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THE "SICK" BUILDING SYNDROME

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This chapter is based on deliberations of a subgroup on the "sick" building syndrome of the WHO Regional Office for Europe Working Group on Indoor Air Research which met in Stockholm, 27-31 August 1984. This material is presented here for the benefit of the indoor air scientists who participated in the INDOOR AIR '84 Conference, but does not necessarily represent the decisions and stated policies of the World Health Organization. This material will serve for the preparation of the final report on the Working Group, which should appear in 1986.

Introduction

There have been some advances in our knowledge of "sick" buildings during the last few years (1,6,8). It can only be diagnosed, up until now, from complaints by the users of the building. It has been found that specific causes of complaints symptoms usually have not been identified. Generally, monitoring of chemicals has not led to any more information than simple inspection of the site. Inspection has frequently led to common broad conclusions about the idiopathic nature of the complaints. Some complaints have been related to ventilation. We do not include bad engineering, design and design practice in the "sick" building syndrome (SBS). Good practice can produce energy-efficient buildings and this should be a pre-requisite. Generally, problems have been thermal (discomfort and possibly some irritation), chemical (irritation), or biological (e.g., humidifier fever, Legionnaire's disease) or more commonly, "allergic" reactions of the "irritant type" (8). Synonyms of the "sick" building syndrome (SBS) are: building illness syndrome, building-related illness, ill buildings, stuffy offices, tight office building syndrome.

The frequency of sick buildings still varies by country or region: up to 30% of new or remodelled buildings may have unusually high rates of complaints. Often this is temporary, but some are long-term problems. Many buildings are resistant to even extensive remedial action. The sick buildings generally are still those that are energy-efficient and characterized by air tight envelopes (e.g., windows that cannot be opened). Problems in the approach to SBS are due to unsystematic investigations. Studies should progress in a logical fashion from inspection to sophisticated measurements. Advanced/expensive sampling and analysis are not encouraged as an early response to investigating the relationships between indoor air quality and complaints.

Subjective symptoms can be characterized better now. Usually, the sensation of dry mucous membranes is most noticeable in the building illness syndrome; the onset is gradual and the duration long, as compared to the mass psychogenic illness (5) which is characterized by hyperventilation, headache, nausea, dizziness, and the like, or symptoms related to a specific illness, a sudden start preceeded by a triggering event (e.g., a strange odour) and a duration of days to weeks, although repeated relapses may occur. The symptoms can be differentiated from ubiquitous syndromes as found in control buildings and represent more the acute symptoms of discomfort, annoyance and irritation (e.g., eye and throat irritation, odour, sneezing, stuffy or runny nose); acute diseases (e.g., colds, productive cough, asthma, fever) are found everywhere. Symptoms found in all buildings, can be grouped into those of: (a) sensory skin and upper airway irritation, along with headache and abnormal sensory skin and upper airway irritation; (b) odour; (c) general symptoms such as fatique, dizziness and nausea; (d) lower airway or (e) gastrol-intestinal symptoms. Only (e) is not typical to SBS. It is agreed also that psychogenic symptoms may be present in some cases, and this will require much more investigation.

Basic mechanisms. By looking at the symptoms described in the sick building syndrome most seems to be described by sensory reactions in the fifth cranial nerve (the common chemical sense) (4) and in the first cranial nerve (odours) (2). A few symptoms seem to be connected with irritation of the lower airways.

The indoor air contains a complex pattern of sensory stimuli, but irrespective of the pollution pattern the response is almost identical. No single irritant can therefore be held responsible.

It is known that during prolonged exposures an odour substance appears weaker in intensity compared to its intensity when the system is unadapted. For the common chemical sense similar mechanisms so far have not been described. It also seems feasable to expect that reactions of the "referred pain type" may take place so that facial skin sensations, headaches etc could be due to irritation of the free nerve endings of the fifth cranial nerve in the nasal mucosa.

The most plausible mechanism is that the upper airway symptoms are due to the net result of a summation and interaction of numerous subthreshold sensory stimuli involving several sensory systems after absorption of the pollutant in the nasal mucosa (2). The lower airway symptoms could be due to less water soluble or less reactive components due to chemical bound to particles depending on the mucous surface of the region of the airways.

It should also be borne in mind that the increased prevalence of allergies makes mucosal reactivity more common and that psychosocial stress may induce a sensitory unbalance in the autonomous nervous system.

