EUROPEAN CONCERTED ACTION

INDOOR AIR QUALITY & ITS IMPACT ON MAN

COST Project 613

Environment and Quality of Life

Report No. 4

Sick Building Syndrome

A Practical Guide

Commission of the European Communities
Directorate General for Science, Research and Development
Joint Research Centre - Institute for the Environment

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Report No. 4
Sick Building Syndrome
A Practical Guide

prepared by
Working Group 1
Claude MOLINA *(chairman)*
Université de Clermont Ferrand (France)

C. Anthony C. PICKERING
Wythenshawe Hospital, Manchester (United Kingdom)

Ole VALBJØRN
Statens Byggeforsknings Institut, Hørsholm (Denmark)

Maurizio DE BORTOLI *(secretary)*
C.E.C., Joint Research Centre, Ispra (Italy)

reviewed by the Community-COST Concertation Committee

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FOREWORD

This report deals with what is called "sick building syndrome" (SBS). However, the methods employed to investigate SBS can be also used to tackle other building related illnesses. "Sick building syndrome" is the name given to a set of varied symptoms experienced predominantly by people working in air conditioned buildings, although it has also been observed in naturally ventilated buildings.

The syndrome, the cause of which is probably multifactorial, is not usually accompanied by any organic lesion or physical sign and is, therefore, diagnosed by exclusion. SBS is currently the subject of numerous research projects. It has been found in all the major cities of the Western world, among people who work or live for several hours a day in an artificial atmosphere. SBS can be diagnosed only after eliminating all other building related illnesses.

I. BACKGROUND

As a result of the measures taken to control domestic heating and emissions of industrial smoke and car exhaust fumes, outdoor pollution in the major towns and cities is now on the decrease (except in cases of accident). However, the problem of indoor air quality is becoming a matter of concern. Most town-dwellers spend less than an hour a day in the outside environment; the rest of the time they are at home, at work or in some means of transport.

Since the seventies and the oil crisis, energy-saving measures have led to a reduction in the ventilation of rooms. The use of synthetic materials which emit various chemical substances has led to an increase in the concentration of indoor pollutants.

In 1970, following the observations of Bansazak et al., the attention of the medical profession was drawn to the development of an allergic respiratory disorder (allergic alveolitis) among the employees working in air-conditioned offices. It is similar to "humidifier fever" which has been described both in homes (De Weck, Patterson et al., Burcke et al.) and in industrial situations where cold water spray humidification systems have become heavily contaminated with microorganisms.

In Philadelphia in 1976 there was an outbreak of a hitherto unknown infectious disease: Legionnaire's disease. This serious illness, which primarily affects the lungs, was caused by a previously unidentified bacterium which had probably developed in a cooling tower adjacent to the air conditioning systems of a Philadelphia hotel where the members of the Legion of Veterans of the American Army were meeting. It was given the name *Legionella*. By extension from these observations, Legionnaire's disease and its more benign homologue, Pontiac fever, are also considered to be illnesses caused by air conditioning systems. They are in fact nothing of the kind, but rather a result of contamination of the incoming air by *Legionella* organisms in vapour drift from contaminated cooling towers located near to the air-conditioning system. Several epidemics have been reported worldwide. These have been associated with a significant mortality. This publication is not concerned with diseases associated with *Legionella pneumophila* (Legionnaire's disease and nonpneumonic legionellosis). These usually present with easily recognised acute clinical manifestations.

Apart from these allergic and infectious disorders, doctors are confronted every day with a number of complaints affecting mucous membranes of eyes, nose and throat; headache and lethargy. These symptoms appear to be benign and related to the building in which the individuals work or live and constitute the SBS.

II. EXTENT OF THE PROBLEM

"Sick building syndrome" is a worldwide problem. Air conditioning is used in many different situations for the purposes of comfort, safety and even noise abatement, it is used in large blocks of flats or individual dwellings in hot countries (for example detached houses, hospitals, hotels, department stores, city office blocks, museums, libraries containing valuable documents). It is also used in numerous industries where humidification is necessary, such as printing and high-tech industries of electronics, data processing and magnetic tape manufacture. There are, therefore, millions of people living or working in premises where the ventilation is regulated and where use is made of air conditioning systems. However, the problem is not limited to air conditioned buildings (Finnegan et al. 1987).

An investigation carried out by Woods et al. on 600 office workers in the USA showed that 20% of the employees experience symptoms of SBS and most of them were convinced that this reduces their working efficiency. Other estimates report that up to 30% of new and refurbished buildings throughout the world may be affected by this syndrome (WHO 1983 and 1986).

A study performed in the UK on 4373 office workers in 46 buildings revealed that 29% of those studied experienced five or more of the characteristic symptoms of SBS (Wilson et al.).

III. COST-EFFECTIVENESS

As WHO has pointed out in the publication on Indoor Air Quality Research (WHO 1986), the effort to save energy will continue in the coming years. Unless those responsible for designing and operating buildings realise that energy economy is not the sole criterion in evaluating costs there will be increasing problems in buildings. They point out that "energy-efficient but sick buildings often cost society far more than it gains by energy savings" and "people's confidence in the effectiveness of health and building authorities may be seriously harmed if sick buildings become a common phenomenon. For many people sensory warnings have a great emotional impact that may cause exaggerated responses even in buildings with only minor environmental problems and may cause unjustified claims of serious and persistent health effects. The added cost to society of the increased sensory irritation, the increased discomfort and the fear of more serious, persistent health effects among the occupants is likely to exceed any of the gains that can be made on the margins of energy savings."

Recently Robertson made a comparative evaluation of the possible realistic cost reduction in the heating and ventilation of a large building on the one hand and of a 1% increase in absenteeism among the employees on the other. Under the hypotheses assumed for the calculation, the cost of the absenteeism is approximately 8 times greater than the money gained through energy savings. Moreover, the absenteeism attributed to SBS is probably much greater than 1%. This does not take into account the reduced working efficiency. An improvement which could be introduced in the organization of enterprises is that of establishing links between personnel management and the management of buildings. These two functions are normally strictly separated.

