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The Sick Building Syndrome: Where Are We in 1992?

Key Words

Sick building syndrome
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Abstract

Independent epidemiological studies in the UK, Denmark, Holland, Sweden and Germany have identified a group of common symptoms that are temporarily related to occupancy of office buildings. The principal symptoms are lethargy, headache, blocked nose and dry eyes, throat and skin. The average number of work-related symptoms per building occupant (the building symptom index) varies widely between buildings in all these studies. In general, air-conditioned buildings are sicker than naturally ventilated ones, despite indoor environments that conform more closely to environmental comfort standards. Sicker buildings are assessed by their occupants as drier and stuffier than healthier buildings, however, the sensation of dryness relates to increased temperature rather than water content of the air, and stuffiness does not relate to the air change rates. There is an association between the presence of humidifiers and chillers and sicker buildings. It is likely that either soluble products from micro-organisms, or the biocides used to control them, are the link between symptoms and air-conditioning. Control over the indoor environment depends on better design, and improved training, supervision and work practices of those maintaining the building plant.

Introduction

The sick building syndrome (SBS) consists of a number of common symptoms that tend to occur together, and are temporarily related to working in particular buildings. The common symptoms are lethargy, headache, blocked nose, dry eyes, dry throat, dry skin, and sometimes runny eyes and nose, and perhaps asthma (often regarded as a separate disease). Major epidemiological studies of randomly selected workers in a wide range of buildings have been completed in the UK [1, 2], Denmark [3], Holland [4] and Sweden [5], together with a survey in Germany, where workers were selected using market research techniques away from their workplace [6, 7]. Despite many differences in the methods used, there are a number of common findings between the studies. In particular, there is not one group of healthy buildings and another of sick ones, but rather a continuous gradation from one to the other. Studies involving a range of naturally ventilated and air-conditioned buildings have consistently shown that, in general, air-conditioned buildings are 'sicker' than naturally ventilated ones, despite enviromental conditions that are better (with respect to comfort standards) than the naturally ventilated buildings. The central di-

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chotomy is, therefore, that buildings which are designed for the comfort of workers are not necessarily healthy.

Workers who have symptoms suggestive of SBS also complain of environmental discomfort. For instance, they rate the working environment as less satisfactory, hotter, drier and stuffier than their colleagues from the same buildings who rate the environment as more satisfactory [2]. The complaints of dryness and stuffiness have been interpreted as arising from a lack of water content of the air and a lack of fresh (new outside) air, with the supposition that increasing the volume of fresh air supplied to the HVAC (heating, ventilation and air-conditioning) system and installing a humidifier will solve the problem. Unfortunately both these arguments are flawed.

Measurements indicate that environments assessed as dry by the building occupants do not differ in water content from those considered to be more humid; in fact, the relationship is sometimes inverse, i.e. the environments that have the higher water content are judged the drier [8]. The factor being assessed by the individual is therefore something other than water content, and probably relates to both increased temperature and higher particulate levels in the air. At present we do not know what it is that occupants perceive as freshness of the air; we do know that the healthier, naturally ventilated buildings have consistently lower air change rates (and higher carbon dioxide levels) than the sicker air-conditioned buildings. There is no direct relationship between new air change rates and SBS; in fact, a recent attempt to investigate this by altering the fresh air make-up in a building and monitoring symptoms in the workforce showed that symptoms decreased as the fresh air make-up was reduced [9]. It is therefore unlikely that problem buildings will be 'cured' by increasing the supply of fresh air. This conclusion is directly opposed to the opinion from North America, where lack of fresh air is regarded as the most common cause of SBS [10]. Common sense suggests that there must be a minimum volume of fresh air needed, below which the indoor environment deteriorates sufficiently to produce symptoms in workers; however, it is possible that American buildings have been designed to be less leaky and more energy efficient than the European buildings studied. The usual method of attributing the cause of building sickness in north America is by the identification of an indoor air parameter that lies outside the environmental standard [11]. Thus, if the ventilation rate is below the standard, the cause is assumed to be the lack of fresh air make-up. This assumption has not been supported by objective measurements on occupants after increasing the volume of outside air fed into the HVAC system.

