STUDY OF SICK BUILDING SYNDROME IN AIRCONDITIONED OFFICE BUILDINGS

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Abstract: In recent years, sick building syndrome has emerged as a major problem in the workplace, not only in India but also in various countries like Canada, USA, Japan, UK etc. The main significance of this problem is in the working environment which is mainly associated with the use of mechanical ventilation and air conditioning systems in the glass packed office buildings. Multiple deficiencies in HVAC system design, construction, operation, or maintenance, etc. which causes pollutants emission, may contribute in increase of the adverse effects of this syndrome. Worldwide, there is an increasing interest in understanding the impact between green building design and occupant's personal wellbeing. In India, airtight building envelopes and energy efficient systems are increasingly becoming an integral requirement for building design. In most buildings ineffective functioning of these systems results in build-up of polluted environment that causes SBS. This study on the sick building syndrome is based on user perception, through survey. It focuses on preventive and corrective strategies required to mitigate the harmful effects of SBS.

Key Words: Sick Building Syndrome, Building occupants, Indoor environment quality, Air Conditioned buildings

1. INTRODUCTION

People of the developing Countries spend 90% and 70% of their time indoors [14] and, as a result, increasing attention is given to comprehension and IEQ enhancement because it is known to Human health effect. In India, individuals, spend more time indoors in hot or very hot conditions, cold weather. Occupant exposure, therefore, airborne products are closely associated with Indoor pollution [15]. The physical environment (temperature, humidity, noise, the configuration of workstations), chemical environment (chemical and biological agents), and social environment are components of IEQ (management and organization of work). Physical and chemical environment components contribute to the total internal air quality (IAQ). High levels of outdoor contaminants, pollutant sources, sinks and, airflow between the exterior and interior of the building are included in the IAQ [2].

The importance of human exposure to air pollutants has therefore changed from outdoor to indoor exposure. For this purpose, an IAQ evaluation is important for the implementation of IEQ control strategies for an appropriate setting. IAQ is becoming a major problem for workplace, health and, safety. Canada, Japan, Korea, Singapore, Sweden, the United Kingdom and, the United States [16], [17], [18] and, [13] have developed international standards for achieving an acceptable IAQ.

Researchers are reportedly more interested in exploring the dynamic interrelationship between the constructed environment and the occupants (their position in the environment) and a variety of physical, chemical and design factors. The fact that there are now both increased recognition and concern that sustainable green design and human well-being are both integral components of building efficiency is a key reason for this transition. This fact is confirmed by a recent study in which up to 60% of US office workers want to improve the air quality inside their spaces.

2. OBJECTIVE

The main purpose of this study is to know about the concept of sick building syndrome in air-conditioned office buildings and analyzing how green buildings can reduce the risk of sick building syndrome through a survey of two different buildings, i.e. one green-rated and one non-green rated office buildings.

3. WHAT IS SICK BUILDING SYNDROME

The term '**Sick Building Syndrome**' is used to explain the phenomena in which building occupants experience various symptoms in some particular buildings. There are no specifically identified casual factors or adverse outcomes. The syndrome can occur in any part of the building or throughout the building. The main identifying symptoms are irritation of the eyes, nose, throat, and eyes combined with a headache, lethargy, irritability and lack of concentration. [6] The phenomena are described with various names such as 'sick office syndrome', tight building syndrome, office eye syndrome etc. But the term 'Sick Building Syndrome' has been awarded by the World Health Organization (1982) and

is the most widely used description. Though the symptoms are temporary as it disappears for hours or days when the occupant leaves the building. Therefore, the symptom is called building-related.

It is to be noted that SBS does not include all airway infections and coughs, nausea, dizziness, high blood pressure. They are more of environmental perceptions and should not be included in the symptoms.

SBS definition does not include causes in it because there is yet not any identified cause and including any would be misleading as there are various factors included which will be discussed later in the essay. There are then temporary sick buildings and permanent sick buildings, in the former one the symptoms decrease and disappear with time while in the latter one, they persist despite best alterations and modifications.

