International Journal of Home Science 2016; 2(2): 338-343

International Journal of Home Science

ISSN: 2395-7476
IJHS 2016; 2(2): 338-343

www.homesciencejournal.com
Received: 21-03-2016
Accepted: 22-04-2016

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A comparative study on green and conventional buildings

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Abstract
Green building is the 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 study entitled, "A comparative study on green and conventional buildings" was conducted by covering the two districts i.e. Gurgaon and Panchkula. Four green and four conventional buildings were selected purposively for comparing the IEQ level in both seasons winter as well as summer. The floors were divided into five zones and data were collected from all the floors of the building. Considering all the IEQ data of green and conventional buildings, green buildings were far better than that of conventional buildings in all the IEQ aspects except the humidity level which was found out be higher in green building 1 than the conventional buildings 1 (1.91%) and the noise level in conventional building was less than that of green building 1 during winter afternoon (11.66 dB), evening (1.34 dB) and afternoon of summer as well (5.6 dB).

Keywords: Indoor environment quality, green building, Haryana state

1. Introduction
A green building is one which uses less water, optimizes energy efficiency, conserve natural resources generate less waste and provide healthier spaces for occupants as compared to conventional buildings (USGBC 2010) [5]. A green building design focuses on increasing the efficiency of resource use- energy, water and material- while reducing building impact on human health and the environment during the building's lifecycle, through better sitting, design, construction, operation, maintenance and removal.

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) [3]. 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 in developed countries like US, EU and USA (Harvey 2009) [2].

Green building is a concept, an idea incorporating a wide spectrum of solutions and best practices. Buildings should be designed and operated to reduce the overall impact of the built environment on human health and natural environment by efficiently using energy, protecting occupant health and improving employee productivity, reducing waste, pollution and environmental degradation. Effective green building can lead to a) Reducing operation costs by increasing operation productivity and using less energy and water b) Improving public and occupant health due to improved indoor air quality, reduce environmental impacts by, lessening storm water runoff and the heat island effect (Dorgan 2006) [1]. So, it is important to examine the quality of indoor air of the building.

Indoor air quality (IAQ) has been defined as a subset of IEQ that includes temperature, humidity, room air motion and contaminant concentrations. Many researches have concluded that if IEQ is not satisfactory, then work quality degrade along with the satisfaction level of both occupant's and customer. A comparative study was conducted with the objective of comparing the IEQ of green and conventional buildings.

2. Methodology

The present study was conducted in Haryana state from which two districts Gurgaon and Panchkula were selected purposively. Four green buildings three from Gurgaon and one building from Panchkula was selected purposively as they were rated by GRIHA (Green Rated Integrated Habitat assessment) the green rating system in India. Permissions were sought from the green building owners for collecting specific data. Four conventional corporate buildings including three Gurgaon and one from Panchkula, having proximity with the selected green buildings were also selected. In both green and conventional buildings all the IEQ parameters in bot 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, 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**.**

3. Results

Results pertaining to assessment of green vis-à-vis conventional buildings in terms of indoor air quality i.e. air contaminants, temperature, humidity, noise and light was done both during summer and winter season. Data are presented in following tables.

3.1 Comparative assessment of green and conventional buildings

Table 1: Comparison of IEQ of green building 1 and conventional building 1(n=8)

Parameters	Season	Winter			Summer		
	Time	Morning	Afternoon	Evening	Morning	Afternoon	Evening
Air contaminants (ppm)	GB1	0.45	1.21	1.73	1.28	1.87	1.36
	CB1	4.23	4.48	4.67	6.64	6.68	6.38
	Difference	3.78	3.36	2.94	5.36	4.81	5.02
Temperature (ºC)	GB1	20	21.8	19.4	27.33	31.86	26.33
	CB1	12.26	12.28	11.3	42.66	48.66	45
	Difference	7.74	9.52	8.1	15.33	16.8	18.67
Humidity (%)	GB1	56.71	54.01	56.51	52	54	52.66
	CB1	58	57	54.6	74	79	78
	Difference	1.29	2.99	-1.91	22	25	25.34
Noise (dB)	GB1	40.66	52.66	46	64	73.6	62
	CB1	43	41	44.66	64.33	68	64.45
	Difference	2.34	-11.66	-1.34	.33	-5.6	2.45
Light (Lux)	GB1	854	941	874	1015	1208	987
	CB1	226	245	237	346	368	366
	Difference	628	696	637	669	840	621