Methodology

How sizeable is the problem with sick buildings? It would seem desirable to get measures of the extent of the problem. This holds both for numbers of buildings/cases and of persons. Connected to that are problems and constraints to be overcome in sampling procedures.

Equally important is to arrive at some measure of the intensity of the problem. Gradings of responses are necessary, preferably expressed as measures on standardized scales, permitting comparisons between populations of building and occupants over time. Selfreported responses of discomfort or medical symptoms need be correlated with direct measurable effects, although most subtle symptoms reported in connection with sick buildings are not accompanied by positive findings in clinical measurements. These methods are designed for sick persons and are probably not sensitive enough at present for use in population studies.

It is likewise important to relate the sick building problem, as a product of extent and intensity of reactions, to other public health problems. Although not serious in the individual case, the spread of reactions to sick buildings may qualify the sick building syndrome as an important environmental health problem. Finally, it would seem desirable to find out whether the sick building illnesses are only short term, transitory effects or if there are long-term and persistent adverse effects as well.

Starting points for exploring possible causal relationship. It should be evident that knowledge of basic biological mechanisms and of human sensitivities to environmental agents are needed for the full understanding of the relationships between environmental factors and the symptoms shown by occupants of sick buildings. In this context, it may be worthwhile to use the expressions "critical effect" and "critical levels". Critical effects in the sick building syndrome, are:

- sensory reactions, especially responses measured by psychophysical methods
- air way reflex reactions
- neuropsychological effects including effects as measured by performance tests
- changes in attitudes that may or may not show up as changes in affective behavior.

Groups at risk. Studies of the sick building syndrome and other environmental related effects should devote special attention to persons who are hyperreactive in any of the following critical organs:

- the senses, especially the chemical senses
- the nose
- the skin, especially the facial skin
- the upper airways
- the lower airways.

Other groups who probably are at higher risk than others and who can be expected to suffer more from environmental irritants and sick buildings, are persons with astenopia (defined as "any subjective visual symptom or distress resulting from use of one's eyes"), mouth breathers, selfselected persons avoiding the more polluted, often industrial, indoor environments, and psychosocially isolated workers with repetitous work.

There is a definite need for the development of better methods for the identification of the groups at risk and symptoms related to sick buildings. One must be able to combine the frequency and severity of medical symptoms and feelings of discomfort.

Environments at risk. Seemingly, many energy efficient buildings with air tight envelopes are at risk in developing the sick building syndrome. This may hold, especially for buildings with large ventilation systems depending on limited fresh air sources. Another condition that would increase the risk for developing indoor air quality problems is the lack of integration of climatic factors, e.g., imbalances in thermal and ventilation conditions or between environment protection measures such as against noise, thermal radiation etc. Finally, important features of work places at risk in developing the sick building syndrome are buildings in which the occupants lack control of the climate conditions and of the working conditions.

Measures of health outcomes. Standardized questionnaires which are carefully tested (calibrated), should be used to measure subjective acute symptoms (by category, as discussed above). The questionnaires should include questions, where appropriate, on diagnosed diseases and chronic symptoms, on the time frame of these diseases, on medications, on demographic and anthropomorphic characteristics, on behaviourial factors (e.g., smoking, alcohol consumption), and attitudes. Questionnaires should obtain a work history, residential history and a time budget. If the subject works in the sick building, specific information about work location, duration, type, and exposures should be asked in the questionnaire. There should be a place for comments from the subjects. Along with the questionnaires, there should be provided a background and instructions for the interviewers and subjects. The investigator should be aware of that unless the questionnaires and the psychometric scales used are calibrated and carefully tested, there are definite restrictions in the utility of the measurement data. Different attitudes, different response behaviour and different environment experiences may result in variations in response criteria which make response grading difficult to compare.

Objective tests of health effects should be conducted at the site. The choice of tests is based on what is expected medically and/or from environmental monitoring. Measurements of the external eye could include close-up photographs of the eyes, eye blink rates, slit lamp investigations (for epithelial cell studies), tear fluid examinations (for cell counts and lysosomal enzymes). Nasal examinations could include nasal inspection, nasal scrapings and rhinomanometry. Studies of skin reactions could include standardized immediate hypersensitivity skin tests for allergens (and general reactions) and patch tests for chemicals. Studies of airway responsiveness could include pre- and postbronchodilator pulmonary function and tests of bronchial reactivity through bronchoconstricting challenge tests. Blood tests should be performed if lower airway disease is suspected (e.g., alveolitis, humidifier fever, Legionnaire's disease).