4. HISTORY OF SBS

The HSE notes that during the 1960s, the SBS problem was first identified, but it was not, further papers were released until the 1980s, raising awareness of this. Newfound 'common' problem 'common problem' (HSE, 1992).

The word SBS became more prevalent in the 1970s because of the effects of more and more individuals are experiencing this newly discovered condition, leading to there is improved monitoring and investigation. [5]

It is suspected (Murphy, 2006) that the causes for the 'sickness' of buildings in the 1970s stemmed from the energy conservation campaign, which culminated in the following Event series. The energy crisis of the 1970s forced all buildings to become energy efficient because of the rise in prices for energy. This then led to the focus of architectural techniques on designing buildings to be 'air-tight' such as offices, thereby providing reduced thermal loss inside the framework and becoming more energy-efficient.

5. PREVALENCE

'Sick building' is a complex term that cannot be defined completely but depends on what is considered as acceptable symptoms of prevalence.

Several factors have been found which are associated with SBS:

- Mechanical ventilation, particularly air conditioning
- Low Fresh air ventilation
- Volatile organic compounds
- Illumination
- Dust
- Wall-to-wall carpets and textiles
- Noise
- Indoor temperature fluctuation
- Subordinate position in the work hierarchy
- Tobacco smoking
- Poor Building service maintenance and cleaning agents

5.1 Factors affecting SBS

Building factors	Air condinitional building
	Fresh air ventilation rate
	High indoor temperatures
Environmental factors & pollutants	Volatile organic compounds
	Carbon monoxide
	Dust & fibres:asbestos, fibre glass & dirt

Table 1. Factors of SBS

Detailed factors and causes:

1) Indoor Air Quality(IAQ):
- Particulate
  - Viable: bacteria mould and mildew that comes from contaminated air handling systems, carpets etc.
  - Non-Viable: airborne dirt, lead, asbestos
- Volatile organic compounds
  - Chemicals such as formaldehyde and other gases from building materials, furniture or ozone from copiers.
  - CO2 concentration

2) Ventilation(fresh air rate and types of systems)

Indoor Air Quality (IAQ) and **Ventilation** have a very important role in commercial buildings as it has a major effect on occupant's health and comfort.

The ASHRAE Standard 62.1-2013(ASHRAE, 2013) [8] recommends a minimum ventilation rate of 2.5 l/s-person (5 cfm/person) for office spaces. Given a typical occupant density of 5 per 100 m2(1000 ft2) and a ceiling height of 3 m (10 ft), the current ASHRAE standard would require an air exchange rate of about 3 air changes per hour (ACH) for an office space. There are many direct and indirect ways in which indoor air quality might influence the performance of occupants. For instance, the characteristics and conditions of HVAC systems and building materials strongly influence IAQ which in turn would affect the performance of occupants.

CO2 concentrations

The concentrations of carbon dioxide are also used as a proxy for the amount of external air supply per occupant. Indoor CO2 concentrations above approximately 1000 ppm are commonly considered to be representative of ventilation rates that are inappropriate for body odors. CO2 concentrations below 1000 ppm do

not always ensure that the ventilation rate is sufficient for air pollutants to be eliminated from other indoor sources. Since CO2 is an occupancy and ventilation feature and both differ as a function of time, the indoor co2 concentration is difficult to characterize.

Indoor pollutants

The generally found pollutants in buildings are total volatile organic compounds (TVOC), formaldehyde (HCHO), and biological contaminants. **VOCs** are considered as one of the causes of SBS.

Effect of indoor pollutants on SBS

There is a limitation for VOC to cause SBS as according to a fact the levels would decrease gradually over a period of time. But it contradicts the finding which evident that 1980 buildings were more 'sick' than 1970 buildings (Wilson & Hedge 1987). Undoubtedly VOCs are potential cases in new as well as old buildings and along with that, there might be other factors too.

