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# IMPACT OF INDOOR ENVIRONMENT QUALITY ON SICK BUILDING SYNDROME IN INDIAN LEED CERTIFIED BUILDINGS

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***Abstract:*** *This study was carried out with the intent of studying indoor environmental quality and relationship to "sick building syndrome" (SBS) in LEED certified buildings in India. 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 buildup of polluted environment that causes SBS. Building occupants are one possible source of information to understand the relationship between indoor environmental quality (IEQ) and SBS.*

***Key words:*** *green building, indoor environmental quality, sick building syndrome.*

## 1. Introduction

People in developed and developing countries spend 90% and 70% of their time indoors [8] and for this reason increasing attention is being paid towards understanding and improving IEQ since it is known to impact on human health. In India, people spend more time indoors in very hot or cold climates. Therefore, occupant exposure to airborne materials is closely related to indoor pollution [4]. The components of IEQ include physical environment (temperature, humidity, noise, work station design), chemical environment (chemical and biological agents), and social environment (management and organization of work). Elements of physical and chemical environment contribute to the overall internal air quality (IAQ). The IAQ contains high levels of outdoor pollutant levels, pollutant sources, sinks and movement of air between the building's exterior and interior [2]. Consequently, the importance of human exposure to air pollutants has shifted from outdoor to indoor [7]. For this reason, an assessment of IAQ is critical for developing IEQ control strategies for acceptable environment. IAQ is becoming an important occupational health and safety issue.

International standards for attaining appropriate IAQ have been established by Canada, Japan, Korea, Singapore, Sweden, UK and USA [3], [10], [13] and [22].

Previous work on IEQ was mainly concerned with indoor air contents (aerosols, chemicals and particles) and comfort

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factors (temperature, air flow and humidity; [12]). Currently, researchers are more interested in investigating the complex interrelationship between the built environment and occupant's (their role in the environment) and an array of physical, chemical and design factors [11]. A key reason for this shift is the fact that there is now both an increased awareness and concern that sustainable green design and human well-being are both integral elements of the building performance. This fact is supported by a recent review where up to 60% of US office workers chose improving air quality as the thing they would most like to improve.

The terms SBS, tight building syndrome and building related illnesses (such as nausea, skin irritation and allergies) are used describe the relationship between poor IAQ and wellbeing. However, the symptoms of SBS involve an array of little understood sensory reactions and this makes diagnosis very difficult [1]. It has been demonstrated that SBS symptoms are influenced by sex, allergy, job nature, psychosocial factors and room parameters [17]. General SBS symptoms that have so far been recorded include eye irritation, blocked nose and throat, headache, dizziness, sensory discomfort from odors, dry skin, fatigue, lethargy, wheezing, sinus and skin rash [21]. Hedge A. [6] demonstrated that IAQ complaints and SBS are a product of many complex issues that are started by several stressful entities that cause personal stress. The term SBS defines acute health effects that are experienced by building occupants and are linked to the time spent in buildings and for which no specific illness or underlying condition may be identified [16]. Acceptable IAQ is the air that has no known contaminants at harmful concentrations and when 80% of the people exposed to this air express satisfaction with it [20].

## 2. Objective

The present study was done with the aim of studying indoor environmental quality and relationship to "sick building syndrome" (SBS) in LEED certified buildings in India.

## 3. Methods

### 3.1. Buildings

The study was done in 33 LEED certified buildings in silver ($N$ = 5), gold ($N$ = 16) and platinum ($N$ = 11) categories located in various Indian cities.

### 3.2. Surveys

Questionnaires were issued to 314 occupants in 33 high occupancy LEED certified buildings between October 2011 and January 2012. To understand the occupant's perception, a questionnaire taking into account various factors was prepared. Different components of the questionnaire are given in Table 1. The main symptoms used to evaluate the SBS score included eye irritation, nose irritation, throat dryness, tiredness/ lethargy, headaches and skin dryness.

Table 1

*Components of the SBS Questionnaire*

| | |
|---|---|
| Part I | Purpose and background information |
| Part II | Questions about the workplace and workplace conditions |
| Part III | Questions about bothering factors at the workplace |
| Part IV | Questions about job satisfaction |
| Part V | Questions about rating of workplace |
| Part VI | Questions about medical condition and six SBS symptoms and signs |

### 3.3. Correlation among different parameters and mean SBS symptoms/person

The questionnaire responses were utilized to establish the correlation between mean SBS symptoms/person and different parameters including age, sex and perceived IEQ (satisfaction from temperature comfort, satisfaction from IAQ, satisfaction from noise level and satisfaction from workplace). These were subjected to standard statistical tests, including chi square and "T" tests for paired samples to see whether any differences existed between silver, gold and platinum LEED certification levels.

