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Health-Care IAQ: Guidance for Infection Control

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EDITOR'S NOTE : The Sunday Times of India, Mumbai, April 8, 2001 carried the following news item which I am reproducing in part. “A year ago, four people lost an eye each after going though cataract surgery at the 'five-star' Lilavati Hospital at Bandra Reclamation Mumbai. All four were operated on the same day - March 10, 2000 - by the same doctor, in the same operation theatre. Within 24 hours, all four contracted a ferocious fecal infection called E Coli which resulted in their losing an eye each.” Several other cases of infection have been reported earlier in another well known ‘five-star hospital’ as well as smaller hospitals in Mumbai. The problem is very critical and this article explains what HVAC designers and maintenance staff can do to eliminate the problem.

Indoor-air-quality (IAQ) challenges outnumber all others in the health-care industry. Unfortunately, the cost-conscious powers that be have failed to make the management of critical infection-control systems a top priority.

This article provides guidance in the assessment of infection-control risks so that maintenance practices for health-care IAQ can be prioritized.

Infection-Control Risk Assessment

Making IAQ a top priority in the health-care industry starts with building design. To understand the design process, it is necessary to identify the areas where the risk of airborne infection is the greatest. This can be done through a process called infection-control risk assessment (ICRA), a basic outline of which follows:

Step 1: Identify patient groups among which the risks associated with airborne infection are the greatest. There are two basic groups. They are:

- Patient infectious. This group consists of patients who may spread infectious agents such as tuberculosis, varicella (chicken pox), and rubella (measles).
- Patient susceptible. This group consists of patients who are especially vulnerable to common opportunistic airborne infectious agents. These patients include bone-marrow-and solid-organ-transplant recipients, patients undergoing cancer treatment, babies born prematurely, AIDS patients, and patients whose immunity is compromised by interventions such as surgery.

Step 2: Identify the areas where airborne-infection control is necessary. These are:

- Airborne-infection-isolation rooms, where airborne infectious agents must be contained. Examples are convalescent rooms, emergency rooms, examination rooms, intensive-care units, radiology and diagnostic rooms, and procedure rooms.
- Protective environments, such as operating and bone-marrowtransplant rooms, which must be free of airborne infectious agents.

