The real enemies are not the smokers themselves, but the tobacco industry who continue to promote a dangerous product worldwide, and governments who are unwilling to introduce a fully effective control on tobacco promotion. In 1991, several major organisations published a document on the health risks of passive smoking,[23] and included in it a poster which listed the organisations who had spoken on the passive smoking issue. The poster listed 61 organisations which supported the view that passive smoking was harmful, including the Royal College of Physicians of Edinburgh: on the list of organisations stating that passive smoking is not harmful there was only one entry—'the Tobacco Industry'.

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SICK BUILDING SYNDROME*

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The sick building syndrome consists of dryness of the eye, nose, throat and skin together with headache and lethargy, which improve when the sufferer is away from a particular building. Symptoms are more common in women than men, in those lower down the office hierarchy, and in those who are stressed by their working environment. Symptoms are slightly more prevalent in those working with a visual display unit (VDU), in those handling paper and in non-smokers exposed to the tobacco smoke of others. Office workers have been the principal group studied, because of their uniform exposures and general lack of confounding factors. Many of the factors associated with sick buildings, such as lack of windows, increased temperature and lack of environmental control, are common in hospitals, particularly in x-ray departments. The main determinant of symptoms is the building; factors associated with air-conditioning being the most important.

SYMPTOMS

All the symptoms described are common in the general population and the distinguishing feature which identifies the syndrome is their temporal relationship with work in a particular building; all but the skin symptoms should improve within a few hours of leaving a problem building.

Lethargy and headache

A general feeling of tiredness is often the most prevalent symptom,[1] usually starting within a few hours of coming to work, and improving within minutes of leaving the building. In the more severe variety recovery takes some hours. Symptoms may be seasonal in northern climates and being worse in the winter months, a potential relationship with sunlight is suggested.

The typical headache is non-migrainous, and is often described as a pressure on the head. It is rarely throbbing, usually being described as dull. It is rarely referred to the face, making an association with rhinitis or sinus disease less likely.

Involvement of the mucous membranes

The eye, nose and throat are affected; the most common symptom is the sensation of a blocked or stuffy nose and, less often, sneezing and running of the nose. The latter are typical of allergic rhinitis due to an inhaled allegen and their lack makes an allergic mechanism less likely.

A dry throat, perhaps associated with increased thirst, is the next most prevalent mucous membrane symptom. It can be an important problem in those who use their voice professionally, such as broadcasters or telephonists.

Although the least prevalent mucous membrane symptom, dry eyes can cause problems in those wearing contact lenses, who may be unable to use them throughout the day. Objective signs include a reduced foam in the inner epicanthus, and an increased tear film break up time[2–4]

*Based upon a lecture delivered at the Symposium on *The Lung under Attack* held in the College on 8th November 1995.

Dryness of the skin
This is a difficult symptom to elicit from questionnaires, which generally require a symptom to improve on days away from the building for it to be classed as part of a sick building syndrome. The more prolonged recovery of skin dryness may lead to its under-recognition. A facial rash related to the use of visual display units (VDU) use has been described but is very rarely identified, and may be related to precipitation of charged particulates onto the face.[5-7]

EPIDEMIOLOGY AND AETIOLOGY

Although there is a general agreement on the principal symptoms of the sick building syndrome, this does not imply that the cause for each symptom are the same, as the mechanism underlying the symptoms are largely unknown. A suspected factor of association with a particular symptom should be widely distributed among different workers. A possible factor such as temperature cannot be associated with symptoms if all the workers studied come from areas with very similar ambient temperatures. Epidemiological studies can generally only detect an association of a factor with a symptom; identifying that factor as causal is more difficult but would be favoured by consistency between different studies, the strength of the association, and a dose response relationship. It is best confirmed by an experimental approach with blind alteration of that factor with independent monitoring of workers symptoms. Such studies are in practice very difficult to achieve in the workplace; for instance it is very difficult to change the temperature, humidity or airflow individually without changing one of the other factors.[8] It is easy to jump to conclusions from worker interviews, as most workers attribute their symptoms to something they perceive in their environment. For instance many workers perceive the indoor air to be dry but there is a poor relationship between dryness of the air as perceived by an individual and the actual water content measured in the air.[9] It is likely that the perception of dryness in the air relates more to increased temperature and particulates in the air than to water content; one study showed a fourfold reduction in perceived air dryness following air filtration, without changing the water content of the air.[10] The situation in x-ray departments is compounded by the belief that the problems are caused by chemicals in the developer. If the problem is assumed to be chemical contaminant, the measurement of very low levels of aldehydes and amines in the air can result in the environment being classed as satisfactory, whereas in reality the wrong measurements may have been made.