### 3.4. SBS Score

To evaluate the total levels of SBS, an integrated index - as described by [5], the SBS score was calculated. This score described the total number of SBS symptoms that included eye irritation, nose irritation, throat dryness, tiredness/lethargy, headaches and skin dryness. The SBS score directly indicated number of different types of SBS symptoms. As suggested by [5] and [14], the questions in part VI (see Table 1) asked for information about SBS symptoms, that was analyzed on a scale of 0-6 [21]. The expected answers were 'often', 'sometimes' or 'never' and these were assigned the scores of 1.0, 0.5 and 0 respectively. The questions on health were used to calculate the score prior to occupying the building ("Pre SBS Score"). The SBS analysis was restricted to the buildings identified in Table 2. The responses to questions about medical condition and six SBS symptoms and signs were insufficient for platinum level LEED-NC buildings and four LEED-CS buildings were used instead.

In analyzing the SBS symptoms, standard statistical test chi square was used and comparison of samples between buildings with different levels of certification was done using 'T' test for paired samples.

## 4. Results and Discussions

### 4.1. IEQ and IAQ in Silver, Gold and Platinum Certified LEED Buildings

Analysis of satisfaction for building, thermal comfort, air quality and noise level for all silver level LEED certified buildings is given in Figure 1. Comparative results for the gold and platinum certified buildings are provided in Figures 2 and 3, respectively.

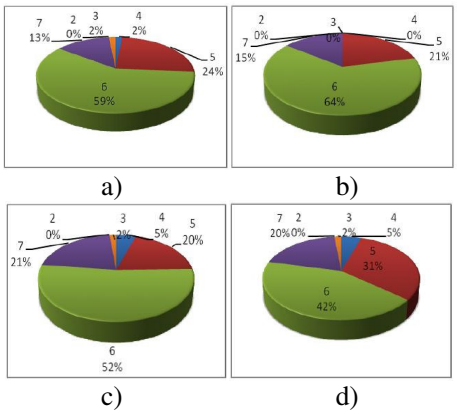


Fig. 1. *Satisfaction for a) building; b) thermal comfort; c) air quality; d) noise level for all silver level LEED certified buildings*

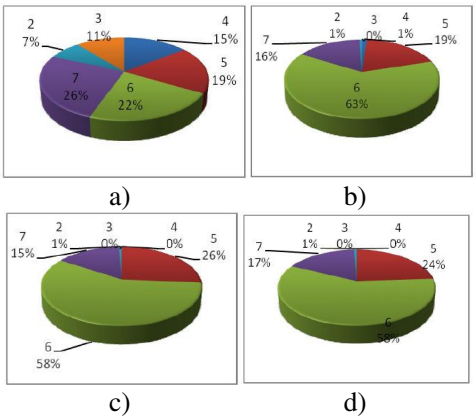


Fig. 2. *Satisfaction for a) building; b) thermal comfort; c) air quality; d) noise level for all gold level LEED certified buildings*

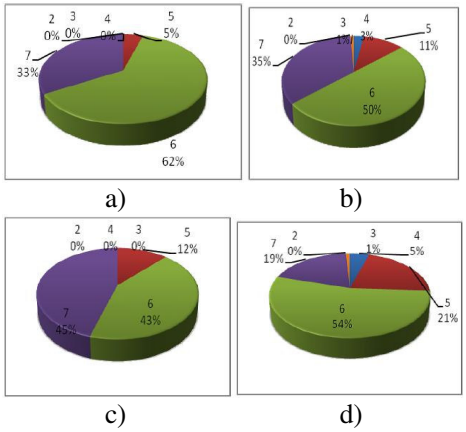


Fig. 3. *Satisfaction for a) building; b) thermal comfort; c) air quality; d) noise level for all platinum level LEED certified buildings*

Fifty nine per cent of the silver LEED Certified occupants were satisfied with the working space and gave a rating of 6. Ratings of 7 and 4 were provided by 13% and 2% of the occupants respectively. In contrast 22% of the occupants were satisfied with the working space in gold LEED certified buildings and a rating of 7 was given by 26%. No one gave a rating of less than 4. In platinum LEED certified buildings, 62% of the occupants were satisfied with the working space and 33% gave a rating of 7 and only 5% or less gave rating lower than 5.

Sixty four per cent of the occupants were satisfied with the environmental temperature in silver LEED certified buildings and 15% gave a rating of 7. None gave a rating of less than 4. The number of satisfied occupants in gold certified buildings (58%) was slightly less and gave a rating of 7. Only 17% of the respondents gave a rating of 7 and less than 1% gave a rating of 4 or less. The number of satisfied occupants in platinum certified buildings was lower (50%) than in gold certified buildings and rated thermal satisfaction at 6. Ratings of 7 and 5 were given by 35% and 11% of the occupants.

