

Chapter 2

Theories and Knowledge About Sick Building Syndrome

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2.1 Introduction

In 2005 I commenced work in the offshore oil and gas industry in the South East Asia region. The rig allocated was an old tender barge that was built in 1976. The décor had remained the same for many years until “refurbishment” in 2005. A majority of the upgrade was purely aesthetic without review of ceiling or wall panels. In fact, new wall panels were placed directly over the old ones. The installation of a new industrial ducted air-conditioning system was well received in the hot and humid region of the equator. However, little thought was given to any other requirements of the incoming air. After all, it was nice to be cool for once.

In 2009, on the same tender barge, several of the catering and office crew started to contract some severe dermatological conditions that presented similar to anything from *tinea corporis* to eczema. Several crew members contracted severe upper and lower respiratory infections with two requiring hospitalisation onshore and the remainder retained and treated onboard. As the frequency of dermatological and respiratory conditions in crew members increased over approximately two to three months, I discussed the cases with the onboard Medic. Through investigation of the medical documents and identifying the specific personnel involved, it was realised that a majority of the patients were those with office/accommodation type appointments such as cleaners, catering staff, and supervisors to name a few.

Approximately two weeks later the beloved air-conditioning unit failed and required repair from a specialist tradesman. It was at this point the specialist identified that UV lighting had not been installed with the ducting system. This allowed an extraordinary amount of spores, moulds, and fungus to populate within the ducting system. It was during the inspection of the ducting system that several small leaks from piping were found within the ceiling panels with the water being directed down into the wall panelling. Small bulges had been noticed in the walls but had not been investigated. On removal of the wall panels, “friends” of those living in the air-conditioning duct had made quite a home within the walls.

The identification of these two “fields” prompted the removal, cleaning, and reinstalment of all wall panels, cleaning, sterilising, and installation of UV lighting in the air-conditioning

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Fig. 2.1 Pictures of the wall panelling onboard one of the rigs

duct and repair of the leaking pipe work. All dermatological & respiratory conditions deteriorated quite rapidly after the cleaning took place. The exact type of bacteria, fungus, and mould was not identified/reported back after the episode.

Pictures of the wall panelling onboard one of the rigs are shown in Fig. 2.1. The photos are all of the lower accommodation in which there are approximately 75 personnel accommodated. The capacity of the vessel is 112 personnel. Some photos I have highlighted with a red circle just to point out the bulging in the walls as it may be hard to see due to the quality of the photos. (Lee)

This Occupational Safety Professional's story is a typical sick building syndrome story. Sick Building Syndrome has been defined as "a generic term used to describe common symptoms which, for no obvious reason, are associated with particular buildings" (TSSA 2010, p. 1). Clayton Utz's Property Issues (1996, p. 25) records that sick building syndrome is "a clinical diagnosis without any cause, or causes, having been specifically identified." Thorn (1998) reported that the diagnosis of Sick Building Syndrome is made when all other building related causes of ill health are eliminated. The Property Council of Australia (2009) states that as air quality measurement techniques improve and are more widely used, and as knowledge of the causes of sick building syndrome grows, the term building related illness is being used more commonly than sick building syndrome.

In the first part of this story from Lee the cause of the employees becoming sick at work was unknown. In this case the health effects experienced by employees were respiratory and skin effects. These are typical sick building syndrome health effects. When the air conditioning system was examined it was found that mould and other fungus in the duct system and in the building walls was the cause of these employees' ill health. These employees were now suffering a building related illness as the

causes of the employees' illnesses were determined. It is notable that not all employees who entered the accommodation became ill. This frequently happens with sick building syndrome as not all employees may have been exposed to the same level of the hazard, and because there is an individual difference in people's susceptibility to environmental contaminants. In a research study conducted by Hedge et al. (1995), 4,479 health survey questionnaires were completed and returned from the occupants of 27 office buildings. The results of analysing the responses identified that over 76% of the 4,479 respondents reported at least one work-related symptom of Sick Building Syndrome at least once a month.

The most common theories about the cause of sick building syndrome are that it can be caused by some of the following factors.

- Building materials (identified in the book of Leviticus in the Bible). The building materials may allow micro organisms to grow on or in them, or the building materials may have chemicals or other substances in them or off gassed from them that may irritate the person's skin or pollute the building air that people breathe.
- Poor sanitation (identified in the Ohio State Capital Building investigation).
- Ozone, organic solvents and formaldehyde in the atmosphere (Jeanne Stellman of the Women's Occupational Health Resource Centre).
- Office equipment, furnishings and other materials and products located or used in the building which can produce fumes or contact dermatitis (Jeanne Stellman of the Women's Occupational Health Resource Centre).
- Air borne chemical fumes or gasses from anything in the building (these cause were publicised by Gray Robertson, President of Healthy Buildings International, and supported by the tobacco industry).
- Building air conditioning, inadequate ventilation (which could cause a buildup of carbon dioxide, carbon monoxide or other gasses) and pollutants from inside or outside the building that were circulated by the air conditioning system (these cause were publicised by Gray Robertson President of Healthy Buildings International, and supported by the tobacco industry).
- Mould, bacteria, dust mites, other micro organisms; endotoxins and other microbial products (these causes were publicised by Professor Ragnar Rylander of the University of Geneva, and supported by the tobacco industry).
- Poor building cleaning and maintenance resulting in air borne dust and fibres (Environmental Protection Authority (EPA) building investigation).
- Inadequate light and /or space for work tasks (EPA building investigation).
- Vermin (particularly mice, rats and cockroaches) infestation (EPA building investigation).
- Poor indoor air quality (this cause was brought to prominence by the research work of Lance Wallace of the EPA).
- Other environmental factors that include building temperature, humidity, lack of negative ions in the workplace atmosphere, building odours, noise, electrostatic charges, electro-magnetic fields and/or vibration in the building (Godish 1995).

- Psycho social issues (identified in an American court decision).
- Poor management practices (identified in an American court decision).

The first dot points are factors that affect the air quality and physical environment in the building. The last two points are people factors. When building occupants become sick due to sick building syndrome causes there can be legal implications.

2.2 Legal Implications

The following information on legal implications refers to Australian and American laws and cases, but other countries in the world have similar laws to protect the health of the people in their country.

Pengilley (1994) highlighted the legal responsibilities of the building owners and tenants in New South Wales (NSW) in relation to indoor air quality. There is a general duty of care for an employer, under the Occupational Health and Safety Act 1983 of NSW, to provide a safe workplace that does not harm the health of employees or anyone else who comes to the workplace. There are Common Law requirements and the Occupier's Liability Act that require the air that people breathe in a building to be safe.

In Australia there are Australian Standards. Two Standards that are relevant to the air quality in buildings are AS3666-1989 Air-handling & water systems of buildings- Microbial control, and AS1668.2-1991. The use of mechanical ventilation and air-conditioning in buildings, Part 2: Mechanical ventilation for acceptable indoor-air quality AS1668.2-1991 includes looking at the occupancy space and ventilation requirements for people. For example, in a commercial organisation and in office areas the requirements are 10 meters square (m^2) per person occupancy space with an air flow in the building of 10 litres/person/second. In a library each person requires 5 m^2 of floor space per person with the same air flow rate. In a conference room the air flow is required to be 15 lps/person. In an Australian court of law the building owner and the tenant (s) would have been expected to have met the requirements of these Australian Standards.

In a court of law the person who would be prosecuted for poor indoor air quality would be the person who had ownership and control of the air conditioning unit. Pengilley (1994) states that the case of *Cunard v Anifyre* [1993] 1 KB 551, the case of *Taylor v Liverpool Corporation* [1993] 3 ALLER 329 at p. 337 and the case of *Wheat v E. Lacon & Co Ltd* (1966) AC 552 provided precedence for this decision.

As an example of a court case related to a building's air quality, Pengilley (1994) cites the case of *Carey v Australian Telecommunications* (1985) 2 AAR 457. In this case a postal clerk, who had a history of having asthma, claimed that on being changed to working in an air conditioned office his asthma became worse. He produced evidence in court that mould and dust found in the building's air conditioning system aggravated his respiratory condition.

Telecom presented evidence that the air-conditioning system had been well maintained and clean. On this point the Tribunal stated:

Irrespective of the state of maintenance and cleanliness, the fact is that certain moulds, fungi and other substances are being circulated by the system and, for whatever reason, they have an adverse effect on the applicant. . . If every component was cleaned daily, if every nut and bolt was tightened regularly, if the system was a paragon of punkahs, he would still be incapacitated. (Pengilley 1994, p. 22)

In this case the employee was awarded Worker's Compensation for his asthma becoming worse when in his employer's air conditioned building.