Figures in parentheses indicate units of measurements GB: Green building CB: Conventional building

The results regarding comparison of IEQ of green and conventional buildings 1 are presented in Table 1. The data illustrate that the air contaminants in green building 1 were maximum in evening (1.73ppm) followed by afternoon (1.21ppm) and morning (0.45ppm) in winter. During summer, it was maximum in afternoon (1.87ppm), evening (1.36ppm) and morning (1.28ppm). Temperature during winter was minimum in evening (19.4 ºC) followed by morning (20 ºC) and afternoon (21.8 ºC) as compared to summer where the temperature was maximum in afternoon (31.86 ºC) followed by morning (27.33 ºC) and evening (26.33 ºC). Humidity was found to be maximum in morning (56.71%) followed by evening (56.51%) and afternoon (54.01%) in winter and was maximum in afternoon (54%) followed by evening (52.66%) and morning (52%) during summer. The noise level in the green building 1 was found to be maximum in afternoon (52.66dB) followed by evening (46dB) and morning (40.66 dB) during winter while during summers it was found to be maximum in evening (44.66dB) followed by morning (43dB) and afternoon (41dB). Maximum light measured was in afternoon (941lux) followed by evening (874.66lux) and morning (854lux) in winter and during summer it was maximum in afternoon (1208lux) followed by morning (1015lux) and evening (987lux). The results regarding air contaminants in conventional building 1 were maximum in evening (4.48ppm) followed by afternoon (4.67ppm) and morning (4.23ppm) in winter. During summer these were maximum in afternoon (6.68ppm) followed by morning (6.64ppm) and evening (6.38ppm). Temperature was found to be minimum in evening (11.3 ºC) followed by morning (12.26 ºC) and afternoon (12.28 ºC) in winter while during summer, it was maximum in afternoon (48.66 ºC) followed by evening (45 ºC) and morning (42.66 ºC). Humidity was found to be maximum in morning (58.0%) followed by afternoon (57.0%) and evening (54.6%) in winter. It was found to be maximum in afternoon (79.0%) followed by evening (78.0%) and morning (74.0%) in summer. The noise level in the building was found to be maximum in afternoon (73.6dB) followed by morning (64dB) and evening (62dB) in winter. During summer it was found to be maximum in afternoon (68dB) followed by evening (64.45dB) and morning (64.33dB). Maximum light measured was in afternoon (245lux) followed by evening (237.66lux) and morning (226.33lux) in winter and it was maximum in afternoon (368lux) followed by evening (366lux) and morning (346lux) in summer.

Table 2: Comparison of IEQ of green building 2 and conventional building 2

Parameters	Season	Winter			Summer		
	Time	Morning	Afternoon	Evening	Morning	Afternoon	Evening
Air contaminants (ppm)	GB2	0.47	1.23	1.13	1.19	1.54	1.58
	CB2	5.81	6.42	6.23	5.81	5.51	6.76
	Difference	5.34	5.19	5.1	4.62	3.97	5.18
Temperature (ºC)	GB2	19.06	20.53	19.4	27.33	29.73	28.33
	CB2	9	11.6	8.3	42	46	48
	Difference	10.06	8.93	11.1	14.67	16.27	19.67
Humidity (%)	GB2	51.6	53	55	52	54	52.66
	CB2	56	57	59	75	74	76
	Difference	4.4	4	4	23	20	23.34
Noise (dB)	GB2	48.4	40	46.4	43	41	44.6
	CB2	72	68	66	73.6	85.6	84.6
	Difference	23.6	28	19.6	30.6	44.6	40
Light (Lux)	GB2	876.3	950.6	894	975.6	1337	976
	CB2	327	438	364	377	475	364.6
	Difference	549.3	512.6	530	598.6	862	611.4

