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INTERIOR ENVIRONMENT ASSESSMENT OF GREEN BUILDINGS – AN EXPLORATORY STUDY

KANIKA[1], SINGH. K[2], RANA. K[3] & DAHIYA. M[4]

[1]Assistant Professor, Department of Home Science, Pt. C.L.S. Government P.G. College, Karnal, Haryana, India

[2]Professor and Head, Family Resource Management, CCS HAU, Hisar, Haryana, India

[3]Associate Professor, Directorate of Extension Education, CCS HAU, Hisar, Haryana, India

[4]Professor, Extension Education and Communication Management, CCS HAU, Hisar,

ABSTRACT

Green building is one which uses less water, optimizes energy efficiency, conserves natural resources generate less waste and provides healthier spaces for occupants as compared to conventional buildings (**U.S. Environmental Protection Agency 2008)**.The present study was designed with an effort to rediscover the Indian ethos by studying the green building rating system of India i.e. GRIHA. The present study was conducted in Haryana state. Secondary data regarding the number and ratings of green buildings were collected and compiled. Four green buildings were selected purposively from the secondary data collected. A sample of 100 occupants of the four selected green buildings was drawn randomly to assess occupant's satisfaction level regarding IEQ of building.Study found that green buildings are better than that of conventional buildings on all the parameters except in case of humidity. The satisfaction level of the respondents regarding the IEQ aspects i.e. air contaminants, temperature, humidity, noise and light of green buildings were found to be highly satisfactory.

KEYWORDS: Green Building, Conventional Building, IEQ, Occupant's Satisfaction

INTRODUCTION

Green building is an outcome of design philosophy which focuses on increasing the efficiency of resource use – energy, water and materials- while reducing building impacts on human health and the environment during the building's lifecycle, through better sitting, design, construction, operation, maintenance and removal **(USGBC 2010) .** Buildings, being the largest primary energy consumers, make the world's biggest contribution to this growing menace. Globally, studies have revealed that, buildings were responsible for 7.85Gt, or 33.0 percent of all energy-related CO_2 emissions worldwide **(Price *et al*., 2006).** Buildings account for more than 41.0 percent energy consumption in developed countries. Energy consumption in building is mainly for building services like, HVAC, lighting, water heating, pumping and fans amount to 40.0 percent. It is said that 18-20.0 percent of primary energy and 40.0 percent of total consumption takes place developed countries like US, EU and USA. As reported by **(Harvey 2009).**

It is a documented fact that occupant's wellbeing and performance are affected by various aspects of the buildings exposure to daylight and views, air quality, temperature, odor, noise, ergonomics, design of the built environment **(Heschong Mohane Group 1999, Kolleeny 2003, Madavi and Unzeitig 2005, Leather et al. 1988)**. Furthermore, since people spent most of the time indoor and the IEQ (indoor environmental quality) has an impact on occupants hence, it is beneficial to get feedback from the users themselves **(Zagreus et. al. 2004).** This has important implications since

occupant's comfort and related behavior can impact a building's energy and environmental performance, particularly in green buildings. The primary objective of this study was to explore satisfaction level of occupants in green building. Keeping above points in mind the following objectives were studied by the researcher.

- Status profile of green buildings in Haryana state.
- Comparing the IEQ of green and conventional buildings.
- Occupant's satisfaction regarding IEQ of green buildings.

Methodology

Secondary data pertaining to number, location, built up area, year of construction, rating of green buildings were collected and compiled. A well prepared schedule was used for the collection of data through telephonic communication. The main source of exploration were GRIHA (Green Rating for Integrated Habitat Assessment), IGBC (India Green Building Council), (LEED- India) Leadership in energy efficiency and BEE (Bureau of energy efficiency). Further, from the secondary collected datafour green buildings were selected purposively as they were rated by GRIHA. Four conventional corporate buildings having proximity with the selected green buildings were also selected. In both green and conventional buildings all the IEQ parameters in both seasons' winter as well as summer were carried out on each floor of the building and further dividing floors into five zones viz. east, west, and north, south and central part. Observation sheet was prepared for the recording the data about the different parameters of IEQ. The data were analyzed by using different statistical tools i.e. mean and paired't'-test to compare the data related to IEQ of green and conventional buildings**.** . Further, a sample of 100 occupants of the four selected green buildings was drawn randomly. The respondents were personally interviewed. The data were collected with the help of duly prepared schedule and checklist. The data were coded and tabulated by working out frequencies, percentages and weighted mean score.