Clayton Utz's Property Issues (1996, p. 25) records that in the United States of America "law suits arising from sick building syndrome causing personal injury have been brought against manufacturers, distributors, employers, real estate brokers, contractors, lenders, engineers, architects and building owners." Evans (2008, p. 39) stated that there were five possible ways that a person with sick building syndrome in Western Australia (WA) could find to instigate legal action against building architects, builders, engineers, employers or product manufacturers.

1. *Breach of contract.* For building construction the materials used should be of good quality and fit for purpose. For the building owner to ensure that these requirements are met there are warranties for most building materials and equipment purchased. If these requirements are not met then there is a breach of contract.
2. *Negligence.* The Civil Liability Act 2002 (WA) applies to ill health that occurs due to products purchased. However, with new and innovative materials, that the product may cause harm needs to be reasonably foreseeable. For example the potential health hazards, associated with volatile organic compounds (VOCs) which can be released from fibreboards and particle boards, has been known since the 1980s so it is reasonable foreseeable VOCs will be released from these building materials. VOCs are a cause of sick building syndrome symptoms so these building materials need to have a warning as to the health effects that they can cause so that employers, building owners and other people are aware of this.
3. *Occupiers' liability legislation.* The Occupiers' Liability Act 1985 (WA) requires the building to be safe for everyone who enters the building. This includes the air that people breathe.
4. *Occupational health and safety legislation.* The Occupational Safety and Health Act 1984 (WA) requires the employer to keep a safe workplace for everyone who comes on to the business premises and to have safe work processes for employees.
5. *Actions against manufacturers and importers under the Trade Practices Act 1974 (Commonwealth).* For example, this law could be used to make product manufacturers liable for the health effects caused by formaldehyde-based building materials, if there is no warning of the effects of formaldehyde provided with the product as the health effects of formaldehyde (a cause of sick building syndrome) are well known.

For claims to be successful the person making the claim would have to prove that the building owner or employer or others had a duty of care to the building occupant. The person would then have to prove that a breach of this duty had occurred. They next must prove the cause of their illness was due to factors in the building and lastly the occupant would have to demonstrate the company or person to be liable to pay damages for a breach of this duty and that “the breach produced the claimed injury by a natural and continuous sequence, unbroken by any efficient intervening cause, and they must establish that the claimed injury would not have occurred without the breach” (Air conditioning and indoor air quality 2006, p. 4). Air conditioning and indoor air quality (2006) describes two cases in the United States of America where this proof has been successful in relation to a person, or people, suffering sick building syndrome. In both cases the cause of sick building syndrome was identified to be mould in the building.

Case 1. Copper piping leaked water underneath a 22 room mansion in which Melinda Ballard lived. She suffered adverse health effects from the mould that grew in this area. When this case was taken to court a Jury awarded Melinda Ballard US\$32 million. This compensation was paid to Melinda by her building insurance company.

Case 2. A mould related ill health case in California was settled for US\$18.5 million.

Air conditioning and indoor air quality (2006) described two other cases that were before the American courts. In one case a New York employee had initiated a claim for US\$65 million against his employer for ill health suffered due to exposure to mould in his workplace. In the other case Richard Kramer had brought a complaint for compensation and punitive damages of US\$2 billion against 28 defendants. In the building in which Richard lives he stated “that mould infestation has resulted from massive leaks and other water problems throughout the building, which the defendants knew about for well over a year, but concealed from apartment owners and failed to remedy.” Not remedying these problems caused Richard Kramer’s 3 year old daughter, Alana, to develop “severe and disabling respiratory and other illnesses attributable to toxic mould exposure as well as affecting Mrs Kramer, who had developed severe allergic reactions to this toxic mould” (Air conditioning and indoor air quality 2006, p. 4). In Australia there are also sick building syndrome stories where the cause of this ill health can be attributed to mould as is documented in the following story.

2.3 Health Effects Attributed to Sick Building Syndrome

2.3.1 Introduction

As an Agency Registered Nurse I went to work a shift at a nursing home because there were registered nurses on sick leave due to having respiratory infections. One of the first

Fig. 2.2 Pictures of the *Stachybotrys Trichothecenes* mould that grow on cellulose rich material



things that I noticed in the nurses' hand over room was that there was water damage on the ceiling and the walls. In the water damaged areas there was mould growing. The staff told me that when it rained the roof leaked and water came through the ceiling and ran down the walls. All of the windows in this nursing home were made so that they stayed shut to keep the building at a comfortable air conditioned temperature for the residents. As well as staff frequently becoming ill some of the residents had respiratory and other symptoms of ill health. I completed a hazard report form on the mould, but did not return to work at this nursing home to find out if any steps were taken to eliminate this biological hazard.

The picture shown in Fig. 2.2 comes from Google Images. It is of the *Stachybotrys Trichothecenes* mould that grows on cellulose rich material, particularly if there is a moist environment and causes health complaints including eye, nose and/or throat irritation, headaches, dry cough, dry itchy skin, difficulty in concentrating, dizziness, nausea, fatigue & sensitivity to odours. This looks like the mould that was on the nursing home ceiling and walls. The ill health effects caused by this mould resemble symptoms that some of the nursing home residents and staff were experiencing (Patricia).

This is a Sick Building Syndrome story because the cause of the employees' and of the residents' ill health was not determined, but seemed to be related to being in the nursing home building. Many of the symptoms of exposure to the *Stachybotrys Trichothecenes* mould are similar to the symptoms of sick building syndrome.

2.3.2 Ill Health Effects

The Environmental Protection Agency (2010), Environmental Illness Resource (2010), Odle (2010), Kipen (2010), Roy (2010), Unionsafe (2009), Milica (2009), Property Council of Australia (2009), Gomzi and Bobic (2009), Joshi (2008), Evans (2008), Tyler (2007), Greer (2007), Marmot et al. (2006), Kreiss et al. (2006), Shoemaker and House (2005), Burge (2004), Hodgson (2002), Unionsafe (2002), Mendelson et al. (2000), Workplace Services (2000), Niven et al. (2000), Thorn (1998), Brinke et al. (1998), Redlich et al. (1997), Bachmann and Myers (1995),

Hedge et al. (1995), the Health and Safety Executive (1992), Stenberg (1989) and Finnegan et al. (1984) state that Sick Building Syndrome can cause the following ill health effects.

1. *Respiratory*

- Runny nose
- Sneezing
- Dry sore throat
- Blocked nose
- Nose bleeds
- Allergic Rhinitis (repetitive sneezing and a runny nose)
- Sinus congestion
- Colds
- Influenza like symptoms
- Dry Cough
- Throat irritation
- Wheezing when breathing
- Shortness of breath
- Sensation of having dry mucus membranes
- Hoarseness of the voice due to inflammation of the throat and larynx
- Sensitivity to odours
- Increased incidences of building related asthma attacks

2. *Eye irritation*

- Eye dryness
- Itching of the eyes
- Watering of the eyes
- Gritty eyes
- Burning of the eyes
- Visual disturbances
- Light sensitivity

3. *Dermal irritation*

- Skin rashes
- Itchy skin
- Dry skin
- Erythema (Redness or inflammation due to congestion in, and dilation of, the superficial capillaries of the skin.)
- Irritation and dryness of the lips
- Seborrheic dermatitis
- Periorbital eczema
- Rosacca
- Urticaria
- Itching folliculitis

4. *Cognitive complaints*

- Functional headache that affect a person's performance, but which fail to reveal evidence of physiological or structural abnormalities
- Migraine headache
- Tension headache
- Sinus headache due to swelling of the mucus membranes
- Mental confusion

5. *Lethargy*

- Lethargic (The word "lethargy" comes from the Greek word *lethargos* which means *forgetful*.)
- Difficulty in concentrating
- Mental fatigue
- General fatigue that starts within a few hours of coming to work and which ceases after the person leaves the building
- Unable to think clearly
- Drowsy

6. *Gastrointestinal symptoms*

- nausea

7. *Other*

- Dizziness
- Unspecified hypersensitivity reactions
- Personality changes (that may be due to stress or ill health)
- Exacerbation of pre-existing illnesses such as asthma, sinusitis or eczema.

Redlich et al. (1997) found that the duration of time spent working in the building could affect the occurrence of the symptoms of sick building syndrome. For example, clerical staff may spend a longer period of time at their desk than management staff and so be more likely to be affected by adverse building conditions. Finnegan et al. (1984) found when studying sick building syndrome symptoms in 9 buildings that the incidence of the symptoms were much higher in buildings that were air conditioned than in buildings that were not air conditioned.