The symptoms of the sick building syndrome may be due to personal factors, individual exposures in the workplace, to organisational factors or to the building and its services.

Personal factors
Most studies find more symptomatic women than men, even after adjusting for the place in occupant hierarchy, and more symptoms in those lower down the hierarchy.[1,11-14] The reasons for the sex difference are unknown. The more important occupants of buildings usually work in less crowded areas of the office, which are better maintained, and have higher priority from building services personnel; these factors are likely to contribute to the reduced chance of symptoms in managers. The workforce in schools and hospitals is also predominately female.

Organisation factors
There are striking differences in the levels of stress and workload seen in the occupants of different buildings. Symptoms appear more frequently in public sector buildings. One building has been investigated which had both public sector and private sector employees.[1] Both groups had similar levels of symptoms. Available evidence suggests that the differences are due to the buildings occupied by the public sector being poorer and less carefully maintained. There are several studies of different buildings occupied by the same employer and they reveal a wide range of symptoms between buildings although these are sometimes interconnected. This suggests that the main determinant is the building and its maintenance rather than the philosophy of management.[15]

A number of individual exposures in the workplace have been associated with symptoms, the most important being VDU use, paper use and cigarette smoke.

Visual display units
Several studies have shown a fairly weak but positive relationship between the number of hours spent on a VDU and the symptoms of sick building syndrome; the mechanisms are unknown, but could relate to the lack of freedom experienced by a worker whose tasks and speed of work are determined by the computer rather than by themselves. One study only found symptoms increased when the individual was working for seven or more hours a day on a VDU,[16] but other studies have shown an effect with much lower exposure times.[6,11] There appears to be a rare but specific facial rash due to VDU use, perhaps due to precipitation of charged air particulates onto the skin.[7]

Paper
An association has been shown between the amount of paper handled and the symptoms of the syndrome particularly in low technology government departments. Respiratory and dermal symptoms may be due to a release of the inks encapsulated on the back of the top sheets of no carbon required copy paper. This may be a particular problem during paper shredding. Paper is a major contributor to the fibrous dust associated with symptoms in some studies.[17]

Cigarette smoke
Cigarette smoke is the major preventable cause of indoor air pollution in office buildings where smoking is permitted. Smokers complain of sick building syndrome symptoms less often than non-smokers (a varient of the healthy smoker effect). Non-smokers who work in a room with smokers have more symptoms than those working in a smoke-free environment.[18,19] The major location of environmental tobacco exposure in non-smokers is in the workplace.[20] One study showed a reduction of symptoms when smoking was stopped in the workplace.[21] Other studies have not shown an effect of cigarette smoke on symptoms, but in these smokers and non-smokers were not separated and the levels of exposure in the workplaces were low.[22]

X-ray chemicals
A postal survey of radiographers in New Zealand enquired about the frequency of nineteen disorders in the previous year.[23] The most frequent were headache, sore eyes, lethargy, sore throat, nasal discharge and sinus problems. These are

very similar to the symptoms of the common sick building syndrome, although they were attributed to dark-room fumes at the time. Glutaraldehyde is present in x-ray developer, and has been associated with eye, nose and throat irritation in endoscopy workers.[24] The working conditions in x-ray departments can often be improved.[25,26] Glutaraldehyde has been shown to cause occupational asthma in x-ray department staff, including a secretary who reacted to newly processed films.[27] In other situations constituents of the developer[28] or fixative[29] apart from glutaraldehyde have been implicated.