Figures in parentheses indicate units of measurements GB: Green building CB: Conventional building

The results regarding comparison of IEQ of green and conventional building 2 are presented in Table 2. The data illustrates that the air contaminants in green building 2 were maximum in afternoon(1.23ppm) followed by morning (0.47ppm) and evening (1.13ppm) in winter, during summer these were maximum in evening (1.58ppm) followed by afternoon (1.54ppm) and morning (1.19ppm) in summer. Temperature during winter was found to be minimum in evening (19.4 ºC) followed by morning (19.06 ºC) and afternoon (20.53 ºC) as compared to summer where the temperature was maximum in afternoon (29.73 ºC) followed by evening (28.33 ºC) and morning (27.33 ºC) in summer. Humidity was found to be maximum in evening (55%) followed by afternoon (53%) and morning (51.6%) in winter and was found to be maximum in afternoon (54%) followed by evening (52.66%) and morning (52%) during summer. The noise level in the building was found to be maximum in morning (48.4dB) followed by evening (46.46dB) and afternoon (39dB) in winter and in summer it was found to be maximum in evening (44.66dB) followed by morning (43dB) and afternoon (41dB). Maximum light measured was in afternoon (950.66lux) followed by evening (894lux) and morning (876.33lux) during winter while during summer and it was found to be maximum in afternoon (1337.66ux) followed by evening (976lux) and morning (975.66lux). The result regarding illustrates that the air contaminants in conventional building 2 were maximum in afternoon(6.42ppm) followed by evening (6.23ppm) and morning (5.81ppm) in winter and during summer these were maximum in evening (6.76ppm) followed by morning (5.81ppm) and afternoon (5.51ppm) in summer. Temperature was found to be minimum in evening (8.3 ºC) followed by morning (9 ºC) and afternoon (11.6 ºC) in winter while during summer it was maximum in evening (48 ºC) followed by afternoon (46 ºC) and morning (42 ºC) in summer. Humidity was found to be maximum in evening (59%) followed by afternoon (57%) and morning (56%) in winter and was found to be maximum in evening (76%) followed by morning (75%) and afternoon (74%) in summer. The noise level in the building was found to be maximum in morning (72dB) followed by afternoon (68dB) and evening (66dB) in winter. It was found to be maximum in afternoon (85.66dB) followed by evening (84.66dB) and morning (73.66dB) during summer. Maximum light measured was in afternoon (438lux) followed by evening (364lux) and morning (327lux) during winter while during summer it was maximum in morning (475lux) followed by afternoon (377lux) and evening (364.66lux).

Table 3: Comparison in IEQ of green building 3 and conventional building 3

Parameters	Season	Winter			Summer		
	Time	Morning	Afternoon	Evening	Morning	Afternoon	Evening
Air contaminants (ppm)	GB3	1.15	0.42	1.23	1.03	1.46	0.56
	CB3	5.15	5.42	5.23	7.42	7.48	7.23
	Difference	4	5	4	6.19	6.02	6.67
Temperature (ºC)	GB3	20	23.8	22	24	26.9	24
	CB3	9.06	9.4	8	47	49	48
	Difference	10.94	14.4	14	23	22.1	24
Humidity (%)	GB3	48	46	45	56	57	54
	CB3	54.86	52.06	56.07	74	75	73
	Difference	6.86	6.06	11.07	18	18	19
Noise (dB)	GB3	47	47.66	47.33	53	54.33	53.33
	CB3	67.66	66.33	68	67	66	64
	Difference	20.66	18.67	20.67	14	11.67	10.67
Light (Lux)	GB3	819	875	803	965.66	1200	973
	CB3	244	238	263	484	472	467
	Difference	575	637	540	481.66	728	506