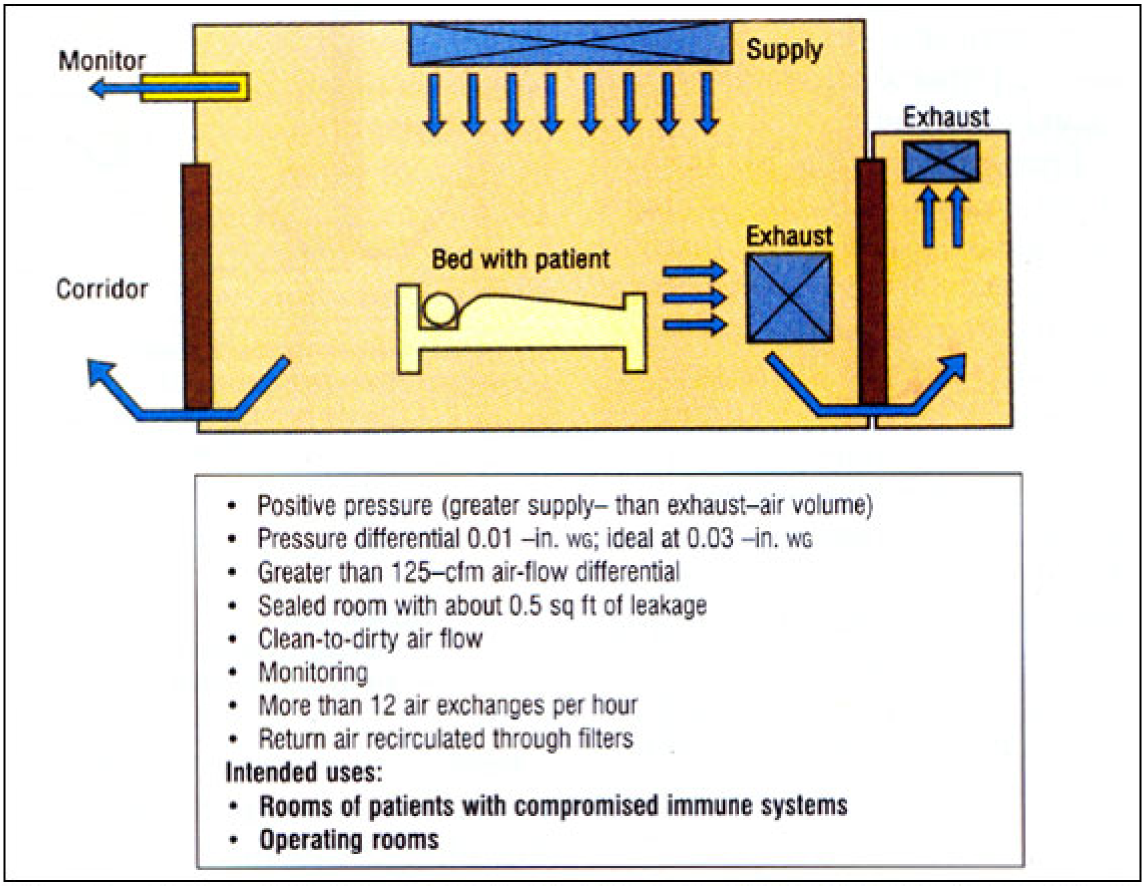

Figure 1 : Positive-pressure room control for protection from airborne infectious agents

All About Aspergillosis

Aspergillous species, which are very common environmental fungi originating from soil, are a component of the biodegradation of organic material. They affect patients undergoing treatment for some malignant diseases and organ failure. Difficult to diagnose and treat, Aspergillosis is fatal over 80 percent of the time, with the incidence increasing as the acute nature of some diseases increases. Exacerbating the problem is the fact that hospitals are continuously occupied, making renovation difficult. Construction is a major risk factor in acquiring Aspergillosis while being treated for an immune-compromising disease.

Pressure control via an offset between supply and exhaust-air volumes is essential to preventing the migration of unwanted airborne contaminants into critical areas. Oversupplying a protective environment provides a clean-toless- clean air-flow direction (**Figure 1**). Likewise, providing a greater volume of exhaust air to an airborneinfection-isolation room will bias the air flow into the depressurized space, which will contain infectious particles (**Figure 2**). To assure consistent air flow, the offset between the supply- and exhaust-air volumes must be significantly different. The amount of leakage is minimized by assuring that a differential of more than 125 cfm is provided for a standard-sized special-ventilation room with less than 0.5 sq ft of leakage. (Note: A standard undercut [1/2in.] on a door is about 0.2 sq ft.)

Pressure differential is a measure of air velocity. If the pressure differential is 0.001-in.WG, then the air will move about 120 linear ft per min. If the pressure differential is 0.01 -in. WG, then the air will move about 400 linear ft per min. This difference in velocity is important in the prevention of infiltration because if designed for that pressure, the room should provide a more consistent airflow direction. When it is 0.001-in. WG or less, the room-pressure differential may be affected more readily by the changes in building pressure caused by the opening of doors, elevator movement, and outdoor climate conditions.

Local exhaust ventilation is used primarily to manage occupational exposures to hazardous airborne chemicals such as waste anesthetic gas, ethylene oxide, and medicated aerosols. These agents, which are defined by OSHA, will not be covered in this article.

Step 3: Identify parameters related to:

- Air changes per hour.
- Filtration.
- Pressurization.

See **Table 1** for ICRA specialventilation- room parameters. The measurements were obtained with instruments such as room-balancing velometers, particle counters, and sensitive pressure-measuring devices. Gathered before occupancy, such data can be used to establish benchmarks that are referenced in subsequent problem-solving maintenance activities.

Table 1 : Commissioning guidelines for special-ventilation rooms

Ventilation Parameters	Airborne infection	Protective environment
Air changes per hour	More than 12	More than 12
Filtration : • Supply • Return • Toilet	 90-percent dust spot 99.97 percent at 0.3 µm 100-percent exhaust	 99.97 percent at 0.3 µm Back through filter or 100% exhaust 100-percent exhaust
Supply versus exhaust offset	More than 125 cfm	More than 125 cfm

Air-flow direction	Into room	Out of room
Pressure differential	Over 0.01–in wg	Over 0.01–in. wg
Minimum room leakage	Less than 0.5 sq ft	Less than 0.5 sq ft