Building factors

After adjustment for the factors described above, the average number of work-related symptoms per building occupant (the building symptom index), still shows a four to fivefold difference between good and bad buildings.[1] The building symptom index is stable over time, provided that proper sampling is used to avoid responder bias, and a sample size of about 100 is used.[15] In general, naturally ventilated buildings have fewer symptomatic occupants than those from air-conditioned offices,[1] despite objective measurements of air quality being better in the air-conditioned buildings. Similar results have been found in a small study of hospital outpatient and ward areas, where the proportion of workers with symptoms increased from 14 per cent in naturally ventilated areas to 54 per cent in workplaces with air-conditioning; the figures for mechanically ventilated areas was even higher at 84 per cent.[30] Hospital studies are more likely to be confounded by the existence of other factors such as latex allergy, patients with infections and a more mobile workforce. It seems that the major factors controlled by air-conditioning can have both positive and negative effects; the balance often being decided by factors other than the design, particularly plant and system maintenance.[15] The main ones which have been studied include fresh air ventilation rates, temperature, humidity, dust and the microbial content of the air. Finding an association between these factors and symptoms does not however imply that altering the suspected factor is likely to reduce symptoms. It is quite likely that all of them are surrogate markers of the underlying causes.

Ventilation rate

Increasing ventilation helps dilute pollutants generated by the building fabric, the equipment and its occupants, but increases exposure to pollutants which may be generated by the ventilation system and its ducting. Some studies show a relationship between ventilation rate and symptoms but not others.[31] Within air-conditioned buildings it is likely that low ventilation rates, less than 10 litres/second/person, are associated with increased symptoms. Studies which have failed to show an effect of changing ventilation rate have generally included only values higher than this. Some studies have shown increased symptoms with increasing ventilation, suggesting that pollutants from the plant are the dominant cause in these instances.[32] This effect has also been shown in mechanically ventilated buildings without air-conditioning, particularly relating to skin and nasal symptoms,[33] and to nurses in long-stay hospitals.[34,35]

Temperature and humidity

Increasing symptoms with temperatures above 23°C has been one of the more consistent findings in Northern European studies.[15,36] There is however an

association between increasing temperature, overcrowding and inadequate ventilation which makes it difficult to pinpoint the causative factor.

As previously mentioned, there is no demonstrable association between the perception of air dryness and the water content of the air.[9] There is an association between the presence of a humidifier in the air-conditioning circuit and symptoms, rather than the reverse.[1] As with many other factors humidity can be good and bad. In parts of Scandinavia the humidity may be below 10 per cent for the winter months, and that increasing this to around 25 per cent may be associated with decreasing symptoms.[8] In more temperate climates the humidity indoors rarely falls below 25 per cent, humidifiers in these circumstances can do more harm than good. Humidifiers in the ventilation circuit provide a place for micro-organisms to flourish, and also provide a reason for adding biocides to humidified water. Many of these biocides are irritants or allergens in their own right, e.g. isothiazolinones,[37,38] glutaraldehyde,[27,39] chloramine,[40] chlorhexidine,[41] benzalkonium chloride[42] and chlorine.[43,44] Their addition to the water used for humidification will result in exposure of the building occupants.[38] There are so far no intervention studies investigating biocides in air-conditioning systems. They provide a plausible cause for the increased symptoms seen in systems containing a humidifier. In other areas dehumidifiers and chillers can be a potential problem. Water removed from the air can become stagnant and act as a reservoir for microbial growth in the air-conditioning system. Many chillers are stituated in ceiling and wall spaces where maintenance is difficult. Microbial contamination of chiller condensate trays has caused asthma in one English office.

Bacteria and fungi

Little relationship appears to exist between viable bacteria in office environments and the sick building syndrome.[45] Building dampness, particularly following flooding, has been associated with significant disease, particularly allergic alveolitis[46,47] and mycotoxicosis (organic dust toxic syndrome);[48] many fungi also produce potent toxins which can cause severe symptoms in building occupants.[49] However viable fungal and bacterial levels are generally much higher in healthier naturally ventilated buildings than in sicker air-conditioned buildings.[45]

Within air-conditioned buildings there is a relationship between airborne fungi and symptoms. The fungi originating from the air-conditioning plant can be removed from the air by high efficiency air filtration, but no reduction in symptoms was shown in a clean room environment with high efficiency particulate air (HEPA) filters compared with an area supplied from the same plant without such efficient filtration, where the fungal levels were higher.[45] This could be interpreted as implying that the fungi are unrelated to the sick building syndrome, that the species of fungi are important, or that soluble fungal products such as mycotoxins, which are not removed by filtration, are causative factors.

