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Effects of Natural Ventilation on Residents Comfort in the Houses of the Traditional Core of Ogbomoso, South West, Nigeria

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Abstract

The study examined the effects of natural ventilation on residents' comfort in the houses of the core of Ogbomoso with a view to determining the ventilation comfort requirements in the core of the warm humid climate of Ogbomoso. Data for the study were derived primarily through the use of questionnaire. The study selected one out of every five residential buildings (5%) using systematic sampling technique giving a sample size of four hundred and nine (409) from sampling frame of eight thousand one hundred and seventy three (8173) residential buildings in the core of Ogbomoso. A household head was sampled in each of the selected houses. The modified comfort and Likhert scales were used for the comfort rating. The Ventilation Comfort Mean Rating (VCMR) of the respondents indicated that morning and night periods were fairly comfortable with the value of 2.5 and 2.8 respectively, while the afternoon and evening periods were ''not comfortable'' with the values of 1.9 and 2.2 respectively. The greater percentage of the respondents (99.40%) were not in the comfort range for the different periods of the day. The study concluded that natural ventilation alone cannot provide adequate indoor comfort in the houses of the core of warm humid climate especially the afternoon and evening, therefore, consideration should be given to other passive control techniques.

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Key words: Natural Ventilation; Ventilation Comfort Mean Rating (VCMR); Warm Humid Climate; Ventilation Comfort Index.

1. Introduction

Natural ventilation has been observed as the only passive strategy with remarkable success in warm humid climate. Natural ventilation is a process, during which the indoor vitiated air flow of a building is replaced by the fresh outdoor air on the condition that no air facilities were used in this case and no irreplaceable energy is consumed either [1].

Natural ventilation is clearly a valuable tool for sustainable development as it relies only on natural air movement, and can save significant amounts of fossil fuel based energy by reducing the need for mechanical ventilation and air conditioning [2]. Reducing electrical energy used for cooling contributes to the reduction of greenhouse gas emissions from the electrical generating plant providing the energy. From the earliest times, building designers have made use of naturally induced air movement to address two basic needs in buildings: the removal of foul air and moisture, and personal thermal comfort. Since the 1950s, the use of mechanical ventilation and, particularly, air conditioning has been adopted as a means of compensating for excess heat gains experienced in many modern lightweight and highly glazed buildings. This increased use of mechanical services has provided building designers and clients with a great deal of freedom in terms of envelope design and internal flexibility.

However, the cost has been much higher energy consumption and the introduction of centralized control systems, rather than user-based controls. The need to reduce our consumption of energy and to give users more control over their immediate environments are good reasons for designers now to re-evaluate the role of natural ventilation in buildings and to become familiar with the basic principles involved [3]. Air movement in and around buildings is a complex, three-dimensional phenomenon. At present, the tools available to design for good natural ventilation are either inexact rules of thumb, or complicated wind tunnel or computer based modeling techniques.

The real test for naturally ventilated buildings is the provision of adequate cooling in hot season [4]. Under this condition, it is necessary to have sufficient external wind pressure to create air movement within the building and, particularly, through the occupied zones. Under hot, dry conditions, when the outside air temperature is well above the tolerable internal level, it may be necessary to shut off the external air altogether until the temperature drops to more acceptable levels.

In warm, humid climates, natural ventilation is utilized to enhance indoor thermal comfort by reducing the effects of relative humidity above 60%. The other testing time for naturally ventilated buildings is in Harmattan, the challenge then is to restrict incoming air to achieve the minimum necessary fresh air without causing cold draughts or excessive heat loss [5]. Even during raining conditions, the difference in temperature between the building interior and outside air will usually create sufficient stack effect to draw in fresh air. The stack effect is brought about by warm air rising up to be exhausted through high level outlets and so drawing in colder, heavier air from outside.

In practice, the use of natural ventilation in modern buildings is most common in relatively low rise, shallow plan buildings such as housing, schools, health centers and small office units. An air movement of 1.0 m/s is the limit before papers on a desk will start to blow around. Natural ventilation is often not used for tall buildings in temperate and cold climates, partly because of excess wind speeds at higher levels, but also, due to problems arising from the stack effect [6].

Natural ventilation is frequently utilized for tall residential buildings in warm humid tropical climates, where average wind speeds are lower than those in temperate latitudes, and stack effects are small. For deep plan buildings, natural ventilation is unsuitable because the air tends to become contaminated long before it is exhausted to the outside [7].

Today's passive solar and energy efficient buildings are reliant on effective natural ventilation as one of their main strategies for the maintenance of thermal comfort.