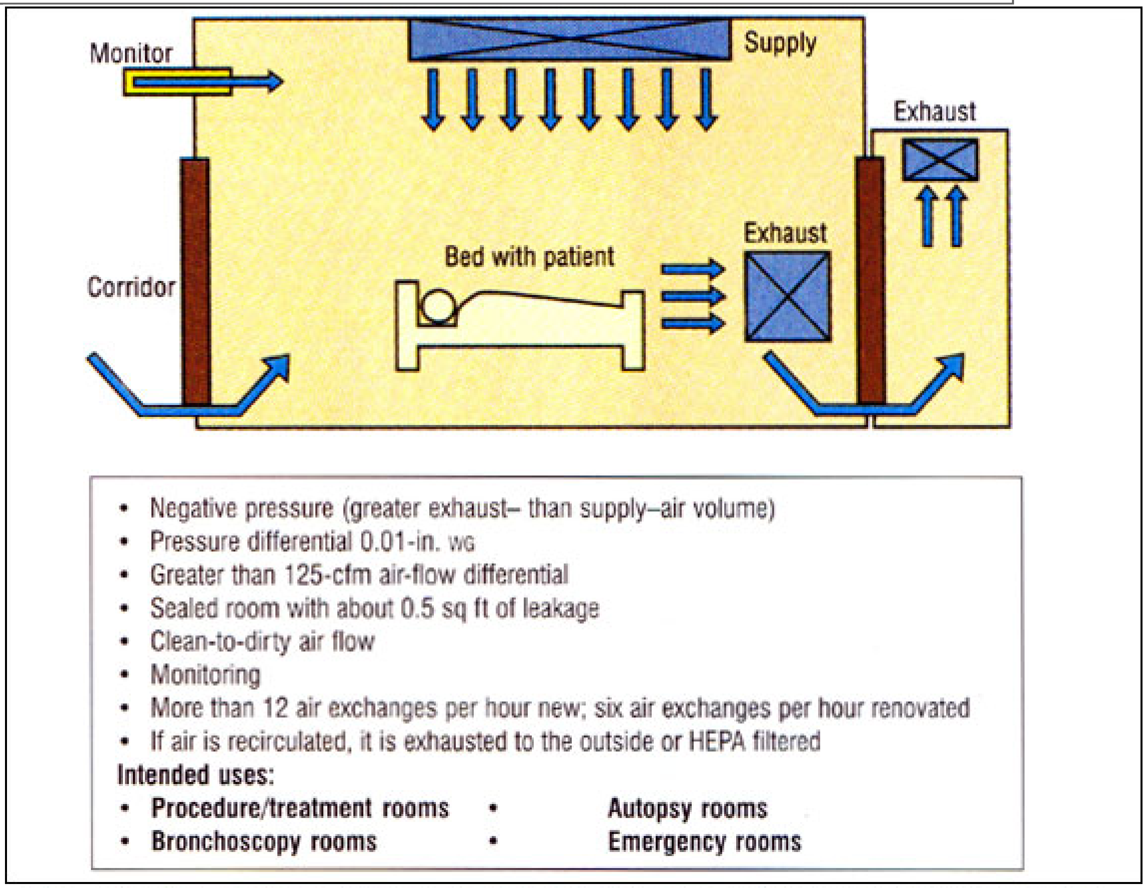

Figure 2 : Negative-pressure room control for isolation of airborne infectious agents

Aspergillosis Outbreak

An Aspergillosis outbreak caused by the infiltration of unfiltered air into an oncology patient-care building was described recently.[2]

The Aspergillosis was thought to have entered the oncology building not through the ventilation system, but though tunnels. The airborne spores then migrated up a stairwell into the bone-marrow unit. About 50 percent of the rooms designated for bone-marrow transplantation were depressurized. It was postulated that the unfiltered air was "siphoned" into the negative-pressure rooms.

To correct the problem, supply-air pressure to the rooms was increased, as was supplemental HEPA filtration from portable units.

Step 4: Maintain accurate, up-todate records in the following areas:

- Maintenance response. It is important to know what preventive maintenance has been performed and what complaints have been received.
- Routine maintenance of critical systems. Critical systems are identified in the ICRA process.
- Quality management. This is objective analysis through the use of instrumentation to determine appropriate air-change, filtration, and pressurization parameters for areas requiring special ventilation.
- Litigation/risk management. The management of a complex patientcare environment is contingent on the knowledge of risks and preventive measures. The proper maintenance and operation of equipment is essential. If records show deficiencies leading to microbial growth, then ICRA should be used to identify and possibly correct resulting IAQ problems.

Critical Areas

Air - quality management is important for the areas listed in **Table 2**. Generally, special-ventilation requirements will be identified through ICRA. The maintenance and operations staffs of the facility should work as a team to manage the ventilation systems. Infection - control personnel must convey the importance of ventilation management to assure that resources are available for appropriate maintenance.

Some important points to consider:

- For special-ventilation rooms, it is advisable to monitor air pressurization. Sensors and monitoring devices should be maintained and calibrated routinely, as they can become ineffective due to lint accumulation.
- Indoor mold contamination generally is associated with water damage or dust accumulation. A disruption of the environment caused by maintenance or renovation may lead to the release of opportunistic infectious fungal particles. Short-term exposures will not always be detected through air sampling. It is better to avoid the presence of fungi though good maintenance and construction practices than it is to rely on sampling to see if fungi are present.
- The testing and balancing of special-ventilation areas is important to the verification of engineering controls. Testing and balancing should be conducted in critical areas such as bone-marrow-transplant rooms at least yearly or before and after a renovation project.

