Sick Building Syndrome

C.P. Ross, Ph.D., D.C., C.O.H.S., F.R.S.H;[1]
J.S. Ross, M.D., F.R.C.P(C)., A.B.I.M;[2] K. Asseiro, B.A., LL.B[3]

Abstract

Economics and the energy crisis of the early 1970's, are two of the major players leading to the indoor air pollution (IAP) problems we face today.[12] Economic changes have translated into the reduced demand for outdoor labourers, with the concomitant increased need for office personnel and other indoor workers. Since 1945 we have seen a marked increase in the development and use of synthetic building materials, each of which have been shown to emit a variety of toxic and non-toxic volatile organic compounds (VOC's). Furthermore, the energy crisis catalyzed the push for changes to building design and structure. These changes resulted in today's 'tight' buildings which allow only a very limited communication between indoor and outdoor environments via highly controlled heating, ventilation and air conditioning (HVAC) systems. This reduction of fresh outdoor air supply, allows indoor contaminants to become concentrated and thus leads to the IAP concerns that we face today.

"Comparing the air of cities to the air of deserts is like comparing the waters that are befouled and turbid to the waters that are fine and pure. In the city, because of the height of its buildings, the narrowness of its streets, and all that pours forth from its inhabitants, the air becomes stagnant, turbid, thick, misty, and foggy. If there is no choice in this matter, if we have grown up in the cities and become accustomed to them, we should endeavour at least to dwell out at the outskirts of the city. Wherever the air is altered ever so slightly you will find men develop dullness of understanding, failure of intelligence, and defects of memory."

–Maimonides, 12th century

1.Vice-President Academic, Canadian College of Naturopathic Medicine, 2300 Yonge Street, Toronto, Ontario, M4P 1E4
2. Staff, Dept. of Nuclear Medicine, Royal Columbian Hospital, New Westminster, British Columbia, V3L 3W7
3.Research Associate.

Introduction

The disorders associated with IAP exposure are dynamic, multi-causational, and often depend on the exposed individual's unique biochemical and biological make-up. Such variability complicates the study of IAP-related illnesses, however, two distinct categories have been identified: 1) Building Related Illnesses (BRI's), and; 2) Sick Building Syndrome (SBS)[1]. BRI's are those conditions for which there is a direct cause and effect relationship between an identifiable indoor pollutant and resulting ailment. (e.g. Legionnaire's Disease, Pontiac Fever and hypersensitivity pneumonitis). SBS is an enigmatic condition, loosely defined as a higher than normal incidence of complaints of mucous membrane irritation, fatigue, headache, nausea, lethargy, and dizziness. No single cause can be isolated and the symptoms are reversible.[1,8,10,15] In fact, if causes can be identified (e.g. specific irritants or pre-existing medical conditions), SBS is then ruled out and we enter the domain of BRI. Our current focus is on SBS and some of the factors that may contribute to its onset.

According to recent literature,[7,8] the first cases of SBS came to light in the mid-1970's. However, the introductory quote clearly indicates an awareness of the effects of poor air quality on mental processes as early as the 1300's. Regardless of its inception and in spite of it's increasing prevalence, SBS remains difficult to define, while its diagnosis is confusing. Further research reveals that the corresponding pathology of SBS is vague, and the precise etiology is unclear. SBS is on the rise and it is one of the most common afflictions affecting office workers today. Typically, the progression of its physical and emotional elements leads to high morbidity, decreased productivity, job dissatisfaction,

and stress. Knowing that an estimated 10 to 25 million U.S. workers are afflicted[9] helps lend a greater awareness of the magnitude of this syndrome.

Discussion

The general population exhibits a normal background incidence (10-20%) of complaints of eye, nose and throat irritation; headaches; fatigue; lethargy; dizziness; and nausea. Classically, SBS is characterized by an elevated incidence of these same core symptoms[2,8,15] (generally around 30% but in rare instances as high as 70%[8]) in people with no pre-existing medical condition to otherwise explain the onset of these manifestations. In addition to its core symptoms, SBS may present the varying degrees of respiratory distress, chest tightness, dyspnea, dizziness, wheezing, sinus congestion, sneezing, unusual tastes, tongue and lip numbness, rash, pruritis, difficulty concentrating, impaired memory and disorientation.[1,5,15]

Alleviation of symptoms when away from the building confirms the diagnosis of SBS and adds credence to the belief that the source of the symptoms is from within the building. Two different schools of thought exist: one pointing the etiological finger at poor ventilation, the other, at increased indoor emission levels. In support of the latter position, experiments have shown that increasing the outdoor air supply has no measurable effect on SBS symptom reporting.[9] However, this could be accounted for by the procedural flaws in the experimental design. The accepted theory now is that increased emissions, further concentrated by poor ventilation, are the main cause for the onset of SBS symptoms.