Also the medical-legal aspect should not be forgotten. In some countries (e.g. France) allergic manifestations in employees working in air-conditioned buildings, where the air conditioning systems are not properly and regularly maintained, are considered among occupational diseases.

These concepts concern existing buildings, but are of primary importance in the conception and construction of new buildings.

IV. SYMPTOMATOLOGY*

The symptomatology of this syndrome is varied, but five symptom complexes are regularly encountered. These symptoms may occur singly or in combination with each other.

1. Nasal manifestations

   The symptoms most frequently experienced are nasal irritation with rhinorrhoea and nasal obstruction, usually described as 'nasal stuffiness'.

2. Ocular manifestations

   Dryness and irritation of the mucous membrane of the eye.

3. Oropharyngeal manifestations

   Dryness and irritation of the throat.

* See Appendix 1 for a more detailed description

4. Cutaneous manifestations

Dryness and irritation of the skin, occasionally associated with a rash on exposed skin surfaces.

5. General manifestations

Headaches and generalised lethargy and tiredness leading to poor concentration.

These symptoms have a characteristic periodicity increasing in severity over the working shift and resolving rapidly on leaving the building in the evening. Most manifestations, therefore, with the exception of some cutaneous symptoms, improve over weekends and all symptoms usually disappear on holiday.

Some constitutional diseases, e.g. eczema, sinusitis, may be exacerbated in certain buildings.

V. DIAGNOSIS*

The diagnosis of sick building syndrome is suggested by the presence of the preceding symptom complexes. Other causes of building related illness (asthma, hypersensitivity pneumonitis or extrinsic allergic alveolitis, humidifier fever, allergic rhinitis) should be excluded.

The consequences of sick building syndrome are a dissatisfied workforce with reduced working efficiency and increased sickness absence rates (Pickering).

VI. RISK FACTORS

Four major groups of factors are to be considered:

- physical;
- chemical;
- biological;
- psychological.

1. The physical factors

These have practically all been the subject of national or international recommendations regarding the standards to be complied with (e.g. American

* See Appendix 1 for a more detailed description

Society of Heating, Refrigerating and Air-conditioning Engineers Standards).

(a) Temperature

The standards for maintaining a certain acceptable level of comfort and occupational activity fluctuate between 20° and 26°C, taking into account the clothing and the relative humidity (ISO 1984). However, there are indications that temperature should be kept in the lower part of the comfort range. A reduction in mental work capacity has been observed above 24°C (Wyon, Wyon et al.). In a recent study, Jaakola et al. found a significant statistical relationship between room temperatures above 22°C and the appearance of SBS symptoms. Similar findings are reported by Valbjørn et al. (1986, 1987) in offices as well as in homes. Finally, higher temperatures will increase offgassing from materials.

(b) Relative humidity:

Humidification processes cause many problems and deserve very close attention. There is no agreement on what constitutes the ideal range of relative humidity. It is known that high values (above 70%), particularly associated with high temperature, are uncomfortable and health may be threatened, at least through the development of surface condensation and mould growth. Moreover, high humidity may lead to structural damages in building, especially in cold climates. Very low relative humidity (less than 20%) can cause, in some individuals, drying of the mucous membranes and of the skin (Andersen et al.) and a dermatitis (Rycroft, see also "Cutaneous manifestations" in Appendix 1). Andersen et al., however, showed that in 78-hour exposures to dry clean air (R.H. 9%) no signs nor symptoms were found, even in people with high metabolic rates. Consequently it appears that the direct effect of low humidity on the prevalence of SBS can be considered unimportant, but indirect effects could play a role, including the buildup of static electricity and consequent electric discharges, offgassing of vapours following a significant humidity change or variation of the respirable suspended particulate matter.

The question should be considered whether humidification systems are necessary, at least in the cases where the relative humidity is already in the acceptable range.

(c) Ventilation

Insufficient ventilation due to energy saving measures following the oil crisis has been claimed as one of the main causes for SBS symptoms. Minimum ventilation rates do nevertheless exist in many countries, but vary from country to country and, of course, from non smoking to smoking conditions (range 2,5 - 20 litres per second per person).

The latest information (IEA) indicates that a rate of approximately 8 litres per second (nearly 30 m^3/h) per person (sedentary activity) will be adequate for non smoking areas in order to extract the bioeffluents of man (odours). At this level a CO_2 concentration of 0.1% will be present and 20% of people entering the room will be dissatisfied with the environment. If a higher percentage of dissatisfied is accepted (25-30%), the ventilation rate can be proportionally reduced (3.8-5.4 litres/sec. per person). In smoking areas the ventilation rate should be higher (Cain et al., Gunnarsen et al.).

The ventilation can contribute by reducing the concentration of contaminants from building materials and processes within the building and also heat produced in the building. The most important measure to reduce such contaminants remains source control.

Ventilation should not by itself cause problems such as draught or odour. Therefore, attention must be laid on accurate commissioning and maintenance (cleaning) of the ventilating plants. Also recirculation of air which introduces contaminants to working areas should be avoided.

(d) Artificial light

Some authors (Sterling et al. 1983), by varying both the quantity of ultraviolet light and the ventilation, noted a reduction in eye symptoms, but not in the other symptoms of SBS. Wilkins et al., using a solid state high frequency ballast resulting in illumination with a reduced fluctuation, decreased the incidence of eye-strain and headache by more than 50% in a group of office workers. It is also possible that visual stress plays a part in the development of eye irritation and headache, for example through the lighting level, insufficient contrast, excessive brightness and glare.

The prolonged use of visual display units requires particularly well designed lighting.

(e) Noise and vibrations

Noise expressed as the equivalent sound pressure A-weighted level may be a parameter causing tiredness in levels of 70-80 dB. The nature of the noise is important. Infrasound which is defined as sound waves in 0.1 - 20 Hz range may cause dizziness and nausea, but this is not found in levels below 120 dB. It is more likely that low frequency noise (20-100 Hz) which is found in buildings with industrial machines or ventilation machinery may cause problems. Tempest has described some cases where the workers complained of unpleasant working conditions in one factory department, but not in another, although the sound levels were approximately equal (61 dB (A)) and the room features were similar. Frequency analysis showed that the sound pressure level in the 8-125 Hz range was much higher in the "unpleasant" department.