In Nigeria however, the task of getting naturally ventilated indoor space seems to be difficult, this is due to environmental problems associated with warm humid climate on the one hand and the difficulty of articulating the design constraints of security, privacy and the desires of the users for large space on the other hand [8].

2. Ogbomoso: The Study Context

Climatically, Ogbomoso has been characterised with high temperature, high radiant temperature, high humidity and low wind and variable wind direction [9].

The core area of Ogbomoso is largely occupied by the indigenous population and early non-indigene immigrants, who engage predominantly in primary activities such as farming, tie and dye, weavings etc. This part of the city still houses the highest proportion of the city's population, especially the low income earners. The area is dominated by clusters of compactly built dwellings and family houses (owner occupier) which make functional open spaces hardly exist. Scholars have reported that the area is non-conducive for human healthy living because of poor sanitation, lack of adherence to basic codes of hygiene; filth, crowded conditions which also make it highly susceptible to epidemics [10].

In view of these, there is the need for active energy systems to maintain indoor comfort, but the use of the active energy system has been established to be too expensive for low income earners in warm humid climate, thus rendering the option inappropriate to the residents of the core area of Ogbomoso. Hence, the need to adopt a passive-energy strategy that would provide adequate indoor comfort for the warm humid climate of Ogbomoso. Provision of adequate natural ventilation was considered as the only passive control strategy in warm humid climates after the application of 'Control Potential Zone Technique' (CPZT) [11].

This study therefore, focuses on natural ventilation as a means of attaining physiological comfort and examines residents' responses to adequacy of natural ventilation in their various houses.

Natural ventilation for comfort in residential houses cannot be underrated in warm humid climate especially in the traditional core (which houses the highest proportion of the city's population). However, there has not been much research work on natural ventilation in this climatic region. The few that were done did not involve the occupants; they were based on simulation technique. This study intends to make use of the subjective feeling of the occupants, the result of which could ultimately assist in developing ventilation comfort index for houses in warm humid climate of Nigeria.

3. Methodology

Field survey through the use of questionnaire was used; this was to solicit information on subjective feelings of the residents on the effects of natural ventilation on their comfort in their respective houses.

The study selected one out of every five buildings (5%) using systematic sampling technique giving a sample size of four hundred and nine (409) from sampling frame of eight thousand one hundred and seventy three (8173) residential buildings in the core area of Ogbomoso. A household head was sampled in each of the selected houses. The modified comfort and Likhert scales were used for the comfort rating.

This objective was realized with the aid of statistical analysis of the survey data relating to ventilation and the corresponding perceived comfort within the indoor spaces of the houses in the core area of Ogbomoso. The statistical tools used are descriptive statistics, frequency, and cross tabulation.

The effects of indoor natural ventilation on residents' comfort in this study, was to confirm or otherwise the existence of subjective factors in the determination of indoor ventilation comfort.

This study has been investigated in the past by scholars in [6, 12, 13, 14, 15, 16, and 17] to involve the climatic and non-climatic parameters. However, the climatic parameters have been dealt with by author in [5], while the non-climatic parameters are the psycho-socio-economic characteristics of the residents which are the focus of this study.

3.1. Psycho social-economic characteristics of Residents of the core of Ogbomoso

Modifying factors of indoor comfort, apart from the climatic factors are the psycho social-economic characteristics of residents.

The studies of authors in [13, 14] have found that differences in indoor comfort perception are attributable to psycho social-economic characteristics of respondents. In the light of this, it is important to look in to the psycho socio-economic characteristics of the residents of the traditional core of Ogbomoso.

A total of three hundred and forty (340) questionnaires out of four hundred and nine (409) distributed were recovered, representing 83.1% of the total questionnaires distributed. The distributions with quadrants are highlighted in Table1 below.

Table 1: Questionnaire Recovered from each Quadrants in the Traditional core of Ogbomoso.

Quadrants	Frequency	Percentage (%)	Cumulative percentage
1	54	15.8	15.8
2	85	25.0	40.8
3	111	32.6	73.4
4	90	26.6	100
Total	340	100	

3.2. Ranges of the Natural Ventilation and Comfort Parameter.

Provided in the questionnaire administered on the residents' comfort of the core area of Ogbomoso are some natural ventilation and comfort feeling variables. The residents were asked to rate the ventilation conditions and the resultant comfort in indoor spaces of their respective dwellings using Likhert's scale. The scale is a five (5) point's scale of the following attributes: (i) Not at all adequate = 1, (ii) Not adequate = 2, (iii) Adequate =3, (iv) Very adequate = 4 and (v) Very much adequate =5. ASHRAE comfort scale which is seven (7) points scale was used for comfort rating. The scales are rated as follows: (i) Hot =1, (ii) Warm =2, (iii) Slightly warm =3, (iv) Neutral =4, (v) Slightly cool=5 (vi) cool = 6 and (vii) cold =7.