The Property Council of Australia (2009) has grouped the symptoms of sick building syndrome into three groups with each group having a common set of symptoms and a set of likely causes or sources to be investigated (Table 2.1).

Roy (2010) reported his investigations into causes of sick building syndrome identified that *irritant*, or *allergic dermatitis* is usually due to fibreglass dust or to formaldehyde particles in the building air. Fibre glass is a skin irritant and is commonly found in building insulation. Fibreglass particles can be blown into the air through the building ventilation system. Roy also identified that a common cause of *hay fever* is mould spores in the building.

Table 2.1 The three groups of the symptoms of sick building syndrome

Common symptoms	Likely causes or sources
<i>Group A</i> Headaches Lethargy Nausea Drowsiness Dizziness	Outdoor air rates and distribution. Possible air pollution. Carbon monoxide may be entering from outdoor air intakes. Other obvious pollutant generators from neighbouring or industrial sources may be present.
<i>Group B</i> Congestion Swelling Itching or irritation of eyes, nose or throat Sub-clinical symptoms (e.g. headache, fatigue, nausea)	Pollutants entering air stream from local pollutant generators; the outdoor air quality; HVAC related problems; building materials. Be aware of hypersensitivities and other pre-existing medical conditions in individuals. Lighting problems, e.g. flicker caused by magnetic ballasts and computer glare, which contribute to eye irritation. Ergonomic problems e.g. muscle strain, eye strain and fatigue.
<i>Group C</i> Cough Shortness of breath Fever, chills and/or fatigue after return to the building Diagnosed infection Discomfort and/or health complaints that cannot be readily ascribed to air contaminants or climatic conditions	Stimulated by thermal discomfort factors including temperature and humidity settings, outdoor air rates and distribution. Particulate pollutants such as dust are often irritants. More serious fever/chill problems can point to microbial contamination in the building. Microbial problems – Acute case scenarios relate to Legionnaires’ disease and acute asthma. Chronic cases of asthma, infection and irritation are more wide spread. Examine cooling towers, HVAC system [including ducting] or outdoor air. May be related to problems with environmental, ergonomic or other job related psychosocial factors.

HVAC in this table is an abbreviation for Heating, Ventilation and Air Conditioning system.

According to the World Health Organisation (1993), definition of sick building syndrome and the Environmental Protection Agency (2010) the symptoms of sick building syndrome fade away after the person leaves the building. The cause of these signs and symptoms are unknown but they can reduce work efficiency, cause employees to take sick leave and to resign their employment position. Stenberg in a Chap. 25 in this book writes comprehensively about the symptoms of sick building syndrome but disagrees with the statement that the *symptoms of sick building syndrome fade away after the person leaves the building*. Stenberg's research (Chap. 25, this volume) has found that sick building syndrome can have a gradual onset and long duration of the symptoms, even when the person has left the building. This author found no research based studies that demonstrated that the person's symptoms resolved immediately on leaving the building; rather the studies examined by Stenberg (Chap. 25, this volume) identified that many of the symptoms remained for years after the person had left the building.

Diagnosis of Sick Building Syndrome is usually made by a Medical Practitioner based on the employee's self reported history of symptoms and of the Medical Practitioner's physical and clinical examination findings. The Medical Practitioner's diagnosis needs to be corroborated with an examination of the building in which the employee works.

To do this a trained occupational safety and health professional is required to perform a walk through survey of the building to identify if any other occupants of the building have the same symptoms, to check building factors (such as building ventilation, cleaning, maintenance, work station layout, if the employee works in an open plan offices with more than 10 work stations, if there are large areas of soft furnishing and open shelves, new furniture, carpets, painted surfaces, air conditioning, lighting levels, particularly if there is glare or flicker that the employee is exposed to when working), environmental factors (such as high temperature or excessive temperature variation, very low or high humidity, noise) and for pollutants (such as tobacco smoke, ozone, volatile organic compounds, dust particles, chemicals or fibres in the atmosphere, microbiological or fungal contaminants), work related factors (such as variety and interest in the work performed by this employee, employee's ability to control particular aspects of their work or work environment), personal factors (such as job satisfaction) and to conduct environmental monitoring to identify any pollutants in the air.

Most office workers spend 70–90% of their work time indoors so are affected by any indoor air pollution. Roy (2010) reports on a NIOSH (National Institute of Occupational Safety and Health) survey of 100 office buildings. This survey found that 23% of the occupants of these 100 buildings reported recurrent Sick Building Syndrome symptoms that included ear, nose and throat irritations and asthma.

2.3.3 Building Related Illnesses

Although Sick Building Syndrome is the popular term used in published literature and common language, building related illness may be a more accurate term because

a building cannot get sick as it is not alive. However, building related illness is a term that is used to describe illnesses that occurs in a person in a particular building for which a cause is known. According to Passarelli (2009) some common building related illnesses include Mass Psychogenic Illness where a large number of people believe that they are affected by a particular set of symptoms where no known microorganism is identified as causing this illness. The difference between Mass Psychogenic Illness and Sick Building Syndrome is that Mass Psychogenic Illness is spread through social networks and the symptoms do not fade away when the person leaves the building. Mass Psychogenic Illness usually occurs in workplaces where there is a lot of tension and employees feel stressed.

Passarelli (2009) states that Neurotoxic Disorder is a building related illness that is caused by the presence of heavy metals and other neurotoxic substances in the building in which employees work. The list of building related illnesses is added to by Kreiss et al. (2006) who include rhinosinusitis, hypersensitivity pneumonitis, inhalation fever and other infectious disease as building related illnesses.

Roy (2010) states that building related illnesses are more serious than sick building syndrome as they do not subside when the person leaves the workplace. Roy lists building related illnesses as including the following.

- Building-related asthma. This is a hypersensitivity illness that has the symptoms of wheezing, coughing, shortness of breath and a tight chest. The symptoms may not appear until up to 12 h after exposure to the allergens in the building (The Property Council of Australia 2009).
- Irritant or allergic dermatitis. Skin rashes are most commonly caused by fibreglass or formaldehyde.
- Humidity fever. This can occur if a humidifier is used with the air conditioner and bacteria or fungi are aerosolized in the air through the humidifier. Humidity Fever is a flu-like illness the symptoms of which are fever, chills, muscle aches, cough, dyspnoea and fatigue. The symptoms usually occur 4–8 h after exposure. The symptoms usually subside once the person leaves the building but, in severe cases, can last 2–3 days.
- Hypersensitivity Pneumonitis. This is usually due to high fungal exposure in the building. It may also be due to regular dust exposure. It can be acute or chronic.
- Pontiac Fever. This is caused by inhaling the antigen of the gram negative bacilli *Legionellae*. Symptoms of Pontiac Fever are a rapidly rising fever alternating with chills. The infected person usually has anorexia, abdominal pain, malaise, myalgia, headaches, a non productive cough and diarrhoea is common. Pontiac Fever usually affects healthy young people and they recover spontaneously in 2–3 days with no treatment (Chin 2000).
- Legionnaire's Disease. This is a more severe form of Pontiac Fever and is caused by the same micro organism. The gram negative bacilli *Legionellae* (of which there are 35 species and at least 45 serogroups) lives in hot water systems, air conditioning cooling towers, evaporative air conditioners, hot and cold water taps, showers and anything in the building that has running water as the transmission of this micro organism from the water to humans is via the air that the person

breaths. Legionnaire's Disease occurs more commonly in people who are over 50 years old. As well as causing a severe form of pneumonia with Legionnaire's Disease there may also be brain, bowel and liver damage and kidney failure (Chin 2000; The Property Council of Australia 2009).

- Aspergillosis. *Aspergillus fumigatus* causes allergic bronchopulmonary aspergillosis in the lungs if a person is immune compromised or has a pre-existing illness that lowers the effectiveness of the person's immune system. This micro organism can cause lung abscess, emphysema or fungus balls to grow in the person's lungs (Chin 2000).
- Other opportunistic fungal infections.

Research by Greer (2007) and by Chester and Levine (1997) identified that sick building syndrome can cause Chronic Fatigue Syndrome with the suffers of this Syndrome having health improvements when no longer working in the building that was causing their illness. Another building related disease is Multiple Chemical Sensitivity.

