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Building related sickness

There is no such thing as a sick building – just sick people. But what is it about some working environments that brings on symptoms of illness? Is it purely a physical issue, or is distress brought on by psychological pressure? In this special 11 page feature we examine some causes and effects of building related sickness. We look at why certain people may be susceptible and how buildings can be improved to cope with allergic reactions. We also analyse other reasons for unhappiness with a work environment – is aromatherapy really good for you? To begin, recent research by the BSRIA reveals the nature of the problem.

Indoor air quality is an increasingly important factor when it comes to designing commercial ventilation systems. Mike Cluff looks at the results of a survey on the subject carried out by the BSRIA.

The BSRIA's Market Intelligence Centre has carried out a research project under the banner 'Opportunities in indoor air quality'. The study adopted the form of a survey to analyse commercial opportunities in building services arising out of the growing awareness of the importance of indoor air quality in the design and operation of commercial buildings.

The study also serves as a useful insight into attitudes towards indoor air quality among a cross section of groups, including developers and letting agents, building services consulting engineers and building owners and operators[1].

In practice, respondents to the research survey were asked how important they considered indoor air quality to be in determining the presence of building related sickness, defined for the purposes of the study as the detrimental effect of the indoor environment of a building on its occupants. In all, 70% of the sample said that it was 'very important', and an additional 26% said 'important'.

The symptoms that building occupiers associated with building related sickness are shown in figure 1. It is clear that headaches are the most common symptom, although mental fatigue, dry skin/itching and nausea/dizziness are all very significant.

Sources of contamination

The sources of indoor air contamination that were identified by respondents illustrate the broad nature of the problem faced by all those concerned with the design, construction and operation of commercial buildings (figure 2). Smoking is obviously a major potential source of contamination, but an increasing number of companies are either banning smoking altogether or introducing no smoking zones in offices.

Materials and furnishings register the highest level of spontaneous awareness; these can be major sources of formaldehyde vapour, and are present in the building envelope, mechanical systems and interior finishes.

They will undoubtedly receive attention in the future from regulatory or even legislative bodies, particularly with regard to what is deemed to be an acceptable or unacceptable level of formaldehyde emissions.

Causes of poor indoor air quality

The study also investigated respondents' views on the causes of deteriorating indoor air quality in the operation of commercial buildings. A wide variety of causes were cited. The predominant ones can be ranked in order of perceived importance, as follows:

- ☐ insufficient fresh air;
- ☐ poor standards of maintenance;
- ☐ poor building design;
- ☐ inadequate air filtration;
- ☐ lack of humidity control;
- ☐ lack of air movement.

Not surprisingly, perhaps, opinions on the actual causes varied among respondent groups. For example, developers and letting agents said the activity or inactivity of occupiers could cause problems. Common among these were poor maintenance control and failure to appreciate the need for good air flow and circulation when planning and fitting-out the internal accommodation of buildings. The last point is chiefly concerned with overcrowding and obstructive internal partitioning.

Building owners and operators generally agreed that fresh air is a fundamental determinant of indoor air qual-

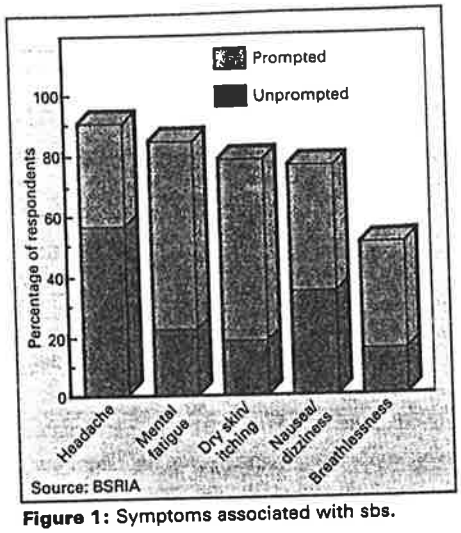


Figure 1: Symptoms associated with sbs.

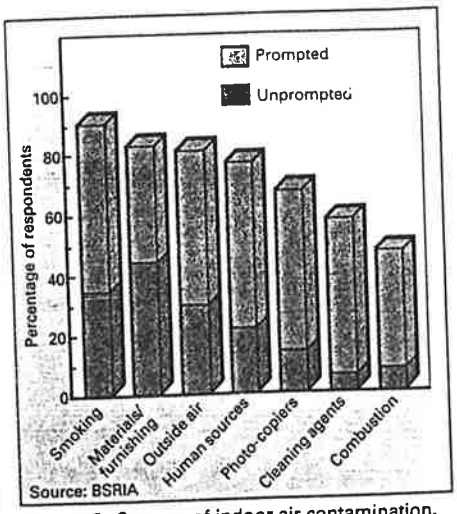


Figure 2: Sources of indoor air contamination.

ity, but problems associated with building related sickness may not be solved merely by increasing fresh air supplies. Some people complain of the symptoms associated with building related sickness even when the air conditioning apparently performs at an optimum level.

The attentions of building owners and operators may now increasingly turn to the design and layout of offices, with the introduction of a degree of local control on behalf of occupiers. The methods associated with these ideas are regarded as a means of tackling the important psychological aspects of building related sickness. They give lie to suggestions that complaints of lethargy and headaches always arise from the same groups of so-called 'whingers', and that among clerical staff, for example, incidents of complaints are a function of the nature of their work.

It is beginning to dawn on building owners and operators that these types of employees – who are often located in deep, open-plan offices – cannot exert any control over their environment, and are thus far more likely to have low tolerance thresholds.

The intensifying division of office space with localised control is a possible future measure that may be used by building owners and operators in increasing tolerance thresholds.

Existing indoor air quality levels

The majority of building owners and operators sampled were satisfied with existing indoor air quality levels. The main factors identified with high degrees of satisfaction were proper, planned maintenance of the air conditioning and the operation of a no smoking policy.

In addition, approximately half of those sampled monitored air hygiene and had ductwork regularly cleaned. Also, the use of air cleaners, air ionisers and air quality sensors was found to be carried out among one fifth of the sample.

A number of advantages were also mentioned in connection with air quality sensors, in particular the capability of responding to changes in fresh air requirements that would lead to improved energy efficiency. However, the consultants interviewed pointed out that developments in air quality sensors need to go beyond the mixed gas equipment currently available – indeed the BSRIA believes that there is a substantial market opportunity in this area.

Air conditioning

The BSRIA found that the majority of building owners and operators were satisfied with the performance of their air conditioning; this applied to both vav and fan coil. There were no overriding preferences for either system among any type of specifier.

Nevertheless, consultants and developers said that, where the ultimate occupiers needs – in terms of office organisation and layout – cannot be defined at the design stage, the flexibility of fan coils could be desirable.

Further problems will probably be experienced with vav in situations of office reorganisation; fan coil or vrv systems may perform better than vav in offices with lots of internal partitioning.

In keeping with the findings related to local control and the break up of large, open-plan offices, the BSRIA expects that increasing consideration could be given to the use of such local systems.

Mike Cuell is a senior marketing researcher at the BSRIA.