Practical investigations. To increase efficiency and reduce costs, any investigation of a sick building should be performed in a step-by-step manner. A following step should not be initiated before a written report about the preceeding step has been evaluated, corrective measures taken, and surveillance introduced. The basic idea is to ensure that the buildings technical equipment, especially the ventilation system is functioning as intended in the design phase and that simple physical investigations and simple questionnaires investigations should preceed more complicated and expensive methods.

The *first* step could include:

- inspection of architectural and engineering plans;
- description of discrepancies between the use originally intended and the actual use;
- description of maintenance and cleaning procedures and their frequency;
- visual inspection of the building and the technical installations. Special consideration should be given to the ventilation system (air intake, humidifier system, contamination of ducts, etc.) and to the cleaning standard. Measurements should only include thermal measurements (air temperature, radiation temperature, humidity, and air velocity) and measurements of the concentration of CO and CO_2 (indicator tubes).

If the first step investigation does not clearly indicate the problem area(s) the *second* step could include:

- simple questionnaire with questions about air quality, thermal comfort, noise, lighting, psychosocial stress;
- measurements of noise, lighting, suspended particulate matter, formaldehyde and distribution of ventilating air (measurement of inlets and outlets in room).

First then, when basic information about the building and its occupants has been collected and problems still prevail, a *third* step could include:

- an extended questionnaire
- objective tests on subjects
- measurements of volatile organic compound, microorganisms and allergens, ventilation distribution and efficiency.

It should be stressed, that the objective tests on subjects should be performed on-site and not in a doctors clinic. Also, the environmental measurements and the subjective and objective measurements on subjects should be performed simultaneously. The possible corrective actions after step 3, therefore, in many cases will be of a general nature, increase of the ventilation rate, improved cleaning procedures, etc.

The two first investigation steps are within the frame of the normal industrial hygiene problem approach and should preferably be performed by investigators with this educational background. Investigators performing step 3 investigations should be specialists in chemistry, bacteriology, psychology, etc., with additional training in environmental occupational health. One should ensure maximum cooperation between managers and employees.

Study design. There are a few basic study designs of SBS. The usual design is a case-control approval. Where the case is the SBS, the control has to be an equivalent healthy building, similar to the workers in the case building in terms of type of job (compare healthy worker effect or reverse), geographical area, other exposures, etc. Sample size is a critical aspect, as are unbiased enrollment and follow-up.

A second approach is a test case vs. worse case comparison, which can be connected as a special form of the case-control design. This approach can be used for long-term studies (retro-prospective or prospective), including surveillance studies. Controls for intervening and confounding factors are more difficult, as they are more extensive.

A third approach is the natural experiment epidemiological design. This approach utilizes a specific exposure information known to be occuring or will be occuring. This is a pre- and post- exposure study, where the person acts as his own control. An appropriate form of this design is to start the study in a new/rebuilt building before occupancy, with pre-employment standard evaluation of workers (subjective and objective) and appropriate surveillance.

Results should be presented so that interpretation can be expanded and comparisons can be made to other SBS study results (same/different countries/regions). Comparisons can be made of measures of change or difference (e.g., case vs control plans) or of trends or gradations, since absolute values may change with time and place.

Remedial actions. Practical experience from sick buildings in the City of Stockholm often shows that heated ceilings, if not carefully dimensioned and installed, may cause stagnation of room air because of a positive vertical temperature gradient. Similarly, extensive use of heat producing lamps may cause the same effect. Overtemperatures in supply air at roof levels of rooms, sometimes as a result of the buildings envelope being not insulated well enough, may also reduce ventilation efficiency. Instead, radiators at floor level may be installed and incandescent lamps exchanged with fluorescent lighting. In rooms with high sun radiation influx, radiation protection may be necessary.

A careful exchange of surface materials may sometimes be necessary. Particle boards and other composite materials may have to be exchanged by gipsum boards, or surface materials which in ad hoc screening tests have been shown to present minimum odours and irritants.

In some cases sick buildings have successfully been heated to 40 gr C for several days in order to speed up the gasing off of irritant compounds. By not lowering air temperature setting during the night, forced heating in the early mornings can be avoided, which may show to be beneficial.

Increased outdoor air rates, increased ventilation rates and starting the ventilation system earlier in the mornings, have been tried as supplementary actions with a satisfactory result. Direct heat exchangers (air-to-air) must be carefully checked as to possible transference of pollutants or otherwise not used. Air cleaning devices are usually not efficient.