Even if HVAC systems are installed properly, changes in space utilization after installation, poor maintenance, and/or inaccessibility of parts of the system to cleaning, all reduce the ventilation rate.[15, 16] Reduced air flow allows the indoor emissions and other existing contaminants to become more concentrated and hence to reach levels higher than would be found in outdoor air. The pooling of water in some systems provides the ideal environment for microbial growth and the ventilation system provides the means for their dissemination throughout the building. Although contaminant concentrations have been found to be elevated in "sick" buildings, they are generally found at levels below threshold limit values[15].

Because of the low contaminant concentration levels and the fact that a minority of building occupants exhibit SBS symptoms, it has been theorized by some that the onset of SBS is more psychogenic than physiologic. This theory has been convincingly challenged. Those exposed to higher pollutant levels display correspondingly greater symptoms[2] and, different symptom rates are reported among workers in buildings with different types of ventilation[7]. This incidence of SBS increases as one moves along the gradient from naturally ventilated buildings, to tightly sealed HVAC buildings, to 'tight' HVAC buildings with water-based fan-coil units.[8,12]

In another study, the polymorphonucleocyte (PMN) levels of office building occupants were monitored. This provided an indication of their inflammatory response as related to nose and throat irritation. Increased PMN levels were evident both 4 hours and 18 hours after exposure[6], quite clearly indicating a physiologic response.

Middaugh, Pinney, and Linz[10] performed physical examinations and mental performance tests on both symptomatic and asymptomatic occupants of 'sick' buildings. Symptomatic individuals were mainly non-smoking, highly educated, and relatively young women.

Although all displayed normal vital signs during SBS attacks, there was a minor abnormality noted in the conjunctivae, nasal mucosae, and oroparynx. More interestingly, considering the subjects[1] degree of education, they displayed acute cognitive impairment, especially short-term memory, and significant poor per-

formance on mental status examinations. Perhaps the most striking finding was that almost the same level of poor performance was demonstrated by the 'asymptomatic' group. In other words, even in the absence of overt SBS symptoms, clinically significant dysfunction was evident. Such a finding makes SBS more prevalent than initially thought as early estimates were based on the number of people displaying overt symptoms.

Ventilation intakes, doors, windows and compromised building envelopes may allow infiltration of outdoor pollutants such as industrial emissions, automobile exhaust, bioaerosols from normal microbial activity and products from atmospheric photochemical processes.[1] In reality, these outside sources do not significantly contribute to indoor air pollution. The 'tightness' of energy efficient buildings effectively reduces infiltration, and the enactment of various Clean Air and Occupational Health and Safety Acts has led to improvement in outdoor air quality. In any event, it is not wise to ignore the potential negative effects of outdoor sources until such a time as their actual synergistic effect vis-à-vis SBS can be determined.

It is accepted that indoor point sources are the greater contributors to indoor contamination levels and hence to the onset on SBS (See **Appendix A** for an abbreviated listing of common indoor air pollutants). As eluded to earlier, this theory has gained popularity with the finding that increased outdoor air supply apparently has no effect in relieving SBS symptoms.[9]

The release of gases from a material during drying, aging, or decomposition is called outgassing. Most building materials created in the last 50 years outgas to some degree.[11] These materials serve as point sources for indoor emissions. Many also act as 'sponges' in that they adsorb pollutants emitted from other sources and subsequently release them in response to indoor environmental changes, such as an increased temperature or increased outgassing.

The toxic potential of both gaseous and particulate airborne xenobiotics exposes tissues and organs at sites of entry into the human body, or in direct contact with the pollutant, to a higher risk toxic damage.[17] Apart from organ or tissue targeting based on anatomical position, highly specialized systems such as the CNS, require fairly constant environments. Even minimal disruption can make them susceptible to toxic damage.Three factors namely surface contact, exposure to the respiratory tract, and CNS sensitivity encompass all the symptoms ascribed to SBS and may help shed some light on its pathological modus operandi.

It has been suggested that because indoor contaminant concentrations never reach threshold limit values, they cannot cause any degree of toxic harm. In fact, levels of 100 to 1000 times below those considered necessary to stimulate a response are the norm.[8,12] It is important to keep in mind that exposure limits for industrial chemicals were established based on single -chemical exposures[8]. Consequently, they may not be applicable in non-industrial, commercial office buildings where occupants are exposed to incalculable combinations of the more than 900 airborne contaminants that have been isolated to date.[1] The effects of common indoor air pollutants including carbon dioxide, benzene, combustion products and VOC's are summarized in **Table 1** (Page 4).

Although the combined effects of chemicals, dusts, and other species of indoor pollutants lead to SBS, factors such as temperature, humidity, lighting,[1,5,11,12] and video display terminal (VDT) use[13] may also play a role. **Table 2** (Page 4) lists four variables that may influence the course of the syndrome.

