BILINGUAL PUBLISHING CO.
Pioneer of Global Academics Since 1984

Journal of Architectural Environment & Structural Engineering Research
https://ojs.bilpublishing.com/index.php/jaeser

ARTICLE

Thermal Indices Influence on Occupants' Window Opening Behaviours: A Case of Ibadan and Ogbomoso, Oyo State, Nigeria

Ayinla Abdulrasaq Kunle[1*] Adebisi Ilelabayo Ismail[1*] Olaoye Olubunmi Adedayo[2*] Aina Emmanuel Oloruntoba[3]

1. Department of Architecture, Ladoke Akintola University of Technology, Ogbomoso, Nigeria
2. Department of Architectural Technology, Osun state polytechnic, Iree, Osun State, Nigeria
3. Department of Architecture, University of Ilorin, Ilorin, Kwara State, Nigeria

ARTICLE INFO

Article history
Received: 24 July 2020
Accepted: 30 September 2020
Published Online: 31 January 2021

Keywords:
Thermal stress
Thermal indexes
Thermal comfort
Indoor comfort
Window opening operations
Traditional core areas

ABSTRACT

Window opening operations are considered as one of the significant way of regulating indoor climate and maintaining thermal comfort in buildings, even when alternative active devices such as fans and air conditioners are available. This study investigates responses of occupants of the traditional core areas of Ibadan and Ogbomoso to thermal comfort conditions (thermal stress) through window opening behaviours. Climatic data of the two cities were subjected to Evans scale to predict their day and night thermal stress and questionnaires were administered to know how occupants respond to changing thermal conditions through window opening behaviours. Descriptive and inferential statistics were used in analysing the data. The study found the morning periods to be the most comfortable, the afternoon periods offer the most hot discomfort condition and cold discomfort is mostly experienced in the evening periods in both cities. Findings revealed that majority of occupants in both cities prefer to keep their windows opened in the morning and afternoon periods and an increase was observed in the numbers of occupants who prefer to keep their windows closed in the evening periods. This is an indication that building occupants in both cities actively respond to thermal stress using window opening operations. Results obtained from chi square analysis concluded that there is a significant relationship between occupants' window opening behaviour and thermal conditions at different periods of the day in both cities. Recommendations were given on how to improve on window opening systems in the future.

**Corresponding Author:*
Ayinla Abdulrasaq Kunle,
Department of Architecture, Ladoke Akintola University of Technology, Ogbomoso, Nigeria;
E-mail: arayinla@lautech.edu.ng;
Adebisi Ilelabayo Ismail,
Department of Architecture, Ladoke Akintola University of Technology, Ogbomoso, Nigeria;
E-mail: ilelabayoadebisi@gmail.com;
Olaoye Olubunmi Adedayo,
Department of Architectural Technology, Osun state polytechnic, Iree, Osun State, Nigeria;
E-mail: leboumi377@gmail.com

DOI: https://doi.org/10.30564/jaeser.v4i1.2229

1. Introduction

The concept of comfort in buildings represents the state of building occupants' satisfaction with the indoor environment [1]. Various scholars have studied the concept of Indoor comfort (IC) in buildings using different approaches and parameters. Among these are sound and acoustic comfort in buildings, light and visual comfort in buildings, ventilation and thermal comfort in buildings, moisture and humidity, odour, colour, ergonomics etc. While all these parameters as they affect human IC are all important, Authors [1-5] all established in their various studies that thermal comfort is of top priority to man. This is because it has a direct effect on occupants' psychological wellbeing, health and welfare. Thermal comfort is said to be the state with which occupants' expresses satisfaction with the indoor thermal condition (indoor temperature) of the environment [6].

Buildings must protect occupants against extreme temperatures because they have a direct consequence on occupants' health and general wellbeing. Factors affecting indoor temperature include Outdoor temperature, Solar radiation, outdoor humidity level, wind velocity, mean radiant temperature-generated from bulbs and other equipments and appliances (mostly cooking appliances) in buildings etc. [7].