Fifty two per cent of the occupants were satisfied with the air quality in silver LEED certified buildings and gave a rating of 6. Only 5% of the occupants gave a rating of 4 or less. Ratings of 7 and 5 were given by 21% and 20% of the respondents. In gold level LEED certified buildings 63% and 16% gave a rating of 6 or 7, respectively and were satisfied with the air quality. Eighty eight per cent of the occupants were satisfied with the air quality in platinum level LEED certified buildings and gave a rating of 6 (43%) or 7 (45%).

Sixty two per cent of the occupants were satisfied with the environmental noise levels in silver LEED certified buildings and gave a rating of either 6 (42%) or 7 (20%). Ratings of 4 and 5 were given by 5% and 31% of the occupants respectively. The number of satisfied occupants in gold level buildings was slightly higher (73%) and 58% and 15% gave a rating of 6 and 7 respectively. The same number (73%) of occupants was satisfied with the noise levels in platinum buildings and ratings of 6 and 7 were provided by 54% and 19% of the occupants respectively.

A similar trend was evident, even if only the data collected for just LEED NC certified buildings was analyzed. Analysis of

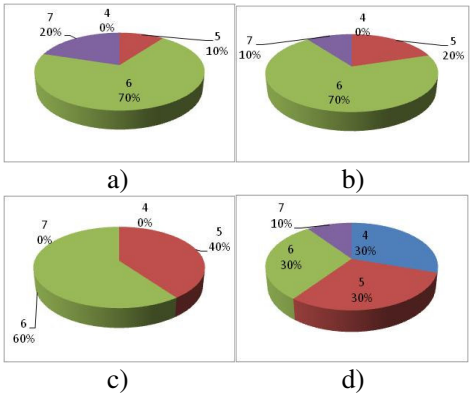


Fig. 4. *Satisfaction for a) building; b) thermal comfort; c) air quality; d) noise level for silver level LEED-NC certified buildings*

satisfaction for building, thermal comfort, air quality and noise level for all silver level LEED-NC certified buildings are given in Figure 4. Comparative results for the gold and platinum certified buildings are provided in Figures 5 and 6, respectively.

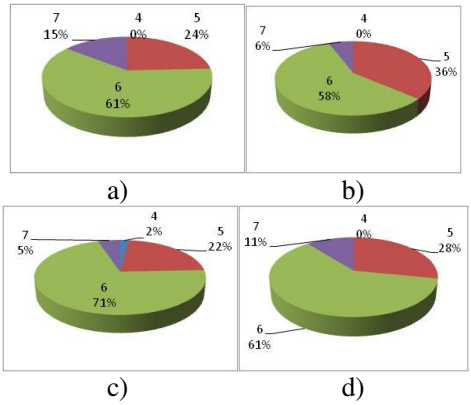


Fig. 5. *Satisfaction for a) building; b) thermal comfort; c) air quality; d) noise level for gold level LEED-NC certified buildings*

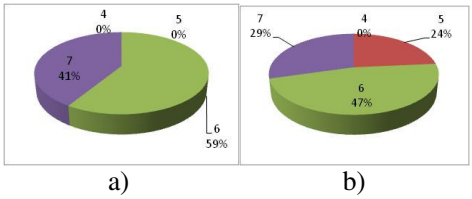


Fig. 6. *Satisfaction for a) building; b) thermal comfort for platinum level LEED-NC certified buildings*

No significant difference was found between silver, gold and platinum LEED certified buildings when occupant's responses to satisfaction for building, thermal comfort, air quality and noise level were analyzed.

### 4.2. SBS Score results

The SBS Score for silver, gold and platinum LEED certified buildings is given in Table 2. The gold LEED certified buildings had a SBS score of 1 suggesting that on an average, the occupants of these buildings had at least one SBS symptom out of 6.

Table 2

*SBS Score in Silver, Gold and Platinum Buildings*

| | Silver | Gold | Platinum |
|---|---|---|---|
| Number of Buildings | 4 | 5 | 5 |
| Surveys Completed | 40 | 50 | 50 |
| Number of Males | 31 | 40 | 33 |
| Number of Females | 9 | 10 | 17 |
| SBS Score | 0.88 ± 0.14 | 1.0 ± 0.13 | 0.90 ± 0.12 |

There was no statistically significant difference between SBS score in either Silver or Gold, Gold and Platinum or Silver and Platinum LEED Certified buildings. There was no significant differences in the SBS score between genders (Table 3).