Humidifiers

Many buildings without HVAC systems (and quite a few with them) have humidity levels below that recommended [11]. This, together with the perception of the air being too dry, leads logically to the introduction of humidifiers into the HVAC system. The two major UK studies so far reported show that there is an association between the introduction of humidifiers and the increased prevalence of SBS [1, 2]. In one of these studies, there was a higher rate of symptoms reported from buildings whose HVAC plants were less well maintained [12].

Contaminated humidifiers are the cause of humidifier fever, a more severe disease than SBS. In affected individuals, IgG antibodies to antigens extracted from the humidifiers can be demonstrated, and the condition can be reproduced by exposing such individuals to sterilised extracts from their humidifiers [13]. Humidifiers fever is associated with headache and lethargy, both also prominent symptoms of SBS. Rhinitis and asthma can be similarly reproduced.

Some humidifiers are treated with biocides, which then enter the air supply. At least one of these biocides, isothiazolinone, is a skin sensitiser [14], so it is therefore possible that biocides may contribute to the symptoms of SBS. The first UK study showed that steam humidification was associated with less symptoms than water spray humidification [1], which would support the hypothesis that microbiological growth is an aetiological factor. The story becomes further complicated with the recent studies of bacterial and fungal levels in indoor air. There are many problems with these measurements; most workers report the results in colony-forming units/m^3 of air. This method only records viable organisms that grow on the selected media, and at the temperature of incubation. Some organisms grow best at room temperature, whereas others grow only at increased temperatures (such as *Legionella* and thermophylic actinomycetes, known to be the cause of some outbreaks of alveolitis from wall-mounted air-conditioning units). Thus it is unclear whether the results should be expressed as the maximum growth at any temperature, the sum of growths at each temperature with each medium used, or as the number grown at room temperature only [15].

Studies have shown that there is no consistent relationship between bacterial levels and SBS. Total fungal levels are much higher in naturally ventilated as opposed to air-conditioned buildings [16]. It is likely that the microbiological species will differ substantially from place to place, with outdoor fungi such as *Alternaria* and *Cladosporium,* predominating in the naturally ventilated buildings. These organism are much less often seen in air-conditioned buildings. Within air-conditioned buildings, there is a relationship between prevalence of symptoms and fungal levels [16]. One study of a clean room and adjacent air-conditioned office showed that the fungal counts (and dust levels) where much lower in the clean room, but that the symptoms were, if anything, increased [17]. It is therefore unlikely that the whole, viable fungi are the cause. It is possible that soluble fungal products, such as mycotoxins, are responsible; alternatively, the fungi may be a marker of some other agent.

The most recent Dutch study was unable to demonstrate a difference between steam and water humidification [4]. This may be because their buildings were better maintained and microbial contamination was not present in the water spray humidifiers, or it might be due to the methodology used. In the Dutch study, symptoms were only scored if they occurred at least weekly, whereas the British studies only required that symptoms be present at least twice a year and improve on days away from work. In Britain and Holland, humidification is only required for some of the year, usually in the winter, so that the requirement for weekly symptoms to be recorded may miss seasonal factors. It is unlikely that the humidifier itself is the cause of the symptoms of SBS, but rather that it introduces an opportunity for microbiological contamination of the supply air, which can be prevented by good plant design and maintenance.

There is therefore reasonable evidence that at least some humidifiers contribute to SBS, which raises the question of whether increasing the humidity to 40%, as required by the comfort criteria [11], is helpful. Measurements in a relatively small number of buildings have shown no increase in symptoms with humidity levels down to 30% [11]. The situation in subarctic climates may be different, as the relative humidity may stay below 15% for several months in the winter. There is one study from Finland, where relative humidity is very low in the winter months, showing a reduction in mucosal symptoms (from 1.6 to 1.49 per worker) when a steam humidifier was installed and the relative humidity increased to between 30 and 35%; there was no change in the occurrences of lethargy or headache [18]. As increased humidity also favours the growth of house-dust mites and the spread of respiratory virus, it is likely that the humidity required for health is well below 40%.