The outdoor thermal temperature can be best described in terms of Thermal (heat) Index (TI). According to National weather service [7], TI is a measure of perceived temperature derived from Ambient Outdoor temperature (AOT) and Outdoor Relative Humidity (ORH) used in calculating Thermal Stress (TS). Similarly, Author [4] submitted that TI is a measure of perceived TS imposed by external conditions which is derived from AOT and ORH; it is used to predict the optimal thermal environment needed for comfort in buildings. Simply put, TI is a measure of perceived range of outdoor temperature causing perceived hot and cold discomforts in buildings resulting from AOT and ORH.

Indoor thermal environment varies according to season, just as Indoor thermal comfort is relative to occupants i.e., it is a measure of the subjective feeling of occupants; meaning that a thermal condition that is said to be comfortable for an occupant may not be comfortable for the other. Author [6] put the comfortable limits for occupants condition at about 74-83°F (23-28°C) in the summer and 67-79°F (19-26°C) in the winter seasons.

Considering the climatic condition of Nigeria and other tropical regions which according to Author [8] is characterised by high temperature, high rainfall, high humidity and intense solar radiation, the effect of AOT is heat build-up in indoor spaces and the constant challenges are how to avoid heat from getting into the building and how to swiftly remove such once they get in [9-10]. High TS is hence a general threat to people in Nigeria and other tropical regions and a greater threat to those whose health, economic situation or social circumstances makes them vulnerable to exposure to high temperatures [7]. This has however caused occupants to adopt different measures of regulating their various spaces to suit their IC conditions. Among these is the use of active driven devices such as fans, air conditioners, humidifiers, ventilators, heaters etc. to dissipate heat and regulate Indoor environment mostly used by the rich and affluent [10].

However, these devices are heavily dependent on electricity and the fact that electricity supply in Nigeria is erratic and with very high costs implications makes them uneconomical and unaffordable for the poor who are mostly found in the traditional core areas of cities in Nigeria [9]. Occupants hence resolved to maintain IC by opening windows as a way of responding to high TS [1]. This can also be inferred from the studies of Author [11] who posited that the most common and economical way to control thermal comfort is through window openings and Author [12] who found window opening behaviour of occupants as the most economical and effective way of responding to TS and maintaining good IC. Understanding TI and TS of cities and how occupants respond to them through window opening operations would further assist architects and engineers in delivering buildings devoid of active driven mechanical devices while maintaining indoor comfort of occupants.

This study attempts to establish the thermal indices of Ibadan and Ogbomoso, both in Oyo state, Nigeria and to study the response and attitude of their building occupants to TS through window opening behaviours. The study specifically focuses on residents of the traditional core areas of the two cities that are adjudged by several scholars as being poor and vulnerable and hence cannot afford the cost and maintenance of active driven mechanical devices [13-14].

2. Study Areas

Ibadan lies on latitude 7 degrees, 23 minutes North and Longitude 3 degrees, 55 minutes East of the Greenwich Meridian and falls within the forest region of Nigeria while Ogbomoso is situated on latitude 8 degrees, 10 minutes North and longitude 4 degrees, 10 minutes East of the Greenwich Meridian and falls within the derived savannah region of Nigeria. Both cities are in Oyo state, South west Nigeria. Ibadan is the largest city in the state and Ogbomoso is the second largest [1].

 DOI: https://doi.org/10.30564/jaeser.v4i1.2229

Both cities fall within the warm humid climate like every other towns and cities in the South western part of the country. Hence, their climates are characterised by high temperature, high humidity, high rainfall and a relatively low wind velocity with their maximum temperature rising above 33 degrees and their humidity rising above 89 percent in some months [15]. However, both cities have variations in their microclimatic conditions because of their geographical uniqueness and their level of urbanization [1].

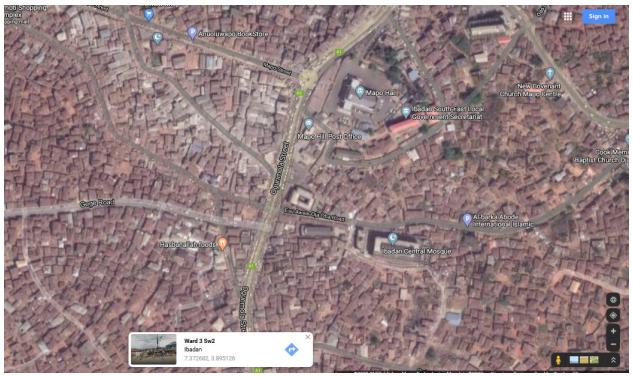

Figure 1. Showing the traditional core area of Ibadan.

