

A Holistic Approach to Indoor Air Quality in Health Care



The health care environment is replete with known hazards such as radiation, chemicals, and infectious agents that must be controlled during both new construction and renovation

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Planning is essential for the proactive approach to indoor air quality. Materials selection, maintenance access, filtration, dehumidification, special ventilation room location, and other design parameters must receive careful consideration during the planning and design stages. This is critical to avoiding problems related to air quality after a building is occupied.

Advanced medical treatments have helped to manage organ failure and cancer in patients. The treatment of such patients, however, makes the patients suscepti-

ble to common environmental microbes. Furthermore, the health care environment is replete with known hazards that must be controlled. These include radiation, chemicals, and infectious agents. Some of these chemical and infectious agents can become airborne, adversely affecting indoor air quality (IAQ). Patients can be put at risk by these airborne chemicals and pathogens while being successfully treated for what originally hospitalized them.

A proactive approach to health care must include an awareness of the hazards associated with the airborne transmission of disease, chemical hazards, or irritating aerosols. These airborne hazards should be recognized in critical settings of hospitals and other health care facilities. Management of these hazards requires

administrative involvement, engineering controls, and personal protective measures to assure occupant safety.

Design criteria for health care facilities are published in the American Institute of Architects (AIA) and ASHRAE documents. Such criteria are commonly adopted by state jurisdiction. Such documents provide only minimum guidance for the construction of new buildings and the renovation of existing facilities. These criteria, while attempting to provide specification, do not always assure that mechanical ventilation is completed and commissioned for appropriate performance. The specification for IAQ must be clearly defined and complete with testing criteria for critical health care facilities. Such parameters must be

verifiable to assure the owner that the IAQ design specification is satisfied.

Occupant exposure to airborne hazards in health care can range from airborne patient-derived infectious particles to airborne latex particles to fumes or odors. The relative hazard often is not appropriately perceived by building management. For example, the concern for asbestos in the environment causes reactive response, but it is not an immediate threat as are infections caused by microbes such as *Aspergillus* or *Legionella*.

Environmentally opportunistic microbes can contaminate the patient care environment and complicate recovery, if patients develop infections from common, opportunistic infectious agents. Consistent performance of special ventilation rooms is necessary to assure minimizing exposure to infectious airborne microbes. Consistent performance of ventilation systems is really state of the art for critical contamination control environments.

Planning

When providing a proactive approach for controlling health care related IAQ hazards, it is important to recognize what controls are necessary for the safe management of known hazards. A lack of understanding of the hospital environment often occurs when planners have direct control of the implementation of a project from design to final owner acceptance. Ventilation requirements for patient protection is different from the safety factors necessary for preventing employee exposure to airborne fumes or particles.

Understanding the difference between occupational and patient IAQ safety is critical to providing the appropriate controls for air quality management. For example, the immune-compromised patient should be provided with a positive pressure room with rec-

ommended air exchanges and filtration requirements. Such rooms will provide safe patient areas that are free from fungi or employee-derived infectious particles such as influenza. Planners must recognize and implement design criteria and also provide safe construction management. This means preventing exposure to common airborne fungal particles generated during construction or renovation in health care facilities.

In contrast, the patient-generated infectious materials require recognizing both the infectious patients and the high risk activity that generates the opportunistic, infectious environmental microbe. Such airborne infection risk is recognized by providing appropriate negative pressure rooms with outdoor exhausts as well as sufficient room air exchanges to help minimize employee exposure. These two types of special ventilation rooms—airborne infection versus protective—are often mixed up. This is a serious matter! It could be a source of potential liability to the health care organization.

The control of chemical hazard fume or aerosol must also be a part

of IAQ management. Utilization of special ventilation is important for laboratories, operating suites, convalescent rooms, and chemical storage areas. The intended use of the space must be the consideration for determining the type of ventilation system necessary to control comfort and risk. The concept of risk assessment must be applied to help in the engineering and management of IAQ.

In health care, the design along with careful placement of special ventilation rooms in various patient care areas must consider future space needs for ventilation design. When laboratory space is determined, hoods and exhaust vents are installed, and because of strict fire protection for lab design, future relocation will probably not occur. Procedure rooms, processing areas, and convalescent airborne isolation rooms require an appropriate design that provides the required ventilation room air changes per hour, filtration efficiency, and room pressure.