6. FACTORS RELATED TO THE HVAC SYSTEM

A significant component of any building is heating, ventilating, and air-conditioning (HVAC) systems. They help monitor temperature, humidity, and air quality to provide the residents and equipment in the buildings with a safe indoor climate. [9]

- Heating is done by using radiators or air supply systems to heat the air inside the house.
- Ventilation is accomplished by keeping the air in the room clean and removing dirty air out of the room. It also keeps moving internal air and reduces unnecessary moisture. Mechanical systems powered by fans typically accomplish this.
- Air-Conditioning decreases the temperature and uses air-cooled or water-cooled devices to maintain acceptable humidity levels.
- The purpose of an HVAC system is to provide an atmosphere in which the following variables are maintained within the desired range:

  - 75 Fahrenheit Degrees
  - 40 to 60% relative humidity, relative humidity
  - ASHRAE 62.0 ventilation or CO2 below 1000 PPM

As per the United States, Local Business, HVAC systems account for nearly 40 percent of commercial building energy use. [9]

- The performance of an HVAC system is directly linked to the comfort levels of the house.
- HVAC systems require large floor space for both the unit/units and the distribution equipment to be stored.
- HVAC systems make up a substantial proportion of building running costs.

There are a variety of HVAC systems, such as centralized, packaged, individual units, typically used in commercial types of buildings. Since HVAC systems account for the high energy use in buildings, by proper design, installation, scheduled maintenance and other activities, each facility may benefit from increased energy and cost savings by improving HVAC operations. [9]

Heating and cooling large buildings in commercial offices is important for facility managers who are involved in ensuring that their workers are relaxed and that their equipment is not harmed by overheating or moisture. Unfortunately, large facilities pose unique heating and cooling challenges that can be difficult to overcome, particularly for those who do not know what is needed to properly heat or cool a larger space that generates some problems with the HVAC systems.

7. WHO GUIDELINES

WHO guidelines for the management of building ventilation systems 75'c. [3]

- Biological pollutants that are introduced into the ventilation air should not be generated in the building and its heating, ventilation and, air conditioning systems.
- If biocides are inevitable, entry into space that can be filled should be avoided.
- Standards and building codes can ensure that ventilation systems are maintained efficiently by defining acceptable access routes, routine inspection, and maintenance schedules.
- In a building in which occupants are unable to efficiently monitor the quality of ventilation air, the occupants should be designated by a person who is responsible for this task.
- Adequate training should be given to the maintenance workers of public and office buildings for regular inspection and maintenance.[3]

8. SURVEY ANALYSIS

8.1 Building selection

The survey was administered in two buildings, one green rated office building i.e. Infosys Jaipur and another one non-green-rated office building i.e., Genpact, Jaipur. Both the buildings are present in the same location with a composite climate. The buildings are air-conditioned for the most part of the year. In these buildings, there is no provision for natural ventilation (or operable windows).

Building 1 – Genpact is a single-storey building of 7 floors, located in the main city of Jaipur and thus a non-green building. Each floor has open plan workspace with several conference rooms and personal cabins. More than 30 people

work in the open shared space with wooden partitions. Operable windows are there but are not in use, so it runs on the centrally air-conditioned system where the temperature fluctuates during the whole day and split ac are there for separate rooms. Glare issues are there in some parts.

Building 2 – Infosys is a multinational IT services and consulting firm. It comprises of two main office buildings with a G+8 structure, food court, pump room for UCR, power generator, parking for solar car port. It is a building graded as LEED Platinum under LEED India NC version 1.0.0. Without a residential facility, it has the strength of over 5000 occupants. It is situated on the outskirts of SEZ in Jaipur. It utilizes radiant refrigeration. Infosys Campus has many green features that contribute directly to the environment in terms of reduced energy usage, greenhouse gas emissions, local environmental effects and the use of natural resources. Energy efficiency measures such as Hi albedo paint on the roof, high-performance glazing, efficient design of lighting, and efficient design of HVAC, VAV systems, heat recovery and VFD AHUs.