2.3.4 Multiple Chemical Sensitivity

Nakazawa et al. (2005) wrote a case study analysis of a woman clerical worker in Japan who developed sick building syndrome due to exposure to formaldehyde and other volatile organic compounds in her building workplace. This clerk's symptoms began when she was shifted to work in a new building that was being refurbished. Like her work colleagues she was aware of strong odours in the refurbished rooms. In May this employee developed nausea and had headaches at work. In June she developed a nettle rash, fever and pharyngeal pain. In July she developed a severe cough and nausea. This employee then took holidays as she felt that she was too sick to continue working. Her symptoms improved to some extent, but then she started reacting to chemicals outside the company building. She reported her medical condition and was diagnosed by a Medical Practitioner as having Multiple Chemical Sensitivity. She was awarded Workers Compensation for her illness and treated with Tachion 150 mg a day. Her symptoms then resolved and she was able to return to work. Not everyone with Multiple Chemical Sensitivity recovers as quickly.

Multiple chemical sensitivity is a building related illness that affects people who are highly sensitive, or allergic, to substances in the environment. Odle (2010, p. 2) states that Multiple Chemical Sensitivity was "recognised by World Health Organisation (WHO) as a medical condition in 1992." Multiple chemical sensitivity has proven difficult to diagnose as the symptoms seem to vary between one person and another as different people are sensitive to different chemicals.

Cullen (2002, p. 6), states that for a person to be diagnosed with Multiple Chemical Sensitivity this person should meet the following case definition requirements.

1. The syndrome is acquired, usually after the occurrence of a more clearly evident (although not necessarily serious) health event caused by environmental exposure, such as solvent intoxication, respiratory tract irritation, pesticide poisoning, or non-specific building related illness.
2. The patient experiences multiple symptoms referable to several organ systems, almost always including the central nervous system.
3. Although there may be persistent complaints between exposures, the symptoms are characteristically and predictably precipitated by a perceived environmental exposure.
4. The agents that may precipitate the symptoms are multiple and chemically diverse.
5. The doses of these agents that precipitate the symptoms are at least two orders of magnitude lower than the established thresholds for acute effects.
6. No test of physiologic function can explain the symptoms. Although there may be clinical abnormalities, such as mild bronchospasm or neuropsychologic dysfunction, these are typically non-specific and insufficient to explain the full scope of the illness pattern.
7. No other organic disorder is present that can better explain the pattern of symptoms.

Murphy (2006) states that some of the symptoms of multiple chemical sensitivity include shortness of breath, memory loss, dizziness, fainting, fatigue, depression, moodiness, nausea and skin rashes. A problem with multiple chemical sensitivity is that the person with this illness finds it difficult to leave a safe space without chemicals that they react to and to go to a workplace or any other building as they may have hypersensitivity reactions to the chemicals in the buildings and any products that are made from the chemicals that they are sensitive to. The American Academy of Environmental Medicine claims to have treated over 30,000 patients with multiple chemical sensitivity. Multiple chemical sensitivity is more likely to have affected people who worked in new or refurbished buildings.

2.4 New and Refurbished Buildings

Building emissions concerns. This account is based on observations at the time of the incident. There is much more information, documented evidence, e-mails and explanations available on file about the incident that could be argued might change the views indicated here.

Late in the year part of a building was refurbished. The refurbishment included new furniture laminates, carpets and painting. Staff were moved into the newly refurbished area and almost immediately started to complain of various health difficulties including (as written in an e-mail by a staff member in the area):

- Headaches/migraines over multiple days;
- Itchy eyes;
- Nose bleeds;

- Running nose; and
- Difficulty breathing – Pain in chest, wheezing, cough, blocked sinuses, heavy feeling in your lungs.

Subsequent checks in the building did detect some odours that could have been the cause of the staff health complaints. An occupational Hygienist was engaged to look into the concerns of the staff. Air monitoring was carried out to measure for Volatile Organic Compounds (VOC's) including formaldehyde, a known by product of the manufacturing process of chipboards and foam furniture. The results of the air monitoring did not find any high levels of any VOC's including formaldehyde.

Advice from the hygienist was that “off gassing”^{***} of the materials and glues that make up some types of new chipboard can produce low level emissions. If the timeframe between manufacture and delivery is short, emissions from the manufacturing process could still be occurring. If furniture is then left in an un-ventilated area, the emissions could build up to a point where the smell could be sufficient to effect individuals depending on their susceptibility and tolerance of those emissions.

Other observations by the Hygienist were that the air conditioning intake and out take vents in this location of the building were positioned so close together that fresh air was being immediately removed from the building without first circulating through the building.

In conclusion:

- Generally speaking the conclusions of the investigation were that due to the use of glues to stick laminates and carpet/vinyl, newly painted surfaces, foams that had been used to manufacture new chairs and fresh air circulation in this part of the building, that the building following the refurbishment did have a strong smell, something that could be described as a “new building smell”.
- A chip board that had been used to manufacture office furniture and the “off gassing” of new chairs were identified as the two main sources of the odours that were apparent in this part of the building.
- There is evidence that some staff in the area did suffer from the ailments that they claimed they were suffering from.
- One person's tolerance to emissions and vapours may differ from another so for those people the odours in the building may have been enough to set off the health effects that they experienced.
- There was some allegation that the staff in the area did not want to move into the building and that the claims that were being made were exaggerated.
- Air monitoring did not detect high levels of any VOC's.

The staff in the area were moved out of the building, the building air conditioning was turned up to 100%, doors and drawers were left open and the building odours were reduced to such an extent that staff returned to work in the building approx 2 weeks later.

^{***}“Off gassing” is a term to describe the process that when foam and chipboard is manufactured, the glues and processes that are used continue to release odours for some time after their manufacture. (Malcolm)

This Occupational Safety Professional's story explains some of the effects that building products can have on the health of building occupants. There were two main causes of employees experiencing these health effects. The first cause was that many of the building's new furniture and fittings produced air borne chemicals that contaminated the atmosphere. Brinke et al. (1998) identified that often the

fumes from volatile organic compounds (VOCs) in a building, when measured with hygiene monitoring equipment, are below the threshold level that is supposed to cause health effects when each VOC is measured individually. This is what was reported in the above case study. When Brinke et al. (1998) conducted research in 22 office areas in 12 buildings these researchers identified that the combined effect of 39 VOCs when measured together produced irritant symptoms and other sick building syndrome symptoms in the building occupants that each substance on its own did not when present in the building at low levels. The combination of VOCs together produced a synergistic effect that caused the symptoms of sick building syndrome in the building occupants. This seems to be a similar situation to what respondents report in this case study.

A second problem in this case study was that the building ventilation was inadequate as the intake and outlet vent for the building's air conditioner were located so close together that air that as air entered the building it was immediately sucked out without circulating throughout the building. For the building odours to disperse the building doors had to be left open for 2 weeks as the windows did not open and the air conditioner was ineffective in dispersing the chemical pollutants.

2.5 Chemical, Gas and Fibre Pollutants

In the 1980s new buildings in Australia started to have chip board, and then particle board, used as a building material instead of real wood. The fibres in chip board are held together by formaldehyde. Out gassing of this formaldehyde occurs for months after manufacture. Formaldehyde is one of the most common indoor air pollutants. Roy (2010) records that common indoor contaminants that can cause sick building syndrome include volatile organic compounds (VOCs) including formaldehyde from building furnishings, coatings and adhesives, building materials and equipment and airborne particulates that include dust and synthetic mineral fibres (SMF) – fibreglass, asbestos, etc.

The Property Council of Australia (2009) identified the indoor air pollution shown in Table 2.2 as causes of sick building syndrome symptoms.

