EDIFICE COMPLEX: AN ANATOMY OF SICK BUILDING SYNDROME CONTROL AND ABATEMENT

HAL LEVIN

UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

APCA FOUNDED IN 1907
The Association Dedicated to Air Pollution Control and Hazardous Waste Management

**For Presentation at the 81st Annual Meeting of APCA
Dallas, Texas
June 19-24, 1988**

INTRODUCTION

Sick Building Syndrome (SBS) may affect as many as 20% of the office workers in the United States. In a survey of U.S. office workers, symptoms associated by respondents with poor air quality included a tired, sleepy feeling (56%), a congested nose (45%), eye irritations (41%), difficulty in breathing (40%), and headaches (39%) (Woods 1987). Efforts to control and abate the causes of SBS in buildings are potentially important to the economy and to public health. The present paper is a review of selected published reports related to SBS and a discussion of some of the problems limiting our understanding of it.

The complexity of modern buildings presents significant unmet challenges to designers, operators and investigators. Problems other than air quality can cause or exacerbate the symptoms of Sick Building Syndrome. Psychological and social as well as physical and biological factors interact to create occupant physiological and health responses to building environments. Yet detailed, comprehensive investigations of building-associated outbreaks are infrequent due to the resources and personnel required to conduct them.

Control and abatement of SBS is dependent upon reliable and useful investigation and diagnosis. An understanding of the nature and causes of SBS is essential to such investigations and diagnoses. Yet no clear understanding of SBS and no widely accepted definition of SBS exists. In fact authorities in the field use differing definitions or confusing terms which do not increase understanding of the phenomenon. And the most widely-accepted definition includes the absence of identified causes, but even those who present this definition fail to use it consistently.

Knowledge and understanding of SBS is obtained through four primary means: (1) investigations of problem or complaint buildings, with or without non-complaint control buildings; (2) multiple building studies which may or may not include complaint buildings; (3) controlled experimental research in buildings or laboratories where environmental factors are manipulated by researchers; and (4) literature reviews where data or findings from various investigations or studies or both are collected and analyzed. The investigations are usually commissioned by building owners, operators or occupants while the studies and research are usually funded by public or private research or by governmental agencies.

SBS is frequently defined by the reported symptoms (NAS 1981; WHO 1983; Stolwijk 1984; Fanger 1987; Finnegan et al 1984; Molhave 1987; Woods 1987). A widely cited World Health Organization report (WHO 1983) refers to a broad spectrum of symptoms reported primarily in Scandinavia and the United States. Those symptoms have many features in common and are listed in Table 1. Molhave (1987) has proposed a classification scheme for the major symptoms of SBS

(Table 2). A World Health Organization Working Group on Indoor Air Quality Research (WHO 1986) has proposed a classification scheme for "sick" buildings (Table 3).

Commonly, several factors are identified which are considered potentially related to an elevated incidence of reported symptoms when a problem is termed SBS (Skov and Valbjorn 1987; Molhave 1987). These factors include chemical (Molhave et al 1984), physical (Alsbirk 1983), biological (Morey 1984) and psychosocial factors (Colligan 1981; Alexander and Fedoruk 1986).

Many authors state that most investigations of SBS have not resulted in definitive identification of causal factors. In fact most definitions of SBS require that the reports of symptoms not be associated with a specific environmental or other causal agent. Other definitions simply require that the causal agent(s) not be clearly identified or demonstrated by the investigation. Generally, where a causal agent is identified, the symptoms are no longer considered "sick building syndrome;" rather, the building problem is specified as contamination by the causative agent. Thus, where a specific factor or group of factors are identified as etiologic agents, the term SBS is not applied by most investigators. But confusion exists because many investigators still apply the term SBS to cases where etiology is clearly identified.

Some Confusion About Terminology

There are two issues around which much of the confusion revolves. One involves definitional differences; the other involves inconsistent use of terms. Where the etiology of symptoms and complaints is identified, most investigators do not label the symptoms or complaints SBS or the building "sick" (WHO 1983; Molhave 1987; Woods 1987). Rather, they consider the illness to be Building Related Illness (BRI - i.e., hypersensitivity pneumonitis, Pontiac fever, allergic dermatitis) (Hodgson 1986; Woods 1987). Such illnesses are caused by contamination by a broad range of agents and factors including infectious microorganisms, allergens, chemicals, moisture, temperature, noise, vibration and illumination.