*Gender and SBS Score* Table 3

| | Men | Women |
|---|---|---|
| Total Number | 114 | 36 |
| Total Showing SBS | 63 (55.2%) | 22 (61.1%) |
| Mean SBS Score | 1.51 + 0.05 | 1.50 + 0.10 |

The main SBS symptoms prevailing were tiredness/lethargy and headaches as shown in Table 4. Only those response that chose 'often' and 'sometimes' as alternative to the health questions were considered in the analysis. The silver LEED certified building occupants had the highest incident of tiredness/lethargy (54.1%) while platinum building occupants had the highest incidence of headaches. Gold certified building occupants

experienced equal amounts of tiredness/ lethargy (48.8%) and headache (48.9%) symptoms.

Table 4

*Prevalence of SBS Symptoms in Silver, Gold and Platinum Buildings*

| | Silver | Gold | Platinum |
|---|---|---|---|
| Number of surveys | 40 | 50 | 50 |
| Eye irritation, % | 0.02 | 0.02 | 0.05 |
| Nose irritation, % | 0 | 0 | 0 |
| Throat dryness, % | 0 | 0.02 | 0.07 |
| Tiredness/ lethargy, % | 54.1 | 48.8 | 31.7 |
| Headaches % | 43.2 | 48.8 | 56.1 |
| Skin dryness % | 0 | 0.02 | 0 |

### 4.3. Discussion

Poor IEQ is recognized as an important public health risk all over the word, 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 hazards include biological and chemical contaminants, as well as poor ergonomics, lighting and physical design. These factors can exacerbate a number of health effects in building occupants including SBS [18].

In spite of the fact that poor IEQ harms human health, the contributing building parameters are difficult to regulate and of little concern to the public [18]. There are several reasons for this. Economics play a key role in political inaction and passive public attitude. The policymakers also lack motivation to act on IEQ. Individual building owners lack incentives for greening since other building issues may be more pressing than IEQ.

The occupant IEQ surveys have been found to be useful tools for assessing the performance of green buildings [19] and such surveys can be used together with physical measurements in buildings. The present study used this tool (survey) to study the correlation between mean SBS symptoms/person and different parameters including age, sex and perceived IEQ (satisfaction from temperature comfort, satisfaction from IAQ, satisfaction from noise level and satisfaction from workplace). A recent study [15] that used surveys to determine overall occupant satisfaction showed that, both in India and England, occupants indicated light, job satisfaction, thermal comfort and noise as the top factors dominating the responses to structured questions. Detailed textual analysis placed thermal comfort, IAQ and control as the most important environmental variables.

An earlier Indian study done in multistory centrally air-conditioned buildings in Delhi showed that the main SBS symptoms were headache (51%), lethargy (50%) and dryness [5]. The current study done in LEED certified buildings supported these earlier findings. In our study we found that silver LEED certified building occupants had the highest incident of tiredness/lethargy (54.1%) while platinum building occupants had the highest incidence of headaches (56.1%). Gold certified building occupants experienced equal amounts of tiredness/ lethargy (48.8%) and headache (48.8%) symptoms. The level of LEED certification had no correlation with the SBS symptoms and making the buildings "green" did not reduce the SBS symptoms.

As previously shown by [5] and [14], analyzing the SBS symptoms on a scale of 1-6 and developing a SBS score, was also a useful tool for understanding the syndrome in LEED certified buildings. Differences in SBS score in different floors of multistory Indian buildings have been previously analyzed [5]. However, our limited data for high occupancy multistory LEED certified buildings did not appear to support this as the incidence of SBS symptoms looked similar.

A clear gender difference in SBS score has been reported in an earlier Indian study that sampled 34% females and 66% males in multistory centrally air-conditioned buildings in Delhi and found that the female occupants showed 50% more SBS symptoms [5]. Our study, that sampled 24.5% females and 77.6% males in LEED certified buildings, showed no such gender bias; both genders have a similar SBS score and percentage of related symptoms (see Table 3).

## 5. Conclusions

The present questionnaire based analysis done in Indian LEED certified buildings showed that:

1. Building occupants experienced SBS symptoms that occurred "often" or "sometimes". The main symptoms prevailing were tiredness/lethargy (54.1%, 48.8% and 31.7% for silver, gold and platinum LEED certified buildings respectively) and headaches (43.2%, 48.9% and 56.1% for silver, gold and platinum LEED certified buildings respectively).
2. There was no gender bias for either the SBS score or the percentage of SBS symptoms.
3. There was no statistically significant difference between SBS score in either Silver or Gold, Gold and Platinum or Silver and Platinum LEED Certified buildings.
4. No significant difference was found between silver, gold and platinum LEED certified buildings when, occupant's responses to satisfaction for building, thermal comfort, air quality and noise level, were analyzed.

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