Indoor Air Quality Standards in Hospitals

a report by
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Nosocominal infection is defined as an infection that is acquired in a hospital and was not present or incubating at the time of admission. It is more commonly known as 'hospital-acquired infection'.

Generally, people go to hospital because they have an illness and are seeking medical treatment to help them to recover. The idea that a life-threatening infection could be acquired at hospital would seem to contradict the purpose of the visit and cause great concern to everyone.

In addition, nosocominal infection does not distinguish between those who have minor illness, serious illness or those who are not ill at all, such as hospital visitors. A seriously ill person is at greater risk due to the fact that his/her immune system is likely to be suppressed but, given the appropriate set of circumstances, any patient could acquire an infection, as could hospital visitors or staff.

This situation is somewhat alarming. A government report in the UK indicated that over 5,000 people died of nosocominal infection, in 2000 and a further 100,000 suffered illness. To put these figures into perspective, the report has identified that, in Scotland, more people died of hospital-acquired infection than from road accidents.

The problem is not specific to the UK and a December 2000 report suggested that, in North America, one in 20 Americans – 1.8 million people – develop an infection with 88,000 of them dying. This report was concerned with the growing threat of 'supergerms' – those that are evolving from existing bacteria and viruses – to become resistant to antibiotics. Currently, antibiotics are relied on to overcome these infections, but there is growing evidence that the evolution of harmful micro-organisms is outstripping the rate at which scientists can develop new antibiotics. Some hospitals are reporting problems with 'superbugs' that are proving difficult to eradicate from their premises using all known sterilisation agents and cleaning regimes.

The government has taken note of this and, through the National Health Service (NHS), is funding better quality cleaning strategies. This may help to improve matters but the real issue, which is airborne infection, is not being addressed. In an article that was published in the July 1998 issue of *HPAC Engineering*, the issue of airborne respiratory disease control of microbes in the mechanical systems in buildings was reviewed. The article identified that many respiratory pathogens have adapted to the comfortable indoor environment and are able to move around the building through airflow movement, whether natural – due to temperature gradients or pressure differences – or mechanical – forced airflow through ductwork.

In the case of mechanical ventilation, there is the opportunity of 'cleaning' the air by filtration, so that harmful micro-organisms are removed. These systems also allow the rooms within a building to be pressurised in a way that controls the movement of air from 'clean' areas outward in a cascading pressure regime towards the less critical areas and, ultimately, the 'unclean' areas.

The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) has realised the significance of properly designed ventilation systems to maintain clean conditions in healthcare premises and the organisation has prepared design guidance – published in 2002 – that provides detailed technical information on design to avoid nosocomial infections.

Through this work, ASHRAE has identified the importance of indoor air quality (IAQ) in healthcare premises and has initiated research to produce a standard that will enable engineers to design systems that meet the needs of the healthcare industry. This standard is likely to be available in 2004. However, the publication of the design guide has provided definitive information on IAQ issues aimed specifically at system design.

It is worth noting that, in the UK, NHS policy limits mechanical ventilation to the principal medical treatment areas such as operating theatres and associated rooms. Patient wards are not required

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to be mechanically ventilated and natural ventilation through opening windows is proposed, even though it is common practice for treatment to occur on these wards, such as changing of dressings, which involves open wounds being in contact with the surrounding air. The problem with natural ventilation is that air movement is unknown and unpredictable, being subject to wind pressures on the building, opening and closing of doors and any other events or features likely to affect airflows. A central atrium, for example, could draw air from lower levels into the volume of the atrium, upward under the effects of thermal buoyancy and into upper floors, distributing contaminated air into any patient areas on these levels if naturally ventilated via the atrium.

Consequently, there are large areas of hospitals that are not under effective pressure control and it is difficult to anticipate the movement of harmful organisms from one area to another.

The NHS has emerged to be one of the largest and most developed in the world, funded completely by the taxpayer until recently when some private healthcare emerged. Nevertheless, healthcare research, codes and standards have been developed at government level through the NHS.

In the 1980s, the NHS developed a series of standard hospital designs, including Harness and Nucleus, etc. These were based on a 300-bed district general hospital that incorporated all of the usual hospital facilities and centred on an energy centre for the provision of heating, cooling, steam, electricity and compressed air.

In the mid 1980s, the NHS decided to investigate the notion of a 'low energy' hospital and adopted the Nucleus hospital design as a model.

Initially, the project was a desktop study that set out to investigate the following:

- where and how much energy was being used;
- what opportunities existed for saving energy;
- how much energy would be required if a deliberate policy for energy efficiency was adopted; and
- how much this would cost.

The conclusions were that a saving of around 50% could be achieved at an increased capital cost of 2.5%.

Following this study, the NHS commissioned the construction of two low-energy hospitals:

- St Mary's, Isle of Wight; and
- Wansbeck, Newcastle.

These are complete and are being monitored as they are now in use. Reports are available from the NHS.

Natural Ventilation versus Mechanical Ventilation

One of the major energy users in hospitals is air treatment. The low-energy hospital study identified this as an area for saving by naturally ventilating all 'non-clinical' areas, and current NHS guidance has adopted this conclusion.

In the ASHRAE design guide, all areas are ventilated mechanically in order to achieve effective pressure gradients and to be able to control airflows between areas as a necessary part of air quality control. This issue was debated carefully because it rules out any opportunity for natural ventilation, no matter what the climate for a particular location. There are many areas in both Europe and North America that benefit from a temperate climate. It is possible to 'design out' air-conditioning in many building types in these regions or to design hybrid or mixed-mode schemes that use natural ventilation when possible and air-conditioning at other times. However, in hospitals, this cannot be considered because it compromises air quality and, therefore, infection control.