Reference

[1] The work on indoor air quality was undertaken by the BSRIA as a market research exercise, concentrating on obtaining views from others in the market and examining commercial opportunities. This is just one aspect of a wide range of subject studies relating to indoor air quality currently taking place at the BSRIA.

Mites, asthma and fresh air

by Donald McIntyre

More than two million people in the UK are diagnosed asthmatics. What they don't need is an army of dust mites adding to their troubles. Donald McIntyre looks at a new ventilation method that could stop the bugs in their tracks.

For many years, an adequate fresh air supply has been considered essential for good health, though it is not obvious just what the health-giving ingredient is, or how it performs its good work. In the case of asthma, it is now becoming clear how the major cause of the disease can be controlled by installing proper ventilation.

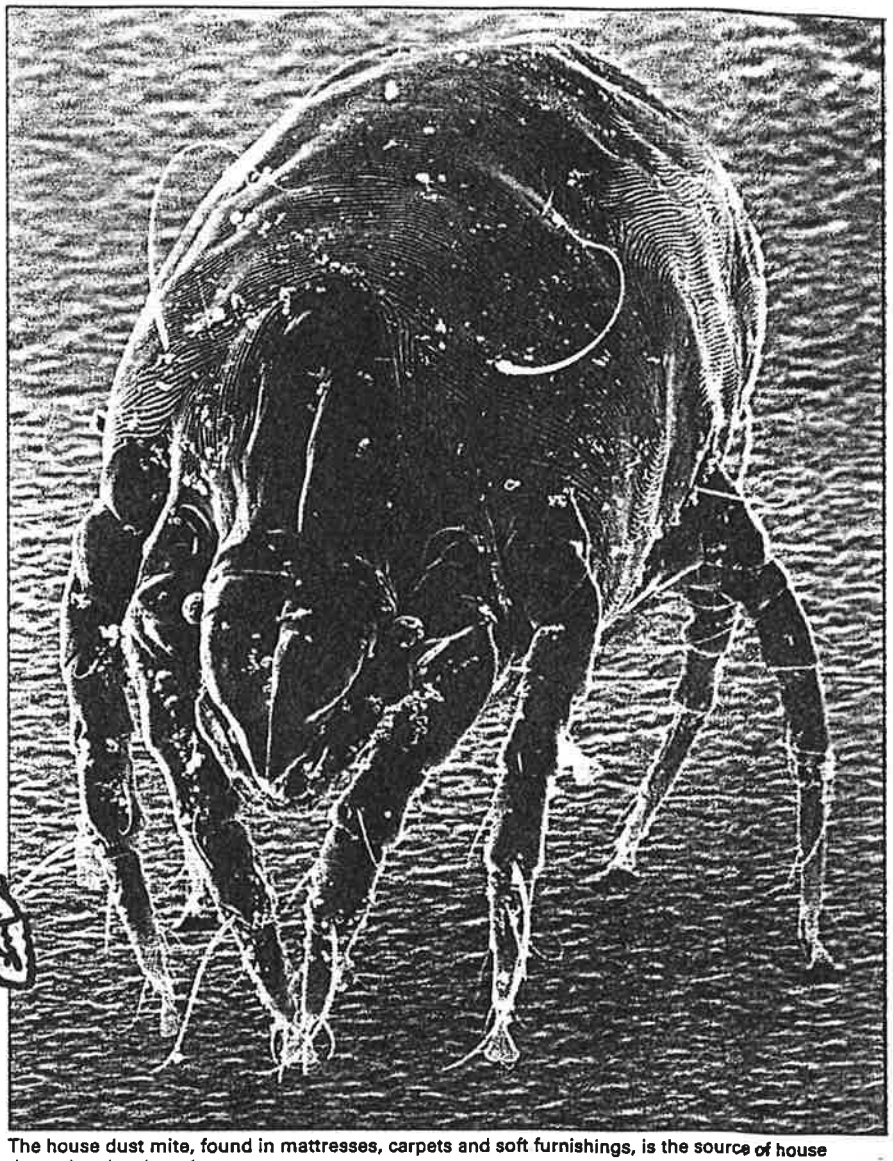
Asthma is widespread in the UK, with one in ten children suffering from the disease at some point in their lives. It is a true allergy, ie an inappropriate and harmful response by the body's immune system to a (normally) harmless substance.

The disease is normally controlled by drugs; in 1989, the NHS spent £217 million in this sector, representing 8% of the total drug budget. However, drug treatment of the disease is expensive and inconvenient for the sufferer. Medical opinion is now moving towards prevention rather than cure, and allergen eradication or avoidance is increasingly being seen as an essential part of the management of asthma.

The causative agent

The effect of house dust in triggering asthmatic symptoms has long been recognised, but it is only in the last two decades that the causative agent has been identified, namely the house dust mite.

This creature inhabits mattresses, soft furnishings and carpets. Its primary source of food is flakes of human skin, which



The house dust mite, found in mattresses, carpets and soft furnishings, is the source of house dust related asthmatic symptoms.

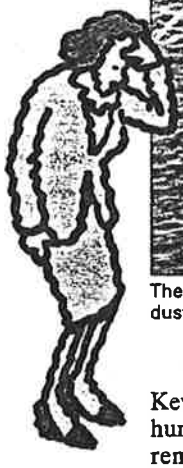
form the main constituent of household dust. The allergen that causes asthma is known as *der P I*, and is contained in the mites' faecal pellets.

If vacuum cleaning is used to eradicate the pellets, their small size and brittleness means it is essential to use a cleaner with a high quality filter capable of retaining sub-micron particles. But vacuum cleaning alone is ineffective in eliminating live mites, since they attach themselves firmly to their home by sucker-like devices at the tips of their legs.

Continuous ventilation

Several methods have been proposed for controlling the mite population. One of these is the use of continuous ventilation to reduce household humidity and thus subdue the mites.

Low humidities have been shown to reduce mite populations, both by causing dehydration in the mites themselves and also by affecting the digestibility of their food supply – they live in an environment without liquid water, and moisture balance with the atmosphere is critical to their survival.



Several ecological studies have demonstrated the relation between atmospheric humidity and the abundance of house dust mites; in general, houses which are damper have more mites. However, 'damp and dry' conditions alone are hardly sufficient design targets for environmental control.

After surveying the evidence, a World Health Organisation (WHO) working party on mite ecology concluded that an absolute humidity below 7 g/kg will not support the growth of mite populations. This corresponds to a relative humidity of 45% at 21°C.

The prevalence of condensation in this country shows that houses in the UK are often damp and underventilated. Indoor humidity, measured in absolute terms of grams of moisture per kilogram of dry air, will virtually always be higher than that outdoors, mainly due to the internal production of moisture by everyday activities. Indoor humidity may therefore be lowered by ventilating with drier, external air.

Examination of weather records for Kew in London shows that the outside humidity in winter, when the air is cold, remains below 7 g/kg for several months. During this period, it will be possible to reduce the indoor humidity below the limit value by ventilation. The corollary is that, during the warmer summer months, the outdoor humidity is mainly above 7 g/kg, and no amount of ventilation can reduce the indoor absolute humidity below this value.