The climatic analysis of the traditional core of Ogbomoso highlighted in Ayinla (2011) indicated that the Ogbomoso is always warm throughout the year, with the hottest month being March while the critical period of the day is the afternoon.

The ASHRAE comfort scale was modified to suit the climate of Ogbomoso and also to make the analysis easier with the SPSS package. The modified comfort scale is presented in table 2 below. The comfort scale adopted in this study is therefore based on modified comfort table while the ventilation rating is based on the five points scale highlighted above.

Table 2: Modified Comfort Table

ASHRAE Scale	Modified Scale	Value
Hot/cold	Not at all Comfortable	1
Warm/Cool	Not comfortable	2
Slightly warm/ Slightly cold	Comfortable	3
Neutral	Very much comfortable	4

The statistical tool of descriptive statistics was used to indicate the ranges of natural ventilation and comfort parameter within the selected indoor spaces. The result is shown in table 3 below. The mean values of both the natural ventilation and comfort from the table were compared to the modified comfort table. The result gave the natural ventilation and Comfort rating as perceived by the residents of the traditional core of Ogbomoso and is presented in table 4.

Table 3: Descriptive statistics of Natural ventilation and Comfort feeling at different period of the day

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation
Bedroom nat. ventilation (mourning)	340	4.00	1.00	5.00	927.00	2.7265	.88508
sitting room nat. ventilation (mourning)	340	4.00	1.00	5.00	723.00	2.1265	.60860
kitchen nat. ventilation (mourning)	340	4.00	1.00	5.00	710.00	2.0882	.53589
Bedroom nat. ventilation (afternoon)	340	4.00	1.00	5.00	701.00	2.0618	.50280
sitting room nat. ventilation (afternoon)	340	3.00	1.00	4.00	635.00	1.8676	.67628
kitchen nat. ventilation (afternoon)	340	2.00	1.00	3.00	486.00	1.4294	.55203
Bedroom nat. ventilation (evening)	340	4.00	1.00	5.00	791.00	2.3265	.63050
kitchen nat. ventilation (evening)	340	4.00	1.00	5.00	620.00	1.8235	.73955
Bedroom nat. ventilation (night)	336	4.00	1.00	5.00	950.00	2.8274	.87415
sitting room nat. ventilation (night)	336	4.00	1.00	5.00	939.00	2.7946	.93175
kitchen nat. ventilation (night)	328	4.00	1.00	5.00	841.00	2.5640	.82145
Bedroom comfort in the mourning	329	3.00	1.00	4.00	886.00	2.6930	.75707
Sitting room comfort in the mouring	340	3.00	1.00	4.00	828.00	2.4353	.66868
kitchen comfort in the mourning	340	3.00	1.00	4.00	760.00	2.2353	.45821
Bedroom comfort in the afternoon	340	3.00	1.00	4.00	571.00	1.6794	.61939
Sitting room comfort in the afternoon	340	3.00	1.00	4.00	618.00	1.8176	.70542
kitchen comfort afternoon	340	2.00	1.00	3.00	565.00	1.6618	.63827
bedroom comfort in thge evening	340	3.00	1.00	4.00	755.00	2.2206	.71737
Sitting room coimfort in the evening	340	3.00	1.00	4.00	735.00	2.1618	.81306
kitchen comfort in the evening	340	3.00	1.00	4.00	790.00	2.3235	.63898
Bedroom comfort in the night	338	3.00	1.00	4.00	934.00	2.7633	.82084
Sitting room comfort in the night	340	3.00	1.00	4.00	902.00	2.6529	1.00888
kitchen comfort in the night	339	3.00	1.00	4.00	933.00	2.7522	1.21527
natural ventilation general afternoon	340	2.33	1.00	3.33	605.67	1.7814	.34481
natural ventilation general mourning	334	3.00	1.00	4.00	773.00	2.3144	.43684
natural ventilation general evening	340	2.33	1.00	3.33	705.34	2.0745	.37844
matural ventilation general night	336	3.67	1.00	4.67	902.73	2.6867	.68262
general comfort in the mourning	320	2.33	1.33	3.67	785.67	2.4552	.38980
general comfort in the afternoon	340	2.33	1.00	3.33	651.67	1.9167	.38649
general comfort in the evening	340	2.33	1.33	3.67	760.00	2.2353	.41068
general comfort in the night	268	3.00	1.00	4.00	767.33	2.8632	.69444
Sitting room nat. ventilation (evening)	339	3.00	1.00	4.00	703.00	2.0737	.67315
general ventilation	340	1.83	1.42	3.25	748.06	2.2002	.27722
general comfort	340	2.00	1.00	3.00	739.44	2.1748	.47628
new comfort range	340	2.00	1.00	3.00	612.00	1.8000	.41506
ventilation range	340	2.00	1.00	3.00	630.00	1.8529	.39408
Valid N (listwise)	247						