However, some authors have asserted that SBS does not involve identified etiology, yet they label as SBS cases which include bacterial diseases such as Legionnaire's disease and Pontiac fever, thermal discomfort, and irritation caused by chemicals. And they call such buildings examples of "sick" buildings (WHO 1986; Berglund and Lindvall 1987). hus the second issue arises out of inconsistent use of the terms "sick" building" and "SBS." The issue is whether "sick" buildings necessarily result in SBS or in specific non-SBS illnesses, some or all of which are labelled BRI.

In listing types of "sick buildings," Berglund and Lindvall (1986) include buildings contaminated with radon, moulds, contagious agents and formaldehyde and add to the list "... buildings in which the occupants show reactions and symptoms similar to those known to be caused by formaldehyde (Andersen et al 1975) but in which the concentrations of formaldehyde are well below known reaction thresholds" (Berglund and Lindvall 1986). Alexander and Fedoruk (1986) have categorized the particular type of problem building added by Berglund and Lindvall as "epidemic psychogenic illness" or "mass hysteria". According to the authors, the terms are interchangeable but the first is preferred due to the tendency to misunderstand the second. Like many investigations of sick building syndrome, the diagnosis of mass psychogenic illness is difficult to document and strongly resisted by the affected building occupants (Alexander and Fedoruk 1986).

An example of confusing labelling is a reported investigation of "tight building syndrome," or "closed building problem," and "new building problem." The authors described the case as fitting the WHO (1983) SBS definition including the usual symptoms and the failure to identify the causative agent(s) (Whorton et al 1987). Later, an extended summary of the Whorton article prepared by others termed the case an investigation of an outbreak of "building related illness" (HESIS 1987).

Building Related Illness

Many authors explicitly distinguish SBS from Building Related Illness (BRI) which includes allergic respiratory disease (sinusitis, tracheobronchitis, asthma, hypersensitivity pneumonitis, and humidfier fever), skin diseases (irritant, allergic, and photodermatitides) irritant syndromes (carpet shampoo, formaldehyde), and infections (Legionnaire's disease, Pontiac fever, Q fever) (Hodgson and Kreiss 1986; Stolwijk 1984; Woods 1987; Molhave 1987).

Building Sickness

Molhave has proposed the term "building sickness" to characterize any building in which "... the occupants report comfort or health problems which they assign to the indoor atmospheric environment." Molhave would limit the use of the term "sick building" to those in which the problem is identified as multifactorial and in which no measured factor exceeds generally accepted thresholds or recommendations (Molhave 1987).

The term building sickness was proposed by Molhave at the 3rd International Conference on Indoor Air Quality and Climate in Stockholm for the above reason. It is possible that the term has not received more use due to the alternate meanings of the initials BS -- (1) British Smoke which is used in epidemiologic studies involving particulate matter and (2) a vulgar American slang expression.

Molhave suggests that the differential use of terminology is an outcome of the involvement of different groups of "indoor climate experts." For example, the term "irritation" is used by medical experts as a synonym for toxic skin damages known from occupational

exposures; by technical and engineering experts to describe acceptability or unacceptability of the indoor environment; and by the occupants to describe subjective feelings of reduced comfort due to dry nose, dry eyes, dryness or stuffiness of the air (Molhave 1987).

Working Assumptions

In the remainder of this paper, the definitions and concepts articulated by the WHO Working Group (WHO 1983), Stolwijk (1984), Molhave (1987) and Woods (1987) are relied upon as the basis for the discussion. These exclude building-related illness and emphasize multifactorial sick building syndrome.

Charactrization of the occupants' conditions in problem buildings will be classified as 1) Unresolved building-related complaints or symptoms; and, 2) Building associated illness including a) Building Sickness, b) Building Related Illness, and, c) Unclassified building associated illness. See Table 4 for definitions of each of these categories.