Maintenance of ventilation during the winter can therefore reduce indoor humidities, and should reduce house dust mite numbers. However, for most people there is an understandable reluctance to maintain ventilation rates in cold weather because of the associated heat loss and the possibility of uncomfortable draughts.

Ventilation and heat recovery

The use of mechanical ventilation with heat recovery (mvhr) provides a satisfactory and practical solution. EA Technology has been involved with its use in all-electric, low energy houses for several years, and has confirmed the ability of the systems to provide effective, whole-house ventilation with low energy consumption.

The pioneering work relating the use of mvhr for house dust mite control has been carried out in Denmark. Research shows that the use of ventilation in the critical winter months can reduce the humidity long enough to cut down the mite population so that it does not have time to recover during the warm and moist summer. The use of mvhr is stressed, rather than simply installing a better ventilation system.

The continuous nature of mvhr is important in maintaining required conditions; short duration airing will be insufficient to remove moisture held in furnishings. Also, a reliance on window opening will not ensure adequate ventila-

tion during cold weather, when outside air is at its driest.

Pilot survey

There are, of course, differences between the UK and Denmark in terms of both climate and house construction. Hence, EA Technology and the Building Research Establishment collaborated in a pilot survey during the winter of 1991/92 to test the hypothesis that the use of mvhr during cold weather would reduce indoor humidities by an amount sufficient enough to reduce the mite population.

A group of Medallion 2000 houses was selected for the study. Medallion 2000 is a specification for an all-electric low energy house, which is required to be fitted with mvhr. The houses were situated in south Wales, each one being visited twice, at the beginning and end of February 1992.

On the first visit a simple questionnaire about the house was administered and dust samples taken from three sites: living room floor, bedroom floor and main bedroom mattress. A small data logger was left in the main bedroom to record temperature and humidity.

On the second visit, further dust samples were taken from the same sites and a second questionnaire administered covering environmental conditions in the house. The dust samples were analysed by flotation and staining of the mites. Results are expressed as mites per 100 mg of dust, after coarse material had been completely removed by sieving.

Test results

MVHR systems are designed to be used on a continuous basis, 24 h per day. However, in our sample of eight houses, four used the system for only a short time each day. These four houses formed the control group, and were compared with the experimental group of houses with 24 h ventilation.

It was found that the mean bedroom air temperatures were similar in the two groups, but that the humidity was significantly lower in the ventilated houses. Dust mite concentrations varied from zero to over 1000 mites per 100 mg of dust. However, there was consistency between measurements taken on the same site with a one month interval between samples, implying that the sampling and analysis methods were satisfactory.

The most consistent samples were

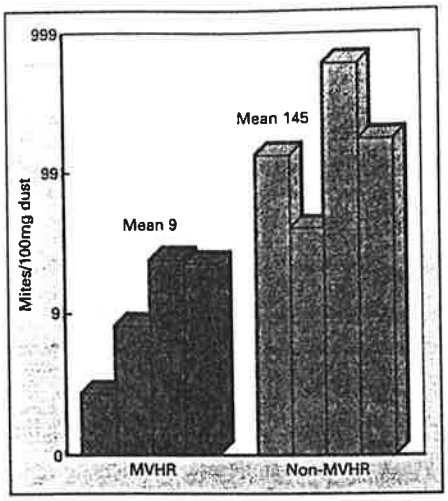


Figure 1: Comparison of mite concentrations in ventilated and non-ventilated bedrooms.

those taken from the bedroom carpet. These showed substantial differences in mite concentration between the test and control samples (figure 1).

Following conventional practice, the concentrations are shown as a logarithmic transform. The geometric mean concentration in the test (continuously ventilated) bedrooms was 9·4 mites per 100 mg dust, while in the control (non-ventilated) group the mean was 144 mites/100 mg. This difference is highly significant on statistical testing.

To put these figures into context, the WHO publication suggests that a mite concentration below 10/100 mg dust produced a low risk of causing sensitisation. At the other end of the range, 100 mites/100 mg was proposed as the level which presented a significantly increased likelihood of causing an asthma attack in an already sensitised patient.

Further research

The study confirmed the expectation that the use of mvhr would reduce the house dust mite population, and in fact reduced it to a level with a low risk of causing asthma.

However, the experiment was designed as a pilot survey; the sample is too small and the duration of measurement too restricted for the results to stand by themselves without confirmation. Further work is needed to relate required ventilation rates to climate and household habits, and to confirm the reduction in mite numbers in a larger sample of houses.

It would be desirable to take the work a stage further and measure both allergen levels in houses and clinical symptoms in asthmatic occupants to demonstrate that ventilation will actually benefit sufferers.

Nevertheless, the study is very encouraging and gives further weight to the evidence accruing from other countries supporting the use of mvhr in the prevention of asthma.

Dr Donald McIntyre is technology group manager, domestic building & systems division at EA Technology, Capenhurst.

The toxic zone

by John Parker

Airborne contaminants are increasing in number within the indoor environment. John Parker takes a look at the causes and culprits, and suggests solutions for control.

It has been estimated that the average person spends between 80-90% of their time inside buildings. This means that, most of the time, we are subject to an artificial environment, one that is modified by the enclosed space of the building.

Some indoor environments are more artificial than others and, unfairly or not, fully-sealed buildings with ducted air systems are often considered as the worst case scenario.

One thing about artificial environments is certain; in the course of energy conservation, buildings are becoming better insulated and sealed. Regulation has caused a dramatic reduction in building design heat losses during the last 30 years, hence infiltration rates have fallen.

To complicate matters, a far greater number of contaminating products are being introduced into buildings, including organic solvents from glues and foams, lead from petrol and paints and man-made fibres from fabrics and insulation. The result of this is that the average concentration of the various pollutants in indoor air has substantially increased.

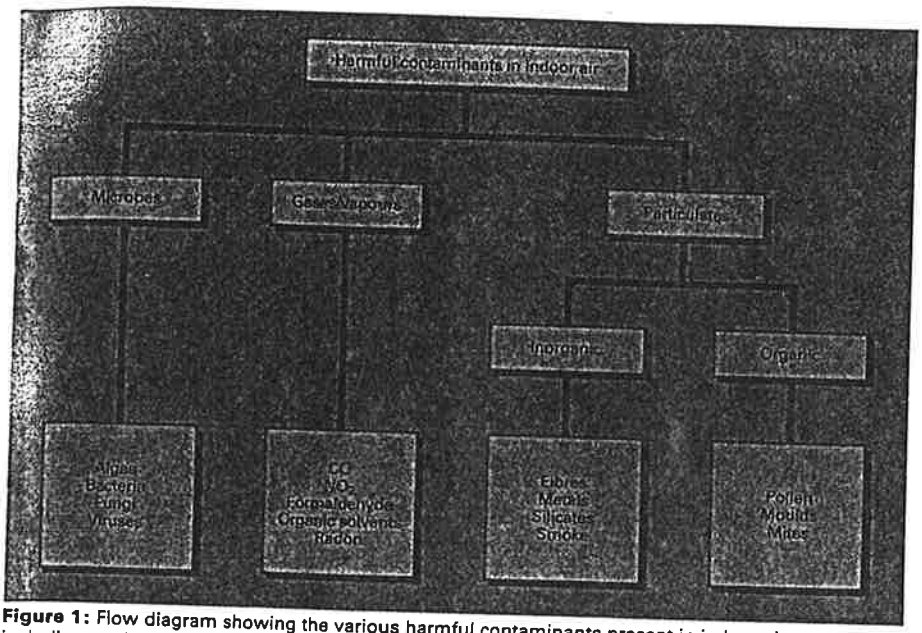


Figure 1: Flow diagram showing the various harmful contaminants present in indoor air, including particulates, gases/vapours and microbes.