Table 4: Natural ventilation and Comfort Mean rating of the Respondent at different period of the day

Spaces	Natural Ventilation			Comfort		
	Mean rating	Range	Remark	Mean rating	Range	Remark
Bedroom mourning	2.7265	3	Adequate	2.6937	3	Comfortable
Bedroom Afternoon	2.0618	2	Not adequate	1.6794	2	Not Comfortable
Bedroom Evening	2.3265	2	Not adequate	2.2206	2	Not Comfortable
Bedroom Night	2.8274	3	Adequate	2.7633	3	Comfortable
Sitting Room Mourning	2.1265	2	Not adequate	2.4353	2	Not Comfortable
Sitting Room Afternoon	1.8676	2	Not adequate	1.8176	2	Not Comfortable
Sitting Room Evening	2.0737	2	Not adequate	2.1618	2	Not Comfortable
Sitting Room Night	2.7946	3	Adequate	2.6529	3	Comfortable
Kitchen Mourning	2.0662	2	Not adequate	2.2353	2	Not Comfortable
Kitchen Afternoon	1.4294	1	Not at all adequate	1.6618	2	Not Comfortable
Kitchen Evening	1.8235	2	Not adequate	2.3235	2	Not Comfortable
Kitchen Night	2.5640	3	Adequate	2.7522	3	Comfortable
General Mourning	2.3144	2	Not adequate	2.4552	3	Comfortable
General Afternoon	1.7814	2	Not adequate	1.9167	2	Not Comfortable
General Evening	2.0745	2	Not adequate	2.2353	2	Not Comfortable
General Night	2.6867	3	Adequate	2.8632	3	Comfortable
Overall	***2.2002***	***2***	***Not adequate***	***2.1748***	***2***	***Not Comfortable***

Source: Author's analysis, November 2009.

4. Pattern of Natural ventilation and Comfort in the Traditional core of Ogbomoso.

Cursory look at the mean natural ventilation and comfort table in table 4 above, series of graphs are generated to look at the pattern by which these two dependent variables varies by different period of the day. Figures 1- 4 show the graphs of mean natural ventilation and mean comfort both on vertical axis and period of the day on horizontal axis.

The figures reveal that both the mean natural ventilation and mean comfort for morning and night periods are comfortable, the morning period shows a graduation from ‘comfortable’, through the bearable transitional period, down to ‘not comfortable’ afternoon period. The pattern in the evening is the transition from hot, ‘not comfortable’ afternoon, through the bearable late evening to ‘comfortable’ night period. The graphs also reveal that the afternoon period is the critical period for all the spaces considered. This is true for all the spaces under consideration. These further affirm the result of climate analysis in chapter four.