In a few cases the counter-measures have no effect. Probably these cases present a fundamental drawback in building design that make remedial actions not cost-efficient.

Guidelines for Future Research Needs

Human studies. In addition to studies of basic biological mechanisms there is an overwhelming need to devise better, standardized, calibrated instruments to measure health effects associated with the sick building syndrome. Tests of performance and psychological tests of stress, annoyance, fatigue and over-reactions to environmental conditions should be conducted in the building work place. Psychophysical tests should be explored, for the evaluation of reaction time and quality and of sensory receptors (neurophysiological signs). These may include tests of feelings, reaction time, electrogalvanic responses, thermal receptors ,and their time sensitivity used in the USSR.

Further and better objective tests of bio-medical responses are needed. They include further development of tests of (a) pain threshold, (b) nasal resistance and peak flow pre- and past-challenges, (c) neurological tests (e.g. neuroconductance, (d) measures of eye effects (e.g. tear viscosity as being developed in USSR), and (e) biological monitoring (e.g., exhaled volatile organic compounds). Field tests of mucociliary clearance and deposition, and tests of lung function (total lung capacity, residual volume, total volume) should be evaluated.

Measures of changes in blood (e.g., carboxy- and methemoglobin, white cell counts, red cell activity, including hematocrit and sedimentation rates) and in nasal-bronchial washes for cell types (macrophages; neutrophils, etc) have not been completely evaluated (though some work has been conducted in cell activity in blood in the USSR). These experimental approaches may be worth exploring. These tests should be performed at the site. Some easy tests that are needed physiologically (eg pulse rate, respiratory rate, blood pressure, pre- and post-physiological load) should be evaluated in these settings.

It is possible that the SBS can occur in residences in new buildings. This has not been investigated thoroughly. It is possible that different methods may be necessary for such studies. Since children may be involved, and there may be long-term exposure, other techniques would be necessary (e.g., measures of development).

Technical studies. At present it is known that building materials emit at least several hundred different chemicals in varying concentrations. Recently it has been shown also cleaning agents, polishers, household appliances etc. also emit atmospheric pollutants. There is a need for studies (budgets) of the relative importance of these sources in different types of buildings, if effective preventive measures shall be introduced.

Further there is a need for the development of methods for studying the cleaning efficiency. Studies for the measurement of dust on hard surfaces are under development (adhesive tape methods, but they need to be evaluated in different building environments and compared with results of bacteriological and allergological studies). For textiles (carpets etc) these procedures so far are not applicable. Thus, new methods should be developed for these.

Furthermore, simple and inexpensive methods for the study of ventilation rates and ventilation efficiency should be introduced. The trace dilution methods used today are very accurate, but time consuming and expensive. In most cases there is a greater need for a broad grouping of ventilation (good, medium, bad) in different areas (rooms) of a building than for very precise measurements in few rooms.

Recommendations

Priority of indoor air research. Conventionally priority setting is based upon a combination of three considerations:

- severity of disease
- number of subjects affected
- possibility for preventive measures.

The sick building syndrome, in all probability, does not cause death or life shortening disease. The effects to be found are an increased absenteeism rate, reduced work efficiency and discomforting irritation.

Even if the severity of disease is low, the number of subjects affected is high, from 10 - 30 % of the occupants in new buildings, its priority among lung and airway diseases ranks high. More than fifty percent of the workplaces in USA and Northern Europe are dealing with information processing in an office or an office-like setting. The increasing importance of this sector in combination with increased use of video display terminals means that the ratio between office workers and workers in traditionel industries will still increase. This forecast (for the year 2000) suggests that 60 % of the North American Workforce at that time will use video display units (6).

The possibilities for reducing indoor generated air pollutants are discussed in a following section. Generally speaking, the experience with radon and formaldehyde have shown that it is possible to introduce effective preventive measures over a five-year period for a reasonable expenditure.

The use of TLV in the non-industrial occupational setting. Threshold limit values (TLV's) have been developed to protect workers in the industrial setting. Emissions from the industrial processes normally stem from a few, strong sources each emitting one or few substances. These process emissions are unavoidable, even with the use of advanced systems for local and general ventilation. Therefore, it is accepted that a small percentage of workers will experience discomfort at concentrations at or below the TLV, a smaller percentage may even be affected more seriously. The health of the workers in industry due to self-selection also is better than in the general population ("healthy worker effect").