Generally, external sources of indoor pollution – traffic fumes, pollen etc – can be excluded from the internal environment by keeping it well sealed, not opening any windows and filtering any ducted fresh air. However, internal sources are much more difficult to deal with.

Although building services are rarely sources of pollution – Legionnaire's disease in cooling towers being a notable exception – they can act as carriers of pollution, particularly solvents used in building materials, tobacco smoke solvents, microbes, ozone and solvents emitted by office equipment.

Microbes, gases and vapours

A recent survey of 233 large office buildings in the USA, all with full hvac systems, showed that not only did 9% have high levels of pathogenic or allergy causing bacteria, but some 34% had various fungi (28 species) growing inside the air distribution systems.

Some of the buildings had a high level of staff complaint, and it was found that these people were particularly allergic to either *aspergillus* or *clodosporium funghi* spores; these were found to be growing 'in excess' inside the ductwork. Removal of the funghi brought immediate relief.

Gases and vapours form an exceptionally large group of compounds and many arise from the vaporisation of solvents in resin, bonded chipboard and furniture, cleaning compounds, tobacco smoke and photocopiers (figure 1).

These compounds can be detached by chromatography. Among those substances highlighted were 1,1,1-trichloroethane. This is present in typewriter correcting fluid, which could be the reason for its appearance during the test.

Some people have allergic reactions to organic solvents. It is well known that short exposures to high concentrations can cause dizziness and hallucinations. Longer exposure at medium concentrations can cause lung and eye irritation and affect the nervous systems, skin, liver and kidneys. Lengthy exposure at the low concentrations found in buildings may not cause any first line reactions, but there may be exceptions.

Formaldehyde is one compound which is giving cause for concern. It is commonly found in chipboard that uses urea formaldehyde glue, and in uf foam for wall insulation.

Formaldehyde is a colourless gas with a pungent smell. Most people can detect it at concentrations well below 1 ppm, and respiratory irritation can occur at concentrations from 0·1 to >5 ppm.

Emission from uf foam insulation is highest when it is new, and reduces with age. However, the high temperatures which can occur within a wall when the sun is shining on it can cause the foam to increase its degradation rate, releasing more gas.

Typical concentrations in homes with foam insulation are in the range 0·01-> 4·1 ppm. Homes without such foam are within the range 0·01->0·1 ppm. It is interesting to note that Canada has banned uf foam insulation, and grants are available to home owners who are willing to remove it.

The effect of NO_2

Nitrogen dioxide (NO_2) is one of the gases produced during the combustion of any fossil fuel, and is present in outside air. It has high concentrations in areas with substantial traffic densities, and in houses that have paraffin or bottled gas heaters, gas cookers and poorly maintained central heating boilers or gas fires.

A worrying issue is the re-introduction of balanced flued boiler combustion gases back into the open windows of the house that the boiler is heating.

The movement of these gases towards the open window, with the coanda effect helping to stick the gases to the wall, is a particular worry if the house is otherwise well sealed and there is no easy escape for the gases once they are inside.

The effect of particulates

The final, and probably most important group are the particulates, both inorganic and organic. Depending on size, they can penetrate to the bottom of the respiratory system. Wherever they come to rest, in the upper of lower respiratory tract or in the lung, most of them spell trouble.

Fibres can be natural or man made. Asbestos is a natural fibre, and its effect on the human respiratory system is well known. Man-made fibres manufactured from glass, rock or minerals, such as clay, often find their way into insulation materials, and there is growing concern about the effect they may have on the lung.

Lead, and its allied metals, is also a particular problem. They enter the internal air from entrained traffic exhaust fumes, lead pipes, flashings and paint. They do not present a general problem, which is just as well given that even low doses may impair childrens' mental and physical development.

The term silicates describes the general building dust that blows around – clay, sand, cement and plaster. This can cause respiratory reactions but normally the particles are both visible and avoidable.

Tobacco smoke is perhaps more organic than inorganic – it is really a nasty mix of compounds, any one of which can cause respiratory difficulties. It produces droplets of tar, lumps of ash, carbon monoxide, ammonia and hydrogen cyanide. There are also the carcinogens, N-nitroscuines, benzene and various other aromatic hydrocarbons.

All in all it is best avoided, but it is

often hard to avoid other people's smoke. It is also becoming increasingly evident that passive smoking can enhance asthma symptoms.

A simple example

All these compounds are commonly found in indoor air, and as a test the BSRIA was commissioned to take some photographs of air inside one of their own offices.

The office overlooked the main road and was occupied by a smoker, although that person was out as much as he was in. A sniffer device sampled the air, which was drawn through a very fine filter paper. Magnified a few thousand times, the filter reveals that the sniffer device picked up a fair number of particles.

The largest lump, some 5 mm in diameter, was that of tobacco ash, composed of magnesium, sulphur, chlorine and aluminium. There were also particles of calcium carbonate and clay – probably from outside. Other particles included lead (probably from car exhaust) and sodium chloride, the likely source of this being perspiration.

The filter also picked up grains of pollen, which can also aggravate asthmatics. The cause is thought to come not from the pollen, but from the particles of starch which stick to the outside of each grain. Recent research has shown that, when the floating pollen passes through rain, the pollen bursts and the atmospheric concentration of the starch can increase by as much as 50 times.

Starch is also a major factor in house dust mite populations. House dust mites feed on flakes of human skin, and when humidity levels reach about 50% rh, the flakes develop a yeast-like mould which makes them soft, juicy and thus a great dust mite delicacy.

The dust mites eat the skin and then excrete hard faecal pellets. These contain the starch which, when inhaled, can trigger asthmatic reactions.

It is clear that indoor air contains many contaminants, and better sealed buildings mean that concentrations of them are increasing, many of which can trigger asthmatic reactions. However, control and reduction may be possible, for example by dilution, filtration and restricting the growth of organic particles as a result of humidity control.

John Parker is environmental manager with Southern Electric.

Remedies for recovery

by Dr Keith Eaton and Basil J Owen

Building related sickness is avoidable if services designers take the right steps. Dr Keith Eaton and Basil J Owen report on how a fresh approach to designing an office building has reduced illness in the workforce.