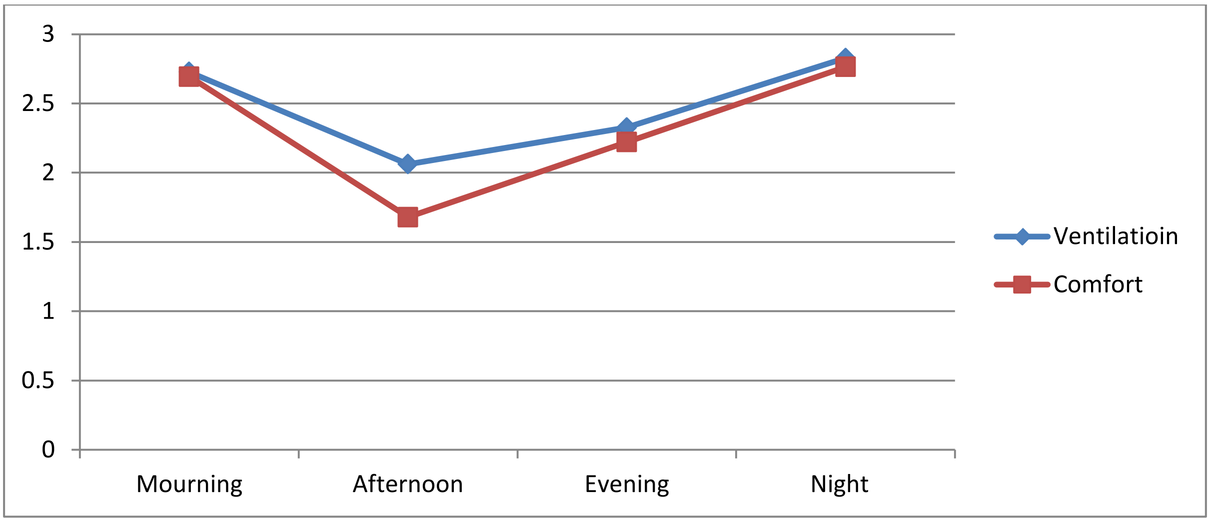

Figure 1: Bedroom natural ventilation and comfort pattern for different period of the day.

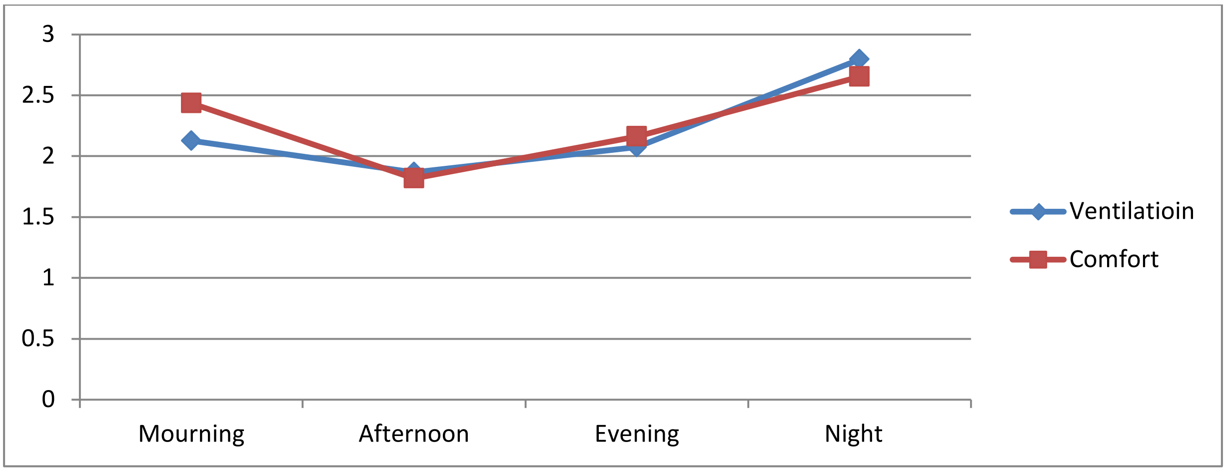

Figure 2: Sitting room natural ventilation and comfort pattern for different period of the day.

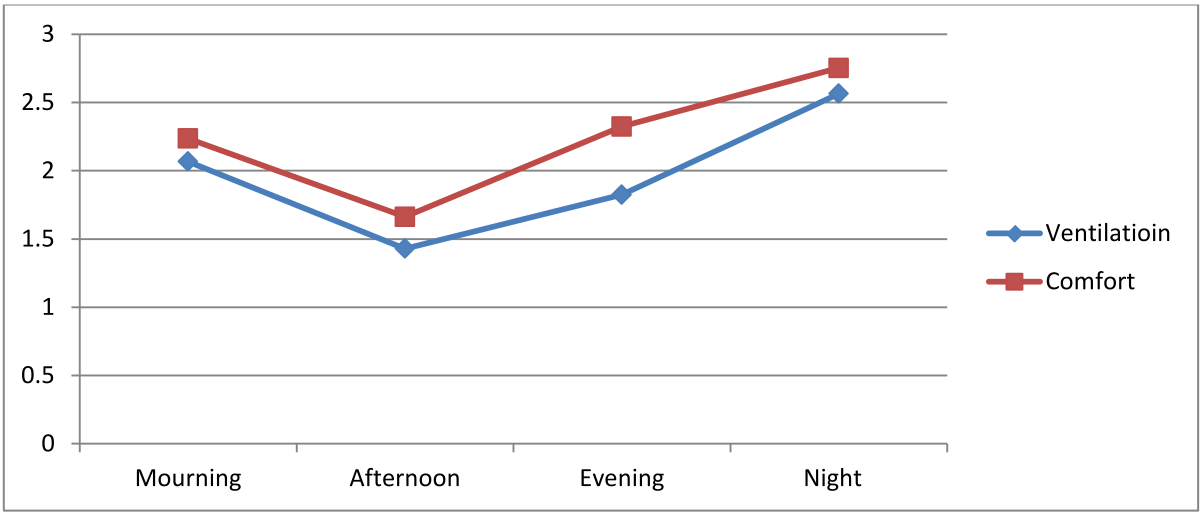

Figure 3: kitchen natural ventilation and comfort pattern for different period of the day.