Table 2.2 Indoor air pollution as causes of sick building syndrome symptoms (Property Council of Australia 2009)

Pollutant	Sources
Carbon dioxide (CO ₂)	CO ₂ is produced from human respiration. If there are too many people in the building space, or if there is inadequate ventilation, then CO ₂ levels can rise. If CO ₂ remains below 800 ppm 95% of the building occupants find the air acceptable.
Carbon monoxide (CO)	Levels above 2 ppm cause headaches, dizziness, nausea, fatigue, flu-like symptoms, breathlessness & decreased work capacity. CO binds to red blood cells to prevent them from carrying oxygen. CO may originate from tobacco smoke, vehicle exhausts, gas appliances, propane refrigerators, solvents, etc.
Nitrogen oxides (NO) & Nitrogen dioxide (NO ₂)	CO can enter buildings through poorly located air intake ventilation ducts, basement car parks and doors or windows. Produced by tobacco smoke, vehicle exhaust, gas appliances and incinerator combustion. Is a deep lung irritant and is carcinogenic. Causes irritation of the eyes & upper respiratory tract. In asthmatics it can cause swelling and reduced lung function. Long term low level exposure can lead to emphysema and make people more susceptible to respiratory infections.
Sulphur dioxide (SO ₂)	Can enter ventilation system from external industrial environments. SO ₂ is an irritant to the respiratory system, reduces lung function, constricts the blood vessels in the lungs and increases mucus flow.
Polycyclic aromatic hydrocarbons (PAHs)	A large family of complex organic substances; includes tobacco smoke. Cause general sensory irritation, cancer and affects the cardiovascular system.
Volatile organic compounds (VOCs)	Over 5,000 VOCs have been identified in indoor air. VOCs are organic (carbon based) substances that evaporate into the air at ambient temperatures. VOCs have widely varying toxicity, irritant and odour properties. Some cause irritation of the mucus membranes of the eyes, nose & throat, dizziness, nausea and headaches. Some are carcinogens and mutagens. Common sources of VOCs include tobacco smoke, office equipment, solvents, cleaning agents, particle board, carpets, floor polishes, furniture, adhesives, paint, printer & photocopier cartridges and emissions, printed materials, marker pens, electronic equipment and air fresheners. Comprehensive information about VOCs in indoor environments is provided in this book in a Chap. 16 written by Gallego et al.
Formaldehyde	Contained in glues, particle boards and bonded mineral fibre insulation. Is a nose, throat & eye irritant, causes headaches & fatigue and is an allergen to asthmatics. It is a carcinogen.
Ozone	Formed by electrical discharges from photocopiers, laser printers, air filters, electric motor brushes and air ionisers. Is toxic even at low exposure levels. Can cause respiratory irritation, shortness of breath, coughs, eye irritation and headaches.
Asbestos	Until the late 1970s was used in more than 3,000 products. Is often present in old buildings. Is hazardous if the fibres become loose and airborne. Can cause lung cancer.

Table 2.2 (continued)

Pollutant	Sources
Synthetic fibres	Synthetic mineral fibres include fibreglass, slag fibre insulation, rock/mineral wool all of which can be used as building insulation. There are other synthetic fibres that can be found in ceiling tiles. Air borne fibres cause skin irritation, eye irritation and aggravate asthma symptoms.
Dust	General dust, construction dust, paper dust, soil particles. Air borne dust causes irritation of the throat, lungs and eyes.
Pesticides & biocides	These are used in some building air conditioning systems.
Odours	The effects of these chemicals have not been studied in relation to being a cause of sick building syndrome symptoms. Odours do not usually cause health effects but can cause discomfort and may be a sign of air borne contaminants. Common building odours can include off gassing from building materials and furnishings, chemical cleaning residues and mould odours.

This is a brief summary of common indoor air pollutants that can affect air quality. As well as being found in new buildings these indoor air pollutants can be found in old buildings.

2.6 Old Buildings

I have a number of proven instances of sick building syndrome with police buildings. A classic example is the situation at a Capital City Central Police Station and Watch House. This is a facility that was built in 1965 and has been in continuous 24×7 use ever since. The building has concrete cancer. The faults in concrete pillars, walls and floors is caused by the reinforcing rusting through the plaster walls and a general break down of the concrete aggregate leaking through the plaster into toilets, change rooms and other areas where dampness is present. The risks associated with health are undetermined regarding silica dust in the atmosphere. Mould spores and bacteria problems are clearly present in the following areas.

1. Spaces between concrete floors and metal ceiling panels. The panels have small holes where the dust debris is able to filter through into the internal areas of the building.
2. Door vents where there has been a gradual build up and blockage of the vents. Dust and bacteria is blown out by the air conditioning air flow.
3. Floor tiles that have asbestos content. Asbestos particles have become loose through rubbing by ill fitting doors and are free to float around the atmosphere.
4. All areas where taps and sink drains have not been cleaned thoroughly, causing mould and bacteria to build up.
5. Build up of mould and bacteria in areas that have been very difficult to clean.

An extensive occupational hygienist report recorded numerous other associated health risks. The situation is not helped by the constant flow of customers who bring with them individual health problems that can spread throughout the complex via the air conditioning; it too is 44 years old, or by lack of complete and thorough hygiene and cleaning practices, which should match those that exist in a hospitals, but fall well short. This is a particular problem in the kitchen facilities that attract slack habits. Fresh air cannot be released into the building. Security considerations demand that the windows are barred and closed.

Another example is the older part of a suburban Police Station built in 1897 from construction methods that did not include damp courses or cavity walls. The building, including the extensions built in 1980, has numerous sick building syndrome issues.

1. Mould spores are emitted through the plaster walls and ceilings in wet areas.
2. Old fire doors have asbestos sheeting.
3. Floor joists, floor boards, skirting boards and doors are constantly attacked by white ants causing collapse.
4. Lead paint is exposed to the environment.
5. False ceiling spaces harbour all sorts of debris and mould that has dropped from the original ceiling (Probably horse hair and fibrous) material. This is exposed to the atmosphere through ceiling vents and manholes.
6. The concrete extensions has an asbestos roof, currently unsealed and presenting difficulties for sealing under the exposed eaves on the third floor. Movement between the asbestos sheets can cause the fibres contained in the sheets to break free and float around the atmosphere.

Although there has been no official comparison research conducted, working in the affected places exposes employees to increased health risks for general illness compared to working in modern facilities that can cope with the hectic nature of contemporary 24×7 policing. (David)

These two stories, told by the same Occupational Safety Professional, highlight problems with the police officers working in old buildings that can cause employees to take sick leave related to experiencing sick building syndrome symptoms. The documented problems in these two stories include police officers inhaling dust debris, asbestos fibres, lead (in Australia both lead and mercury were used in paint prior to 1990 and both can be toxic to humans), mould and other micro organisms.

2.7 Biological Hazards

There are biological contaminants in many buildings. Biological contaminants can include bacteria, fungi and animal products. Air Conditioning and Indoor Air Quality (2006, p. 2) reports that “there are over 200,000 species of fungi and microbes known, of which approximately 60–100 are a cause of concern in the indoor environment.” A common contaminant that causes sick building syndrome is mould. Excess humidity with poor ventilation in a building allows mould to grow. The presence of mould is usually associated with water leakage, condensation or a relative humidity in the building of above 70%.

My sick building story involves a former home in Midland. The house was built around Federation (1900). I moved in and noted that the walls were continually damp, so I researched methods that would be cost effective to combat rising damp. I chose reverse osmosis, not knowing the residual health problems this would cause me. For months I had a terrible cough, so bad in fact that on one occasion the cough was so severe I knocked my head on the floor and I was out cold. I recall the ambulance drivers taking me to Swan Districts Hospital. On my return home I decided to investigate what was going on (by now I had been referred to a specialist at Royal Perth Hospital.) I lifted the skirting boards and it was infested with mould. You could actually see the spores in the air. I was so sick. I put the house on the market and moved out straight away. I recovered within days of leaving the place. There is no doubt that this house was sick and made me very unwell. It still stands today, however it is now used as a psychologist’s suite. (Jeremy)

This story, provided by an Occupational Safety Professional, illustrates the health effects that can occur from having mould in a building. This private home would have required extensive renovations to make it safe and healthy to be used as a workplace for a group of psychologist to see and treat patients in the building rooms. When investigating causes of sick building syndrome in Western Australia Peter Roy (2010, p. 2) identified that a common cause of sick building syndrome in the buildings that he investigated was poor ventilation and mould in the buildings. He provided the following three stories to illustrate these causes.

Pilbara – two Australian energy companies managing large holdings of housing and accommodation units had significant problems with widespread and reoccurring mould growth that contributed to adverse health risks for workers and their families. Although much time and effort had been spent on mould remediation, the major root cause of mould

growth – inadequately designed HVAC equipment – had not been identified or adequately addressed.

South Western Australia – a Public Primary School had wide spread worker complaints and one severely affected staff member in newly refurbished offices. The investigation uncovered problems with lack of effective ventilation, reoccurring moisture leakage and condensation, and presence of an apparently toxigenic form of the mould *Fusarium* sp.

Perth – a large religious organisation had problems with wide staff complaints linked to deficiencies in building ventilation systems (split units) and poor humidity control. Localised moisture infiltration also lead to mould growth in one area of the facility. Corrective actions included mould remediation, interim humidity control measures, building modifications to masonry walls and planned installation of modified HVAC systems.

In these three stories by Roy (2010) it is clear that having inadequate ventilation and excessive moisture can lead to mould growth in buildings. It is also clear that building occupants can have allergic reactions to mould toxins.