Often the noise, although having a relatively low A-weighted, level contains some pure tones, which may cause irritation or other disturbances. A correction for tone adjustments, which takes into account the importance of pure tones in the sound spectrum, is described elsewhere (ISO 1987).

Vibrations produced in the neighbourhood of buildings (for instance underground railways) have also been accused of being a contributory factor. A considerable amount of research has been carried out into the effect of vibration on man and the ISO has issued a Standard on the subject (ISO 1985 a and b).

Hodgson et al. observed that irritability and dizziness experienced by a group of secretaries working in new offices correlated significantly with the vibrations measured on their desks. The vibrations were caused by an adjacent pump-room. The authors see a causative link between these vibrations and their complaints based on the fact that certain body organs, specifically the eyes, have characteristics resonance frequencies in the range 1-20 Hz. However, the finding requires confirmation in view of the very small size of the group studied (3 persons).

(g) Ions

Presenting the hypothesis that the lack of negative ions in the atmosphere may be responsible for SBS, Finnegan et al. (1987 b) used a negative ion generator in a double-blind study of office workers in an air conditioned building, while monitoring various parameters. They found that the ion concentration in the atmosphere did not influence the level of symptoms of SBS. Moreover, negative ionizers have been described releasing significant amounts of ozone, a potent airway irritant (Guillemin).

(k) Particles and fibres

Dust in the indoor air consists of organic and inorganic particles many of which can be classified as fibres. The total dust concentration in a room is dependent on ventilation, cleaning and activity levels and the degree of tobacco smoking. No correlation has yet been shown between SBS and total dust concentration.

Man made mineral fibres (MMMF) have been a matter of concern and there have been reports of a correlation between airborne MMMF and eye-irritation and also between non respirable MMMF on surfaces and skin irritation (Rindel et al.). MMMF come mainly from acoustic ceilings: especially high concentrations were found in rooms with uncovered ceilings, but also where the fibres were bound by a water-soluble glue and exposed to water damage (O. Nielsen). The fibres are transferred from such surfaces to skin and eyes normally by direct hand contact. Further information on the biological effects of man-made mineral fibres may be found elsewhere (WHO 1983 b).

2. The chemical factors

Chemical factors are too numerous to be considered individually, but they can be grouped into major categories.

There are those which are emitted indoors and those which stem from outside air.

It should be noted that threshold limit values in industrial workplaces are fixed for a large number of chemicals by national or international standards. The pollutant concentrations normally observed in indoor air are much lower than such limits. However two factors should be taken into account: firstly indoor environments are characterized by complex mixtures of pollutants, in which synergistic mechanisms cannot be ruled out; and secondly work-place limits are defined for healthy adults working a 40 hour week. Whereas children, elderly people and hypersensitive individuals are exposed to indoor pollution for much longer periods.

Recently the WHO introduced a set of guidelines aiming "to provide a basis for protecting public health from adverse effects of air pollution and for eliminating or reducing to a minimum those contaminants of air that are known or likely to be hazardous to human health and well being" (WHO 1987). The guidelines do not differentiate between indoor and outdoor exposure, hence they cover indoor air as well. The concentration values concerning 28 organic and inorganic substances and fibres are reported in Appendix 4 as a useful reference. These concentrations should not be used without referring to the rationales given in the book.

(a) Environmental Tobacco Smoke (ETS)

Generally speaking, this is by far the most important source of chemical pollution in indoor air. It is now generally accepted that ETS may cause cancer of the lung. Sick building syndrome is statistically more pronounced in smokers than in non smokers (Skov et al.) and there is an excess of symptoms in non smokers and ex-smokers exposed to ETS compared with the same non exposed categories (Robertson et al.1988).

Passive or involuntary smoking by exposed subjects can be measured by a series of markers (CO, cotinine, thiocyanate ion). It is responsible for mucous membrane irritation (the side stream of tobacco smoke being more irritant than the main stream). It is well known, moreover, that tobacco smoke contains several hundred chemical compounds with particularly toxic constituents and that tobacco can also act as an allergen affecting the bronchial or alveolar immune defence mechanisms (Molina et al., Warren, Lehrer). As a rule, smoking should be prohibited in working environments and indoor spaces open to the public.

(b) Formaldehyde

The presence of formaldehyde may result from the use of wood based products (like particle board, plywood), urea-formaldehyde foam for insulation and a variety of products, mainly used for disinfection, cleaning and painting. It has been suggested that formaldehyde may be the cause of sick building syndrome since it irritates both the eyes and the upper or lower respiratory tract. It may also be responsible for allergic disorders including asthma (Hendrick et al.).

Wanner et al. reported symptoms of ocular or pharyngeal discomfort and irritation in connection with high concentrations of formaldehyde in new buildings where insulating materials releasing formaldehyde had been used. Experiments with climatic chambers carried out by these authors seem to confirm the important role of this pollutant.

In fact, concentrations in the ambient atmosphere of buildings are rarely sufficient to cause symptoms. SBS has been described where there was no formaldehyde in the ambient atmosphere (Robertson et al.). It is possible, however, that low concentrations of this pollutant, potentiated by other factors, may become important. It must therefore be considered as one of the possible contributors to the SBS.

The WHO has recently introduced a concentration limit of 0.1 mg/m^3 for indoor air, because this is considered the threshold of irritation, whereas "significant increases in symptoms of irritation start at levels above 0.3 mg/m^3 in healthy subjects" (WHO 1987).

(c) Volatile organic compounds (VOC)

Whether they come from building materials, furniture, household maintenance products (waxes, detergents, insecticides), products of personal hygiene (cosmetics), do-it-yourself goods (resins), office materials (photocopier ink) or ETS these compounds may affect man in different ways and sometimes are also source of odours.