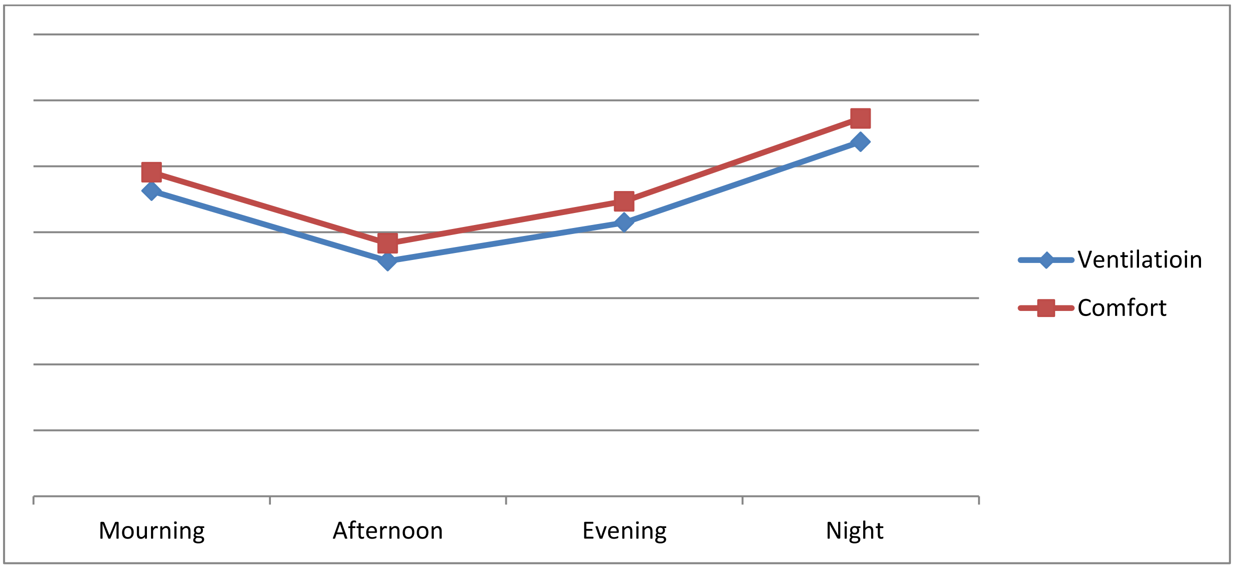

Figure 4: General natural ventilation and comfort pattern for different period of the day.

4.1 Socio-economic Effects of Respondents on Comfort

The statistical tool of cross tabulation was used to examine the distribution of socio-economic variables of respondents on comfort. The results are presented in tables and graphical form below.

4.1.1 Effect of Gender on Residents comfort

Majority of the male respondents (82.2%) felt 'not comfortable' with the comfort range within their various dwellings than female respondents, but the difference is not significant.

The Chi-square value is 2.672 and the P value is 0.263 (Tables 5 and 6). That is, perceived level of comfort is not significantly influenced by gender.

Table 5: Cross tabulation Gender and Comfort range.

			new comfort range			Total
			Not Comfortable at all	Not Comfortable	Bearable	
gender v36	Male	Male Count	31	148	1	180
		% within gender v36	17.2%	82.2%	.6%	100.0%
		% within new comfort range	44.3%	55.2%	50.0%	52.9%
		% of Total	9.1%	43.5%	.3%	52.9%
	Female	Female Count	39	120	1	160
		% within gender v36	24.4%	75.0%	.6%	100.0%
		% within new comfort range	55.7%	44.8%	50.0%	47.1%
		% of Total	11.5%	35.3%	.3%	47.1%
Total		Total Count	70	268	2	340
		% within gender v36	20.6%	78.8%	.6%	100.0%
		% within new comfort range	100.0%	100.0%	100.0%	100.0%
		% of Total	20.6%	78.8%	.6%	100.0%

Source: Author's analysis, November 2009.