The condition known as sick building syndrome has been claimed to be caused by allergy, ventilation problems, chemical contamination, psychological factors, ionising radiation and a lack of full daylight spectrum lighting. Added to this, there may well be others whose alternative hypotheses we have missed.

What follows here is an investigation and resolution of problems in a new building, the UK headquarters of a multinational company producing computer hardware and software. No manufacturing takes place on site, which itself houses administration, customer service/support and engineering services.

The building was completed in mid-1989 and is a steel frame, three-storey structure, glass clad with all indoor air supplied by a central heating and ventilating plant, using a four-pipe fan coil system. After fitting-out, the building was occupied from October 1989 on a phased basis, leading to complete occupation by February 1990.

The problems begin

By April 1990, it was becoming clear that a limited number of personnel working in the building were complaining of health problems. The company undertook a questionnaire to identify the extent of the problem, which resulted in some 30 out of 942 staff with symptoms which they attributed to the workplace. Problems were dry skin, rashes, headache, tiredness and nasal discharge and blockage.

The company retained the services of a firm of consulting engineers, scientists and analysts and an allergist to try and resolve the problem.

This mix resulted in an unusual opportunity for engineers and medical personnel to work together and, although different approaches were used, a close working co-operation was created, at the end of which conclusions were unanimous and recommendations jointly made.

At the time of this investigation a second linked building was being completed, and commissioning took place during the period in which we were involved. The lessons learned from our ongoing investigation were applied during the commissioning of the second building, which was opened and occupied while we were on site.

The investigations

All afflicted staff were offered the following programme of investigation:

- ☐ a hyperventilation (overbreathing) questionnaire. This gave information about a quite common breathing control problem when under stress, either physical or mental. Breathing can become inappropriate and result in exacerbation of symptoms. In the UK the condition is usually thought to be of psychological origin, but on the continent it is often attributed to magnesium deficiency;
- ☐ a medical consultation involving an allergy history and a programme of relevant skin tests to assess inhalant allergens, and an extract of dust from the building;
- ☐ in some patients essential fatty acids (EFAs) and serum organic acids were estimated. These tests only became available after the investigation had started, and proved, in terms of the small number of patients, to be useful investigations.

Of the 28 people that were examined, only one person showed normal results. EFAs and organic acid levels were tested in five patients and were abnormal in all of them. Also, 16 out of 28 had positive skin tests, and 11 out of the 28 had positive hyperventilation questionnaires.

Bacteriological investigations

Bacteriological cultures from various sites revealed no significant variations from the expected level of normal organisms. No measurable pathogenic organisms were found and, in particular, there was an absence of *legionella pneumophilia*. Concentrations of particulates were not a cause for concern.

Cultures for moulds (*fungi imperfecta*) and yeasts were high in the occupied space, but low in the ductwork and plenums, suggesting growth either in the

occupied areas or within the fan coil units which then introduced them to the occupied space.

All genera cultured were common ones and there was no particular pattern of positive skin test response to any individual mould, although individuals exhibited occasional positive reactions. However, the data did not support a conclusion that any individual organism was the cause of the outbreak.

Physical and chemical investigations

These were carried out in two phases. A preliminary investigation considered a wide range of physical and chemical parameters over a relatively short period of time. Based upon the results, longer-term monitoring was carried out on the significant parameters.

Physical and chemical sampling was conducted at six sites. Five were inside the building (three in the occupied areas and two in mechanical ducts in the h&v system) and, for control purposes, the remaining measurements were taken from another unaffected site.

We measured relative humidity (rh) and temperature (using a Casella thermohydrograph), CO_2 (using a Horiba direct-reading CO_2 meter) and total volatile organic compounds (using 3M organic vapour monitors, analysed by solvent desorption, gas chromatography and flame ionisation).

Our initial impressions before this full survey was carried out suggested that the rh was too low, but this was clearly linked to an underfunctioning of the h&v system, which related both to the initial installation and to lack of maintenance, in particular in relation to the filter units.

When this had been remedied, it became clear with the more comprehensive survey that there were no major problems with the h&v – temperatures were never unacceptable, nor were relative humidities.

Some areas did not have sufficient outside air provision, remedied by relocating staff and by providing a separate rest and smoking area. Concentrations of CO_2 were above outside air levels, especially in crowded locations. However, the accepted standards for CO_2 concentration were never exceeded.

A survey of the results showed that rh ranged from 40% to 80%. Temperatures in the occupied space were at the upper end of the set range of 22°C±2°C. CO_2 concentrations ranged from 400 ppm to 825 ppm.

No significant correlation between CO_2 concentrations and temperature/rh measurements was found. Total volatile organic concentrations ranged from 100 $\mu g/m^3$ to 1100 $\mu g/m^3$. High concentrations of CO_2 were associated with high concentrations of volatile organic compounds.

Volatile organic compounds

The most significant discovery of the survey related to volatile organic compounds (vocs) which were found to show very significant trends, both in relation to concentrations correlated with illness (figure 1) and to the number and variety of

Action points for a healthy workplace

The following points are general recommendations which should be applied to all future office developements:

- List all finishing and construction materials used;
- Obtain material safety data sheets (msds) from the supplier on all the materials listed. The data sheets should contain any information on chemicals used in, or produced by, the material, the volatility and toxicity of these chemicals and details of any environmental testing carried out on the material;
- Determine a hierarchy of toxicity within types of materials, for example carpets, flooring and partitions, etc;
- When purchasing construction and finishing materials, it is strongly advised that preference is given to those items which contain the least toxic substances and/or have the lowest emission rate of volatile compounds. When approaching suppliers, request that they provide specifications on how they have reduced the emissions from their products;
- Advise suppliers to store their products in a well ventilated warehouse to allow volatile chemicals to dissipate prior to installation. This is particularly relevant to soft furnishings such as chairs and acoustic partitions etc, which are often dry cleaned in the factory and then wrapped in protective polythene.

In order to control the spread of chemicals and other substances within the occupied space, the following programme is advised:

- Prepare a comprehensive list of all substances used within the building, both by contract staff and employees. Include information regarding mode of use, quantities on site and storage location. The msds should be obtained;
- Inform occupants that, should they need or wish to introduce new substances, each must first be cleared for use by a responsible person;
- Inform all trade contractors, especially cleaners, that they must provide a list of substances they wish to use on site, together with the msds, for initial scrutiny and clearance by a responsible person;
- Initiate a system whereby all the msds and substance data are held together in a co-ordinated system that can be cross-referenced for easy consultation;
- Substances which are designated as toxic or very toxic under the *Classification Packaging and Labelling Regulations 1984* should be removed and less toxic alternatives used if possible. Where this is not possible, they should be stored in secure, ventilated locations.

In the majority of situations, the company will need to carry out the above programme in order to comply with the requirements of the *Control of Substances Hazardous to Health (COSHH) Regulations 1988*.

It is recommended that the hvac system is run continuously through a 24-h period. However, it is recognised that this may not be achievable due to maintenance requirements, etc. Nevertheless, operation time should be maximised to provide the greatest available dilution of indoor contaminants.

