procedures summarize an appropriate approach to the cleaning of environmental surfaces in occupied areas:

1. Select EPA-registered disinfectants and use them in accordance with the manufacturer's instructions.
2. Do not use high-level disinfectants/liquid chemical sterilants for disinfection of environmental surfaces.
3. Follow certain procedures for cleaning noncritical medical equipment in the absence of a manufacturer's cleaning instructions:
    a. Clean surfaces with a detergent/disinfectant.
    b. Do not use alcohol to disinfect large environmental surfaces.
    c. Use barrier protective coverings as appropriate for noncritical equipment surfaces (such as computer keyboards), which are touched frequently with gloved hands or are difficult to clean.
4. Keep housekeeping surfaces (e.g., floors, walls and tabletops) visibly clean on a regular basis and clean up spills promptly.
5. Do not perform disinfectant fogging in patient care areas.
6. Avoid large surface cleaning methods that produce mists or aerosols or disperse dust in patient care areas.
7. Follow proper procedures for effective use of mops, cloths and solutions:
    a. Prepare cleaning solution daily or as needed, and replaced with fresh solution frequently.
    b. Change mop heads at the beginning of the day and also as required by facility policy, or after cleaning up large spills of blood or other body substances.
    c. Clean mops and clots after use and allow to dry before reuse; or use single-use, disposable mop heads and cloths.

8. Wet vacuum or mop operating room floors with a single use mop and an EPA registered hospital disinfectant at the end of each day.
9. Do not use mats with tacky surfaces at the entrance to operating rooms or infection control suites.
10. Use appropriate dusting methods for patient care areas designated for immunocompromised patients:
    a. Wet dust horizontal surfaces daily by moistening a cloth with a small amount of an EPA registered hospital detergent/disinfectant.
    b. Avoid dusting methods that disperse dust (e.g., feather-dusting).
11. Keep vacuums in good repair and equip vacuums with HEPA filters for use in areas with patients at risk.
12. Close the doors of immunocompromised patient rooms when vacuuming, waxing or buffing corridor floors to minimize exposure to airborne dust.
13. Promptly clean and decontaminate spills of blood or other potentially infectious materials.
14. Follow proper procedures for site decontamination of spills of blood or blood-containing body fluids.
15. An EPA-registered sodium hypochlorite product is preferred for decontaminating surfaces after a spill of blood or body fluids, but if such products are not available, generic versions of sodium hypochlorite solutions (e.g., household chlorine bleach) may be used:
    a. Use a 1:100 dilution (500-615 ppm available chlorine) to decontaminate nonporous surfaces after cleaning a spill of either blood or body fluids in patient care settings.
    b. If the spill involves large amounts of blood or body fluids, or if a blood or culture spill occurred in the laboratory, use a 1:10 dilution (5000 -- 6150 ppm available chlorine) for the first application of disinfectant before cleaning.
16. Follow proper procedures to manage occupational exposure to blood and other potential infectious materials (OPIM) during cleaning projects, as described in 29 CFR 1910.1030, *Bloodborne Pathogens*:
    a. Develop appropriate exposure control plans and exposure determinations for all personnel.
    b. Employ all required methods of compliance, including Universal Precautions, engineering controls, PPE, and housekeeping procedures.
    c. Comply with HIV/HBV exposure management regulations.
    d. Implement appropriate hazard communication procedures.
    e. Maintain proper records of exposure and exposure management activities.