Indoor environmental quality

- In order to encourage improved IAQ and long-term well-being of all inhabitants, 30 percent more is given than the required ventilation rates according to ASHRAE requirements.
- The whole building is a non-smoking building that ensures all its occupants' health and safety. Permanent monitoring systems which provide feedback on the performance of the ventilation system to ensure that ventilation systems maintain minimum ventilation requirements in terms of design.
- Provision of a thermally comfortable atmosphere that promotes the efficiency and well-being of all occupants of buildings

8.2 Survey Procedure

The survey has been done in a very efficient way to understand the occupant's perception of indoor environmental quality and various other aspects of the building by which a person gets affected by SBS. The survey was conducted in a very general manner through Google forms and consisted of a core module with 7 categories which are listed below in table 1.

Category	Questions asked
General details	Floor no., gender, age, working hrs.
Thermal comfort	Satisfaction with temperature, temperature regulation capacity
Indoor air quality	Satisfaction with air quality
Lighting	Requirement of artificial light, daylight exposure, glare issues
Comfort	Clean or comfortable spaces
Occupancy	Number of occupants on single floor
Health	Health related problems like headache, respiratory, depression

Table 2. Components of the SBS questionnaire

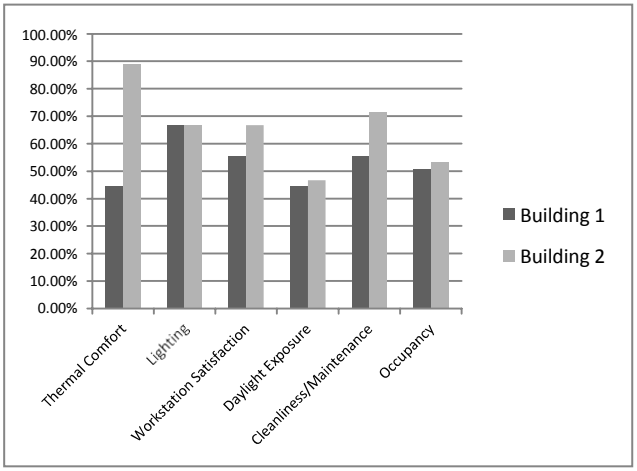
8.3 Results & Analysis

The questionnaire responses were utilized to establish the data about the SBS symptoms per person and different parameters which gave a proper idea about the health and comfort of the occupants.

As the survey is done on the basis of user's perception, so all the data provided by them is monitored properly in the form of charts and then the comparison is been done. Like, the non-green rated building is providing comfort in all aspects as compared to the green one.

So, both the buildings comprise of 7 to 8 floors, and on each floor more than 30 people work at a time, which is done in two shifts, both are BPO (Business Process Outsourcing) buildings, so working is done in two shifts i.e. day and night. If we compare the occupancies of both the shifts, the buildings is more occupied during night time as compared to day time and the occupants are quite comfortable with their night shifts as found from survey no.2 which was of green-rated building.

Analysis of satisfaction for parameters listed in Table2. Of both the buildings are compared in below Graph 1. In building 2 i.e. in Infosys office which is green rated. Building 1 is performing low in thermal comfort, lighting, or in cleanliness as compared to building 2 which performed well in these parameters. In terms of satisfaction, building 2 is ranking highest with more than 60% in all categories except daylight exposure. This is also the one category that receives the lowest level of satisfaction in building 1. So, it can be seen that the basis of dissatisfaction is in design aspects and the use of natural ventilation in both buildings. In occupancy term, both have a higher number of occupants on the single floor, so the working process of these occupants is in open space with discussion.

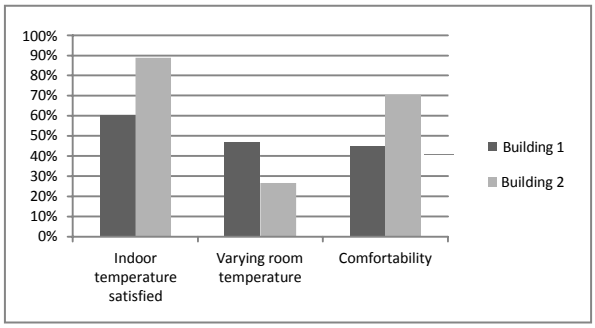


Graph 1. Occupant's Satisfaction with the categories

8.3.1 Thermal Comfort

Occupants were asked about their comfort in the building space in which they work, and some questions were asked to them like how is the temperature inside the building, is it comfortable or not, or too high or varying temperature,

ability to control it or not. For these questions they answered in clear responses. The below graph plots the answer in percentage form for these thermal comfort questions.