FINDINGS FROM MAJOR STUDIES

Two major multi-building, multi-disciplinary studies have been reported, one in Great Britain (Finnegan et al 1984; Pickering et al 1985) and one in Denmark (Skov and Valbjorn 1987). They have come to differing and conflicting conclusions about the nature of the causal factors. The British study found a higher rate of reported symptoms in mechanically-ventilated buildings than in naturally ventilated ones, with humidified buildings having the highest symptom rates. However, no evaluation of building system performance or operation through either inspection, analysis or environmental measurements has been reported by the authors. The Danish investigators found no correlation between complaints and building ventilation type. They did find a number of factors including age of building, sex of occupant, job category, type of work, temperature, the number of occupants, the amount of open shelving, and what they called the amount of "fleecy material." These findings will be discussed in greater detail below.

"Multifactorial Sick Building Syndrome"

Several investigators have suggested that the etiologic agents in SBS were muliple factors, none of which alone is believed capable of causing increased symptoms and complaints (Turiel et al 1983; Molhave 1987; Woods 1988; Valbjorn and Skov 1987). In fact, measurements of a broad spectrum of environmental parameters is insufficient to isolate particular agents as etiologic. Multifactorial analysis identifies clusters of factors associated with higher rates of reported symptoms (Valbjorn and Skov 1987). The most comprehensive study of SBS published to date is known as the Danish Town Hall Study. It covered 27 buildings which were not known problem buildings. The findings may shed some light on building sickness.

The Danish Town Hall Study

In the Danish Town Hall Study (DTHS), measurements of indoor climate were made in 14 town halls. A questionnaire study and a clinical study of 4369 employees in the town halls and 13 affiliated buildings was also conducted. While reported symptom levels were high for mucosal irritation (28%) and for general symptoms in the form of headache, abnormal fatigue or malaise (36%), the measurements of environmental parameters did not result in elucidation of the epidemiology.

However, the differences in the prevalence of symptoms among buildings was significant and was correlated with building factors as well as occupant factors. It was found that the total weight and potentially allergenic fraction of floor dust, the area of "fleecy" material per cubic meter of air, the length of open shelves per cubic meter of air, the number of work stations and the air temperature could explain the difference in the prevalence of symptoms. Occupant factors included sex, type of work, and job category. See Table 5 for the results of the environmental measurements (Valbjorn and Skov 1987).

Among the findings were the following:

1. Elevated rates of reported mucosal irritation was associated with the size of the allergenic fraction of floor dust, the length of open shelves per cubic meter of air, the area of fleecy material per cubic meter of air, the number of work stations, and air temperature.
2. Symptoms correlated strongly with job category. The symptom prevalence varied highly with job category, and the highest prevalence was found in the subordinate job categories. Jobs involving photoprinting, working at video display terminals, and handling carbonless paper correlated with the reported frequency of mucosal irritation and of general symptoms; the number of weekly working hours of women also correlated with reports of these two symptom categories, although less markedly.
3. As in several other studies, women had a higher symptom prevalence rate than men and complained more frequently about indoor climate.
4. Symptom prevalence rates varied significantly among buildings supporting the notion that the symptoms are building-related. Individual town hall correlated significantly with reported mucosal irritation and general symptoms. The lowest prevalence of symptoms was found in the oldest town halls (buildings were mostly newer than thirty years of age, with one almost 50 and another 80 years old).
5. The difference between mechanically and naturally ventilated buildings was not significant for this study. This is in sharp contrast to the findings on the large scale British study (Pickering et al 1984; Robertson et al 1985).

The DTHS shows that investigations involving extensive measurement of environmental variables including air quality will not necessarily result in discovery of "the cause" of the complaints. It is more likely that a constellation of factors including some combination of those identified above as well as chemical or biological contamination and improper ventilation system design, construction, maintenance, or operation will be found in problem buildings.

POTENTIAL ETIOLOGIC AGENTS IN BUILDING SICKNESS

We have listed some potential causal agents/factors identified in the Danish Town Hall Study and hypothesized etiologic relations of each (see Table 6). In Table 7 we have attempted to identify potentially synergistic co-variables. The following discussion elaborates on information presented in these two tables. The discussion is focused on some of the environmental and institutional factors frequently associated with increased symptom or complaint rates in problem buildings. Many of these factors have been identified as potential causal agents (Turiel 1983; Molhave 1987; Valbjorn and Skov 1987; Woods 1987).