The locations of patient care services, however, often change; hence, retrofit of these areas can

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be difficult and expensive. Because of this dynamic nature of health care, the areas for patient care and therapeutic/diagnostic spaces should be designed with consideration for future upgrade negotiations. However, first cost analysis often supersedes life cycle cost. As an unfortunate result, proactive design generally is not included in new or renovated health care facilities.

Architectural coordination is essential to provide the specification for maintaining consistent parameters for critical ventilation. Take, for example, a special ventilation airborne infection isolation room that is designed to operate at a negative pressure relative to surrounding spaces. If the designer selects a lay-in ceiling and operable windows, consistent pressure control may be difficult to maintain because of unwanted air infiltration.

Material selection during planning is also important. This is especially true for installation of carpet or flooring that needs to be glued to the floor. Such materials may contain volatile organic chemicals (VOCs), which outgas over time and can cause IAQ complaints, especially when new. A low volatile adhesive, however, might not stick as well due to its being a water-based material. Because of this, using carpeting in basement areas is discouraged. The adhesive on vinyl wall material may be a source of nutrition for fungi when excessive moisture is present.

Vinyl wall material, when placed on the outside walls of a building—especially where the climate is hot and humid—may become a condensation area if the building is depressurized and the vapor barrier is not intact. Such condensation may then support the growth and sporulation of problematic fungi in the indoor environment. In addition, the odors produced during growth can be irritating, and if the growth

colony is disturbed during investigation, the fungal spores may contaminate the environment.

Physical parameters

As facilities are occupied with patients, personnel, and equipment, the space sensible cooling load can—in time—exceed the design load that existed when the building was originally designed. When load exceeds cooling plant capacity, the space relative humidity (RH) rises. The result can be condensation on cooler surfaces, e.g., water pipes or other cold surfaces. This in turn may result in the amplification of microbial growth. Building conditions associated with excess humidity in the occupied health care space can contribute to fungal growth contamination.

When moisture is present with nutrients for greater than 72 hr, spores will germinate and reproduce. If the surfaces are moisture resistant, the ability of the microbe to grow will lessen. Designing bathrooms, showers, janitor closets, and other known moisture areas with moisture-resistant materials will help reduce future water damage and subsequent microbial growth. For example, water from a shower leaking on gypsum board having paper backing can become a deadly fungi reservoir if it occurs in a bone marrow transplant unit. During repair of this damage, a release of fungi such as *Aspergillus fumigatus* can occur due to the repair disturbance. Such a release can cause an infection that is difficult to detect or treat.

Anticipating and eliminating potential moisture control problems in the design stage requires some additional initial cost. It would, however, reduce the life cycle cost and liability cost associated with nosocomial acquisition and infection from an environmental opportunistic fungi such as *Aspergillus*. Water damage will occur in all buildings; anticipating the location of this damage is not

always easy. With experience, however, such issues can be logically considered because we know, for example, that roofs leak, condensation can form on windows, and vapor barriers fail.

A motivation for some contractors is to finish a project as quickly and cheaply as possible. Such a priority can create conditions that could be hazardous to future building occupants. For example, on one project the contractors did not protect elevator shafts during recent storms. The resultant water damage created ideal conditions for mold growth in the four affected elevator shafts in an acute care hospital under construction. The mold growth contaminated 14 stories of fire-rated sheet rock in these shafts. This required removal of all affected sheet rock due to liability concerns and the proactive construction specifications that stated that sheet rock shall be protected from water damage during weather conditions.

Harsh weather conditions can occur with regularity during many construction projects. Unfortunately, water damage is often overlooked because of a lack of understanding of what mold growth could mean to the health of the future occupants. Such contamination has even greater consequence in an acute care hospital.

Whenever projects are planned in and around a health care facility, a risk assessment should be conducted to determine the impact of the project on patient areas, personnel, and mechanical systems. Such an assessment is critical for determining the phasing schedule for the various projects. Because hospitals are occupied 24 hr a day, year-round, careful consideration for project timing is necessary.

Health care facility projects will often require phasing because it is not feasible to fix all of the affected spaces at once. Such projects must be planned in phases to continue

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uninterrupted treatment of seriously ill patients. For example, a crowded neonatal intensive care unit is difficult to completely vacate if a renovation project is planned. In the process of careful, deliberate planning for barrier separation, demolition, ventilation, and reconstruction, the project may also require the relocation of patients. The training of construction and patient care personnel to minimize disruption and risk for the patient occupants should be included for most health care projects. During this training, contractors can also be advised regarding the safety of their personnel as well as the safety measures needed to protect patients.