Source: Google maps, 2020

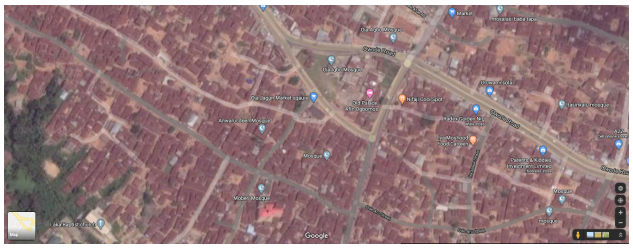

Figure 2. Showing the traditional core area of Ogbomoso

Source: Google maps, 2020

3. Research Method

The data presented in this study were drawn from a larger research project designed to assess the indoor environmental quality of houses in selected cities in Oyo state, Nigeria. The study subjected 5 years climatic data of Ibadan and Ogbomoso to the Evans heat index scale to determine the day and night thermal stress of the two cities. The climatic data were between the periods of 2011 and 2015. In a study conducted by Authors [4] in 2003, the Evans heat index scale and the Mahoney tables were adjudged to be the best method of calculating TI of any city, owing to their accuracy, low error of prediction and their ability to predict the day and night comfort conditions.

Questionnaire was used to collect data on the social-economic characteristics of occupants, their tenure status, length of stay in their various houses, their subjective feelings of thermal stress in their various houses at different times of the day (morning, afternoon and evening) and to determine their response and attitudes to TS through window opening operations and behaviours at those periods of the day.

Respondents are expected to express their subjective feeling to indoor temperature on a likert 5 point scale ranging from cold, cool, neutral, warm and hot at those periods of the day and were simply asked to indicate whether they prefer to open their windows or keep them closed anytime they are in their various spaces at those periods as a way of moderating the indoor climate.

Data obtained from the National bureau of statistics (NBS) [16] indicated that a total number of 5,310 and 5,240 buildings are in the traditional core areas of Ibadan and Ogbomoso respectively. This data was a subset extracted from the broader research project earlier mentioned. 2.5% of buildings were studied in each of the cities and hence, 133 and 131 houses were sampled in Ibadan and Ogbomoso respectively. Summarily, a total of 249 buildings were sampled out of a population of 10,550 buildings. However, 131 questionnaires representing 98.5% were retrieved in Ibadan and 118 (90.1%) questionnaires were retrieved in Ogbomoso. A total of 249 (94.3%) questionnaires were retrieved and analysed. See table 1.

Table 1. Building population and sampling in the two study areas

Study areas	No of buildings in the study areas (Population)	No of buildings studied (Sample)	No of questionnaires retrieved	Percentage of questionnaires retrieved
Ibadan	5,310	133	131	98.5
Ogbomoso	5,240	131	118	90.1
Total	10,550	264	249	94.3

Simple random sampling technique was adopted to select houses studied in each of the city. This was done after the areas had been divided into segments and houses in each segment have been numbered. An adult respondent of above 18 years was simply selected in a building to be studied.

Descriptive and inferential methods of analysis were employed to analyse the data. Chi-square was used to determine the relationship between respondents' attitude to windows openings and periods of the day. Findings are discussed below.

DOI: https://doi.org/10.30564/jaeser.v4i1.2229

4. Findings and Discussions

4.1 Evans Scale

As earlier mentioned, Author [4] in 2003 posited that the Evans heat index scale and the Mahoney tables were adjudged to be the best method of calculating TI of any city in Nigeria, owing to their accuracy, low error of prediction and their ability to predict the day and night comfort conditions. The Evans scale employs air temperature and relative humidity to predict the thermal stress [10]. See Table 2:

Table 2. Comfort limits proposed by Evans

Relative humidity (%)	Day comfort limits (°C)	Night comfort limits (°C)
0-30	29.5-32.5	27.5-29.5
30-50	28.5-30.5	26.5-29
50-70	27.5-29.5	26-28.5
70-100	26-29	25.5-28

Source: Author [10]

Table 3. Categories of thermal stress

Category of thermal stress	Conditions	Symbol
Very cold	Temperature less than 5 degrees below the lower comfort limit	--
Cold	Temperature below the lower comfort limit but more than 5 degrees below the lower comfort limit	-
Comfortable	Temperature within the comfort limits	0
Hot	Temperature above the upper comfort limit but less than 5 degrees above the upper comfort limit	+
Very Hot	Temperature more than 5 degrees above the upper comfort limit	++

Source: Author [10]

* Monthly mean maximum temperature (°C) and monthly mean minimum humidity (%) are used to determine day comforts.