VOC as Potential Sources of Complaints

Reporting on an earlier study, Molhave (1982) identified 42 commonly used building materials and measured their volatile organic compound (VOC) emissions. A total of 52 compounds was identified. An average of 22 compounds was identified from each material, and the range of emission rates was extremely large. The arithmetic average emission rate was 9.5 mg/m^2h. Three model rooms constructed from the materials were found to contain between 23 and 32 of the compounds at concentrations from 1.6 to 23.6 mg/m^3. When the cancer risks and health effects (Molhave classifies irritation as a health effect) of each of the 52 compounds were reviewed, 82% were known or suspected mucous membrane irritants and 25% were suspected or known animal carcinogens.

Considering that a very high percentage of common VOC emitted from building materials are known or suspected mucous membrane irritants, it is reasonable to expect significant numbers of building occupants to experience mucous membrane symptoms in newly constructed, remodeled, or furnished buildings. Turiel et al (1981) suggested that a number of contaminants acting synergistically may have been responsible for the higher symptom incidence in a comprehensively investigated problem building. Hollowell (1981) suggested that the reason building occupants complained about what they ought not to be able to perceive (VOC) at the very low measured airborne concentrations was that the composite effect might give rise to the reported health effects. Others have supported that theory (Molhave 1982; Stolwijk 1984).

Thermal Factors
Elevated temperature in a building can have many effects on the building environment and directly or indirectly on the occupants. Not the least among them are discomfort from the temperature itself. This discomfort can reduce tolerance to other factors, many of which may be exagerrated by the elevated temperature.

Microorganism contamination. Biological aerosol concentrations might increase due to increase growth and proliferation of microorganisms associated with higher temperatures, reduced outside air flow, and increased demand on air conditioning equipment. Some organisms may proliferate outdoors or building equipment in warmer weather. An important example is the legionella bacteria responsible for Pontiac fever which has been reported as occurring almost exclusively in spring and summer (Friedman et al 1987)).

VOC Emissions. VOC emissions will increase as a result of the temperature-based increase in vapor pressure. Girman (1987) has calculated that a 13°C rise in temperature will result in a 200% increase in typical VOC vapor pressure. The increase in emissions will be particularly significant from materials with large surface areas in the air stream such as free standing partitions, bottoms of ceiling tiles facing the interior, tops of ceiling panels facing concealed spaces serving as return air plenums, fibrous linings of air ducts, and textiles or fabrics covering walls, furnishings or floors.

Ventilation, Air Flow. Many mechanical ventilation systems will reduce airflow and outside air supply to the interior when temperatures rise toward the upper end of the comfort range. This is particularly true of variable air volume (VAV) systems Thus, exactly when increased ventilation is required to remove contaminants resulting from higher emission rates and when increased air flow is required to provide evaporative cooling of occupants' exposed skin surfaces, airflow or ventilation or both may be reduced.

High Surface Area Interiors
"Fleecy material" and "open shelves" were identified as risk factors in the Danish Town Hall Study. This might be due to their extremely large "effective" surface areas facing the interior space when these materials or shelving systems are present. "Effective" surface area referes to the actual surface area available for adsorption and re-emission sites for VOC. Recent advances in measurement mathematics emphasize that the actual surface area is many times larger than the two dimensional (plane geometry) measured surface area.

Carpets, textile wall coverings, insulation materials facing the interior or the air flow in mechanical ventilation systems, upholstery, and other high surface area materials provide more adsorption sites for VOC and more deposition sites for small

particles. Fibrous materials also provide more source material for airborne particles. And housekeeping (cleaning, vacuuming, dusting) are made more difficult by the rough surfaces and the larger surface areas.

