



Anil Deisingh looks at the often overlooked microbiological side to sick building syndrome

# Sick Building

**M**ODERN ADVANCES in engineering technology have allowed buildings to be sealed tightly with the air being allowed to re-circulate within them while indoor air contaminants build up. Employee complaints result from cigarette smoke, odours, low-level contaminants, poor air circulation, thermal gradients, humidity, job pressures, lighting, workstation design or noise (OSHA, 2002). Indoor air quality (IAQ) investigations often fail to identify any harmful levels of toxic substances. According to OSHA (2002), complaints are

often of a subjective, non-specific nature and are associated with periods of occupancy. Symptoms include headache, dizziness, nausea, tiredness, lack of concentration and irritation of the eyes, nose and throat. The symptoms tend to disappear when the building is exited. The primary sources of IAQ problems were identified by a survey carried out by the National Institute for Occupational Safety and Health (NIOSH, 1989) and these are summarised in Table 1. Employee complaints can be due to two types of building problems: sick building syndrome (SBS) and

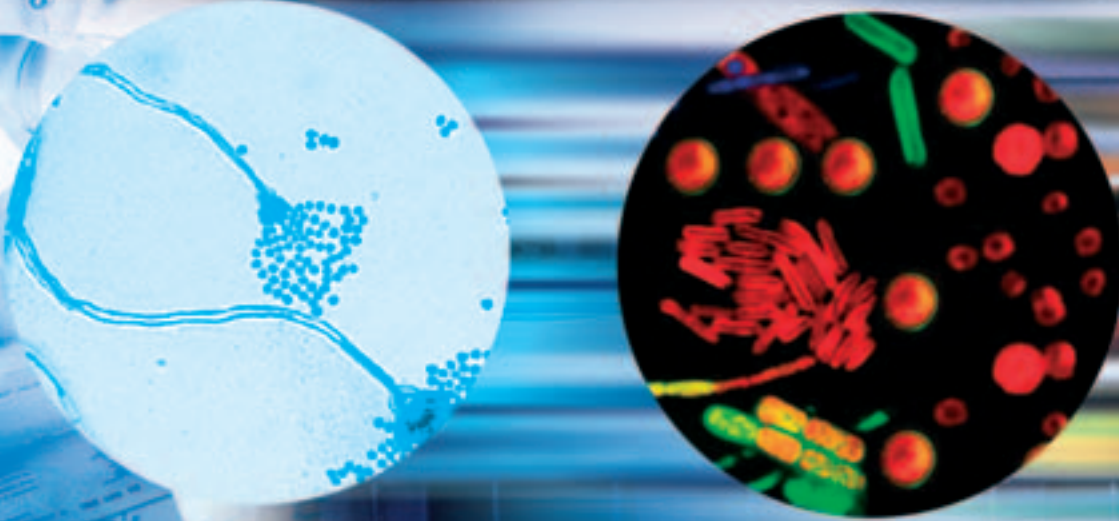
building-related illnesses (BRI). The former is used to describe situations in which the occupants of a building experience acute health effects linked to being in a building but no specific illness can be identified. Most of the affected people indicate relief soon after leaving the building. The latter term is used when symptoms of illness that can be diagnosed are identified and may be attributed directly to airborne building contaminants (EPA, 1991). Indicators of BRI include symptoms such as cough, chest tightness, fever, chills and muscle aches. The affected workers may require

prolonged recovery times after leaving the building.

Several factors have been listed as contributing to sick building syndrome. These include (EPA, 1991):

- Inadequate ventilation.
- Chemical contaminants from indoor sources e.g., adhesives, carpeting and pesticides.
- Chemical contaminants from outdoor sources e.g., motor vehicle exhausts and plumbing vents.
- Biological contaminants such as bacteria, moulds, pollen and viruses.

In this article, we will concentrate on biological contaminants and their impact upon indoor air quality.



# Syndromes

## Biological Contaminants

Microorganisms (Figure 1), mainly fungi and bacteria, are important factors that influence indoor air quality. Many bacterial and fungal species are isolated from indoor air with the species found dependent on nutrient source, water availability and temperature (Institute for Environment and Health, 2000). Temperature and relative humidity are major factors influencing the levels of fungi and bacteria in indoor situations.

Several health effects have been associated with fungal and bacterial species in the

indoor environment. These include rhinitis, upper respiratory symptoms, asthma, allergic skin reactions, tiredness and headache. There is much evidence of a relationship between damp and mouldy housing and reports of respiratory symptoms in children.