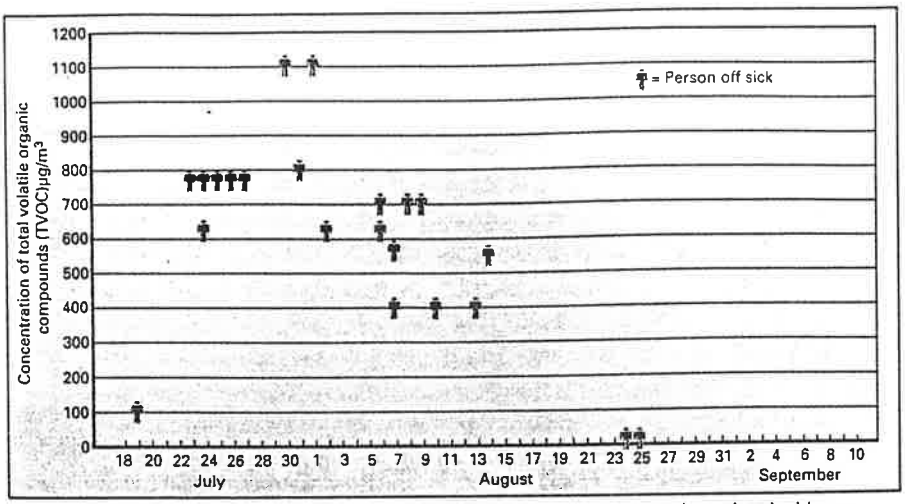


Figure 1: Scatter graph of concentrations of total volatile organic compounds against incidences of ill health of employees at Building One.

substances found (table 1).

A number of these vocs have a particular significance for the humans working in the buildings. They are substances for which man has no metabolic requirement, and indeed we cannot use them within the body. Nevertheless, because they are organic they will enter our systems and thus need to be eliminated.

In biological terms, they are named xenobiotics and undergo a process of modification in the liver to facilitate excretion. The ability people have to successfully transform this process depends upon their nutritional state, their pre-existing levels of xenobiotics and their allergic status.

Possible remedies

Our initial approaches were to improve the function of the h&v plant. Subsequently, we were able to show that when it was run continuously, including weekends when the building was unoccupied, symptoms were markedly reduced. However, it had not been designed for this pattern of use, and alternatives had to be sought to provide a solution.

A no-smoking policy was agreed by the workforce, together with a more rigorous cleaning policy and steam cleaning of carpets. The employee density in the most affected areas was also reduced.

In parallel, affected people were informed about the causes and effects of the condition, and were counselled by a dietician on improving the nutritional value of their diets. Where appropriate, hyperventilation retraining was given, as was advice on the management of concurrent allergic problems.

The response to these measures was excellent. Of the original 30 people affected, one patient with a pre-existing chronic viral fatigue syndrome was transferred to work in another building and another left to work for the company overseas. The remaining 28 were all able to remain within the building with symptoms either absent or so reduced that they considered their problems to be insignificant.

Lessons for new build

At the same time the adjoining building was being commissioned, steps were taken to reduce the likely contamination levels generated by this process.

First, the building was designated a no-smoking area. Extra steps were taken to minimise and control dust generation during building and installation work.

Fittings and furnishings in modern buildings are increasingly using plastics, grp and chipboard materials which involve considerable amounts of vocs in their manufacture. Modern carpets are often nylon-bound and foam-backed, bonded to screeding or vinyl-based coverings.

All of these can be sourced from manufacturers who take steps to reduce the chemical emissions. This can be by alternative manufacturing processes or by storage for some months before sale – this allows natural offgassing to reduce the amount of chemicals released in use.

Manufacturers will rarely volunteer this sort of information: it has to be sought, and this requires a definite policy to be instigated and rigorously followed from an early stage in the project by clients, architects, builders and engineers (see Action points).

When commissioning a building, care should be taken regarding the considerable volume of vocs present in the structure which will be released during occupancy. These can be cleared faster if the h&v system is run continuously during the early stages.

It is also desirable to undertake an appropriate programme of investigation to ensure that results have been obtained, and to determine at what stage the h&v plant can be allowed to revert to intermittent operation.

By these means, we were able to obtain a high degree of company and employee satisfaction in a situation which could have given rise to continuing illness, sickness absence, employee dissatisfaction and the loss of skilled, trained staff to other, less challenging work.

The cost of all this is not inconsiderable, and should be brought into the equation before any authority decides that such a programme is too expensive to be considered.

Table 1: Identification of volatile organic compounds from cryogenic sampling and analysis by thermal description/gas liquid chromatography/mass spectroscopy inside Building 1

Substances	Facilities		CIC		Payables		Outside Blank	
	W	C	W	C	W	C	W	C
2-Methylbutane	–	–	–	–	19	1·8	9	0·9
Trichloro-fluoroethane	–	–	150	40·7	9	0·8	–	–
Acetone	43	5·9	110	29·8	44	4·2	–	–
2-Methyl-1, 3-butadiene	–	–	–	–	28	2·9	–	–
1,1,2-Trichloro-trifluoroethane	–	–	420	113·9	67	6·4	–	–
Dichloromethane	50	6·8						
2-Methylpentane	–	–	–	–	9·2	–	9	0·9
3-Methylpentane	–	–	17	4·6	9	0·9	–	–
Hexane	14	1·9	3·9	10·5	–	–	7	0·7
Methylcyclopentane	–	–	41	11·1	6	0·6	–	–
1,1,1-Trichloroethane	–	–	300	81·4	48	4·6	2	0·2
Benzene/Cyclohexane	–	–	35	9·6	5	0·5	–	–
Trichloroethylene/Heptane	–	–	98	26·6	–	–	–	–
Methylcyclohexanone	–	–	22	5·9	–	–	–	–
Toluene	–	–	490	132·8	28	2·7	11	1·1
Hexanal	–	–	–	–	23	2·2	–	–
Total VOC ug/m³	14·6		476·0		28·5		3·6	

W = mass of VOC recovered in µg, C = concentration of VOC in µg/m³.

Dr Keith Eaton is a consultant allergist at the Princess Margaret Hospital, Swindon. Basil Owen is head of occupational hygiene at Clayton Environmental Consultants.

It is intended that a detailed report on this work will be published in the near future.

Aromatherapy: heaven scent?

by Jane Thurnell-Read

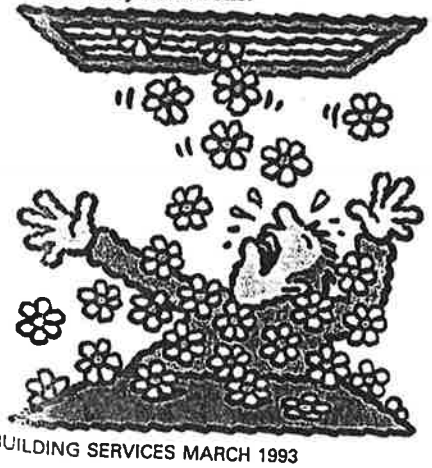
Jane Thurnell-Read explains why aromatherapy may be a dangerous technique to use in air conditioning systems.