VOC Emissions. VOC emitted from building materials have been shown to distribute themselves on exposed materials throughout enclosed spaces and then be re-emitted for several weeks or more (Berglund et al 1987). Many "fleecy" materials (such as carpets, upholstered furnishings, fabric wall coverings, fiberglass insulations and air ducts) are known sources of VOC. Many carpets and wall coverings- are fastened to the floors and walls respectively with adhesives which are known sources of VOC. It is apparent then that buildings with large surface areas, from both "fleecy materials" and open shelves, will likely be associated with elevated VOC air concentrations. It is also likely that VOC concentrations in such buildings will decrease more slowly than in buildings with hard or smooth surfaces and less surface exposed to the interior.

Age of Building
A clear association was found in the Danish Town Hall Study between age of building and complaint or symptom rate, with the oldest buildings having the lowest rates. And newer offices are often constructed from softer, less durable materials on the major surfaces -- floors, walls, ceilings. This could result in higher airborne particle concentrations from deterioration of surfaces or finishes and polishes applied to them. Newer offices are usually planned with some or all "open office planning" rather than predominantly enclosed or private office spaces typical of older offices.

Densities of workers (per unit of area) in open offices are usually higher than in private offices. This results in many potentially problematic environments including noise; chemical, physical and biological contamination of air; lack of visual privacy; lack of audial privacy; and lack of personal control.

The open office acoustic problems are addressed by increasing surface area (open sheves, free standing partitions) and partially addressed by utilizing fleecy materials (carpets, fibrous glass ceiling panels or insulation, fabric covered partitions). This reduces reverberation time and breaks direct paths of sound transmission. The partitions, where used, also provide some visual privacy and a feeling of occupant control (at least over the immediate work station area). However, they do substantially increase surface area and impede space air distribution.

Job Category and Type of Work
Lower status jobs were associated with higher complaint and symptom rates in the DTHS. Subordinate workers such as clerical and drafting personnel tend to spend more time at the work stations than

their supervisors who often must move about within the building or go elsewhere to attend meetings. Thus, there is less environmental variety and larger exposure to the particular work environment of the subordinate workers.

Work Station Locaton and Amenities. The supervisors are more likely to have perimeter offices, often with windows, whereas clerical and drafting personnel are more likely to be on the interior. The window offers views for visual relief and may offer the opportunity to admit outside air at will. Radiators or forced air systems are often limited to the perimeter of office buildings, and in older buildings especially, they offer occupants more potential control.

Forced mechanical ventilation systems in newer buildings sometimes provide more airflow and ventilation to the perimeter to control thermal loads from the exterior environment. Some buildings deliver primarily or only recirculated air to the interior spaces. Thus, interior spaces may have stagnant or stale air.

Type of Work. It is obvious that certain jobs involve exposure to chemical and physical agents known to cause irrition, nervous system effects, and other health outcomes. Equipment and materials used in duplicating, printing, mailing, and clerical activities in general are all associated with various chemical and physical agents which may contaminate indoor air. It is also likely that individuals performing such work will be in subordinate positions and therefore at risk as discussed above.

Occupant Density and Number of Work Stations

It is not clear whether the Danish study found high occupant density associated with higher symptom report rates because of the density or the possible correlation of high density with job category and type of work, as described above. Lower status workers are likely to have less assigned personal work area, i.e., higher occupant density. And at higher densities, the occupant-generated air contaminants (metabolic and activity based) will be more concentrated prior to dilution or removal by ventilation.

A higher number of work stations might be associated with increased anonymity, a lack of personal privacy and control, and a higher rate of generation of contaminants. All of these could affect occupant stress and comfort levels.

LIMITATIONS OF INVESTIGATIONS

There are numerous limitations on investigations of problem buildings which suggest explanations for the frequent failure to identify etiologic agents or contributory building factors. Among these limitations are cost, timeliness, investigatory methods, building complexity, building dynamics, institutional contraints, and insufficient guidance to investigators.

Unsystematic and incomplete investigations result in inadequate diagnoses and unsuccessful remedial efforts. Yet complete, systematic investigations are rare. Expert investigators are usually selected by the occupants or building owner according to their perceptions of the etiology of the problem. Expertise is usually confined to one or a limited number of fields resulting in incomplete investigations in many buildings (Molhave 1987).