Results:- Results pertaining to Status profile of green buildings in Haryana state, Comparative assessment of green and conventional buildings, Occupant's satisfaction level regarding IEQ of building and Productivity at work place are presented and discussed in subsequent tables as follows:-

Status Profile of Green Buildings in Haryana State

Table 1: Status of Green Buildings

Sr. No.	Name	Certification Level or Rating
GRIHA rated buildings		
1	Administration building of GAIL compressor station	☆☆☆☆☆
2	AkshayUrjaBhawan HAREDA	☆☆☆☆☆
3	S P Infocity	☆☆☆
LEED rated buildings		
4	Fortis Memorial Research Institute	☆☆☆☆☆
5	ITC Maurya hotel	Platinum
6	IIRAD Institute	Platinum
7	IOCL- Admin building and learning center	Gold
8	Orris spring homes	Gold
9	WIPRO	Gold
BEE rated buildings		
10	PEDA office complex	☆☆☆☆☆

Data in Table 1 regarding status of green building pertaining to number of green buildings in Haryana, location,

build up area, year of construction rating of green building according to different organization dealing with the green building rating system are shown. It was seen that four green buildings were rated by GRIHA, five green buildings were rated by LEED while BEE rated one green building.

Comparative Assessment of Green and Conventional Buildings

Table 2: Overall Comparison in IEQ of Green and Conventional Buildings in Summer

Sr. No.	Parameters	Green Buildings Mean Values		Conventional Building Mean Values	Mean Differences	T-Value
1.	Air Contaminants	GB1	1.50	5.43	3.92	32.41*
		GB2	1.43		3.99	34.35*
		GB3	1.01		4.41	21.48*
		GB4	1.62		3.80	27.75*
2.	Humidity	GB1	52.88	56.46	3.57	2.77
		GB2	75.33		18.87	13.14*
		GB3	55.66		0.79	0.618
		GB4	66.23		9.77	89.23*
3.	Lighting	GB1	1070.00	277.49	792.50	12.23*
		GB2	1096.44		818.94	7.13*
		GB3	1046.22		768.72	10.83*
		GB4	1328.22		1050.72	37.21*
4.	Noise	GB1	42.88	71.12	28.24	13.38*
		GB2	42.28		26.84	11.53*
		GB3	53.55		17.57	23.64*
		GB4	44.67		26.45	47.94*
5.	Temperature	GB1	28.50	13.04	15.46	11.88*
		GB2	28.46		15.42	28.01*
		GB3	24.96		11.92	19.19*
		GB4	25.21		12.17	18.31*

*Significant at 5% level of significance **GB:** Green building **CB:** Conventional building

Based on the mean scores and t-values, it was observed (Table 1) that there was a significant difference between the air contaminants of all green buildings 1, 2, 3 and 4 with respect to conventional building (t =32.41*, 34.35*, 21.48*, 27.75*). The significant difference was also found in humidity of green building 2 and 4 with respect to conventional building (t= 13.14*, 89.23*) respectively but humidity was found to be non-significant in green building 1 and 3 with respect to conventional building (t= 2.77 and 0.618 respectively). Significant difference was found in lighting aspect of IEQ in all four green buildings with conventional building (t= 12.23*, 7.13*, 10.83*, 37.21*). Noise was found to be significant in all green buildings with respect to conventional buildings (t= 13.38*, 11.53*, 11.53*, 23.64*). Temperature was found to be significant in all green buildings with respect to conventional buildings (t=11.88*, 28.01*, 19.19*, 18.31*) in summer.

Table 3: Overall Comparison in IEQ of Green and Conventional Buildings in Winter

Sr. No.	Parameters	Green Buildings Mean Values		Conventional Building Mean Values	Mean Differences	T-Value
1.	Air Contaminants	GB1	0.95	5.43	4.47	14.05*
		GB2	0.94		4.48	21.50*
		GB3	0.93		4.49	13.93*
		GB4	1.13		4.30	12.08*
2.	Humidity	GB1	55.74	56.46	.71	1.72
		GB2	53.02		3.26	2.25
		GB3	46.33		10.12	15.46*