Sources of micro-organisms in indoor air include air handling system condensate, cooling towers, water-damaged materials, high humidity in indoor areas, damp organic material and porous wet surfaces, humidifiers, hot water systems, outdoor excavations,

plants, animal faeces, insects and food and food products (OSHA, 2002). In addition, *Legionella pneumophila* may be found in hot water tanks, washing systems and pools of stagnant water but health effects only appear when the contaminants are aerosolised within the indoor region.

In this article, we will concentrate on the effects of bacteria and moulds as these tend to be implicated in major health concerns more readily than other microbes.

## Bacteria

The most common bacteria found in indoor environments include *Bacillus*,

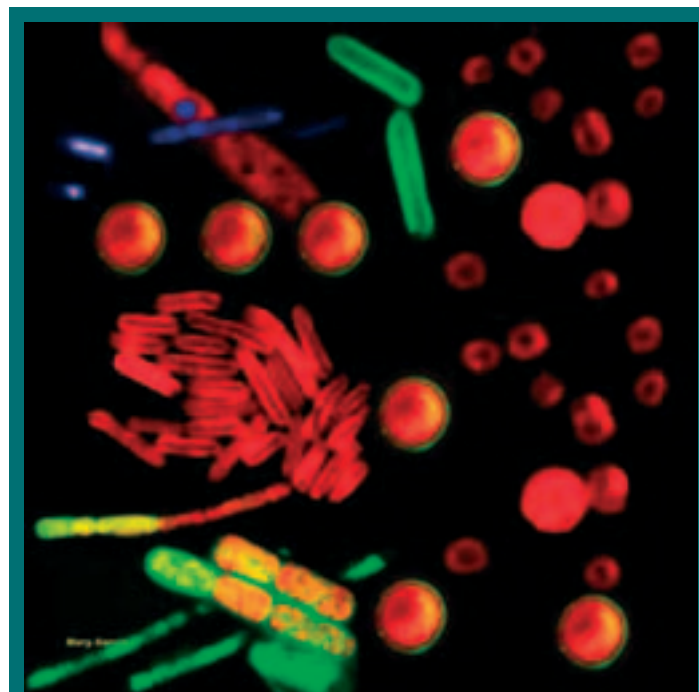
*Pseudomonas*, *Staphylococcus*, *Micrococcus*, *Methylobacterium* and *Flavobacterium*. It is of interest to note that some bacteria which cause infections are part of the normal microflora of indoor air and, if they are present, this should not be a particular cause of concern (Haury, 1998). Other species of importance include the Actinomycetes and the *Legionella* species.

The primary source of bacteria, in most interior situations, is the human body. About seven million skin scales are shed every

minute per person with each fragment containing an average of four viable bacteria. The main factor in dispersing these bacteria is abrasion, although showering increases the loss rate for bacteria. It has been claimed that *Staphylococcus aureus* is shed more abundantly by men than women, but other organisms are not sex-dependent (Solomon and Burge, 1984). Bacteria are released from the human respiratory tract, especially during coughing and sneezing. *Streptococcus pneumoniae* and *Mycobacterium* species are readily transferred through droplets expelled from the respiratory tracts of infected people.

*Bacillus* is a genus of Gram-positive organisms which are ubiquitous in nature (soil, water and airborne dust). Most species of *Bacillus* are harmless saprophytes but two species (*B. anthracis*, the cause of anthrax and *B. cereus*) are medically significant. Anthrax infection can occur in three ways: cutaneous (skin), inhalation and gastrointestinal. The spores of *B. anthracis* can live in the soil for many years with humans becoming infected by handling products from infected animals or by inhaling the spores from contaminated animal products (Centres for Disease Control, 2003). *B. cereus* has a wide distribution in soil, dust and air and it has been implicated in wound infection, meningitis and diarrhoeal food poisoning.

Air-conditioning units are sources of bacterial aerosols with *Pseudomonas* and *Acinetobacter* being common. More than 140 species of the former have been described with most of these being saprophytic. The Pseudomonads are Gram-negative rods and they may be responsible for urinary tract infections, pneumonia and eye and ear infections. They are



**Figure 1:** A range of micro-organisms highlighted by fluorescence. (Reprinted by permission of Dr. Conrad Mullineaux, University College London).

found in the soil, water or on plants. Similarly, bacteria of the genus *Acinetobacter* are Gram-negative and widespread in water, soil and living organisms. Some strains of *Acinetobacter* can cause disease especially in very ill and/or hospitalised patients.