*Monthly mean minimum temperature (°C) and monthly mean maximum humidity (%) are used to determine night comforts of each month.

4.2 The Comfort Condition (Thermal stress) in Ibadan and Ogbomoso

Table 4. Climatic data of Ibadan

Town: IBADAN latitude7°, 23[1] longitude 3°, 55[1] Year: 2011-2015

Month	Temp. °C (Max.)	Temp. °C (Min.)	Temp. °C Mean monthly	RH(AM) %	RH(PM) %	Rainfall (mm)	Radiation MJ/m^2/day	Wind Speed(m/s)
Jan	33.6	19.7	26.7	78.8	28.0	1.3	14.2	0.98
Feb	35.0	21.8	28.4	93.7	30.2	12.8	15	1.16
March	34.6	23.1	28.9	96.4	38.0	66.9	17.3	1.28
April	33.1	23.2	27.0	98.1	59.5	174.3	16.2	0.99
May	31.6	22.3	27.0	98.1	59.5	174.3	16.2	0.99
June	30.0	21.8	25.9	98.8	63.8	233.6	13.9	0.96
July	28.1	21.5	24.8	99.0	67.7	195.7	11.7	0.92
August	27.6	21.3	24.5	99.6	72.4	109.7	12.8	0.87
September	29.2	21.5	25.4	98.2	68.2	197.7	12.8	0.87
October	29.1	21.7	26.0	98.1	60.8	187.9	13.3	0.83
November	31.9	22.6	27.3	98.2	49.6	28.9	15.2	0.81
December	32.5	20.9	26.7	95.6	35.4	1.2	13.5	0.78
Average	31.4	21.8	26.6	96.0	52		14.2	0.98

Source: Author [1]

Table 5. Human Comfort condition (Thermal stress for Ibadan)

Ibadan 2011-2015	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Mean Max Temperature (°c)	33.6	35.0	34.6	33.1	31.6	30.0	28.1	27.6	29.2	29.1	31.9	32.5
Monthly Mean Min. Relative Humidity (%)	28.0	30.2	38.0	51.1	59.5	63.8	67.7	72.4	68.2	60.8	49.6	35.4
Day Thermal Stress	+	++	+	+	+	+	0	0	0	0	+	+
Monthly Mean Min Temperature (°c)	19.7	21.8	23.1	23.2	22.3	21.8	21.5	21.3	21.5	21.7	22.6	20.9
Monthly Mean Max. Relative Humidity (%)	78.8	93.7	96.4	97.2	98.1	98.8	99.0	99.6	98.2	98.1	98.2	95.6
Night Thermal Stress	--	-	-	-	-	-	-	-	-	-	-	-

Source: Authors' Analysis, 2020.

 DOI: https://doi.org/10.30564/jaeser.v4i1.2229

Table 6. Climatic data of Ogbomoso.