Chillers

Increasing symptoms with increasing temperature, particularly over 23 °C, is a finding common to several studies [3, 12, 19]. Again there is a dichotomy, as naturally ventilated buildings tend to get hotter in the summer than do air-conditioned ones. Within sealed buildings, there is an increase in symptoms once the air is chilled. Chillers also have the potential for microbial growth, particularly when condensation is not drained from the drip trays under the chiller unit. Microbial growth is the probable cause of symptoms due to chillers, and has been shown to cause asthma in an office with opening windows and air-cooling with chiller units [Robertson, A.S., pers. commun.]. Chillers are often placed peripherally in buildings, in ceiling voids and in wall recesses, i.e. in positions where maintenance is often difficult.

Some standards for thermal comfort have separate requirements for temperature, humidity and airflow [20]. Thermal comfort depends on all of these factors; increased air temperature can be made comfortable (and healthy) by increasing airflow, for instance, with the opening of windows. Standards should include this as an option to encourage natural ventilation when possible.

Dust

The Danish study found an association between floor dust and symptoms. They also introduced the fleece factor (the area of fabric, such as carpets, curtains and screens, divided by the volume of the room) and the shelf factor (the area of open shelves and similar surfaces divided by the room volume), and found both to be related to symptoms [3]. They also found more symptoms in workers who handle paper. The Dutch study was unable to reproduce these results [4], which may be due to the Danish buildings being predominantly naturally ventilated, whereas most of the Dutch buildings were air-conditioned.

It is likely that there are different causes for the symptoms of SBS in different types of buildings. Sick, naturally ventilated buildings tend to be old and dirty, have poor space management and poor storage facilities. Passive cigarette smoke exposure also contributes more to symptoms in naturally ventilated buildings, probably because of the lower air change rates [21]. Carpets have also been associated with symptoms, the likely mechanism being again dust creation [4]. One study has attempted to investigate the effect of steam cleaning, using before and after measures of workers' symptoms [22]. It is very difficult to make such a study blind; nevertheless, workers in one particularly dirty office building showed a significant reduction in symptoms, which persisted for 2 months after the cleaning took place.

Visual Display Units

Visual display units (VDUs) have often been blamed for symptoms. Some studies show an association between VDU use and symptoms, while others do not. If the relationship is causal, there should be increasing symptoms with increasing use. The Danish study found an effect of VDU use [3], but only categorised workers into those not using them, and those using them for more or less than 1 h per day. The second British study [2] found no increase in symptoms when non-users were compared with those using VDUs for up to 6 h a day. Those working ≥ 7 h a day with VDUs had more symptoms, but might have other reasons for this, such as immobility and a lack of control over their jobs. A recent study from the USA [23] has shown an effect of VDU use increasing with each hour worked per day, suggesting a causal relationship. VDUs can charge particles in the air, and the deposition of particles on the face is thought to be the cause of the rare rash specific to VDU users [24]. It may therefore be that VDUs aggravate symptoms when the air is dusty, and not when the air is cleaner. A similar mechanism may account for the benefit claimed of air ionisers.

Chemical Pollutants

This review has so far said nothing about formaldehyde, volatile organic compounds or ozone, all of which have their proponents as causes of SBS. In high concentrations, all of these are recognised causes of symptoms; however, none has been shown to be convincingly higher in a range of sick office buildings than in healthier ones. The main problem in promoting control levels for these, which are lower than the levels found in sick buildings, is their use in industry, where levels are often 100 or even 1,000 times higher. It is difficult to set one standard for office workers and an inferior one for industrial workers.

Conclusion

By medical standards, the symptoms of SBS are relatively trivial. Symptoms are generally more common and more problematic in individuals who feel stressed, unloved and powerless to change their situations. There is a strong association between the lack of control over the office environment and symptoms [2]. There is also an association between environmental and job stress and symptoms [25]. The Dutch study showed that the strongest correlation with symptoms was reported to be an inadequate system for dealing with environmental complaints [4]. The reduced symptoms seen in managers and men may be due to their greater success in getting the indoor environment to their liking. Good communication between workers, occupational health staff and building service managers and their plant staff is fundamental to improving sick buildings.

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