		GB4	52.30		3.44	2.88
3.	**Lighting**	GB1	889.88	277.49	612.39	31.41*
		GB2	906.99		629.50	39.61*
		GB3	832.33		554.83	28.50*
		GB4	864.11		586.61	59.39*
4.	**Noise**	GB1	46.44	71.12	24.68	10.07*
		GB2	44.62		26.50	6.63*
		GB3	47.33		23.79	24.61*
		GB4	43.58		27.54	10.52*
5.	**Temperature**	GB1	20.40	13.04	7.35	22.79*
		GB2	19.66		6.62	21.89*
		GB3	21.93		8.89	9.31*
		GB4	19.58		6.54	26.52*

*Significant at 5% level of significance **GB:** Green building **CB:** Conventional building

Based on the mean scores and t-values, it was observed (Table 3) that there was a significant difference between the air contaminants of green buildings 1, 2, 3 and 4 with conventional buildings (t =14.05*, 21.50*, 13.93*, 12.08*). Regarding humidity significant difference was found only in green building 3 with respect to conventional building (t=15.46*) but humidity was found to be non-significant in green building 1, 2 and 4 with respect to conventional building with t=1.72, 2.25, 2.88 respectively. Significant difference was found in lighting aspect of IEQ in all four green buildings with conventional building with (t=31.41*, 39.61*, 28.50*, 59.39*). Noise was found to be significant in all green buildings with respect to conventional buildings (t=10.07*, 6.63*, 24.61*, 10.52*). Temperature was found to be significant in all green buildings with respect to conventional building (t=22.79*, 21.89*, 9.31*, 26.52*) in winter season.

Occupant's Satisfaction Level Regarding IEQ of Building

Table 4: Satisfaction Level of the Occupant's Regarding Building Interiors (N=100)

Sr No.	Statements	Frequency			Mean Score	Rank
		Highly Satisfied	Satisfied	Neutral		
1.	Overall Rating of building	92(92.0)	6(6.0)	2(2.0)	0.96	III
2.	Needs accomplishment	96(96.0)	4(4.0)	0(0.0)	0.98	II
3.	Personal safety in building	93(93.0)	2(2.0)	5(5.0)	0.96	IV
4.	Cleanliness facilities	87(87.0)	3(3.0)	10(10.0)	0.92	V
5.	Meeting rooms availability	100(100.0)	0(0.0)	0(0.0)	1	I
6.	Storage arrangement	94(94.0)	2(2.0)	4(4.0)	0.96	IV
7.	Furniture	94(94.0)	4(4.0)	2(2.0)	0.97	III
8.	Work space	100(100.0)	0(0.0)	0(0.0)	1	I
9.	Privacy	93(93.0)	2(2.0)	5(5.0)	0.96	IV
10	Air quality	100(100.0)	0(0.0)	0(0.0)	1	I

Figures in parentheses indicate percentages

The results regarding satisfaction level of the respondents for building interiors are presented in Table 4. The results revealed that meeting room availability (mean score=1), work space (mean score=1) and air quality (mean score=1) fetched first rank and need accomplished (mean score= 0.98) (mean score= 2.95) got second. Furniture (mean score= 0.97) got third rank respectively. With mean scores of 0.96, overall rating of building, personal safety, storage arrangement and privacy got forth rank respectively. Last but not the least cleanliness with the mean score of 0.92 got fifth rank.

Table 5: Occupant's Satisfaction Level Regarding IEQ Aspects in Green Building (N=100)

Sr. No.	IEQ Aspects	Frequency			Mean Score	Rank
		Highly Satisfied	Satisfied	Neutral		
1.	Overall thermal conditions of building	32(32.0)	68(68.0)	0(0.0)	0.77	X
2.	Temp. in summers	48(48.0)	52(52.0)	0(0.0)	0.82	VIII
3.	Temp. in winters	43(43.0)	57(57.0)	0(0.0)	0.81	IX
4.	Humidity in summers	20(20.0)	62(62.0)	18(18.0)	0.67	XI
5.	Humidity in winters	54(54.0)	23(23.0)	23(23.0)	0.77	X
6.	Overall air quality of building	100(100.0)	0(0.0)	0(0.0)	1	I
7.	Indoor air quality at your work place	100(100.0)	0(0.0)	0(0.0)	1	I
8.	Overall acoustic condition of building	82(82.0)	6(6.0)	12(12.0)	0.90	VI
9.	Acoustic conditions at your workplace	84(84.0)	10(10.0)	6(6.0)	0.92	IV
10.	Noise from outside the building	86(86.0)	6(6.0)	8(8.0)	0.92	IV
11.	Overall lighting conditions of building	84(84.0)	10(10.0)	6(6.0)	0.92	IV
12.	Amount of day lighting	93(93.0)	4(4.00)	3(3.0)	0.86	VII
13.	Lighting conditions at your workplace	84(84.0)	12(12.0)	4(4.0)	0.93	III
14.	Visual comfort	84(84.0)	8(8.0)	8(8.00)	0.92	IV
15.	Glare from sunlight or sky	63(63.0)	26(26.0)	11(11.0)	0.57	XII
16.	Glare from light in room	79(79.0)	17(17.0)	4(4.0)	0.91	V
17.	Building overall ventilation facilities	94(94.0)	4(4.0)	2(2.0)	0.97	II
18.	Ventilation at your work place	84(84.0)	10(10.0)	6(6.0)	0.92	IV
19.	Outdoor condition of building	76(76.0)	17(17.0)	7(7.0)	0.89	VII
20.	Overall IEQ of building	86(86.0)	6(6.0)	8(8.0)	0.92	IV