Evidence on the role of VOCs in SBS cases has not been convincing. Sterling et al. (1987) found no significant difference in the VOC concentration between rooms with and without complaints in the same building: the levels in the latter were even higher than those in the former. On the other hand Mølhave (1986, 1987) reported effects (detectable through subjective sensation, performance tests or fine clinical observations, like the tear film stability of the eye) in chamber experiments with total VOC concentrations equivalent to those found in new or refurbished buildings.

Berglund et al. have found, moreover, that the concentration of some VOC was inversely proportional to the relative humidity, which would explain why SBS disorders can be more severe in winter than in summer. The correlation was attributed to the effect of air humidity on the emission from materials. P. A. Nielsen working on data obtained in the Danish Townhall study, speculated on the effect of VOC dissolution in (and successive release from) the water adsorbed on material surfaces, particularly books and papers on open shelves and surfaces with high adsorption rates (carpets, fabrics, etc.); the complaint rate in fact correlated strongly with the amount of such surfaces in rooms, referred to as shelf factor and fleece factor, respectively. In the same study Wolkoff reported very large variations of VOC concentrations in space and time, depending on activities within the space.

In a recent paper comparing the levels of VOCs in two preschools, one healthy and the other closed because of SBS problems, Noma et al. put forward the hypothesis that concentration gradients rather than absolute concentrations of VOC may trigger SBS.

(d) Biocides

Biocides are currently used in most cold water spray humidifiers to control microbial growth. These products are highly irritant in concentrated form; when dispersed in the indoor atmosphere, at low concentrations, they may cause mucous membrane irritation in susceptible individuals. Consequently this practice should not be recommended.

(e) Other gaseous substances

Carbon dioxide (CO_2) is a gas which occurs naturally in the atmosphere and is an indicator of adequate ventilation within buildings. A concentration higher than 0.1% is associated with an increased percentage of dissatisfied occupants (see above "Ventilation"). The concentrations of CO_2 normally observed in buildings are not associated with any symptom, except the sensation of stale and stuffy air.

Carbon monoxide (CO) is produced in incomplete combustion processes: unvented heating, gas cooking, tobacco smoking; it is present also in car exhaust, so that the indoor CO concentrations may be increased if the air intake of the building is at street level. The 8-hour mean concentrations observed in outdoor urban air are generally lower than 20 mg/m^3; in homes concentrations exceeding 50 mg/m^3 have been reported (Boleij et al. 1982). The World Health Organization has recently introduced a guideline concentration of 10 mg/m^3 (8 hours averaging time), designed to protect non smokers from CO contained in ETS (WHO 1987).

Nitrogen dioxide (NO_2) is also a possible source of irritation, especially in households using unvented heating or gas cooking. In the frame of the COST 613 Action a paper is in preparation. It concludes that the association between respiratory illness and/or impaired lung function on one side and indoor NO_2 exposure or the use of gas for cooking (as a surrogate measure of exposure) on the other side shows that there is a small, but real effect, even though several negative studies have been reported (Community-COST Concertation Committee). The above mentioned WHO Guideline indicates for NO_2 a concentration limit of 0.15 mg/m^3 and of 0.40 mg/m^3 for exposure periods of 24 hours and 1 hour, respectively.

Ozone (O_3), which is an irritant to the respiratory tract, may be produced by photocopying machines, laser printers (especially when not properly maintained) and certain types of ionizers: relatively high concentrations can be achieved in the proximity of these sources.

Sulphur dioxide (SO_2) from outside pollution enters buildings by air infiltration. The concentration indoors is normally lower than outdoors (roughly half) because of adsorption or reaction. The gas is irritant to mucous membranes, but has never been reported as a source of SBS.

(f) Odours

Many gases and vapours give rise to sensory discomfort from odour and irritation, which may be a disturbing factor, leading to anxiety and stress, especially when the sources are not identified.

Recently Fanger (1988) introduced two new units, "olf" and "decipol",to quantify air pollution sources and levels of pollution as perceived by human beings. One olf is the emission rate of air pollutants (bioeffluents) from a standard sedentary person in thermal comfort. The source strength of any other pollution source can be quantified in olfs, i.e. the number of standard persons required to make the air felt equally annoying. One decipol is the air pollution caused by one standard person (1 olf), ventilated by 10 litres/second of unpolluted air. The decipol value can be assessed by a panel of judges. This method has been used successfully by Fanger et al. to quantify pollution sources in spaces and ventilation systems in 15 office buildings. Comprehensive "hidden olfs" were identified in the buildings. The hidden olfs from materials and systems are claimed to be the major reason for the sick building syndrome. However at the present time no studies have been conducted comparing olf levels with sickness levels within buildings.

3. The biological factors

Office buildings normally present very low concentrations of mites , because they do not provide appropriate conditions for the growth of such microorganisms. Mites are, however, relatively abundant in household dust. Korsgaard has suggested that mites can be destroyed keeping absolute humidity below 7 g/kg of air (about 45%) during the winter time. In cases of buildings with structural faults or bad maintenance (leading to high humidity or cold surfaces) moulds can develop. Health problems related to moulds are usually allergic in origin. Mould proliferation has not been suggested as a cause of SBS.

Recent studies (Nexø et al., Valbjørn et al. 1987) demonstrated a correlation between the organic dust content of carpets (predominantly skin scales, bacteria and moulds) and the symptoms of SBS. Therefore, the role of organic dust and in particular of moulds and their metabolic products needs to be further investigated.

4. The psychological factors

It has been the initial reaction of a number of professionals confronted with repeated complaints of ill-defined discomfort to blame psychological factors, and all the more so since these symptoms appear to have no organic basis and women are the most frequently affected.

Various studies have been carried out testing these patients either with a set of performance tests (memory, vigilance, reaction time, Berglund et al.) or in the form of a psychosociological survey evaluating how these complainants viewed their working conditions in air-conditioned environments (Breugnon et al.). The performance tests show no significant differences between symptomatic and control groups.

Some researchers (Morris et al., Hedge et al.) have investigated the possible links between SBS and stress: their results, though not clear-cut, lead to think that SBS may well be responsible for the stress rather than the reverse.