High-levels of Gram-positive organisms such as *Micrococcus* and *Staphylococcus* indicate overcrowding and inadequate ventilation.

The Actinomycetes (*Actinomyces*, *Nocardia* and *Streptomyces*) family of bacteria are primarily found in soil and are widely distributed; they are vital in the mineralization of organic

matter. However, a few are pathogens and may cause skin and mouth lesions. *A. viscosus* and *A. naeslundii* have been isolated in large numbers on teeth that have decayed to a large extent. These species are early colonizers of teeth surfaces in the formation of plaque. The medically important aerobic actinomycetes can cause mortality especially in immunocompromised patients.

Legionnaire's disease is a pneumonia-like condition caused by *Legionella pneumophila*. The incubation period of the disease ranges from 2 to 10 days and symptoms include tiredness, weakness, fever, cough,

diarrhoea and chest pain. The disease is transmitted via drinking water (legionella.org, 2002). The bacteria are natural inhabitants of water and can be detected in rivers, lakes and streams. It was long believed that the organism is aerosolised in water and people inhale the droplets containing *Legionella*. New evidence suggests that aspiration is the most common way for the bacteria to enter the lungs. This is the process whereby a choking mechanism causes the secretions in the mouth to enter the lungs rather than the stomach (legionella.org, 2002). Aspiration occurs most readily in patients who smoke or have lung disease.

The major source of Legionnaire's disease is the water distribution systems of large buildings such as hotels and hospitals. Other sources include cooling towers, mist machines, humidifiers, whirlpool spas and hot springs. It is now being claimed that air-conditioning systems, once thought to be implicated in disease transmission, are not a source (legionella.org, 2002).

## Moulds

Moulds are widespread in nature and they assist in breaking down organic matter. It has been estimated that there are more than 100 000 species of moulds with some of the most common being *Cladosporium*, *Penicillium* and *Aspergillus* (Figure 2). Moulds are more likely to grow in water or in damp conditions.

In general, most moulds are not health hazards but for individuals who have allergies or compromised immune systems there may be symptoms such as fevers and breathing difficulties. Other symptoms of mould infestation include eye irritation, cough and runny nose. Levels of indoor fungi are higher in

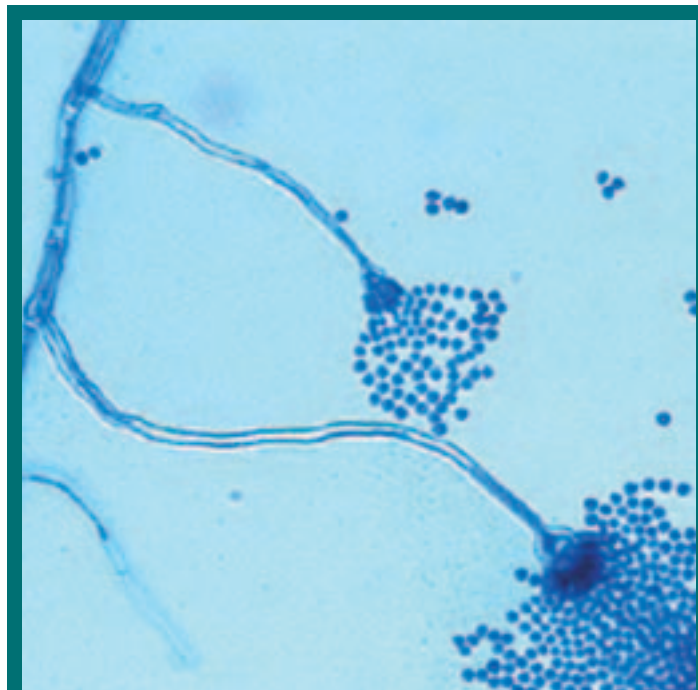
**TABLE 1** Primary sources of IAQ problems

Inadequate ventilation	53%
Contamination from inside a building	16%
Contamination from outside a building	10%
Microbial contamination	5%
Contamination from building fabric	4%
Unknown sources	13%

summer than in the winter months indicating the influence of outdoor sources (Solomon and Burge, 1984). Central air-conditioning reduces indoor spore levels by about 50% once the doors and windows remain closed. Window air-conditioning reduces indoor spore concentrations to 5% of those in normally ventilated rooms while rooms with open windows average about 60% of those outdoors (Solomon and Burge, 1984). A major factor in decreasing spore levels is the resultant decreased humidity of air-conditioning systems.