Graph 2. Occupant's Satisfaction with room temperature

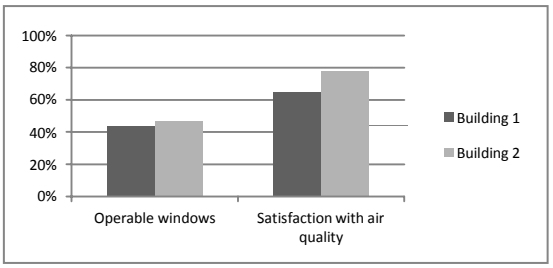
So, it can be analyzed that the occupants working in building 1 which is non-green rated; are not as comfortable with the temperature inside the building as fresh air is not induced in the area moreover in building 2 occupants are highly comfortable with the indoor temperature, so the air movement is there in building 2.

So, the dissatisfaction with the indoor temperature is present therein building 1, as due to the overcooling of the area when occupants are less in number which is not maintained by the facility team. It also implies the process that if occupancy is less in too big spaces like these office ones, one machine will work. But here the situation is completely different. Occupants also expressed their views mostly on the varying room temperature or the temperature is too high for the whole day, as in summers and it is mainly due to the outside temperature as it generates the heat faster in glass buildings so, the area is cooled but after some time it affects the whole area as it becomes colder and later on after raising query several times the temperature is maintained on a normal level. By these measures health issues like headache, the cold or sneezing problem arises which makes a person sick. This source of problems creates major health problems to the occupants, which the performance of them also affects.

In building 2, the situation is slightly different like if the occupancy is less so the occupants inform the facility team and they run only single-phase supply by which the load also reduced on the system, the flow is maintained and the temperature becomes comfortable for working. If any occupant reports about the temperature issue, high or low, at the time action, is taken by the facility team and the issue is resolved, so the handling procedure of the management teams of the office also plays an important role in these types of problems.

8.3.2 Indoor Air Quality

In response to the IAQ level, 2 or 3 questions asked from the occupants about the quality of air inside the building, is it satisfied or not, or is there any type of fresh air movement by using the windows. So the response came out different like there are operable windows but are not properly accessible as they are directly connected to some private offices or to the rear lobby areas but not in their working environment, which is seen in both the buildings.



Graph 3. Occupant's Satisfaction with air quality

By analyzing the graph above, the percentage is almost the same for using the windows in both the buildings but the occupants of building 2 are highly satisfied with the air quality they are introduced to. So the proper circulation of air is there and fresh air is being added through ducts as it is a green building, the mechanical cooling system is been done in a very efficient manner, also being monitored properly.

In building 1 some of the occupants around 22.3% have also reported about the unpleasant odor and second-hand smoke, which creates uncomfortable situations during work and strongly implies on the performance of any occupants, also some occupants can get affected by this, reason can be the recirculation of polluted indoor air in the environment.

In building 2 same problems is persisting there, but in less percentage, like 6.7% have reported the unpleasant odor and stuffy bad air, and around 13.3% reported the second-hand smoke. So the quality of air is needed to be identified here properly, as the reason is also the same above mentioned the recirculation of indoor air in the environment.

8.3.3 Ventilation

Generally in glass buildings or in air-conditioned office building the source of cross ventilation is not present everywhere and is also been seen here. As such, no proper questions related to the ventilation is asked to the occupants, but yes for fresh air, they do they take breaks in between their working time and go to their outdoor relaxation spaces which is being provided in office layouts.

According to ASHRAE standards 62.1-2013(ASHRAE, 2013) discussed above in IAQ and Ventilation.[8] the current ASHRAE standard would require an air exchange rate of about 3 air changes per hour (ACH) for an office space. But the ventilation rate here is not being measured as the survey is done on the basis of secondary data collection, so a proper result of this analysis cannot be justified here, that the ventilation rate is maintained or not.[8]

From the above analysis, it can also be stated here that no fresh air circulation is there in the workspaces as the operation of the window is not present. Also, they don't have the ability to control the ventilation in their spaces.