The Property Council of Australia (2009) divides biological building pollutants into those that are living and those that are non living. Living biological pollutants are viruses, bacteria, moulds and other fungi. These are capable of causing infections. Viruses are usually introduced into the building by humans, but the stability, concentration and distribution of the viruses may be influenced by the building's ventilation rate and relative humidity level. Bacteria and fungi become established and proliferate in humid conditions and on wet surfaces, particularly if there is dust present or if the building has been water damaged. Components of the air conditioning system, particularly if poorly designed or maintained, may be a site of bacterial, fungal or protozoan growth and may spread these micro organisms throughout the building atmosphere. People can have allergic reactions to micro organism mycotoxins, endotoxins or antigens (Shoemaker and House 2005). Protozoans and dust mites can be present in building air and these usually cause allergic conditions such as asthma. There are two chapters in this book, one by Pinzari (Chap. 9, this volume) and the other by Pinzari and Montanari (Chap. 11, this volume) that provide further detail about biological hazards, particularly mould, that can grow in buildings and cause sick building syndrome.

Bholah and Subratty (2002) conducted research in 23 buildings with offices in Mauritius to identify if there was any relationship between bio-contaminants in these buildings and the incidences of sick building syndrome symptoms. These researchers collected viable colonies of micro organisms from the researched buildings using a Casella slit sampler and gave a self report health questionnaire to the occupants of these buildings. The researchers identified that there was a strong association between offices that had moderate to heavy microbial contamination and the symptoms of sick building syndrome as the occupants of these offices experienced headaches, excessive mental fatigue, loss of concentration and forgetfulness, particularly if there was high fungal spore counts in the building atmosphere.

Cooley et al. (1998) conducted a 22 months research study in 48 schools in the United States of America in which there were complaints of sick building syndrome

symptoms by the building occupants. The indoor air quality of these buildings was tested. In all cases it was identified that the cause of the occupants experiencing the symptoms of sick building syndrome were either fungal contamination with *Stachybotrys* species or *Penicillium* species of mould. In all cases it was determined that the initial microbial growth commenced after a water leak occurred and wetted the building materials. Following this the HVAC system had become contaminated with the microbial growth. Based on the findings of this research it was determined in these 48 schools the cause of sick building syndrome symptoms in the building occupants was due to the *Stachybotrys* or *Penicillium* species of mould. Remedial action was under taken to remove the mould in these schools building materials and air conditioning systems.

Non living biological pollutants can also cause sick building syndrome symptoms as they are associated with allergic conditions in susceptible people. These pollutants can originate from both inside and outside the building. If the outdoor air filtration system is inadequate or damaged then outside air contaminants, such as pollen, can enter the building. Inside the building dead skin cells, animal excreta, insect body parts (such as parts of a dead cockroach that are an allergen for some people) and dander may be circulated, particularly where the filtration of recycled air is inadequate. These factors do not just affect old buildings they can affect the occupants of all buildings.

2.8 All Buildings

2.8.1 Introduction

In all buildings the indoor building environment is affected by the air quality, lighting, building windows, acoustic comfort, radiation, layout of the building rooms and equipment and by ergonomic factors. Indoor air quality is important to the occupants of all buildings. Hedge et al. (1995), when analysing health survey results from 4,479 respondents from 27 air conditioned office buildings, reported that claims of sick building syndrome symptoms increased when employees perceived that the indoor air quality was poor. Indoor air quality is affected by the environmental factors of temperature, humidity, amount of carbon dioxide in the air, air contaminants, air circulation and the ratio of outdoor air to recirculated air. All of these can affect the building occupants' health, comfort and productivity. For all indoor areas having adequate ventilation is important in preventing the occurrence of sick building syndrome symptoms.

2.8.2 Ventilation

An experienced medical practitioner commenced work in a new building. This building had 4 air conditioners. Each air conditioner was used for a group of rooms. A problem with this sharing arrangement was that some rooms were too hot for the occupants while other rooms

were too cold. The medical practitioner's room shared that air conditioning with the patient waiting room. Some of the people came to see the medical practitioner because they had respiratory infections. While sharing the same air conditioner as the patients the medical practitioner constantly had viral infections. As a risk control measure this medical practitioner first blocked the air conditioner with cardboard. His health improved immediately. He then organised for his room to have a sky light and a separate air conditioner. He has had good health ever since. (Andrew)

This story, provided by a Medical Practitioner, illustrates problems that can occur when a ventilation system is shared in a building and micro organisms are recirculated throughout the building by the air conditioning system. It also highlights that not all building occupants are comfortable working in the same indoor air temperature.

Roy (2010) provided two stories about the effects of having inadequate ventilation in a building. His first story, which was reported in the Lewiston Morning Tribune, concerned the students and teachers at Pomeroy High School in Washington where 12 of the 21 staff members reported experiencing sore eyes, dry throats, coughing and other symptoms of sick building syndrome. An investigation determined that the school's ventilation system was not operating properly and that this was the cause of the building occupants' symptoms. The second incident, which was documented in the Boston Globe Newspaper, occurred at the University of Massachusetts in Boston. In two incidents at this University that occurred a few days apart first 8 people, then 27 people, from this university were treated for burning lips, nausea and tight throats. The Boston Health Department closed the entire campus so that indoor air quality investigations could be conducted. The problem was identified as buildings in this University having an inadequate ventilation system.

From these stories it can be seen that having adequate ventilation in a building is important. Roy (2010) states that in the United States of America between 1978 and 2005, when NIOSH investigated the causes of sick building syndrome in more than 700 problem buildings, in 53% of the cases the root cause, or the contributing root cause, was inadequate ventilation in the building. For best practice Roy (2010) recommends that the fresh air ventilation flow rate should be 15 litres per second (lps) per person for an office or for other building rooms that are occupied by people who are performing work tasks.

In Australia, New Zealand, the United Kingdom and the USA the minimum acceptable air flow rate is 10 litres of fresh air per second (lps) per person for each person working in an office. Research by Roy (2010) identified buildings with higher than the minimum fresh air ventilation rates have lower employee absenteeism and fewer complaints of employees experiencing adverse health effects while working in the building. For each increase of 0.5 lps/person in fresh air employee absenteeism was decreased by up to 2%. It was found that there was a decrease in sick building syndrome symptoms of 33% when the ventilation rate was increased from 8.5 to 25 lps/person. Conversely, when the fresh air flow rate was decreased from 8.5 to 5 lps/person there was a 15% increase in employee reports of sick building syndrome symptoms.

Roy (2010) reported that research work conducted by Seppanen (2006) demonstrated that with a ventilation rate of 15 lps/person workers performance in typing, maths problem solving and in proof reading was much higher than when this work was performed with the minimum ventilation air flow rate, but a flow rate of above 17 lps/person made little additional improvements in employees' work productivity. This knowledge is important to have when designing building ventilation systems and when maintaining ventilation systems.

Roy (2010, p. 9) had been told by some employers that "More fresh air and greater capacity HVAC systems are just too expensive to operate!" His answer to this was that employee salary, staff turnover costs, recruitment and retraining costs are much higher than the cost of having adequate ventilation in a building. Roy's calculations demonstrated to employers that staff costs are 100 times the total building energy costs to provide adequate ventilation. He demonstrated that even a 1% increase in employee productivity would offset a 50% increase in building energy costs. Dingle (2010) supported Roy's comments and provided the following information. On average employees' salaries are \$100–\$200 per ft² of a building. Energy costs are \$1–\$2 per ft² of a building. For increasing employee productivity and comfort, as well as having adequate ventilation, it is important to also consider the building's indoor air temperature and humidity as complaints of being either too hot or too cold can be associated with mucosal irritation, headaches and fatigue (Hodgson 2002).

2.8.3 Thermal Comfort and Humidity

The most comfortable temperature inside a building is between 20 and 23 degrees Centigrade (°C) in winter and 20–25°C in summer with relative humidity of 40–60%. An indoor building temperature above 25°C can cause headaches and fatigue while indoor temperature below 18°C is likely to cause chills and influenza like symptoms. In Australia the building temperature of an air conditioned building is usually set at 22°C. Indoor air comfort can also be affected by radiant heat from the sun coming through windows on the west or north side of the building in the afternoon. Comfort of building occupants is also subjective as some people like a warmer room temperature while others prefer the temperature to be cooler. Individuals have different metabolic rates; some people are over-weight and some are under-weight, some employees are very active performing physically demanding work while other employees perform sedentary work, but in many air conditioned public buildings all people are subjected to the same building temperature. The higher the humidity in the building air the warmer the air feels.