Town: Ogbomoso latitude 8^0, 10^1 longitude 4^0, 10^1 Year: 2011-2015

Month	Temp. °C (Max.)	Temp. °C (Min.)	Temp. °C Mean monthly	RH(AM) %	RH(PM) %	Rainfall (mm)	Radiation $MJ/m^2/day$	Wind Speed(m/s)
Jan	35.5	19.6	26.6	66.3	41.3	0.3	12.1	1.47
Feb	34.8	20.5	27.7	68.2	35.9	10.8	12.8	1.45
March	34.6	22.6	28.6	62.6	46	47.7	13.6	1.44
April	33.1	22.2	27.7	77.2	61	103.2	13.1	1.42
May	32.0	22.2	27.1	80.8	65.6	149.5	12.3	1.51
June	30.9	21.8	26.4	84.7	69.1	180.1	10.9	1.51
July	29.3	21.5	25.4	89.1	71.6	181.6	9.7	1.49
August	28.9	20.8	24.9	84.8	73.6	141.3	8.9	1.47
September	29.4	20.8	25.1	87.3	71.6	222.6	9.5	1.5
October	31.3	19.6	25.5	85.3	66.3	185.2	10.6	1.47
November	33.0	20.5	26.8	83.5	54.9	79.7	11.9	1.47
December	33.2	18.7	26.0	73.9	44.5	12.2	11.8	1.43
Average	31.9	20.9	26.4	78.6	58.5		11.4	1.47

Source: Author [1]

Table 7. Human Comfort condition (Thermal stress for Ogbomoso)

Ogbomoso 2011-2015	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Mean Max Temperature (°c)	35.5	34.8	34.6	33.1	32.0	30.9	29.3	28.9	29.4	31.3	33.0	33.2
Monthly Mean Min. Relative Humidity (%)	41.3	35.9	46	61	65.6	69.1	71.6	73.6	71.6	66.3	54.9	44.5
Day Thermal Stress	++	+	+	+	+	+	+	0	+	+	+	+
Monthly Mean Min Temperature (°c)	19.6	20.5	22.6	22.2	22.2	21.8	21.5	20.8	20.8	19.6	20.5	18.7
***Monthly Mean Max. Relative* Humidity (%)**	66.3	68.2	62.6	77.2	80.8	84.7	89.1	84.8	87.3	85.3	83.5	73.9
Night Thermal Stress	--	--	-	-	-	-	-	--	--	--	--	--

Source: Authors' Analysis, 2020.

Analysis from the Evans heat index scale reveals that Ibadan witnesses a comfortable thermal condition during the day for four months which are: July, August, September and October. The city experiences hot discomfort throughout the rest of the months except February which presents a very hot discomfort condition. Cold discomfort is experienced at night throughout the year except January which presents a very cold discomfort condition.

The thermal condition of Ogbomoso is very different from that of Ibadan. Comfortable condition is experienced during the day in just one month which is August; the city experiences hot discomfort during the day throughout the rest of the months and even experiences a very hot discomfort condition in January. Cold discomfort is experienced at night for 5 months; these months are March, April, May, June and July. Very cold discomfort condition is experienced at night throughout the rest of the months.

4.3 Residents' Social-economic Characteristics

Data obtained from field work revealed that 49.6% respondents in Ibadan are male while 50.4% are female. Similarly, 39.0 % respondents in Ogbomoso are male while 60.2% are female (see table 8). Respondents' age distribution in the study areas indicated that majority of the respondents in the two cities falls between the age ranges of 31- 45 years. This age structure makes up 74.0% of the respondents in Ibadan and 45.8% of the respondents in Ogbomoso. Second to this are those that fall between the ages of 18-30 years with Ibadan having 15.3% and Ogbomoso having 26.3%.

Data also revealed that 90.1% respondents in Ibadan are married while only 9.9% are single. Also, 84.7% respondents in Ogbomoso are married while only 14.4% are single. Obtained data revealed that 71.8% of respondents in the traditional core of Ibadan either have no formal education or does not complete primary school, 15.3% completed primary school, 9.2% completed secondary school and only 3.8% have a tertiary education. Similarly, 91.5% respondents in Ogbomoso have either an incomplete primary education or no formal education at all, only 6.8% completed primary education and 1.7% has a secondary