Psychological factors may play a role by increasing the stress of people and thus making them more susceptible to environmental factors (WHO 1986). Skov et al., in a multifactorial analysis of the data from the Danish Townhall Study, showed that in addition to the building factor other factors like sex, job and psychosocial factors are associated with the prevalence of mucosal irritation and general symptoms.

The psychophysical load at the working place (e.g. visual display units) can cause eye irritations, tiredness and headache, and can be an additional factor for complaints on indoor climate and indoor air quality (Wanner).

VII. HOW TO CONDUCT BUILDING ASSOCIATED INVESTIGATIONS

Usually, building related problems show up when one or more persons complain to the management or the persons responsible for the occupational environment that they have direct troubles from the physical climate as e.g. draught, changing temperature, noise, or the like, or that they have symptoms of mucous membrane irritation, skin irritation, tiredness, or headache.

The initial response should be to ask the maintenance engineer responsible for the technical installations whether operational conditions are abnormal e.g. if the ventilation is cut off. Furthermore it should be investigated whether the persons complaining are able to change their indoor climate e.g. by adjusting temperature and airflow.

If the operational conditions are considered normal and the complaints continue, a technical and hygiene investigation of the conditions should be carried out. The purpose of this investigation is to decide the extent and the nature of the problems. The investigation also forms the basis of the estimation of whether the problems should be considered only from a technical point of view or if hygiene or psychosocial experts should be consulted.

The stepwise actions recommended in the following are primarily worked out for a building with SBS problems, but can be used with minor variations in all buildings with indoor air quality and climate problems. Before undertaking the next step, the results of the initial investigation should be evaluated, corrrective measures taken and the effects of the measures observed. More details on this subject can be found in a paper by Valbjørn et al. (in danish with english summary) from which this chapter has been largely derived.

Table 1. Summary of stepwise investigations of buildings with problems

Step	Type of investigation	Performed by (proposals)	Actions (examples)
1	Technical survey and use of questionnaire	Industrial physician Safety representative Maintenance engineer	Contact experts for evaluation, organize new actions, inform.
2	Inspection and guiding measurements of climate-indicators	Safety engineer Ventilation engineer	Clean and adjust ventilation, stop humidifiers,(re)move smokers and pollution sources
3	Measurements of ventilation, climate indicators and other implicated factors	Safety engineer Industrial hygienist Ventilation engineer	Increase ventilation, arrange sun-shielding
4	Medical investigation, specific measurements of suspected components	Medical doctor Industrial hygienist	Renew furniture, change on-going activities or building materials; move staff, mount local exhaust

Step 1. Technical and hygiene investigations.

At this preliminary step a hygiene and technical review of the type and severity of the indoor problems is carried out, in order to decide whether further investigations and external expertise are required.

When general agreement is reached, that the problems have been satisfactorily documented and that actions should be taken, it is recommended that the personnel experiencing problems are informed of the results of the review. A technical survey of the building is also performed in order to decide the relevant actions to be taken.

A simple questionnaire concerning symptoms and complaints about different factors is distributed to a randomly selected sample of employees. It is not the primary intention to use the answers for individual actions. They should be used for a statistical judgement of whether the prevalence of symptoms exceeds an acceptable level. This level should be established by appropriate investigations in each country.

An example of a questionnaire is in Appendix 3. The questionnaire should clearly distinguish between symptoms experienced in the building and those experienced when away from the building. The questionnaire may also include psychosocial questions. The information contained in individual questionnaires and the identity of specific buildings should be treated as strictly confidential.

A technical survey of the building and the installation conditions is worked out based on project plans and information from the building maintenance staff. An example of a checklist is shown in Appendix 2.

Step 2. <u>Inspection and guiding measurements.</u>

At this step the actual use and functioning of the building is compared with its original plan design and function.

The following aspects should be observed:

- Tobacco smoking. Where, how much, spread by recirculating air?
- Building and furnishing materials.
- Location of copying machines and laserprinters (preferably in separate and ventilated rooms).
- Odours. Characterize them and identify sources.
- Cleaning level. Dust on floor carpets, bookshelves etc.
- Intensive paper handling. Source of organic dust and gases from print.
- Presence of green plants. Are chemicals used for treatment?
- Water damage, water stains.
- Occurrence of moulds.
- Air infiltration from garage, laboratory, restaurant, workshop etc. in the same building.
- Siting of outside air intake regarding short-circuiting of pollutants from exhaust ventilation systems.
- Use of centrally or locally situated humidifiers. Are they cleaned regularly?
- Inlet and exhaust openings. Are they clean or blocked with dirt?
- Use of sunshielding.
- Number of employees in the offices. Are there more than planned?
- Random measurements of climate indicators such as carbon dioxide and air temperature, control of airflows by using smoke ampoules and evaluation of factors which in the questionnaire are mentioned as disturbing (e.g. noise or lighting) should be carried out. Check both rooms with and without problems.

Step 3. Measurements of ventilation, climate indicators and other implicated factors.

At this stage a thorough analysis of the ventilation system and the indoor climate is carried out, assuming the actions taken during the preceding steps have not resulted in a reduction in the problems. This may be assessed by readministering the simple questionnaire a few months after the remedial actions have been taken. There may be a seasonal variation in symptoms and in complaints on specific climate factors and this may complicate the evaluation of the repeated questionnaire.

The following factors should be investigated:

Ventilation:

- Visual inspection of filters, heating and cooling batteries, heat exchangers with regard to the accumulation of dirt and dust.
- Control of adjustment of temperatures, start and stop settings etc.
- Testing of all functions of the automatic control systems.
- Measurement of the degree of recirculation.
- Measurement of supply and exhaust flows for the whole system and for a representative sample of the rooms.
- Air change measurements.
- Ventilation efficiency measurements where risks of low efficiency are suspected.

Air quality and other factors:

- Again indoor air quality indicators like carbon dioxide, carbon monoxide and air temperature should be measured, but more extensively than previously and including measurement of diurnal changes which may be occuring. In this step, if not earlier, measurements of specific factors should be made. The specific factors to be measured will be suggested by initial inspection of the building and by the questionnaire responses.