In the non-industrial, occupational environment no industrial processes take place (except for photocopying and the like) which normally and preferably is performed in a spécial room. Therefore no need exists for inclusion of emission from technical processes in the limit values for workers at these premises. The pollution sources also are different, they are multiple (building materials, furniture, carpets, cleaning products, paper, plastic bindings etc. each emitting a complicated blend of pollutants) for which reason the probability of combination effects is great. However, generally speaking, concentrations are low. The work force in the non-industrial occupational environment is also selfselected, but it is more sensitive to and have a stronger attitude against pollutants than the industrial work force.

For all these reasons use of industrial TLV's is not to be advocated for in the non-industrial, occupational setting. In some cases a direct use would be without meaning as for example in cases where the industrial TLV has been set due to a high skin penetration capacity or due to a chronic effect. The majority of TLV's, however, have been set to avoid acute irritation effects. For substances with such effects, it seems reasonable in the non-industrial occupational environment to use a TLV which should be only a fraction of the industrial TLV.

It is therefore recommended that those components for which the TLV has been set due irritation effects are listed and that a fraction of the industrial TLV is used for a non-industrial TLV.

In those few cases where limits have been set for outdoor air pollutants, these are directly applicable for the non-industrial occupational environment. In cases where the ambient air quality standards are based on the exposure-effect relationships obtained through epidemiological studies and outdoor exposure estimations only, the standards may underestimate or overestimate the risk depending on whether outdoor concentrations are lower or higher than indoors. For pollutants with an outdoor/indoor ratio above 1, these limits normally will be too high and the opposite will be true for those with an outdoor/indoor ratio below 1. The magnitude of these differences is not big and as TLV always should be used as guidelines in the control and not used as fine lines between safe and dangerous concentrations, the direct use of these limits is advocated as long as TLV's specific for the non-industrial indoor environment are not available.

The introduction of special, lower TLV's for the non-industrial occupational environment will only have consequences for very few existing buildings. Most important is that the introduction of these new values will make it possible for producers of building materials, etc, in a meaningfull way to develop strategies and priority setting by reduction of emissions.

Testing of major changes in design and engineering practices. When a new drug is introduced, the introduction always is preceded by year-long, extensive studies in in-vitro studies (e.g. tissue cultures), animals and special groups of volunteers. Major changes in building design and engineering practices are always preceded by extensive theoretical considerations and in many cases also by small scale experiments. However, there is no need in these areas for follow-up studies where it is investigated how the building actually functions and how the experiences of the occupants are during normal use.

It is recommended that follow-up studies are introduced and used by architects and engineers on cases where major changes in design and engineering practices are introduced. These studies, and the following health surveillance, should start with the occupance of the building.

Cost effectiveness. Most countries will continue their efforts to save energy for the next coming years. For example, the Swedish energy saving programme is aiming at a reduction of 30 % of energy for heating in 10 years. The first step is always to put heating and ventilation under control. The second step is to improve insulation and tightness. This cannot be done without a thorough control of the air flow, including the input of fresh air. Often this results in the need for a totally new canalization system which may reduce considerably the profit of energy saving.

The choice of the most cost-efficient methods for energy saving in buildings should include evaluation of how the buildings and systems will work in the long-term perspective, the ease and cost for maintenance, the acceptance of the system and its intended use by the consumer and the risk evaluation with respect to its impact on health and comfort.

Energy efficient but "sick" buildings many times cost society far more than is gained by energy savings. The capital cost of a detached kindergarten building being closed for climate problems indoors, which repeatedly has happened, e.g., in the City of Stockholm, exceeds by a factor of up to 100 what is to be gained by the introduction of specific, energy-saving equipments or other means.

The confidence the population are showing health and building authorities may be seriously disturbed if "sick buildings" become a common phenomenon. Sensory warnings to many people have a great emotional impact that may cause exaggerated responses, also to buildings with only minor environment problems and cause unjustified claims of serious and persistent health effects. The added costs to society of the increased sensory irritation, the increased discomfort and the fear for more serious, persistent health effects among the occupants, is most probably exceeding the gains that can be made on the margins of energy saving.

Too far going energy saving measures, more and more often cause a real drop in capital value of buildings. Market prices go down in buildings classified as "sick" or affected by mould odours or contaminated by radon or formaldehyde. Furthermore, too high humidities indoors, as in buildings not ventilated and heated well enough, may destroy the building structure itself, require expensive exchanges of building materials, or furnishings, or the introduction of expensive compensatory auxilliary equipment.

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