It is recorded that, at a dinner in the mid 19th century in Edinburgh, 50 persons dined in an apartment where the gas chandeliers were ventilated and "large quantities of a mild atmosphere were constantly supplied and passed in quick succession through the apartment throughout the whole evening, the effect being varied from time by infusing odouriferous materials so that the air should imitate successfully that of a lavender field or orange grove, etc."

The members dined well and drank about three times their usual alcohol consumption. It is not possible to state whether the increase in comfort and alcohol consumption was due to ventilation or smells.

Chapter 12 of the *ASHRAE Fundamentals Handbook* deals with odours and their removal. In its development over many years, this chapter has sought to counteract smells by introducing complimentary – and thus negating – aromas or using filtration, etc.

Moving this a stage further, Ole Fanger developed the Olf unit – the aroma or smell given off by a person seated at rest – as measured subjectively by a team of sniffers. In his work he has endeavoured to relate comfort and healthy buildings to the Olfactory conditions.



When a sick building investigator walks round a building, his most important instrument is his nose, and sensation of stuffiness or freshness. From this preliminary assessment he can deduce the further investigations that are necessary.

Thus two streams of experimentation have been present in buildings; first, the overcoming of smells generated by people and buildings through ventilation and the introduction of a counteracting or overpowering smell and, second, the introduction of aromas which are intended to give an impression of freshness.

In the 1960s there were suggestions that smell should be introduced into air conditioning systems to improve the general ambience or aroma of the workspace. This was achieved by dosing concentrated essences into the air handling plant. This process should not be confused with aromatherapy; the volume of essence added was not based on any form of scientific analysis and was applied generally.

In parallel with the developments of air conditioning, but completely separate from that, aromatherapy was becoming established as an alternative medicine.

Remedial massage with a mixture of essential oils is one of the fastest growth areas in complementary medicine. Essential oils are produced from a wide range of plants and can come from varying parts of the plants. Chemists have also made synthetic equivalents. Most room fresheners and pot pourri, which have recently gained tremendously in popularity, contain these synthetics rather than the true essential oils due to cost considerations.

Essential oils are used both therapeutically – to alleviate a wide range of health problems including stress – and for pleasure, so the idea of adding essential oils to air conditioning systems seems on the face of it to be very attractive.

It is a small step to consider aromatherapy in one or all of three ways within an air conditioning system:

- ☐ to counteract the symptoms of sick building syndrome, generated from various sources including thermal conditions and chemical/biological pollutants;
- ☐ to stimulate the workforce;
- ☐ to relax the workforce.

The Japanese news item in the June 1992 edition of *Building Services* indicates that blanket treatment of a workforce to control their activities is in use, but introduction of a random aroma to buildings could have consequences disproportionate to the action.

A brochure from the Kajima Corporation of Japan describing the aromatherapy technique.

Apart from the technical practicalities of introducing essential oils into air conditioning systems, there are considerations of a more general nature.

Different oils have different therapeutic activity. Usually the action of the oils is divided into three categories; top notes, middle notes and base notes. Top notes are the most volatile and the most stimulating and uplifting, whereas the base notes are slower to evaporate and are more relaxing and calming.

The need for calming or uplifting will vary depending on the person and their state of mind. Someone who is apathetic and tired would need a combination of a large proportion of oils from the top note range, whereas someone who is inappropriately aggressive would need more calming from oils with a base note.

One can envisage a situation where different combinations could be used throughout the day according to the situation. Arriving at work in the morning, a person may benefit from a combination of largely top note oils for stimulation.

During the morning, faced with a difficult interview in which tact and diplomacy were important, a combination with more middle notes would be appropriate. After lunch, the stimulation of a top note combination would come to the fore again, whereas at the end of the day lots of base notes to help the switching off and unwinding process would be preferable. This would involve individual control of aroma delivery, which is not possible in today's open-plan offices.

Even if these problems could be solved, it would be difficult to find an aroma that is liked by most of the people who are being exposed to it. The old adage that one man's meat is another man's

poison is particularly appropriate here.

Although some oils, such as geranium and rose, are almost universally popular, many others are not so clearly appreciated by the vast majority of people. Finding one (or more probably a blend) that people like may be exceedingly difficult. Also, establishing the correct strength for maximum comfort would be difficult.

A further complication is that some individuals may be allergic or sensitive to the oil used. It is often erroneously believed that "natural" substances do not cause allergic reactions, so that if good quality oils are used then all will be well. But one only has to consider hayfever, where people are allergic to natural, organic substances in the form of pollens.

It is quite likely that essential oils in air conditioning systems would lead susceptible individuals to develop a range of symptoms, such as allergic rhinitis, migraines, sinus and throat problems and even asthma).

In 1989, there were reports that psychologists at Duke University, North Carolina, were developing fragrances which could be used in the New York Subway system to induce perceptions of good feelings and friendliness among underground train passengers. It was hoped that hostility, aggression and tension – often linked with this hectic mode of travel – could be curbed. Parallel work was being carried out in Britain in an endeavour to link specific odours with electrical activity in the brain.

Thus it was hoped that aggression could be damped down by using pleasant odours. For the reasons already discussed, serious questions should be raised on the correctness of large-scale, indiscriminate attempts to modify human behaviour.

It is possible to see perfumes generally as being a form of environmental pollution. Indeed, there have been moves in the USA to promote this viewpoint. In one UK allergies clinic the use of perfumes is banned. Also, some people may percieve that the use of such oils in air conditioning systems further reduces their ability to control their own environment.

Although at first sight the use of aromatherapy oils in air conditioning systems may seem an exciting possibility, these further considerations make its implementation something to be avoided.

Jane Thurnell-Read is a health kinesiologist (a branch of natural health care) with Rooley Consultants.

Designing for manageability

by Adrian Leaman

Building users need their surrounding environment to be adaptable – and they don't want to be kept waiting. Adrian Leaman takes a look at building control response times.

What are the variables that we really need to worry about in architectural and services design? A year ago I would have said that depth of space was fundamental – the deeper you go, the more services you need. Similarly, the more complex the building becomes the harder it is to manage, and the greater the subsequent risk that things will go wrong.

Having spent the past year studying how people make use of controls in buildings, I would suggest that response time is an even more important factor than the depth of an office.

What, then, is response time? Simply, it is the time taken for the building or the building's management system – which can be either human or automated – to respond to requests for change made by building users. Building users can be individuals, working groups, departments and their representatives or the whole organisation. Organisations are almost always hierarchical, therefore decisions affecting the building may come from different types of users at different levels in the organisation.

Requests for change can be commonplace, everyday activities such as individuals turning lights on or off, adjusting the window blinds, using the radiator control valves or setting room thermostats. Alternatively, they may be less frequent requests from working groups or departments for the new positioning of furniture, network cabling or partitions, for example.

In our research[1], we have found that the faster the overall response times, the greater the likelihood that staff will be healthier, happier and also more productive, and the higher the likelihood that the building will be energy efficient. Health, productivity, energy efficiency and rapid response – all of these variables are indeed linked.