8.3.4 Noise level

Another important aspect which came from the survey done was the noise level part, as the occupants of both the buildings reported about the noise level in their working spaces. In building 1 almost 56% of occupants reported this factor and in building 2 almost 46.7% of occupants reported it. This is happening due to the open-plan workspaces. It firms mainly works together in form of groups so the noise level increase from there and if more than 30 people work on the same floor, so the problem will arise. It can only be resolved by making planning better or providing some acoustic details to the open spaces which are large in size like here in these two buildings.
This also creates some hearing aid issues for multiple persons and concentration levels can be reduced. By which any type of health problem can get affected.

8.3.5 Maintenance

This is also a very important aspect in the quality of any building, sick building syndrome can be developed in any manner rather than from the smell or a bad odor, stress, or from any other aspects but if the building is not maintained properly, so it can cause various health issues.

General questions was asked in the survey in the cleanliness and maintenance part, from building 1 occupant reported that the cleaning is done weekly according to the shifts and the maintenance of any other part takes time which affects the whole scenario of working.
Building 2 occupants reported that their workspaces including their working table, chair or the area where meetings are held are cleaned properly on daily basis, avoiding any kind of dust allergy to the occupants, as per the timing of the shift. Cleaning agents used here are mainly low in VOC's So that any type of strong chemical smell would be avoided and thus will not create suffocation.

9. DISCUSSION

Poor IEQ is recognized as an important public health risk all over the world, including India. In most societies (and India), occupants spend more than 90% of their time in indoor environments [9] and for this reason, it has a significant impact on health and well-being. Indoor risks include biological and chemical pollutants, as well as poor physical architecture, lighting and ergonomics. In building occupants, these variables can worsen a number of health effects, including SBS. [18].

The fact is poor indoor environmental quality affects human health in several manners, the parameters under this are very difficult to regulate within the building but somehow it can be controlled by a little concern to the public [18].There can be several reasons for it and the main driver can be the economics which plays a key role in these aspects. Owners of individual buildings lack incentives for greening as other building issues are more of concern than indoor environmental quality. So, the survey which was mainly done on the user's perception has been found very useful for giving an idea about how the green buildings can reduce the impact of sick building syndrome in offices or in any other type of buildings. Also, this syndrome is not known to any normal person, they don't know that their health problems can arise from these problems.

The present study used the general survey procedure to know about the key measures of this syndrome, several studies have been done on this SBS earlier and found out that any type of building can create problems if indoor air or ventilation is not maintained and it is also found in educational institutes.

The survey revealed that almost more than 70% of occupants are comfortable in building 2 which is green rated in all categories. The only problem present there is the noise level which is mainly due to the design layout factor by which occupants are dissatisfied. Other than those occupants are found quite comfortable in their spaces. In building 1 which is a non-green rated building occupants are found dissatisfied in comfort level, noise level, IAQ. Occupants were also dissatisfied with the fact of not able to control the temperature inside the building. So, from these points, it can be found that the maintenance of the building is not done properly on a regular basis which is also the main consideration point of creating a habitable atmosphere inside the building.

10. CONCLUSION

The present questionnaire-based analysis done on two buildings, one green-rated and one non-green rated building of Indian offices air-conditioned buildings, shows that occupant's health and comfort is much necessary for the better performance in their comfort and this comfort was not there in the Genpact which is the non-green rated building. Building occupant's experienced SBS symptoms sometime during office time, tiredness/lethargy, and headache problems were identified.

In Infosys building which is LEED-certified office building, occupants are not often found symptomatic with so many SBS symptoms which gives a proper image of how the building can be created, which gives the statement that green buildings can reduce sick building syndrome not in a full manner but in some aspects. It is now highly recommended that, if the owner does not need any kind of certification in green buildings, they should make buildings more comfortable so that people working over there should not get affected with any health problems.

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