The excessive quantity and poor quality of typical office lighting, with or without extended VDT use, can either cause

Table 1. Physiological effects of common indoor air pollutants

	CO_2	CO	O_3	Formaldehyde	NO_x	VOC	Dust	Microorganisms	ETS	SO_2
Eye irritation		●	●	●	●	●	●	●	●	
Nose irritation			●	●	●	●	●	●	●	●
Throat irritation			●	●	●	●	●	●	●	●
Respiratory complaints			●	●	●	●	●	●	●	●
Headache	●	●	●	●	●	●			●	
Vertigo	●	●	●	●		●				
Fatigue	●	●	●	●	●	●	●			
Confusion		●	●		●	●	●			
Nausea		●		●		●			●	
Skin rash				●		●	●			
Altered smell/taste				●						

Table 2. Contributing Factors to SBS

Fluorescent Lighting	Brightness	Before 1945, workplace lighting was generally around 20 candlepower. Today it is commonly in the area of 150 candlepower
	Flicker	Fluorescent light vibrates on and off at 60 cycles per second
	Colour	The cool whites of typical fluorescent fixtures do not stimulate the eye evenly as do other lights
	Shadow	Continuous lighting is designed to remove the very shadow which is necessary to assist the eye in distinguishing boundaries
Temperature	Above 26	Increased outgassing of VOC's
	Above 24	Reduced alertness
	Above 22	Statistically correlated with SBS symptoms
Relative Humidity	<40%	Dryness leads to elevated levels of airborne dust and other allergens
	>60%	Damp conditions promote fungal, bacterial, viral, and dust mite growth, and also increase the outgassing of formaldehyde
Extended VDT use		Those who work extensively with VDT's tend to blink less often than those who do not

or further aggravate irritation of the eye and conjunctivae. The role of VDT's in eye irritation has been elucidated. While using VDT's people tend to blink less.[13] This leads to two effects: 1) reduced lubrication resulting in increased dryness, and; 2) foreign particles are removed from the eye less frequently, allowing a longer period of exposure to potentially harmful agents. Acting together, these factors lead to increased susceptibility to eye irritation. Finally, in the absence of proper temperature and humidity levels, direct physiological effects such as reduced alertness and the onset of typical SBS symptoms are common. Poor temperature and humidity control also stimulate the preliminary events that encourage high levels of irritating or toxic compounds.

Conclusion

Indoor emission levels are the major players in SBS development, with poor ventilation, inadequate lighting, and poor temperature and humidity control playing supporting roles. In spite of its increasing prevalence, SBS has arguably been neglected in the field of scientific research. The exact pathological sequelae leading to many of its symptoms have remained elusive. The reality is that initial estimates of the number of people affected, now appear to have been grossly underestimated. Armed with the knowledge that even 'asymptomatic' occupants of 'sick' buildings display significant reduced mental acuity, it is clear that in addition to the millions of symptomatic individuals, millions more may unknowingly be affected. The mental, emotional, and financial costs of ignoring SBS are incalculable and we are setting a very dangerous precedent by treating SBS as a trivial syndrome.

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Appendix A

These pollutants have variously been implicated as initiators of immune or allergic responses, free radical generators, and carcinogens.

Source	Typical Pollutants Emitted
Adhesives	Alcohols, Amines, Benzene, Formaldehyde, Toluenes, Xylenes
Caulking compounds	Alcohols, Benzene, Formaldehyde, Xylene
Carpeting, underpadding	Formaldehyde, Styrene, Dust and Particulates
Ceiling tiles	Formaldehyde
Particle board	Alcohols, Alkanes, Benzenes, Formaldehyde, Toluene, Terpenes
Floor and wall coverings	Acetates, Alcohols, Benzenes, Formaldehyde, Methylstyrene, Dust and Particulates
Paint, Stain, Varnish	Acetates, Alcohols, Benzenes, Formaldehyde, Polyurethane, Toluene
Appliances	Carbon Monoxide, Nitrogen Dioxide, Sulfur Dioxide, Polyaromatic Hydrocarbons
Carbonless copy paper NEC paper	Chlorobiphenyl, Cyclohexane, Formaldehyde,
Computers, VDT's	n-Butanol, Caprolactam, Cresol, Ethylbenzene, Ozone, Phenol, Phosphoric Acid, Toluene, Xylene
Photocopiers	Ammonia, Benzaldehyde, Benzene, Carbon Black, Isopropanol, Ozone, Styrene, Terpene, Toluene, Trichlorethylene, Xylene
Preprinted paper forms	Acetylaldehyde, Acetic Acid, Acetone, Benzaldehyde, Butanol, Isopropanol, Paper Dust, Proprionaldehyde
Typewriter correction fluid	Acetone, Trichloroethane, VOC's
HVAC systems	Fungi