The best buildings are those that not only keep the majority of people comfortable and support their work tasks efficiently and inconspicuously for most of the time, but which also respond rapidly when people need to make a change to their conditions. Generally speaking, buildings need to:

- ☐ keep as many people as comfortable as possible, (ie people should remain within their individual tolerance thresholds) for as long as possible;
- ☐ deal with circumstances quickly when people do become uncomfortable.

Many modern offices only seem to have been designed with the first of these needs in mind. Often, they only work reasonably well when people stay within comfort or performance bands. Once these thresholds are breached – an occurrence which is on the increase, for reasons that will become apparent – the buildings do not respond properly at all. As a result, consequences like thermal discomfort and occupant ill-health quickly follow.

The need for fast response

One of the main reasons why thermal discomfort and ill-health in offices especially has increased in recent years – although the general argument also applies to other building types – is that the number of requests from users for changes to their surrounding conditions has risen appreciably.

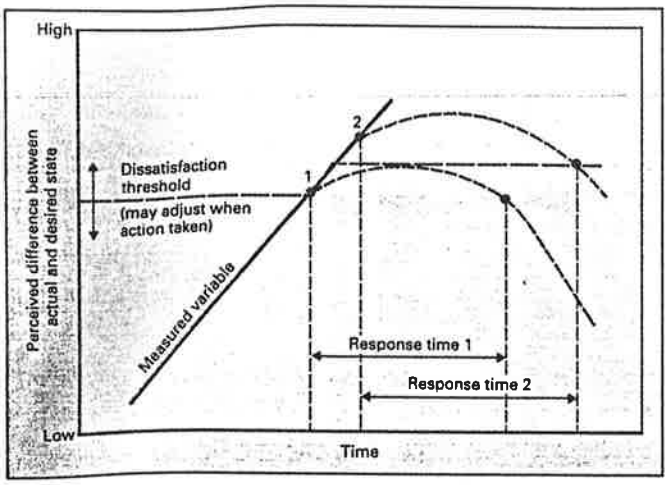


Figure 1: Control behaviours and response times. Note that the measured variable can be either analogue, like air temperature or discontinuous like draughts.

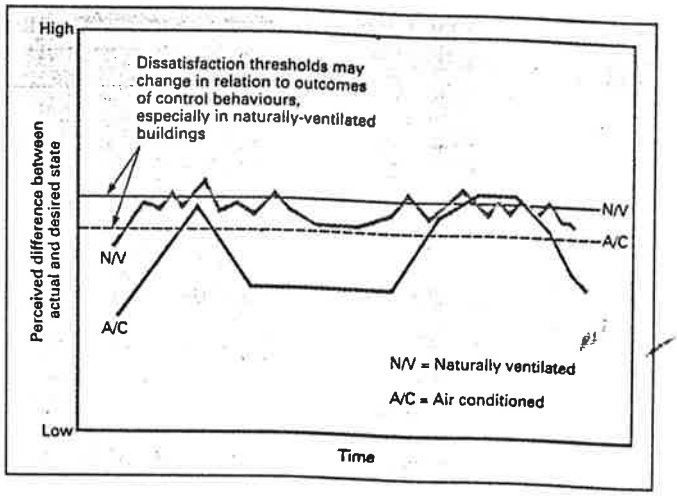


Figure 2: Control behaviours and response times in naturally-ventilated and air-conditioned office buildings.

Organisations are now placing greater demands on their buildings; they are using them more intensively over longer time periods, and for wider ranges of activities. Buildings are also becoming more complex spatially, technically and behaviourally. All this adds up to a greater likelihood that more and more requests for change will be made by the occupants.

This process is broadly illustrated in figure 1[2]. A measured variable, say temperature, gradually increases but stays within the dissatisfaction threshold until point 1. Here, the individual perceives discomfort and must decide: "Do I act now to alleviate the discomfort or not?" Notice, by the way, that the setting of the threshold will vary for different people in different situations, and may adjust when any action is taken.

If the person decides to act, then they will look for the appropriate control device or system to assist them. This is the crucial moment; if the building systems can support the request and bring the measured variable quickly back within the comfort threshold – with the individual immediately perceiving that the change has happened to their benefit – then they will probably be satisfied.

A rapid perceived reaction may also help to widen the person's tolerance threshold in the future, thus the next time a request is considered the individual may delay action, knowing that the building systems can respond if needs be.

As long as the response is rapid and the individual believes that a change has in fact been made for the better, it does not really matter whether the system providing it is a physical system or a management system.

The advantage of manual controls

All this helps to explain why people often seem to prefer naturally-ventilated buildings to air conditioned ones, even though the measured conditions in the latter are better.

A naturally-ventilated building will breach the dissatisfaction threshold more frequently, but its control systems – often of the simple and robust mechanical type – will often bring it back inside again very quickly. An air conditioned building may run with a lower tolerance threshold and take a longer time to respond when conditions become uncomfortable.

Although the air conditioned building may be better in terms of the measured conditions, it runs outside the dissatisfaction threshold for a longer period compared with the naturally-ventilated building, and so is perceived as being more uncomfortable overall (figure 2)[2].

These observations appear to reinforce the points made by Nigel Oseland (*Building Services*, July 1992). Theoretical predictions of thermal comfort derived from controlled conditions in comfort chambers seemingly over-predict temperatures that people find comfortable in reality. As our everyday experience tells us, comfort depends on contexts and circumstances.

The reason why people appear to set temperatures lower at home than in the office is not because they are paying the bills, but because their naturally-ventilated homes are much more controllable. They can set the temperatures closer to their own preferences, and the control systems act quicker when conditions do become uncomfortable.

However, people in offices must observe the norms and preferences of working groups and colleagues. Not only does this render decision-making more difficult if several people are involved (especially in open-plan areas), it also sacrifices the comfort of the majority to the wishes of a minority – the least comfortable or the most dominant personality, perhaps. It also takes longer for people to reach a decision, and longer for the system to adopt the new state required once a decision is taken.

Simple lessons

Achieving rapid response in buildings is very important, both for individual users and for building managers. Overall, the design strategy should be to design for manageability, because this will help to focus detailed thought on the areas of buildings which seem to have been most neglected – the control systems and their human interfaces.

Adopting this approach brings considerable benefits; people are happier with more responsive controls, and are more productive and healthier. Also, buildings which work well for the people are very often energy efficient.

The reason for this? The buildings are more manageable. It's as simple as that!

Adrian Leaman is managing director of Building Use Studies.

References

[1] "The office environment survey", (1985-1987) and "User and automated controls and management in buildings", (1991-1993) by Building Use Studies.
Further details of the DoE/BRE project "User and occupant controls in office buildings" will be given in the April issue of *Building Services*.
[2] Figures 1 & 2 were developed by the author and W T Bordass.

More details will be found in: Wilson S and Hedge A, "The office environment survey: a study of building sickness", Building Use Studies, May 1987, and Bromley A K R, Bordass W T and Leaman A, "Improved utilisation of building management and control systems", CIB/IEA Symposium on Energy Efficient Buildings, Stuttgart, 9-11 March 1993.