The perseverance of the investigators and the availability of methods can determine whether chemical and biological agents can be eliminated as etiologies of building-associated outbreaks (Kreiss and Hodgson 1984). In many instances, ventilation system problems are identified early in the investigation. Modifications to the system equipment, operating schedule, or operational modes (air flow, temperature) will result in a significant reduction of complaints and symptoms, and the investigation will be terminated before problem causes are defined.

Timely investigations rarely occur due to institutional constraints. Frequently, when complaints or symptoms are initially reported, there is hesitation by management to give importance to them. It is often only after the complaints become very numerous, or after upper level management personnel are affected, or after worker organizations initiate action that management engages investigators.

Comprehensive and systematic investigations are expensive, difficult, and more time-consuming than building operators or users can tolerate. In many cases it is not considered necessary to identify causes if remedial measures can effectively reduce complaints and symptoms, as in the case of ventilation system modifications.

Protocols to guide investigations of problem buildings have not been widely tested, validated or promulgated by any standards development organization. Standardized sampling and analytical methods for indoor air are limited, and those which exist are not uniformly applied or widely used. Efforts to address these shortcomings are underway by ASTM and are described in a separate paper (Levin 1988). However, inter-building variations limit standardization of investigations and comparability of results.

Even where extensive environmental monitoring is conducted, interpretation of results is limited to guidelines and standards developed in and for different contexts such as the industrial workplace and ambient air.

Comprehensive monitoring for airborne contaminants is extremely expensive and rarely definitive in problem building investigations. Monitoring for airborne VOC is expensive and there is a lack of general agreement regarding appropriate monitoring methods.

Characterization of total VOC is not expensive, although the methodological problems are significant. But identification of most of the compounds is expensive and time-consuming.

Limitations Imposed by the Problem Context

Buildings are dynamic, responding to changes in the external environment, interventions by occupants, manipulation by building operators, and signals from building systems controls. Variations within a single building can be enormous. Significant variations in environmental factors occur hourly, daily, and seasonally. Small distances between locations can involve large differences in some environmental variables including critical air quality factors. Therefore, monitoring of environmental factors including but not limited to the sampling and analysis of indoor air can produce misleading results unless an adequate number of representative samples is collected over extended time periods.

Designer, operator and occupant perceptions frequently differ from each other and from actual building conditions. Understanding, communicating and resolving these differences is necessary to improve total building performance and occupant comfort and satisfaction.

DIAGNOSING PROBLEM BUILDINGS

Building Ecology - A Proposed Conceptual Framework

"Building Ecology" is described as a conceptual approach to understanding indoor environments. The term is derived from the field of ecology in the biological sciences. The classic definition of ecology as the study of the relationships between organisms and their environment is adapted to include humans and their buildings. Application of the concept requires an interdisciplinary structure patterned after ecosystems analysis in biology. It views buildings in relationship to their larger environment and their occupants and contents. The concept of building ecology stresses the dynamic, interdependent nature of the system being studied (Levin 1981). It presents a useful framework for designers, operators and investigators in order to improve the understanding and control of indoor air quality and other building factors resulting in SBS.

Building Diagnostics

"Building diagnostics" is the name given to a set of practices used to assess the current performance and capability of a building and to predict its likely performance in the future (NAS 1985). While building diagnostics can be valuable at many stages in the life of a building, it may be most useful in investigations of problem buildings. Four elements are essential to building diagnostics, according to the NAS report; they are as follows:

(1) knowledge of what to measure

(2) availability of appropriate instruments and other measurement tools

(3) expertise in interpreting the measurements

(4) capability of predicting the future condition of the building based on that interpretation.

Several authors have proposed phased investigations of problem buildings or in other applications of building diagnostics (NAS 1985; Sterling et al 1987; NIOSH 1987; Woods et al 1988). Woods et al (1988) have divided the phases as follows:

1. Consultation: scope of the investigation is defined and observations of the building and its systems are made (walk-through survey). Few or no instrumented measurements are made.
2. Qualitative diagnostics: Hypotheses are formulated through engineering analysis; system performance will be initiated with limited mesaurements (such as airflow, pressure differences. Medical evaluation will be used to identify suspect pollutants and air or bulk samples will be collected for these substances.
3. Quantitative diagnostics: If further investigation is needed to test hypotheses, samples will be collected and analyzed and other environmental measurements will be made.