Certain fungi will produce mycotoxins which are very toxic. The *Aspergillus* species are the main producers of these compounds which include aflatoxin, ochratoxin and sterigmatocystin. Species of *Aspergillus* known to produce mycotoxins include *A. flavus*, *A. parasiticus*, *A. versicolor* and *A. ochraceus* (Hauray, 1998).

*Aspergillus fumigatus* is a widespread fungus and can be present even in small quantities of organic material. In the presence of compost, the number present can exceed 1 million / m<sup>3</sup> while in relatively clean indoors, the levels are generally low (1-200 / m<sup>3</sup>). In regions where organic materials are stored, concentrations may exceed 20 x 10<sup>10</sup> / m<sup>3</sup> (Solomon and Burge, 1984). Various reports have indicated that symptoms of aspergillosis can include any of coughing, shortness of breath, bronchitis and pneumonitis. Houseplants have been suspected as sources of increased *A. fumigatus* levels in homes and hospitals and pets have also been implicated although no direct evidence exists. Other factors leading to increased levels of indoor moulds include poor landscaping practices including the accumulation of



**Figure 2:** *Aspergillus*. (Reprinted by permission of Dr. Joanne Weber, Department of Medical Microbiology and Immunology, University of Wisconsin-Madison).

organic debris and high shade levels and the use of appliances such as evaporative humidifiers and air-conditioners (Solomon and Burge, 1984).

*Cladosporium* species are probably the most common fungi recovered both outdoors and in indoor situations during summer in the USA, Europe and Asia. However, they are always more abundant outdoors. *Penicillium* will be present in larger concentrations in winter months and are more abundant indoors than outdoors. Surprisingly, it has

been reported that levels of *Penicillium* increase with house cleaning and repair (Solomon and Burge, 1984).

Contamination of domestic interiors usually involve outdoor fungi which can easily grow indoors especially when water and/or moisture levels increase. Moulds can grow on any organic material which is wet. For example, damp walls will have increased growth of *Cladosporium cladosporoides* and *Aureobasidium* while damp leather, cotton and paper will become rapidly covered with *Penicillium* or *Aspergillus*

species (Solomon and Burge, 1984). Other indoor materials which can easily support mould growth include carpets, furniture stuffing (e.g. feathers), fire-proofing materials and stored organic material.

One mould of interest, although it is not present as commonly as *Aspergillus*, *Penicillium* or *Alternaria*, is *Stachybotrys chartarum* (*S. atra*). It is a greenish-black mould which can grow on material with a high cellulose and low nitrogen content such as fibreboard, paper, dust and lint. Growth occurs when there is water damage, high humidity, water leaks or flooding (Centers for Disease Control, 2002). There have been suggestions that *S. chartarum* can cause acute idiopathic pulmonary damage in infants but this has not been proven so far.

## Other Factors Affecting IAQ

Although we have concentrated on bacteria and moulds, several other parameters are involved when determining indoor air quality and the presence of sick building syndrome. These include (OSHA, 2002):

(a) Pollen grains can enter buildings through windows, doors and even cracks in the walls. Air-conditioning systems can considerably reduce the levels of pollen in indoor air.

(b) Carbon monoxide which may arise from tobacco smoke and engine exhausts and can lead to dizziness, nausea, cardiovascular problems and death.

(c) Oxides of nitrogen which are derived from gas furnaces and appliances, tobacco smoke and engine exhausts. These cause eye, respiratory and mucous membrane irritation.

(d) Volatile organic compounds (VOC's) such as benzene, toluene, alcohols, pesticides and polycyclic

**TABLE 2 Guidelines for spore and pathogen levels in indoor air (ref.1)**

Organism	Limit (cfu/m <sup>3</sup> )
Fungi	100 - 1000
Actinomycetes	0 - 100
Bacteria	0 - 500
Pathogenic Bacteria	0
Viruses	0
<b>Total Microbes</b>	<b>Up to 750</b>

aromatic hydrocarbons. Sources include paints, glues, insecticides, tobacco smoke, cosmetics and photocopiers. Acute health effects are nausea, dizziness, eye and respiratory tract irritation and headache.