Figures in parentheses indicate units of measurements GB: Green building CB: Conventional building

Table 3 illustrate the results regarding comparison of IEQ of green and conventional building 3. The data revealed that the air contaminants in green building 3 were maximum in afternoon(0.42ppm) followed by evening (1.23ppm) and morning (1.15ppm) in winter, during summer and they were maximum in afternoon (1.46ppm) followed by morning (1.03ppm) and evening (0.56ppm). Temperature during winter was minimum in morning (20 ºC) followed by evening (22 ºC) and afternoon (23.8 ºC) as compared to summer where, the temperature was maximum in afternoon (26.9 ºC) and was equal in morning and evening (24 ºC). Humidity was found to be maximum in morning (48%) followed by afternoon (46%) and evening (45%) in winter and was found to be maximum in afternoon (57%) followed by morning (56%) and evening (54%) during summer. The noise level in the building was found to be maximum in afternoon (47.66dB) followed by evening (47.33dB) and morning (47 dB) during winter while during summer it was found to be maximum in afternoon (54.33dB) followed by evening (53.33dB) and morning (53dB). Maximum light measured was in afternoon (875lux) followed by morning (819lux) and evening (803lux) in winter, during summer and it was maximum in afternoon (1200lux) followed by evening (973lux) and morning (965.66lux). The results regarding air contaminants in conventional building 3 were maximum in afternoon(5.42ppm) followed by evening (5.23ppm) and morning (5.23ppm) in winter, during summer these were maximum in afternoon (7.48ppm) followed by morning (7.42ppm) and evening (7.23ppm). Temperature was found to be minimum in evening (8 ºC) followed by morning (9.06ºC) and afternoon (9.4ºC) in winter while during summer it was maximum in afternoon (49 ºC) followed by evening (48ºC) and morning (47ºC) in summer. Humidity was found to be maximum in evening morning (56.07%) followed by afternoon (54.86%) and (52.06%) in winter and was found to be maximum in afternoon (75%) followed by morning (74%) and evening (73%) in summer. The noise level in the building was found to be maximum in evening (68dB) followed by morning (67.66dB) and afternoon (66.33dB) in winter and during summer it was found to be maximum in morning (67dB) followed by afternoon (66dB) and evening (64dB). Maximum light measured was in evening (263lux) followed by morning (244lux) and afternoon (238lux) during winter while during summer and it was maximum in morning (484lux) followed by afternoon (472lux) and evening (467lux).

Table 4: Comparison in IEQ of green building 4 and conventional building 4

Parameters	Season	Winter			Summer		
	Time	Morning	Afternoon	Evening	Morning	Afternoon	Evening
Air contaminants (ppm)	GB4	0.48	1.90	1.01	1.68	1.48	1.71
	CB4	5.87	5.86	5.76	6.53	6.51	6.76
	Difference	5.39	3.96	4.75	4.85	5.03	5.05
Temperature (ºC)	GB4	19.06	20.6	19.1	25.66	24.66	25.33
	CB4	12.73	12.93	12.7	39	46	47
	Difference	6.33	7.67	6.4	13.34	21.34	21.67
Humidity (%)	GB4	50.9	52	54	62	64	63
	CB4	62	55	56	67	64	68
	Difference	11.1	3	2	5	0	5
Noise (dB)	GB4	46.42	41	43.33	44.35	46	43.66
	CB4	75.66	85.66	84.66	75.66	74.33	78
	Difference	29.24	44.66	41.33	31.31	28.33	34.34
Light (Lux)	GB4	864	862.33	866	1357	1290	1337
	CB4	236	238	273	387	471	473
	Difference	628	624.33	593	970	819	864