Most advocates of phased diagnostic investigations of problem buildings urge extremely limited use of airborne monitoring during the initial phase. They assert that the majority of building problems can be solved or resolved without extensive monitoring. Furthermore, it is argued that monitoring is of limited effectiveness until it can be focused on hypothesized causal agents or factors.

CONCLUSION

Buildings are complex, and their effects on humans appear extensive and are poorly understood. Attitudes towards and understanding of building effects on occupant health and comfort are not generally shared. This problem may be termed "edifice complex" to convey both the physical reality and the perceptual context.

A conceptual framework has been provided for understanding problem buildings and SBS. Suggested causes of SBS have been discussed. An approach for conceptualizing and conducting problem building investigations has been outlined. More work is necessary to better understand the nature and causes of SBS and to refine methods for investigation of problem buildings.

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Table 1
Common Features of Symptoms Reported in Cases of Sick Building Syndrome (WHO 1983).

Eye, Nose and Throat Irritation
Sensation of Dry Mucous Membranes and Skin
Erythema
Mental Fatigue
Headaches, High Frequency of Airway Infections and Cough
Hoarseness, Wheezing, Itching and Unspecific Hypersensitivity
Nausea, Dizziness

Table 2. Molhave's classification scheme for symptoms related to sick building syndrome and examples of each (Molhave 1987).

1. Sensoric irritation in eye, nose or throat
   - dryness
   - stinging, smarting, irritating sensation
   - hoarseness, changed voice
2. Skin irritation
   - reddening of skin
   - stinging, smarting, itching sensation
   - dry skin
3. Neurotoxic symptoms
   - mental fatigue
   - reduced memory
   - lethargy, drowsiness
   - reduced power of concentration
   - reduced memory
   - headache
   - dizziness, intoxication
   - nausea
   - tiredness
4. Unspecific hyperreactions
   - running nose and eye
   - asthma-like symptoms in non asthmatic persons
   - respiratory sounds
5. Odour and taste complaints
   - changed sensitivity
   - unpleasant odour or taste

Table 3. WHO classification scheme for symptoms found in sick buildings (WHO 1986).

1. Sensory irritation of skin and upper airways, along with headache and abnormal taste
2. Odour
3. General symptoms such as fatigue, dizziness and nausea
4. Lower airway and gastrointestinal symptoms (*)

(*) Not generally found in sick building syndrome

Table 4. Proposed classification scheme for occupant condition in problem buildings.

1. Unresolved.
   Symptoms reported or complaint rates are deemed unacceptable by owners, operators or occupants but do not meet standard statistical tests to confirm their association with occupancy of the building. This can occur where contamination or complaints are limited to a small area of a building or occur among the general building population but at rates similar to those found in buildings in general.

2. Building associated illness.
   Complaint or symptom rates are elevated compared to control buildings or numbers derived from large population studies. Investigation confirms that the complaints are related to occupancy of the building.

   a) Sick Building Syndrome (SBS) or Building Sickness (BS).
   Symptoms are similar to those identified in Tables 1 and 2, but no specific cause of the complaints can be demonstrated by the investigators.

   b) Building Related Illness (BRI).
   The disease entity is medically identified and verified. Contamination problems determined as directly associated with the disease(s) involve a wide range of agents and factors including infectious microorganisms, allergens, chemicals, moisture, temperature, noise, vibration and illumination.

   c) Unclassified building associated illness.

Table 5. Indoor climate measurements in 14 Danish town halls (Valbjorn and Skov 1987).