Table 6: Chi-Square Tests on Gender and Comfort range.

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.672(a)	2	.263

4.1.2 Effect of Educational Status on Respondents on Comfort

More respondents with no formal education felt 'not comfortable with the comfort range in the traditional core of Ogbomoso than other respondents with primary, secondary and post-secondary education. However, the differences in their feelings are not so significant (figure 5). That is, education does not affect the level of comfortability they feel.

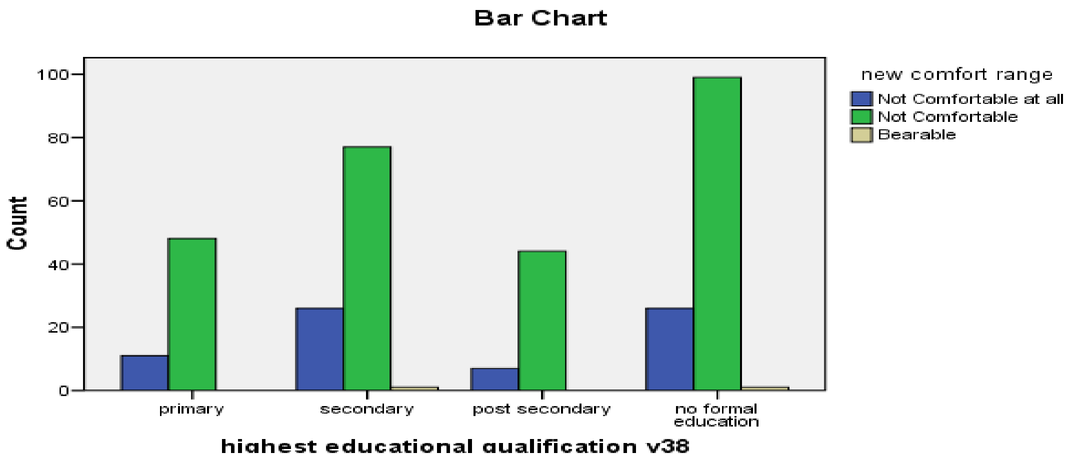

Figure 5: Effect of Educational Status.

4.1.3 Tenancy Effect of Respondents on Comfort range

Major proportions of the respondents who are owner-occupiers in the core of Ogbomoso felt more 'not comfortable' than other tenants (figure 6). This difference is significant at the alpha level of 0.035 (Table 7 and table 8).

Table 7: Effect of Tenancy Status of Respondents on Comfort.

tenure status of respondent v43

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	owner occupier	147	41.9	46.5	46.5
	tenant	87	24.8	27.5	74.1
	squatter	8	2.3	2.5	76.6
	free houses	14	4.0	4.4	81.0
	multiple ownership	58	16.5	18.4	99.4
	6.00	1	.3	.3	99.7
	12.00	1	.3	.3	100.0
	Total	316	90.0	100.0	
Missing	System	35	10.0		
Total		351	100.0		

Table 8: Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	22.261(a)	12	.035

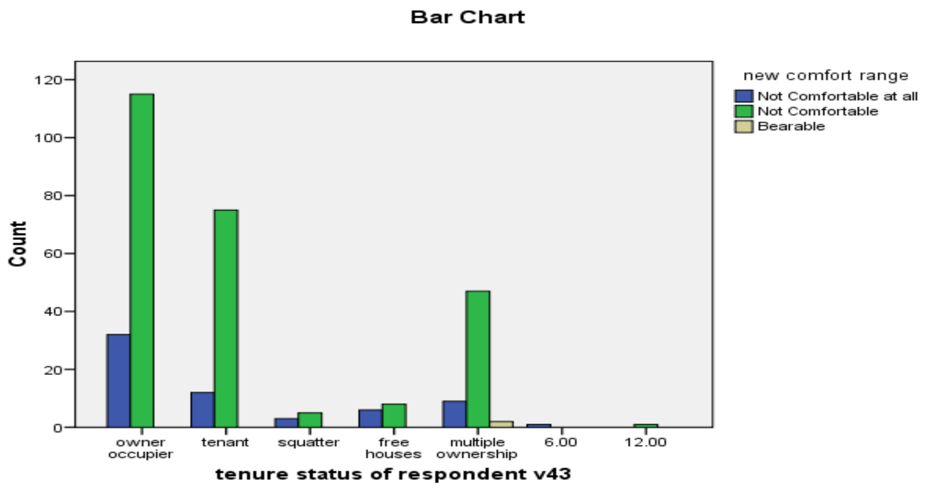

Figure 6: Effect of Tenancy on residents' comforts

4.1.4 Effect of Age of Residents on Comfort

Differences in preference for home types are associated with age. The highest number of residents fall within the age bracket of 61-70 and they feel 'not comfortable' than all others age groups. The difference is not significant as the Chi-square value is 17.567 while the p- value is 0.63 (table 9 and figure 7)

Table 9: Chi-Square Tests on Effect of Age of Residents on Comfort.