Figures in parentheses indicate percentages

The results revealed that majority of the respondents were highly satisfied regarding overall air quality at work place and air quality of building; similar trends were observed on all the other five components of thermal conditions in the building with variations in percentages (table 5). Rank wise information revealed that ventilation facilities (mean score=0.97) was given rank II followed by lighting conditions of the building (mean score= 0.93). All the respondents expressed high satisfaction for acoustic conditions, noise from outside, overall lighting conditions, visual comfort and ventilation at and overall IEQ were given rank IV with mean score of 0.92. Maximum occupants were highly satisfied with all the other aspects given i.e. glare and light (mean score= 0.91), acoustic conditions (mean score= 0.90). If we talk about thermal conditions and humidity they were ranked X and XI respectively.

It was observed that majority of the respondents expressed high satisfaction in terms of acoustic comfort in office, intrusion to acoustic conditions, acoustic conditions for working and acceptability of acoustic conditions.

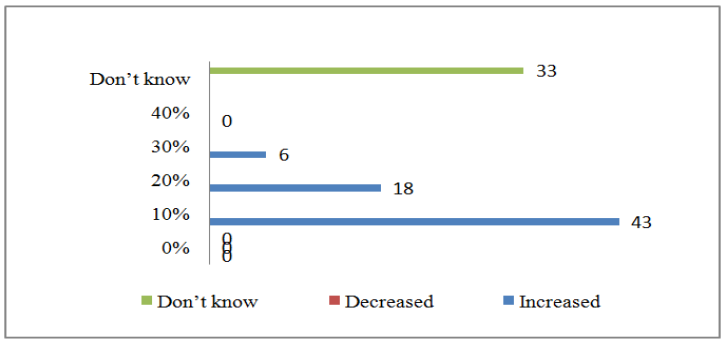

Figure 1: Productivity at Work Place

Figure 1 illustrates that a sizeable number of the respondents (43.0%) reported that working in green building increase their productivity followed by those who reported twenty percent increase in productivity (18.0%) and thirty

percent increase in productivity (6.0%). Nearly one-third of the respondents expressed no idea on the issue of increase in productivity while working in green building.

CONCLUSIONS AND SUGGESTION

Summarizing, the main sources of exploration of secondary data were GRIHA, IGBC, LEED- India and BEE. Ten buildings were found out to be green buildings out of them four were rated by GRIHA. The results regarding all the green buildings versus mean value of conventional buildings reveal that green buildings are better than that of conventional buildings except in case of level of humidity in green building 1(t= 2.77) during summer while during winter the humidity was found out be non-significant in case of green building 1(t= 1.72) followed by green building 2(t= 2.25) and 4(t= 2.88).The satisfaction level of the respondents regarding the IEQ aspects i.e. air contaminants, temperature, humidity, noise and light of green buildings were found to be highly satisfactory and also the results for controlling those aspects were seen to be satisfactory too. It can be concluded that an integrated approach to design a building is essential in providing a productive and comfortable atmosphere. It was noticed that the IEQ parameter i.e. Humidity was more in green buildings so it would be advisable to look into humidity parameter of IEQ. Green buildings are far better than that of conventional buildings in every aspect of IEQ. Green and healthier environment anticipate less illness and therefore reduce absenteeism. So, more and more institutes should promote green building concept and green model villages as a result our earth planet will be healthy planet to live in as it reduces global warming.

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