(e) Miscellaneous inorganic gases including ammonia, sulphur dioxide and hydrogen sulphide which arise from acid drain cleaners and combustion products. These may cause effects similar to those listed in d) above.

(f) Tobacco smoke which can result in eye and nasal irritation, coughing, wheezing, sneezing, headache and sinus problems. Tobacco smoke is a major contributor to IAQ problems as it contains hundreds of toxic substances, including those described above.

### Threshold Limit Values for Microorganisms

At present, no comprehensive standards exist for acceptable levels of indoor air contamination with respect to micro-organisms. This is due to the extremely large numbers of both bacteria and moulds present and generating standards for each species is impossible. However, a few

#### References:

- 1. [www.arche.psu.edu/iec/abe/purge.html](http://www.arche.psu.edu/iec/abe/purge.html), (2002), *Aerobiological Engineering*.
- 2. Centers for Disease Control (2003), *Anthrax*, [http://www.cdc.gov/ncidod/dbmd/diseaseinfo/anthrax\\_g.htm](http://www.cdc.gov/ncidod/dbmd/diseaseinfo/anthrax_g.htm).
- 3. Centers for Disease Control (2002), *Questions and Answers on Stachybotrys chartarum and other moulds*.
- 4. <http://www.cgc.gov/nceh/airpollution/mold/stachy.htm>.
- 5. Haury, C C. (1998), *A compilation of indoor environmental quality exposure limits, Presented at the American Industrial Hygiene Conference*, May 1998
- 6. Institute for Environment and Health (2000), *Indoor Air Quality in the Home*, <http://www.le.ac.uk/ieh>.
- 7. [http://www.legionella.org/general\\_info.htm](http://www.legionella.org/general_info.htm) (2002)
- 8. National Institute for Occupational Safety and Health (1989), as reported in reference 8.
- 9. OSHA Technical Manual (2002), *Indoor Air Quality Investigations*, <http://www.osha.gov>, US Department of Labour, Occupational Safety and Health Administration.
- 10. Solomon, W R and Burge, H A (1984), *Allergens and Pathogens in Indoor Air Quality*, Edited by Walsh, P J, Dudley, C S and Copenhauer, E D., Boca Raton, FL, CRC Press.
- 11. United States Environmental Protection Agency, USEPA (1991), *Indoor Air Facts, No. 4: Sick Building Syndrome (SBS)*, <http://www.epa.gov/iaq/pubs/sbs.html>.

guidelines exist and these are summarized in Table 2.

Both the American Conference of Government and Industrial Hygienists (ACGIH) and the American Industrial Hygiene Association (AIHA) indicate that the upper limit for airborne fungi should be 1000 cfu/m<sup>3</sup>

([arche.psu.edu](http://www.arche.psu.edu), 2002).

It should be noted that even these guidelines are not widely accepted and it may be better to use the indoor: outdoor ratio of micro-organisms at a particular site. Values much greater than one may indicate that there are problems with the indoor air quality.

### Building Investigation Procedures and Solutions to Sick Building Syndrome

According to the USEPA (1991), *“the goal of a building investigation is to identify and solve indoor air quality complaints in a way that prevents them from recurring and which avoids the creation of other problems. To achieve this goal, it is necessary for the investigator to discover whether a complaint is actually related to indoor air quality, identify the cause of the complaint, and determine the most appropriate corrective actions.”*

The investigation procedure begins with a walkthrough inspection of the contaminated area in order to obtain information about the four factors which can influence IAQ. These are:

(a) the occupants; (b) the heating, ventilation and air-conditioning (HVAC) system; (c) possible pollutant pathways; and (d) possible contaminant sources.

Once it has been decided that there is a possible case of sick building syndrome, solutions may include one or more of the following (US EPA, 1991):

■ Pollutant source removal or modification which is effective once the sources are known

■ Increasing ventilation rates and air distribution

■ Air cleaning, in addition to source control and ventilation, but this may not be effective as the first two approaches.

■ Education and communication which are effective in both remedial and preventative indoor air quality management programmes.

### Conclusion

In this brief survey, the issue of sick building syndrome has been considered from a microbiological viewpoint as this is sometimes overlooked, especially in developing countries, in favour of chemical contaminants. Usually, problems arise when a building is operated in a manner which is inconsistent with its original design and/or prescribed operating procedures and, on a few occasions, problems result due to poor building design or occupant activities (USEPA, 1991).

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