- Emergency power must be provided to assure the continuous operation of essential-ventilation systems in special-ventilation areas. These systems must be available at all times to ensure patient and employee safety. Essentialventilation fans should be labeled for the scheduling of maintenance to prevent unnecessary or uncontrolled shutdowns.
- A "tight," well-sealed room is essential to the prevention of the infiltration/exfiltration of air in a special-ventilation room. Cracks in the ceiling, around windows, and around utility connections must be sealed to assure ventilation control.

IAQ Tool Kit

A tool kit for evaluating healthcare IAQ includes:

- A particle counter for measuring particles per unit volume.
- A pressure-testing device for measuring air-flow pressure
- A smoke stick for demonstrating air-flow direction
- An air sampler for collecting airborne particles capable of growing on growth media.

When evaluating air quality, we are looking for airborne particles. When filtration is appropriate, the lowest counts should be in the areas with the highest filtration. The particle counter will provide realtime air-quality analysis without knowing what the particles are. Reducing the number of particles from the outside air will remove incoming airborne fungi. These devices help to determine air-flow direction and filtration efficiency.

Table 2 : Hospital areas with special-ventilation requirements

At-risk area	Equipment	Planning	Routine Evaluation
Bone-marrow transplant	Air-handling system: • Filtration • Air exchanges • Positive pressure • Emergency power • Redundant equipment	• Preventive maintenance • Air-quality certification • Emergency planning • Training • Outage notification • Bearings	• Air changes per hr • Pressure differential • Filtration analysis • Vibration check • Fan belts
Operating room	Air-handling system: • Filtration • Air exchanges • Positive pressure • Emergency power	• Preventive maintenance • Air-quality certification • Emergency planning • Training • Outage notification	• Air changes per hr • Pressure differential • Filtration analysis • Vibration check • Fan Belts • Bearings
Airborne-infection	Air-handling system:	• Preventive maintenance	• Air changes per hr

isolation	• Negative pressure • Emergency power • Exhaust systems	• Outage notification • Training • Label fan	• Pressure differential • Fan belts
Local exhaust areas	Local vacuum system: • Filters • Hose attachmnts • Air-flow-velocity	• Training of operators • Preventive maintenance • Outage notification • Label fan	• Filter changes • Air velocity and/or room-air-changes

The Importance of Maintenance

Not all patient-care areas are hazardous to patients and/or caregivers. Airborne-contamination control pertains to a few microbial agents, irritating particles, and chemical vapors. The mechanical systems used in the control of these hazardous materials require ongoing maintenance to assure the safe ventilation of indoor air.

The American Institute of Architects' Guidelines for Design and Construction of Hospital and Health Care Facilities1 recently was revised to include the aforementioned criteria. If followed, this standard of care will improve the hospital environment before and after patient occupancy. The prioritization of maintenance should be balanced with the risk involved.

When ventilation is a critical part of hazard management, it is essential that facilities management receive support to assure consistent preventive maintenance. The Centers for Disease Control's upcoming Guidelines on the Role of the Environment in Nosocomial Infections will be instrumental in determining how often evaluations must be conducted.

Ventilation control is important in airborne-infectious-disease management. Additionally, routine maintenance of mechanical systems, rapid response to water damage, and construction management are essential components in the maintenance of good IAQ in healthcare institutions.

Related Reading

The following articles appeared in HPAC Engineering and are available on HPAC Engineering Interactive (**www.hpac.com**):

- July 1999: "Measurements to Solve Indoor Air Problems: Part 1 – Tools of the Trade" by Terry Brennan.
- November 1998: "Controlling Ventilation During Renovation" by William A. Turner, MS, PE.
- October 1998: "A Holistic Approach to Indoor Air Quality in Health Care" by Andrew J. Streifel, MPH.
- October 1998: "The Art and Science of Air Filtration Management in Health Care" by H.E. Barney Burroughs.

- July 1998: “Airborne Respiratory Diseases and Mechanical Systems for Control of Microbes” by W.J. Kowalski, PE, and Willion Bahnfleth, PhD, PE.
- July 1998: “Responding to Indoor Air Quality Problems” by Keith Naumann and Doug Lamecker.

Acknowledgment

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References

1. American Institute of Architects Guidelines for Design and Construction of Hospital and Health Care Facilities 2001, AIA Academy of Architecture for Health with assistance from the USDHHS, AIA Press, Washington, D. C.
2. Thio, CL, et al., "Refinements of Environmental Assessment During an Outbreak of Invasive Aspergillosis in a Leukemia and Bone Marrow Transplant Unit," Infection Control & Hospital Epidemiology, 2000, 21:18-23.