Humidity is the amount of water in the air. The humidity ratio in the air is the mass of water in each kg of dry air. Relative humidity is "the percentage of water vapour in a gaseous mix of air and water vapour, compared to the vapour pressure of water within the mix when saturated at the same temperature" (The Property Council of Australia 2009, p. 17). At 20% relative humidity the air would readily take up water. It would be considered dry air. At 50% relative humidity the air would

hold about half as much water vapour as it can hold. At 100% relative humidity the air could no longer absorb any more water vapour as it would be saturated and the air would feel heavy and oppressive. Indoor building air humidity outside the range of 35–65% can cause adverse health effects.

The Property Council of Australia (2009, p. 18) identifies that excess indoor air humidity can cause the following problems.

- Fatigue, reports of “stuffiness”, headaches and dizziness (particularly when relative humidity exceeds 80% and temperatures are also high);
- Favourable conditions for the growth of micro-organisms, especially when condensation is present; and
- Increased rate of “off-gassing” from building materials, especially in the case of formaldehyde and other volatile organic compounds.

The following problems may occur where humidity levels are too low:

- Dryness of the eyes, nose and throat;
- Increased frequency of static electricity shocks;
- Increased rates of ozone formation;
- Stabilisation of certain viruses, such as influenza; and
- Allergic responses by asthmatics.

As can be seen from these two lists building humidity can very much affect the health of the building occupants. For most of these environmental effects, once the person leaves the building, they should no longer be affected by the building humidity and their ill health symptoms should resolve. Building occupants are also affected by noise (acoustic comfort) in the building. The health effects due to building noise may also resolve when the person leaves the building.

2.8.4 Acoustic Comfort

When building occupants have individual offices or work areas that are enclosed and sound proof the noise that occurs in a normal building is not a problem. However, particularly in open plan offices and reception areas with telephones ringing and with increasing volume of people and the conversations that these people hold, noise (unwanted sound) can become difficult and even irritating to people who are trying to think and concentrate on completing their own work. Too much distracting noise interferes with short term memory processes, can cause headaches and even personality changes as the building occupant becomes increasingly frustrated and irritated with their inability to concentrate.

In a research study by Niven et al. (2000), the researchers conducted significant environmental monitoring, that included building air monitoring and noise monitoring in 5 different buildings. These researchers gave a self report health questionnaire to the occupants of these buildings. Completed questionnaire responses

were received from 1,131 people. Analysis of these questionnaire responses identified that that low frequency noise in these buildings was a significant cause of sick building syndrome symptoms. As well as noise levels lighting levels can affect the health of building occupants.

2.8.5 Lighting

Where ever possible there should be natural lighting in a building as this improves occupants' comfort and health while reducing energy costs. Due to the design of some buildings natural lighting alone is insufficient for work tasks to be performed effectively so artificial lighting is also required, particularly if the building is to be used outside of day light hours. When considering building indoor lighting there are two Australian Standards that should be followed. The first is AS/NZS 1680:2006 Interior lighting, Part 1: General principles and recommendations. The other is AS/NZS 1680.2.2:2008 Interior and workplace lighting – Specific applications – Office and screen-based tasks. Both of these Standards provide appropriate recommendations on the illuminances required for various types of work tasks, activities and building interiors. Passarelli (2009) identified that a significant lack of natural day light, flickering mechanical lights or lights that are too bright or too dull for the work that needs to be performed can contribute to causing sick building syndrome symptoms.

According to the Property Council of Australia (2009, p. 24) common problems that can occur with artificial lighting can include the following:

- inadequate lighting design or intensity leading to widespread or localised dark areas;
- inappropriate lighting for specialised tasks;
- flicker arising from the oscillation of fluorescent lights typically associated with using magnetic rather than electronic ballasts;
- the colour of the lamp source;
- poor configuration of lights; and
- unsympathetic colour schemes can contribute to lighting discomfort.

Inadequate lighting can cause headaches, eye strain and other symptoms of sick building syndrome. Most of the health effects due to poor lighting should cease when the person leaves the building, but continued eye strain may contribute to long term vision problems. More details about how lighting can affect the occurrences of sick building syndrome symptoms occurring in building occupants and ways to prevent this occurring are included in the chapter in this book written by Abdul-Wahab and Ahmed (2011) titled "Improvement of the illumination levels combined with energy savings for a residential building."

When looking at the occurrence of sick building syndrome symptoms and building related illnesses a group of people that the Property Council of Australia (2009)

recommends considering are the building maintenance workers. The following story was supplied by a building maintenance worker when asked if he had a story about sick building syndrome.

2.9 Building Maintenance

I have worked in a major metropolitan hospital in Australia as the maintenance fitter with responsibilities for the general upkeep and maintenance of the HVAC air conditioning system. I can say with certainty these systems don't get better with age. The upkeep/service and maintenance to wearing equipment for an ever growing system that must function efficiently on a tight streamline budget have consequence. I will cite a couple of examples I experienced at the hospital.

The hospital was built in the 1980s. The four chillers (one large and three small) operate in sequence as the need arises, that is to say the large Chiller due to its capacity to cool a greater volume of water and push it out and around the hospital plus the nursing home is the main operating system and functions alone, on its own. They are expensive to run, more so during start and warm up prior to going into service. The second chiller is basically there to "take up slack" and supplement the larger to supply additional cooling water to the system when the core temperature of the hospital rises. This is most noticeable in the warmer months. When the desired temperature of 23°C is achieved the second chiller drops out. For this second chiller to start up and drop out many times during the day is cost prohibitive. The three smaller chillers are all electronically attached to the larger and are controlled automatically.

Power consumption in the hospital runs into tens of thousands of dollars per month and as a cost saving measure the three smaller chillers are removed from the system, placed into manual mode to remain in the off position. During the cooler months this is not problematic to the extent that it requires constant vigilance and is left to the monitoring system.

The hospital expanded and renovation work was undertaken in its second decade of operation increasing the patient capacity from approximately 180 to 260 beds in addition to the private practice located north of the building and a significant user of the ventilation system. The problem is the existing large chiller was not upgraded to cope with the extra work load and went from 70% running capacity to nearly 90% and for a machine that is being pushed to its limit.

In the warm months as soon as the outside temperature reached 25°C it became problematic in that the system was unable to keep with demand. This is due to the new larger areas drawing more cooling water at a faster rate, the cooling chiller unable to produce any more fluid into the system, therefore the rate of flow to area's further away have a slower rate (trickle) of water insufficient to fill the coolers and in some instance not at all.

An example of this is one of the operating theatres that was used by Dr X has the cooling system at the end of two larger theatres and when the draw on the system occurred there was no water left in the system for his operating theatre. In a normal situation his theatre temperature is steady at 18°C with the air taken directly from outside, filtered and cooled. On a hot day when a draw occurs and zero water flows through the cooler the temperature can rise equivalent to the outside and on occasion it was 36–40 degrees Centigrade and the temperature rose inside of ten seconds while the doctor was in the middle of a procedure. I know of two occasions where the doctor moved out of the theatre and into another further down the hall that was on a different cooling line while the patient was still on the table.

As areas become cooler the system draws less cold water and the flow to the hot areas slowly returns. The time period for this is usually between 30 minutes and 1.5 hours. The quick

solution is obviously to start the second chiller. Unfortunately only the assistant engineer had authority to do this and his familiarity with the system made the judgment call cost verses quick comfort gain.

The higher areas of building and extremities are always the first to suffer. The third story of the building can take a long time on a very hot day to cool down and to see staff and patients alike who are hot, lethargic, sweaty, irritable and generally uncomfortable does not reflect best practice when it comes to the dollar as the bottom line.

The hospital has had a further expansion in recent times by adding two extra wings to the existing structure and upgraded the chiller. The same problem exists because the new chiller is designed more to the pre expansion size and problems experienced earlier have been repeated with the additional new buildings.

Experience and handover knowledge is essential to the servicing of equipment within the hospital. An example of knowledge not being passed on and not known is the filtration system feeding the elevator shaft. The engineering staff had always assumed the filtration system feeding wards two and three also fed the elevator. This was not the case and it was only after doing a task in the vicinity I noticed a door at the far side. On opening it I found very dirty, slimy thick dirt caked row of filters that had not been changed in over a decade.

A systematic approach to regular maintenance is essential to the wellness of any building, more so being a caring environment to the sick. Although I never had an induction into the hospital there was certainly no training provided into the system and for the most part you were left to fathom it out.

The engineering department comprised the following people

- Head Engineer
- Assistant Engineer
- Two Electricians
- Fitter
- Carpenter
- Plumber

The following people developed cancer.