Dust

The first major multi-building study, the Copenhagen town hall study, showed an association between macromolecular dust and symptoms.[11] Most of these buildings were naturally ventilated. Associations have been demonstrated between the gram negative bacterial content of the dust and symptoms, between the particulates and mucous membrane symptoms, between volatile organics desorbed from the dust and general symptoms, and between the macromolecular content

of the dust and general symptoms.[50] A controlled study of office cleaning showed a reduction in symptoms, which persisted for at least two months after cleaning.[51]

ECONOMIC CONSEQUENCES

These relate to the changes in productivity resulting from the working environment, the costs of labour and the costs of providing the environment. These factors vary widely in different countries and environments. The costs of running a building include the building and equipment depreciation on invested capital as well as the operational costs. The economics have been worked out for an office building in Norway (Gaute Flatheim, personal communication). He calculated that doubling the outdoor ventilation rate and restricting the use of materials liable to offgas volatile organic compounds results in insignificant changes in the total costs; these were dominated by the wages of the workforce (89.9 per cent of the total costs, reducing to 89.3 per cent with double ventilation). It would take only a very small increase in productivity or reduction in sickness absence to pay back the increased investment (Gaute Flatheim estimates this to be between 7 months and 2 years for his office building).

Evidence submitted to the UK parliamentary select committee on the environment reported an assessment of the costs of sick building syndrome in a large government office with 2,500 occupants, assuming one days sickness absence per year attributed to sick building syndrome and one hour per month dealing with or complaining about the indoor environment. At 1990 prices the costs to the organisation were £400,000 for one year.[52]

Unfortunately it is very difficult to measure productivity in thinking workers, and sickness absence has many determinants apart from the health of the worker. The British office environment study[1] included a question asking the worker how much they thought the office environment affected their productivity (on a 9 point scale from −40 per cent to +40 per cent). There were some workers who thought that the indoor environment increased their productivity but there was a clear linear relationship between the number of work-related symptoms of sick building syndrome and self assessed productivity, suggesting that the 'disease' was the cause of reduced productivity.[52] The study also showed a clear relationship between the type of building and the building symptom index. Those with an average of two (out of 10) work-related symptoms had a neutral effect on productivity. The majority of buildings with a building symptom index under two were naturally ventilated with cellular offices and substantial worker control of their environment.

Studies of sickness absence have shown variable results. Guberan in Switzerland[53] found increased sickness absence in a group moving from a naturally ventilated to an air-conditioned office. Moreover most of the increased sickness absence was related to respiratory complaints. We have studied the relationship between ventilation type, sick building syndrome and sickness absence in groups of workers employed by the same government department.[54] One group of workers moved from naturally ventilated offices to a central air-conditioned headquarters building, the other group moved in the opposite direction. Sickness absence data was collected prospectively. The differences in sickness absence were small, with six days per hundred workers per month less sickness absence in those working in naturally ventilated buildings (excluding sickness

absence unlikely to be due to working in an office building such as operations, accidents and pregnancy). Sickness absence due to the sick building syndrome was also studied in the Dutch multi-building cross-sectional study.[12] There were 34 per cent less days off sick in workers who could control their own environment in their offices. Sickness absence was also higher in buildings with humidifiers.

A small study has shown improvement in both self-rated productivity and measured sickness absence in an office building retrofitted with an air filtration system fitted to each workstation, taking air from the room. It was fitted with both carbon and HEPA filters, and reduced the levels of particulates in the air.[10] The intervention area was compared to a control floor of the building. The questionnaire asked whether productivity was disrupted by poor air quality, rather than asking whether productivity was altered overall. There was a 61 per cent reduction in certified sickness absence compared with a similar period the previous year, equivalent to a 3.1 per cent increase in productive time per worker. A small control area was included on the intervention floor, where the furniture and fan unit was installed without the filtration system. Similar improvements in air quality assessment and symptoms were seen in this area, raising the possibility that the fan unit rather than the filtration were responsible for the improvement.

The current evidence suggests that individuals vary significantly in their requirements for indoor air quality, so that it is not possible to provide one environment that suits a large proportion of the workforce. Workers who are unable to alter environments which they find unsatisfactory are more likely to develop sick building syndrome. Their inability to improve their environment is a source of stress which can contribute to their symptoms, and perhaps to their reduced productivity.[14] The workers in a building are much its most expensive commodity; looking after their environment as well as caring for the mainframe computer is likely to be cost effective.

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