- In newly built or refurbished buildings, if significant odours are present, total or individual volatile organics (in particular strong irritants) are measured and if building materials or furniture are a possible source of odour, also formaldehyde. Large variations in levels can occur during short periods of time (hours).

  Pollution sources can be found by estimating the perceived air quality (in decipol) and measuring the outdoor air supply as described by Fanger et al. To identify sources, the different compartments must be tested separately.

- In the rooms where internal acoustic ceilings with man-made mineral fibres appear unprotected or damaged, measurements of airborne fibres may be made; the replacement or sealing of such ceilings is recommended.

- In situations where poor cleaning is suspected or where large quantities of paper are being handled, the dust content in the air and on the floor should be measured. An evaluation of the composition of the dust may be of importance.

- Lighting measurement - even in the absence of complaints. Visual display users may have lighting problems that are not recognised.

- Sound measurement: attention should be drawn to low frequency noise from ventilation systems or other machinery and to irritating pure tones from office machinery.

- Measurements of air velocity distribution.

- Where the ceilings are warmer than the air temperature either the ceiling temperature or the radiation temperature in the direction of the ceiling should be measured.

Step 4. **<u>Medical examination and associated investigations.</u>**

At this step a medical examination takes place. It may be necessary to examine employees with and without symptoms. The examination is normally carried out by an occupational medical unit.

In addition to these examinations some specific exposures may be studied. This might be a qualitative study of the volatile organics together with a toxicological evaluation. A microbiological study together with provocation tests is another possibility.

The medical examination can incorporate a detailed questionnaire related to symptoms and should ask questions about the psychosocial conditions at work, the relationships of individuals to their colleagues and superiors and the type of work they are performing, all of which may influence symptoms. This last step requires co-operation between specialists, but must be administered by occupational physicians. It is normally not necessary as most of the problems in buildings are solved by the previous steps. This should be tested by using the original questionnaire some time after remedial measures indicated by Step 3 have been carrried out.

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SYMPTOMATOLOGY

1. Nasal manifestations

Nasal stuffiness. This is the most frequently described nasal symptom. The sensation of 'stuffiness' develops rapidly on entering the building, it persists while the individual remains in the building and resolves rapidly on leaving the building. It is not usually associated with either nasal itching or rhinorrhoea. In certain individuals it is specifically temperature related, appearing when high temperatures occur within the building.

Nasal irritation and rhinorrhoea. These symptoms are more variable and not necessarily persistent. Their character is highly suggestive of an allergic aetiology.

These symptoms do not necessarily occur separately and may occur in combination with each other.

2. Ocular manifestations

Dry, gritty or burning sensations of the eyes are experienced. These symptoms are not usually associated with any objective evidence of inflammation. A recent Danish study (FRANCK) has suggested that there is break up of the tear film covering the anterior aspect of the eye in those experiencing symptoms. The presence of these ocular symptoms demonstrates considerable variability in their severity from day to day. There is one group of individuals, contact lens wearers, who are particularly prone to the development of ocular irritation. Many find they have to return to wearing spectacles.

3. Oropharyngeal manifestations

The main symptom is one of dryness of the throat which is partially relieved by drinking large volumes of liquid. Physical examination of the throat does not usually reveal evidence of inflammation.

4. Cutaneous manifestations

Dry skin is frequently experienced in buildings. Female subjects are particularly aware of this symptom. It usually improves on holidays but not over shorter periods away from work, such as a weekend. A specific dermatitis has been described (RYCROFT et al.) which is caused by warm dry air and high air movements. It tends to affect exposed skin surfaces.

5. Respiratory manifestations

There is one lower respiratory tract symptom which is associated with sick building sickness syndrome. This is a sensation of chest tightness or 'difficulty in breathing in fully'. This symptom clears on taking two or three deep breaths of fresh air outside the building and is not a symptom of bronchial asthma.

6. General manifestations

Headaches and excessive tiredness are two of the most frequent building related symptoms. Headaches may occur daily, are frontal in position and usually occur in the afternoon. In its most severe form work related migraine may be present. This is usually relieved by moving the individual away from artificial (fluorescent tube) lighting. Headaches are also reduced by wearing lightly tinted glasses. An additional symptom described sometimes is "heavy headedness".

7. **Constitutional diseases**

Some constitutional diseases, e. g. eczema, sinusitis, may be exacerbated in certain buildings
Excessive tiredness occurs over the second half of the working day. It is not usually alleviated by manipulating dietary intake at lunchtime and is often directly related to high room temperatures.

DIAGNOSIS

Building related illnesses other than sick building syndrome fall into two main categories as follows:

Allergy	-	Asthma, rhinitis
		Hypersensitivity pneumonitis (extrinsic allergic alveolitis)
		Humidifier fever
Infections	-	Bacterial, fungal, viral.

Allergy

Asthma, rhinitis

In general allergic responses of the upper and lower respiratory tracts occur secondary to the inhalation of allergens in poorly maintained buildings where the cold water spray humidifiers have become contaminated by micro-organisms. Bronchial asthma in a family has been described caused by a simple, contaminated home humidifier (SOLOMON) and also in a factory situation where print workers developed asthma due to heavy microbial contamination of a central cold water spray humidifier (FINNEGAN et al, 1984). The features are those of any form of occupational asthma with increasing asthmatic symptoms over the working week, improving on days away from work, over weekends and holidays.

Hypersensitivity pneumonitis

This is the most serious form of allergic response which may be related to buildings. It occurs when heat exchange systems become contaminated usually by thermophilic actinomycetes (for example *micropolyspora faeni*). The number of cases reported in the literature have been small, occurring both in air-conditioned office blocks in the centre of cities (BANSAZAK et al.) and also in air-conditioned homes (BURCKE et al., PATTERSON et al.). The principal symptoms which occur some hours after exposure include fever, malaise and breathlessness. Profound loss of weight may be an accompanying feature. On auscultation of the lungs late inspiratory crackles are generally present and chest radiographs reveal a micronodular infiltrate. Pulmonary function tests are abnormal. The classical pattern is that of a restrictive lung defect with impaired gas transfer.