Figures in parentheses indicate units of measurements GB: Green building CB: Conventional building

The results regarding comparison of IEQ of green and conventional building 4 are presented in Table 4 illustrate that the air contaminants in green building 4 were maximum in afternoon (1.90ppm) followed by evening (1.90ppm) and morning (0.48ppm) in winter, during summer these were maximum in evening (1.71ppm) followed by morning (1.68ppm) and afternoon (1.48ppm). Temperature during winter was minimum in morning (19.06 ºC) followed by evening (19.1 ºC) and afternoon (20.6 ºC) as compared to summer where, the temperature was maximum in morning (25.66 ºC) followed by evening (25.33 ºC) and afternoon (24.66 ºC). Humidity was found to be maximum in evening (54%) followed by afternoon (52%) and morning (50.9%) in winter and was found to be maximum in afternoon (64%) followed by evening (63%) and morning (62%) during summer. The noise level in the building was found to be maximum in morning (46.42dB) followed by evening (43.33dB) and afternoon (41dB) in winter, during summer it was found to be maximum in afternoon (46dB) followed by morning (44.35dB) and evening (43.66dB). Maximum light measured was in evening (866lux) followed by afternoon (864lux) and morning (862.33lux) during winter while during summer it was maximum in morning (1357lux) followed by evening (1337lux) and afternoon (1290.66lux). The results regarding air contaminants in conventional building 4 were maximum in morning (5.86ppm) followed by afternoon (5.87ppm) and evening (5.76ppm) in winter during summer these were maximum in evening (6.76ppm) followed by morning (6.53ppm) and afternoon (6.51ppm) in summer. Temperature was found to be minimum in evening (12.7 ºC) followed by morning (12.73 ºC) and afternoon (12.93 ºC) in winter while during summer it was maximum in evening (47 ºC) followed by afternoon (46ºC) and morning (39ºC). Humidity was found to be maximum in morning (62%) followed by evening (56%) and afternoon (55%) in winter and was found to be maximum in evening (68%) followed by morning (67%) and afternoon (64%) in summer. The noise level in the building was found to be maximum in afternoon (85.66dB) followed by evening (84.66dB) and morning (75.66dB) in winter, during summer it was found to be maximum in evening (78dB) followed by morning (75.66dB) and afternoon (74.33dB). Maximum light measured was in evening (273lux) followed by morning (238lux) and afternoon (236lux) during winter while during summer it was maximum in evening (473lux) followed by afternoon (471lux) and morning (387lux).

Table 5: Overall comparison in IEQ of green and conventional buildings in summer (n=8)

S. 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 5) that there was a significant difference between the air contaminants of all green buildings1, 2, 3 and 4 with respect to conventional building (t =32.41*, 34.35*, 21.48*, 27.75*). The significant difference was found in humidity of green building 2 and 4 with respect to conventional building with t values of 13.14* and 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, 0.618). 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 6: Overall comparison in IEQ of green and conventional buildings in winter

S. 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*

Based on the mean scores and t-values, it was observed (Table 6) that there is a significant difference between the air contaminants of green buildings1, 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*) respectively 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. Significant difference was found in lighting aspect of IEQ in all four green buildings with conventional building (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*).Similarly temperature was found to be significant in all green buildings with respect to conventional building with (t=22.79*, 21.89*, 9.31*, 26.52*) in winter.

4. Conclusion and Suggestion

Summarizing, Considering all the IEQ both in green and conventional buildings it was found that on the basis of critical evaluation of IEQ data reveal that the humidity of green building 1 was higher than the conventional building 1 (1.91%). The noise level in conventional building was less than that of green building 1 during winter afternoon (11.66 dB), evening (1.34 dB) and afternoon of summer as well (5.6 dB). This might be on account of the density of population which was higher in green building one. The more open space in green building might have resulted into the higher humidity level than the conventional building 1. 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 humidity of 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).

As, we can see 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 buildings 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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