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.567(a)	10	0.63

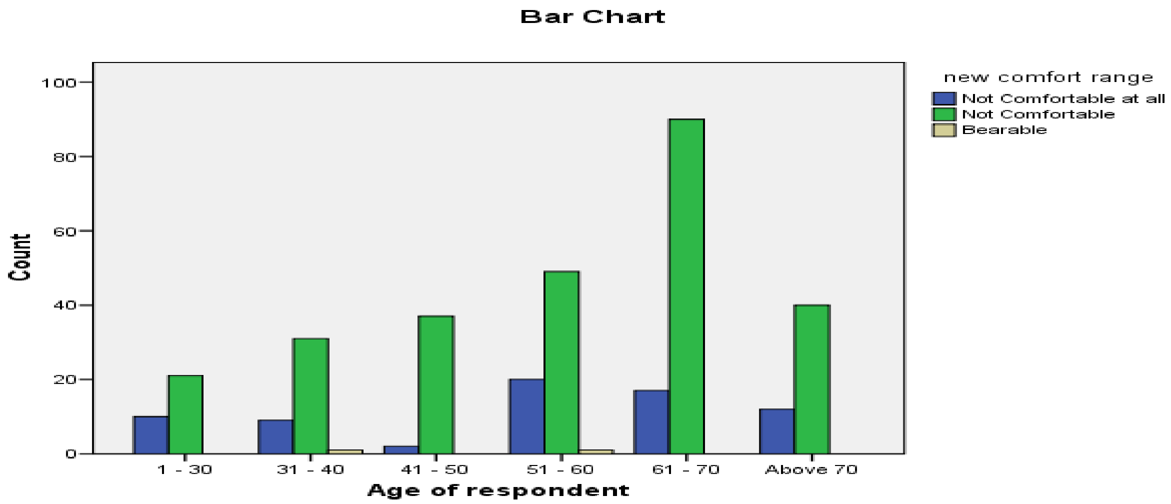

Figure 7: Effect of Age of Residents on Comfort.

4.1.5 Effect of Residents House types on Comfort

House types were shown to have relevance in the determination of comfort feeling of respondents. It was noticed that more proportion of respondents felt more uncomfortable with house type B (Brazilian rooming house), than those in all other house types. Their differences are, however, observed to be statistically insignificant as the Chi-square value of 15.53, has the p-value of 0.17 (Table 10).

Table 10: Chi-Square Tests on Effect of Residents House types on Comfort

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.53(a)	8	0.17

5. Conclusions and Recommendations.

Subjective response of the residents about the effects of indoor natural ventilation on comfort revealed that apart from climatic factors, psycho-social-economic characteristics of the residents also modify the indoor ventilation comfort in the houses of the core area of Ogbomoso.

Likhert scale and modified comfort scale respectively were used for the rating. Statistical tool of descriptive statistics was used to indicate the ranges of the subjective ratings. The mean rating of bedroom natural ventilation in the morning was 2.7262, with subjective remark of 'comfortable'. Mean ratings for living and kitchen for the same period of the day are 2.1265 and 2.0662 respectively. With the subjective remark of "not comfortable". The afternoon period offers the most critical period for all the spaces, the subjective remarks are that natural ventilation in those spaces are not adequate and as a result not comfortable. Only the night periods offered adequate natural ventilation and thus comfortable. The mean natural ventilation and comfort graphs revealed the gradation of the comfort condition with the morning period of 'bearable' to the afternoon period 'not comfortable', through the 'bearable' evening period to the 'comfortable' night period. The Comfort Mean Rating (CMR) of the respondents indicated that morning and night periods were fairly comfortable, while the afternoon and evening periods were not comfortable. Since the greater percentage of the respondents were not in the comfort range for the different periods of the day. It was concluded that natural ventilation alone cannot provide adequate indoor comfort in warm humid climate especially the afternoon and evening and as such consideration should also be given to other passive control techniques such as Thermal mass, Thermal mass with night ventilation, Evaporative cooling, and or combination of two or more of these passive control techniques.

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