Serological tests usually show the presence of precipitating antibodies to the causative allergen. Bronchial provocation studies may be used to confirm the diagnosis.

Occasionally lung biopsy is necessary to establish the diagnosis. The characteristic histological changes are of a histiocytic cellular infiltration with giant cells and granuloma formation.

Humidifier fever

This condition was first described in 1956 by PESTALOZZI. He described an outbreak of systemic and respiratory symptoms in a group of workers in a carpentry shop. Symptoms occur on the first day of the working week, a similar periodicity to byssinosis, developing over the second half of the working shift or in the evening after leaving the workplace. Although exposure continues at work, symptoms improve progressively over the working week and subsequent weekend, recurring again on the first day back at work after a weekend or holiday. The symptoms of humidifier fever are 'flu-like', lethargy, myalgia, arthralgia, headache and fever. In more severe cases these symptoms are associated with cough and breathlessness. They resolve over a twelve hour period and the individual is normally able to work normally the following day.

Physical examination at the height of the reaction reveals the presence of late inspiratory crackles on auscultation and lung function shows a restrictive defect with impaired gas transfer. Lung function is normal between attacks. In all cases the chest radiograph is normal.

Immunological investigations almost always reveal the presence of precipitating antibodies to antigens extracted from the humidifiers.

Bronchial provocation tests with water from the humidifier usually reproduce the symptoms and physiological changes in affected individuals but not in control subjects.

The cause or causes of humidifier fever are not known. Outbreaks often occur when humidifiers have become heavily contaminated by micro-organisms. A number of different causes have been postulated including *Naegleria gruberi*, *Acanthamoeba polyphaga*, *Bacillus subtilis* and endotoxin. All of these suggested causes are based on serological investigations. At the present time none has been proved to be the cause by provocation studies.

Infections

Bacterial

The most serious infection associated with air-conditioning systems is that caused by *Legionella pneumophila*. Individuals are infected by vapour drift containing this bacterium from contaminated cooling towers. This may occur in the streets in the vicinity of the cooling tower or inside buildings when water droplets are drawn into the building via the air-conditioning system. Legionnaire's disease has not been described as a result of contaminated cold water spray humidifiers.

Fungal

Infections caused by the fungal species *Aspergillus* have been described as a result of contaminated incoming air to buildings and due to contamination of duct work. This is a particular problem in hospitals, affecting old and immunocompromised patients. Good maintenance procedures and appropriate filters will prevent outbreaks of this type of disease.

Viral

An epidemic infection of measles has been described where the mode of spread appeared to be via the air-conditioning system (RILEY et al.).

Checklist for description of the building, its materials, installations, and the conditions of both

Building age

Renovation within the latest years (work done and date).

Number of persons per office (average and max).

Office area per person (average and min).

Air volume per person (average and min).

The floor: material and covering.

The walls: material and covering.

The ceiling: material and covering.

The heating system: type and regulating system.

The ventilation system: natural ventilation, mechanical exhaust and/or air supply system, filters. For air supply systems: additional information on recirculation, humidification, cooling, air intake location.

The magnitude of ventilation: outdoor air change rate (ach) and the corresponding average and minimum outdoor rates per person (litres/second·person)

(Indicate whether these values are based on assumption, design criteria or measurements.)

The running procedure for heating and ventilation systems: night setback, recirculation, humidification.

Cleaning procedures: daily, weekly, monthly, annual procedures for floors, furnitures etc.

(recent changes in procedures?).

Lighting conditions: general, individual.

Equipment producing noise, pollutants, heat: type and location.

Products used which can deteriorate the air quality (cleaning products, spray for plants, etc.).

Water damage (previous or present).

Indoor climate measurements carried out.

Appendix 3

Questionnaire for SBS investigations*

INDOOR CLIMATE Work environment 1-6 ENGLISH VERSION	MM 040 EA Date year month day	Name Company/institution
7-11 Number	Profession	Department
12-21 User Filled in by investigator	Group	

This questionnaire concerns your indoor climate and possible symptoms you may be experiencing.

BACKGROUND FACTORS

22-23 Year of birth 19 ☐			Occupation ....
24 Sex	male ☐ 1	female ☐ 2	How long have you been at your present place of work? ☐ years 26-27
25 Do you smoke?	Yes ☐ 1	No ☐ 2	

WORK ENVIRONMENT

Have you been bothered during the last three months by any or several of the following factors at your work environment?	Yes, often (every week) (1)	Yes, sometimes (2)	No, never (3)
28 Draught	☐	☐	☐
29 Too high room temperature	☐	☐	☐
30 Varying room temperature	☐	☐	☐
31 Too low room temperature	☐	☐	☐
32 Stuffy "bad" air	☐	☐	☐
33 Dry air	☐	☐	☐
34 Unpleasant smell	☐	☐	☐
35 Static electricity, often causing shocks	☐	☐	☐
36 Passive smoking	☐	☐	☐
37 Noise	☐	☐	☐
38 Light that is dim or causes glare and/or reflections	☐	☐	☐
39 Dust and dirt	☐	☐	☐

WORK CONDITIONS

	Yes, often (1)	Yes, sometimes (2)	No, seldom (3)	No, never (4)
40 Do you regard your work as interesting and stimulating?	☐	☐	☐	☐
41 Do you have too much to do?	☐	☐	☐	☐
42 Do you have any chance to influence your working conditions?	☐	☐	☐	☐
43 Do your follow-workers help you with problems you may have in your work?	☐	☐	☐	☐

PAST/PRESENT DISEASES/SYMPTOMS

		Yes (1)	No (2)
1	Have you ever had asthmatic problems?	☐	☐
2	Have you ever had hay-fever?	☐	☐
3	Have you ever had eczema?	☐	☐
4	Are there other allergic diseases in the family (asthma, hay-fever, eczema)?	☐	☐

PRESENT SYMPTOMS

During **the last 3 months** have you had any/several of the following symptoms?