Source management

Whenever a building is constructed with design for proactive

IAQ, ventilation should be selected that minimizes irritating volatile organic chemicals. In areas where disaffectation and sterilization are required, the design must provide sufficient exhaust to outdoors to eliminate the presence of nuisance or hazardous chemical vapors.

A lack of ventilation and the presence of chemicals such as gluteraldehyde, a high level disinfectant, can result in irritation problems due to exposure. Retrofit changes in ventilation to control chemical fumes are expensive. The sterilant ethylene oxide is also hazardous. It too must be carefully controlled, utilizing local sensors to detect leaks and exhaust systems to eliminate waste gas or leaks from the usage areas.

Ideally, hazardous chemical sources should be centralized and provided with sufficient engineer-

ing controls to eliminate hazardous airborne chemicals from the local usage areas. Likewise, the hazard problems associated with water damage mold growth and cooling tower microbial (*Legionella*) contamination must be considered in a proactive health care IAQ program.

Mechanical systems

Perhaps the most complex and critical aspect of health care IAQ management is the need to provide proper control for the air handling systems to achieve comfort and safety. Considerations for new construction versus renovation are fundamental to design and implementation. New is often easier to consider due to minimal disruption. Renovation of existing space is more likely in today's health care market; however, this has the potential to cause haz-

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ardous disruption while attempting to provide the right kind of ventilation necessary to protect the compromised patients.

Complicating such projects is the need to protect employees and patients from airborne infectious agents such as TB due to potential ventilation outages. The ventilation system in a hospital is a vital component needed to assure health, safety, and comfort.

Regulation is necessary for fire protection; however, required testing may jeopardize the safety of patients especially when they are immune compromised. Fire management systems require testing that changes the air handling air flow for a short time. Such interruptions of the system may dislodge particles, especially if the system is new, and the duct systems were not protected from construction debris. In one recent

case, fire testing caused a damper to fail to reset itself, compromising a patient room. Fortunately, room alarms alerted the staff to summon maintenance personnel to correct the problem.

Hospitals must be designed to provide filtered air, required room air exchanges, and pressure relationships to protect both patients and employees. Such systems, if they are not maintained, have components that can cause IAQ problems. For example, if an air handling system is designed with insulation lining the inside of the fan housing or steam humidifiers in front of the filters, any moisture on the insulation or filters will enhance mold growth. The subsequent spore proliferation can cause spore migration into patient care areas.

Mechanical systems are sometimes installed in a manner that

vital components are not accessible for maintenance. Concerning ventilation systems, facilities have been built without access to filters, cooling coils, or dampers. In other instances, when access is provided, it may be so cramped that proper service is difficult or impossible to perform. Yet, too often owners accept this inexcusable situation in their efforts to get the building up and occupied. It is essential to recognize and eliminate deficiencies in ventilation and other systems before building occupancy. Deficiencies are much more difficult (and expensive) to eliminate after occupancy.

Commissioning

As previously discussed, many building systems have the potential to impact adversely patients and occupants if they do not function properly. This means that if

the designer has a specification for air supply filtration, room air exchanges, or room pressurization, then verification that the specifications are satisfactory to the owners must be among the acceptance criteria for that area.

Designers and contractors

must be aware of verification parameters assuring ventilation performance. Today, instruments exist for such verification that must be included in contract bid documents.

In an effort to provide special ventilation environments, we

must be aware that controversy exists when certain mechanical components are provided for controlling infectious particles. This is true with respect to portable filters, ultraviolet light, and ozone for controlling airborne microbes in health care facilities. Careful consideration must be taken by planners and owners not to rely on unproved technologies.

Planning guides are available from both AIA and ASHRAE with criteria for planning health care facilities. Health care facility acceptance criteria for heating, plumbing, refrigeration, and cooling systems must not be compromised. Ventilation parameters must be verified before occupancy to assure that the environment is ready for isolation of infectious diseases or is safe to protect the immune-compromised patient.

Conclusion

To develop and implement a state-of-the-art IAQ program that assures a safe environment of care in a dynamic environment, health care planners, patient care personnel, and administration must work together. The challenge remains for developing and implementing a practical and safe IAQ program that enhances care without disrupting or extending it.

Education and training programs are needed to bring all staff up to date on risks and risk management during normal operations and during construction and renovation projects. Professional training can be obtained from experts involved with IAQ problem-solving issues specific to the health care environment. IAQ, hazard awareness, and management training begin with reading relevant publications and attending seminars with specialized information not found in standard colleges and universities. **HPAC**

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