	Mean	Range	
Mean external temperature (24 hours)(°C)	2.4	-1.2 -	11.4
Average daily sunshine hours	2.3	0 -	6.4
Air temperature (°C)	22.7	20.5 -	24.1
Person-weighted air temperature (°C)	23.0	22.0 -	24.4
Temperature rise during a work day (°C)	2.5	1.0 -	8.0
Vertical temperature gradient (°C/m)	0.9	0.9 -	2.0
Air velocity (m/s)	0.15	<0.15 -	0.20
Relative humidity (%)	32	25 -	40
CO_2 (%)	0.08	0.05 -	0.13
Formaldehyde mg/m^3	0.04	0 -	0.08
Static Electricity: Observer (kv)	1.4	0 -	4.8
Occupants max. (kv)	1.7	0 -	4.0
Airborne dust (mg/m^3)	0.201	0.086 -	0.382
Dust particles: >0.5 um (l^{-1})	48x10^3	19x10^3	-119x10^3
>2.0 um (l^{-1})	25x10^2	8x10^2	-116x10^2
Airborne microfungi (col/m^3)	32	0 -	111
Airborne bacteria (col/m^3)	574	120 -	2100
Airborne actinomycetes (col/m^3)	4	0 -	15
Vacuum cleaned dust^a (g/12m^2)	3.67	0.32 -	11.56
Vacuum cleaned dust^b (g/12m^2)	6.14	0.66 -	17.04
Macromolecular content in the dust (mg/g)	1.53	0 -	5.24
Macrofungi in the dust^a (col/30mg)	33	11 -	90
Macrofungi in the dust^b (col/30mg)	32	6 -	192
Man-made mineral fibers in air MMMF (f/m^3)	5	0 -	60
Not MMMF (<3 um) in the air (fx10^3/m^3)^c	33.2	18.5 -	59.1
Not MMMF (>3 um) in the air (fx10^3/m^3)^d	3.1	0.7 -	5.0
VOC (charcoal) (mg/m^3)	1.56	0.43 -	2.63
VOC (Tenax) (mg/m^3)	0.5	0.1 -	1.2
A-weighted equivalent background noise (dB)^e	56.7	51.3 -	60.3
A-weighted equivalent background noise (dB)^f	36.2	28.2 -	44.1
Reverberation time (s)	0.41	0.28 -	1.05

Notes:
a = In the office where all the measurements were performed
b = In an office with a considerable loading of clients during the day.
c = Mean readings in 6 buildings
d = Mean readings in 13 buildings, in one building measured 32 mg/m^3
e = $L_{a.eq}$
f = L_{95}

Table 6. Building and occupant factors (Valbjorn and Skov 1987) and their possible connection to the etiology of building sickness.

FACTORS FROM DANISH TOWN HALL STUDY	HYPOTHESIZED CONNNECTION TO BUILDING SICKNESS ETIOLOGY
1. TEMPERATURE	a. Microorganism proliferation b. Higher VOC emissions/air levels c. Reduced airflow, ventilation d. Less tolerance for discomfort
2. FLEECY MATERIAL	a. More VOC sources b. More VOC adsorption surface area c. More airborne fiber sources d. Difficult housekeeping
3. OPEN SHELVES	a. More adsorption sites b. Fine particle deposition sites c. More difficult housekeeping d. More source surface area
4. NEWER BUILDINGS <30 years	a. More fleecy surfaces b. Fewer private offices c. Less occupant control
5. JOB CATEGORY	a. Less mobility during day b. Less control over time/work c. Lower status d. Less control over work area
6. TYPE OF WORK	a. More exposure to toxins b. More exposure to irritants c. Stressful work posture
7. OCCUPANT DENSITY	a. Lack of privacy b. Inadequate ventilation c. More local pollutant sources
8. #/WORK STATIONS	a. Anonymity, impersonal environemnt b. Lack of privacy, control c. More local pollutant sources

Table 7. Identification of Possible Synergistic Risk Factors for SBS or Building Sickness Based on Risk Factors in Danish Town Hall Study.

1. TEMPERATURE + FLEECY MATERIAL + OPEN SHELVES
   More organic sources, emissions
   More biological activity

2. JOB CATEGORY + TYPE OF WORK
   Low status = loss of control, mobility, job satisfaction
   Reduced proximity to windows - light, views, outside air
   Combined stressors of work posture, toxins, irritants

3. NUMBER OF WORK STATIONS + AGE OF BUILDING
   Higher density in open office plan, newer buildings
   More local sources
   Less privacy, control, space

4. SEX + JOB CATEGORY
   Females in subordinate (clerical) positions
   Type of work (see #2 above)