		Yes, often (every week) (1)	Yes, sometimes (2)	No, never (3)	If YES: Do you belive that it is due to your *work environment*? Yes (1)	No (2)
5-6	Fatigue	☐	☐	☐	☐	☐
7-8	Heavy headedness	☐	☐	☐	☐	☐
9-10	Headache	☐	☐	☐	☐	☐
11-12	Nausea/dizziness	☐	☐	☐	☐	☐
13-14	Difficulties concentrating	☐	☐	☐	☐	☐
15-16	Itching, burning, irritation of the eyes	☐	☐	☐	☐	☐
17-18	Irritated, stuffy or runny nose	☐	☐	☐	☐	☐
19-20	Hoarse, dry throat	☐	☐	☐	☐	☐
21-22	Cough	☐	☐	☐	☐	☐
23-24	Dry or flushed facial skin	☐	☐	☐	☐	☐
25-26	Scaling/itching scalp/ears	☐	☐	☐	☐	☐
27-28	Hands dry, itching, red skin	☐	☐	☐	☐	☐
29-30	Other	☐	☐	☐	☐	☐

FURTHER COMMENTS

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THANK YOU!

AIR QUALITY GUIDELINES*

Table 2. Guideline values for individual substances based on effects other than cancer or odour/annoyance[a]

Substance	Time-weighted average	Averaging time	Chapter
Cadmium	1- 5 ng/m³ 10-20 ng/m³	1 year (rural areas) 1 year (urban areas)	19
Carbon disulfide	100 µg/m³	24 hours	7
Carbon monoxide	100 mg/m³ [b] 60 mg/m³ [b] 30 mg/m³ [b] 10 mg/m³	15 minutes 30 minutes 1 hour 8 hours	20
1,2-Dichloroethane	0.7 mg/m³	24 hours	8
Dichloromethane (Methylene chloride)	3 mg/m³	24 hours	9
Formaldehyde	100 µg/m³	30 minutes	10
Hydrogen sulfide	150 µg/m³	24 hours	22
Lead	0.5-1.0µg/m³	1 year	23
Manganese	1 µg/m³	1 year[c]	24
Mercury	1 µg/m³ [d] (indoor air)	1 year	25
Nitrogen dioxide	400 µg/m³ 150 µg/m³	1 hour 24 hours	27
Ozone	150-200 µg/m³ 100-120 µg/m³	1 hour 8 hours	28
Styrene	800 µg/m³	24 hours	12
Sulfur dioxide	500 µg/m³ 350 µg/m³	10 minutes 1 hour	30
Sulfuric acid	—[e]	—	30
Tetrachloroethylene	5 mg/m³	24 hours	13
Toluene	8 mg/m³	24 hours	14
Trichloroethylene	1 mg/m³	24 hours	15
Vanadium	1 µg/m³	24 hours	31

[a] Information from this table should *not* be used without reference to the rationale given in the chapters indicated.

[b] Exposure at these concentrations should be for no longer than the indicated times and should not be repeated within 8 hours.

[c] Due to respiratory irritancy, it would be desirable to have a short-term guideline, but the present data base does not permit such estimations.

[d] The guideline value is given only for indoor pollution; no guidance is given on outdoor concentrations (via deposition and entry into the food chain) that might be of indirect relevance.

[e] See Chapter 30.

Note. When air levels in the general environment are orders of magnitude lower than the guideline values, present exposures are unlikely to present a health concern. Guideline values in those cases are directed only to specific release episodes or specific indoor pollution problems.

* The Tables in this Appendix are taken from WHO 1987

Table 4. Rationale and guideline values based on sensory effects or annoyance reactions, using an averaging time of 30 minutes

Substance	Detection threshold	Recognition threshold	Guideline value
Carbon disulfide in viscose emissions			20 μg/m³
Hydrogen sulfide	0.2–2.0 μg/m³	0.6–6.0 μg/m³	7 μg/m³
Styrene	70 μg/m³	210–280 μg/m³	70 μg/m³
Tetrachloroethylene	8 mg/m³	24–32 mg/m³	8 mg/m³
Toluene	1 mg/m³	10 mg/m³	1 mg/m³

Table 5. Carcinogenic risk estimates based on human studies[a]

Substance	IARC Group classification	Unit risk[b]	Site of tumour
Acrylonitrile	2A	2×10^{-5}	lung
Arsenic	1	4×10^{-3}	lung
Benzene	1	4×10^{-6}	blood (leukaemia)
Chromium (VI)	1	4×10^{-2}	lung
Nickel	2A	4×10^{-4}	lung
Polynuclear aromatic hydrocarbons (carcinogenic fraction)[c]		9×10^{-2}	lung
Vinyl chloride	1	1×10^{-6}	liver and other sites

[a] Calculated with average relative risk model.

[b] Cancer risk estimates for lifetime exposure to a concentration of 1 μg/m³.

[c] Expressed as benzo[a]pyrene (based on benzo[a]pyrene concentration of 1 μg/m³ in air as a component of benzene-soluble coke-oven emissions).

Table 6. Risk estimates for asbestos[a]

Concentration	Range of lifetime risk estimates	
500 F*/m³ (0.0005 F/ml)	10^{-6} - 10^{-5}	(lung cancer in a population where 30% are smokers)
	10^{-5} - 10^{-4}	(mesothelioma)

[a] See Chapter 18 for an explanation of these figures.

Note. F* = fibres measured by optical methods.

Table 7. Risk estimates and recommended action level[a] for radon daughters

Exposure	Lung cancer excess lifetime risk estimate	Recommended level for remedial action in buildings
1 Bq/m³ EER	(0.7×10^{-4}) - (2.1×10^{-4})	≥ 100 Bq/m³ EER (annual average)

[a] See Chapter 29 for an explanation of these figures and for further information.

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EN

The report aims at giving a guide to those facing the problem of «sick building syndrome». After a description of the other building related illnesses, which must not be confused with the syndrome in object, the extent of the problem is presented, with particular emphasis on the economic implications. The report deals also with the symptoms which must be present in order to diagnose the syndrome and with the various environmental and personal factors possibly contributing to the development of the trouble. Finally, the report contains a rather detailed, stepwise procedure for the detection and mitigation of the most frequently observed causes.