- One Electrician (lymphatic cancer)
- Fitter (thyroid cancer)
- Carpenter (stomach cancer)
- Plumber (blood disorder)

We all had different treatments and all were healthy prior to working at this hospital. The area I worked in was directly behind the main switch room for the entire hospital and I have often wondered if there were any effects from this that caused our cancers. Regardless of the cause, after my diagnosed of cancer (the 4th person in a department of 7 staff members to be diagnosed with cancer) this department was relocated to another area of the hospital well away from the switch room. There has been no further incidence of employees in this department developing cancer. (Laurie)

As well as describing ventilation and ventilation maintenance problems that affected the health of people who used the building this story identified that of the five non-management building maintenance workers four developed cancer. This is not a normal symptom of sick building syndrome, but the building maintenance worker who provided this story seemed to think that his, and his co-workers' cancer could have been caused by his workplace being located behind the hospital

switchboard which may have been responsible for electromagnetic radiation from the communication equipment entering the maintenance workshop. Even low levels of electromagnetic radiation, when employees are exposed to these on an ongoing basis, have been known to cause cancer (The Property Council of Australia 2009). It is important to note that once the maintenance workshop was relocated away from behind the hospital switchboard there were no more cases of cancer that developed in these maintenance workers.

Another cause that has been considered as causing sick building syndrome symptoms in building occupants is office work.

2.10 Office Work

Office workers have been the most researched occupational group in relations to the occurrence of sick building syndrome symptoms. Office workers spend most of their working hours in an enclosed building so are very much affected by the indoor air quality and other factors inside their building. Office workers can be affected by the equipment and products that they use as part of their work. This section describes some of these factors that have been documented in research study findings to cause symptoms of sick building syndrome in office workers.

Godish (1995) identified that carbonless copy paper contains many chemical including hydrogen terphenyls, aliphatic hydrocarbons, diaryl ethanes, alkyl naphthalenes, chlorinated paraffins and alkyl benzenes. Colour developers for photocopy paper contain phenolic resins, salts of aromatic carboxylic acids, phenolic resins and many other chemical compounds. In research studies, Godish (1995, p. 95) identified that office workers who handled a large number of papers reported the following symptoms of ill health that they perceived were related to their work. "Itchy rashes on the hands, swollen eyelids, headaches, burning throat and tongue, fatigue, excessive thirst, burning sensation on the face and forehead, backache, nausea, eye irritation, sore and dry burning lips, facial rash and dry throat." It was believed that the rupture of the capsules on the paper containing the colour forming chemicals and the solvents used in the paper were the causes of these health effects. The office employees reported that their ill health effects occurred 2–3 h after commencing work and resolved at night and over the weekends when they were not working in their office.

Hedge et al. (1995) in a research study that included the occupants of 27 buildings, identified employees who used their computers full time reported more symptoms of sick building syndrome than employees who used computers occasionally or not at all. These researchers theorised that this might be because the electrostatic field generated by the VDT screen attracted more particulate contaminants into employees' breathing zone.

Other office equipment that was identified as causing the symptoms of sick building syndrome in office workers by Godish (1995) included photocopy machines whose toner emits VOCs, electrostatic photocopy machines that omit ozone and

laser printers that can produce elevated levels of Freon and Acetone in the breathing zone of the operator. Another cause that has been considered for sick building syndrome in office workers is psychosocial factors as traditionally office workers have had poor control over their work tasks and work environment.

2.11 Psychosocial Factors

Roy (2010), when investigating cases of sick building syndrome only found psychosocial factors present when there had been long standing indoor air quality issues and the people in the workplace had not had their incidences of ill health, usually due to the poor air quality in the building, dealt with effectively. Greer (2007) agrees with these findings stating that her review of published literature identified that psychosocial factors were a symptom of sick building syndrome, not the cause, with the effects of exposure to some toxins causing anxiety, changes in mood and in behaviour due to ill health being experienced by the building occupants.

The Property Council of Australia (2009) identified that work related stress can cause people to become sick, but, this is not something that is in the control of the building owner, unless the building owner is also the person's employer.

In the case study under "New and Refurbished Buildings" the Safety Professional wrote that *There was some allegation that the staff in the area did not want to move into the building and that the claims that were being made were exaggerated.* This would be a psychosocial factor that could increase complaints about the symptoms that these employees were experiencing as they were dissatisfied with their new accommodation. When people are dissatisfied, or angry, they are more likely to make complaints about factors that, if they were satisfied with their work and workplace, they would have ignored.

Workplace Services (2000) agrees with this and documents that poor management practices and other factors that cause employees to have low morale, while not causing sick building syndrome symptoms, do affect the way that the symptoms of sick building syndrome are perceived and affect the building occupants' level of tolerance of their ill health. Particularly important was the level of control that the person could exert over their work and over their work environment and the response of management staff to their ill health complaints.

Marmot et al. (2006) agreed with this as their research findings from the Whitehall 2 study, which analysed the questionnaire results from 4,052 participants from 44 buildings in which occupants of the building reported sick building syndrome symptoms, identified that respondents who had high work load demands, low work related support, low control over their work and low control over their work environment reported more symptoms of sick building syndrome than those with control. The research study by Hedge et al. (1995) identified that employees with low job satisfaction reported more symptoms of sick building syndrome than employees with high job satisfaction.

A research study was conducted by Mendelson et al. (2000) in 5 hospitals in Canada. Hospitals 2 and 5 were not defined by their Occupational Health and Safety

Committee as being sick building sites. Hospitals 1, 3 and 4 were and these hospitals all had employees on long term sick leave with symptoms of sick building syndrome. Hospital 3 had over 200 employees on extended sick leave with sick building syndrome symptoms. In hospital 3 there had been problems with the air quality in the hospital building in that sulphuric acid, hydrochloric acid and sodium hydroxide had entered the building through the air intakes causing adverse health effects in employees. Cleaning fluids used in this hospital contained phenol and formaldehyde. Exposure to these substances also affected employees' health.

At these 5 hospitals 1,853 union members were surveyed in relation to factors that affected their health when at work. It was found that symptoms of sick building syndrome were more likely to be reported by employees who worked in an area in which renovations had taken place in the last 2 years. There was also a positive relationship between employee work overload and reports of adverse health effects. This was similar to the findings of Marmot et al. (2006). It was identified by Mendelson et al. (2000) the less that the management staffs in the organisation were seen as supportive of employees' health concerns the more the employees were likely to perceive that their adverse health effects were caused by their place of work. This psychosocial effect was similar to that identified by Roy (2010).

Bachmann and Myers (1995) when analysing the results of an office workers' health survey completed by 624 respondents from three buildings were unsure if psychosocial factors caused the symptoms of sick building syndrome because employees were dissatisfied with their work or workplace, or if the symptoms of sick building syndrome, such as fatigue, caused psychosocial factors to occur. Both causes seemed to produce psychosocial symptoms in their research findings.

The chapter in this book written by Kinman and Clements (2011) titled "The role of demographic and psychosocial factors in predicting SBS symptoms in workplaces" provides a comprehensive description of psychosocial factors that have been considered to contribute to the occurrence of sick building syndrome symptoms. As well as psychosocial factors there are also personal factors that can cause sick building syndrome.

2.12 Conclusions

This chapter has identified that people are individuals and can react differently to different environmental conditions and airborne toxins, particularly if they have pre existing asthma or another medical condition or if they are just sensitive to an indoor pollutant. The most commonly reported symptoms of sick building syndrome are related to skin irritation, eye irritation, respiratory symptoms, cognitive complaints, nausea, lethargy and the symptoms of exposure to other environmental causes of ill health. There are a wide variety of symptoms of sick building syndrome as a result of there being a wide variety of causes for employees experiencing ill health when in a building.

Factors that have been identified to cause sick building syndrome symptoms include the environmental factors of temperature, humidity, adequate ventilation,

acoustic comfort and lighting. The symptoms caused by these environmental factors are usually relieved when the occupant leaves the building. Symptoms caused by building related chemical and biological hazards can cause either short-term or long-term health effects that do not always resolve when the occupant leaves the building.

The major impact of sick building syndrome on employees are often hidden in increased incidences of sick leave and medical claims, lower productivity of employees and in increased employee turnover. Most people in the work force do not complain about their ill health. They just leave the company to find another organisation to work for where they can have better health.

The legal implications of sick building syndrome for product manufacturers, product distributors, employers, insurance companies, real estate agents, contractors, building architects and building owners have been considered. The following chapters in this book provide research based information about sick building syndrome that help to explain how to identify incidences of sick building syndrome, causes of sick building syndrome symptoms, the incidences of sick building syndrome symptoms, ways to prevent further incidences of sick building syndrome and ways to enhance people's well being when they are occupants of a building.

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