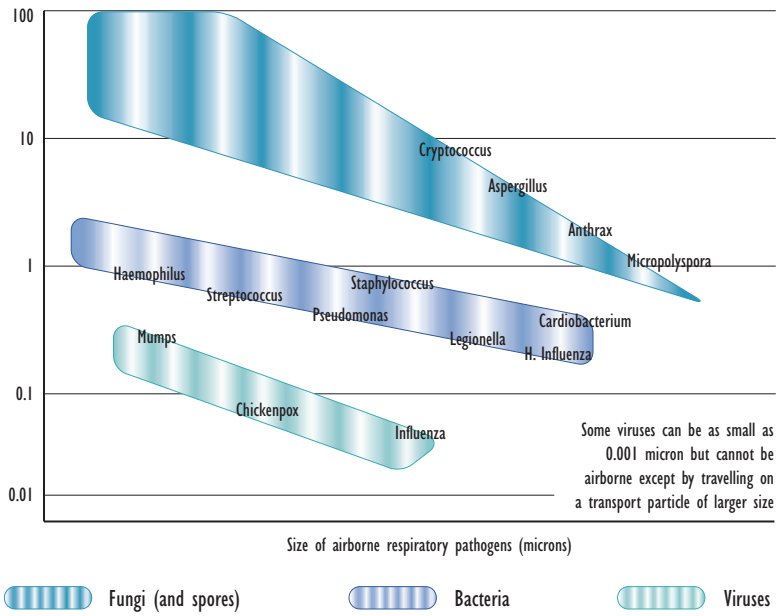
The reason why the UK adopted natural ventilation so readily and why the policy has not been changed probably derives from the Victorian principles of healthcare and the belief that fresh air is good for people. The Victorians sought to escape from the smog and the grime of industrialised cities to seasides or the countryside and, through this, locations such as Brighton, Blackpool and Harrogate became popular.

Therefore, Victorians built hospitals outside cities, in the country, and patients were able to convalesce in a pleasant, rural environment. Convalescence sometimes lasted for months.

Of course fresh air is good for people. However, the air outside is not necessarily fresh or clean. There are other questions, such as the difference in air quality today compared with 150 years ago, in terms of the bacteria, spores and viruses that surround people.

Medical science and expectations of patients have moved on and so too must building services engineering.

Figure 1: Relative Sizes of Airborne Respiratory Pathons (with examples)



Hospitals have been consumed by urban sprawl and patients experience intensive, short periods of treatment – often, with very advanced surgical practices involving deep body surgery, for example heart treatment, organ replacement or bone marrow transplant, all of which require very clean operating environments. After these operations, there may be further treatment in intensive care or on the ward, but the patient leaves hospital at the earliest opportunity and convalescence takes place at home.

The healthcare environment must be clean, otherwise the medical treatment may be negated and patients who are being treated for one illness may contract other illnesses due to their poorly state.

IAQ in Hospitals

With such apparent opposition to mechanical ventilation in NHS policy, it is worth considering further the case for control of IAQ in all medical/patient areas.

Infections are caused by micro-organisms that have evolved and are still evolving to use humans as a place to live/as a source of food, without regard for wellbeing or survival.

Micro-organisms, which generally include viruses, rickettsia, bacteria, prozotoa and fungi, have existed for millions of years and will undoubtedly be around for millions more in the future. Not all micro-organisms are harmful. There are those that ferment wine, produce cheese and medicines and make soil fertile. Some are vital within the human body, such as califorms, which break down unneeded materials.

The harmful organisms are those that invade the body to attack human organs or cells and cause consequent illness. The human body has developed elaborate protections against the invasion of disease-producing (pathological) organisms, but there are some that the body cannot resist without medical assistance and there are those new forms that currently do not have an effective treatment or cure.

In a hospital environment, all of these micro-organisms are potential killers because patients have much lower immunity levels due to their poor condition, the effect of drugs that suppress the immune system and the potential higher risk to attack by a wide range of pathogens. Unfortunately, hospitals tend to be places where harmful organisms are concentrated.

Their routes to humans are either airborne or by contact.

The airborne route requires infectious agents that are either droplet nuclei or dirt particles (dust). *Figure 1* illustrates the range of sizes of the various pathogens. Those of five microns or less in size can stay airborne indefinitely and can travel hundreds of feet from the source by natural air currents or through ducted systems. The risk of infection is proportional to the concentration of pathogens, so that if air is cleaned during high-efficiency particulate air filtration, which can achieve 99.997% removal of particulates, the risk is much reduced. This is due principally to the fact that with a lower number of particles floating around, there is less probability that one will have a micro-organism on board actually entering an open wound.

The risk of infection is linked not only to the purity of the air, but also to the air distribution patterns that should shield a wound site by forming a protective layer. Unfortunately, in many cases, the air systems mix clean air with dirty air and push contaminated air towards and into a wound.

The ASHRAE design guide will provide definitive information towards effective infection control. In producing this guide, ASHRAE has discovered the need for research into the unique nature of air quality control in healthcare premises and will publish a standard in 2004 that will become adopted as the *International Standard for IAQ in Hospital Environments*. This work will see a dramatic improvement in the number of nosocomial infection cases and will signal the point at which hospital engineering services will have caught up with medical practice. This will be a milestone in healthcare, enabling further development of procedures that can only be successful in a suitably clean indoor air environment. ■