DOI: https://doi.org/10.30564/jaeser.v4i1.2229

Table 8. Residents socio-economic characteristic

Cities	Socio-economic characteristics	Attributes	Frequency (%)	Percentage (%)
Ibadan	**Sex**	Male	65	49.6
		Female	66	50.4
		Total	131	100
Ogbomoso		Male	46	39.0
		Female	71	60.2
		No Response	01	0.8
		Total	118	100
Ibadan	**Age**	18 - 30 years	20	15.3
		31 - 45 years	97	74.0
		46 - 60 years	04	3.1
		61 - 70 years	00	00
		71 and above	00	00
		No Response	10	7.6
		Total	131	100
Ogbomoso		18 - 30 years	31	26.3
		31 - 45 years	54	45.8
		46 - 60 years	18	15.3
		61 - 70 years	02	1.7
		71 and above	13	11.0
		Total	118	100
Ibadan	**Educational Status**	No formal education	47	35.9
		Pry. Sch. Incomplete	47	35.9
		Pry. Sch. Complete	20	15.3
		Completed Secondary	12	9.2
		Completed Tertiary	05	3.8
		Total	131	100
Ogbomoso		No formal education	67	56.8
		Pry. Sch.Incomplete	41	34.7
		Pry. Sch. Complete	08	6.8
		Completed Secondary	02	1.7
		Completed Tertiary	00	00
		Total	118	100
Ibadan	**Monthly Income**	Below ₦18,000:00	97	74.0
		₦18,000 - ₦25,000 ₦25,100 - ₦40,000	27	20.6
			07	5.3
		₦40,100 - ₦60,000	00	00
		₦60,100 - ₦80,000	00	00
		Above ₦80,000	00	00
		Total	131	100
Ogbomoso		Below ₦18,000:00	86	72.9
		₦18,000 - ₦25,000 ₦25,100 - ₦40,000	25	21.2
			02	1.7
		₦40,100 - ₦60,000	00	00
		₦60,100 - ₦80,000	02	1.7
		Above ₦80,000	03	2.5
		Total	118	100
Ibadan	**Occupation**	Student/Apprentice	05	3.8
		Farmer	10	7.6
		Artisan	44	33.6
		Trading	44	33.6
		Civil Servant	27	20.6
		Pensioners	00	00
		Clergy	01	0.8
		Total	131	100
Ogbomoso		Student/Apprentice	06	5.1
		Farmer	06	5.1
		Artisan	35	29.7
		Trading	62	52.5
		Civil Servant	06	5.1
		Pensioners	00	00
		Clergy	03	2.5
		Total	118	100
Ibadan	**Marital Status**	Singled	13	9.9
		Married	118	90.1
		Divorced	00	00
		Total	131	100
Ogbomoso		Singled	17	14.4
		Married	100	84.7
		Divorced	01	0.8
		Total	118	100

Source: Authors' fieldwork.

 DOI: https://doi.org/10.30564/jaeser.v4i1.2229

school certificate and none of the respondents have a tertiary education.

Occupation distribution in the study areas revealed that majority of respondents in the two cities are either artisans or traders i.e., 33.6% and 33.6% respondents in Ibadan are artisans and traders respectively and 29.7% and 59.2% respondents in Ogbomoso are artisans and traders respectively. 20.6% respondents in Ibadan are civil servants, 7.6% are farmers and 3.8% are either students or an apprentice. 5.1% respondents in Ogbomoso are civil servants, another 5.1% are farmers and 5.1% are either students or serving as an apprentice.

Data gathered on the monthly income distribution of respondents in the two study areas indicated that 74.0% and 72.9% respondents in Ibadan and Ogbomoso respectively earn below 18,000 naira per month, this implies that they earn less than the minimum wage in Nigeria and hence lives in abject poverty [17]. This further justifies their inability to afford the cost of procurement, operating and maintenance of active driven mechanical devices used in achieving comfort in indoor spaces. 20.6% and 21.2 % respondents in Ibadan and Ogbomoso respectively earn between 18,000 and 25,000 naira per month. 5.3% respondents in Ibadan earn between 25,100 and 40,000 naira per month and no respondent earns above that in a month. However, in Ogbomoso, 1.7% respondents earn between 25,100 and 40,000 naira per month, 1.7% earns between 60,100 and 80,000 naira per month and 2.5% earn above 80,000 naira per month.

4.4 Respondents Tenure Status and Length of Stay

Data on the tenure status of respondents revealed that 21.4% of respondents in Ibadan are owners of their various houses, 38.2% lives in rented apartments and 39.7% houses freely. Similarly, 28.8% respondents in Ogbomoso are owners of their houses, 31.4% lives in rented apartments and 33.9% houses freely.

Data also revealed that 42.7 % respondents in Ibadan have lived in their various houses for between 2- 5 years, 33.6% have lived for between 6-10 years and 19.1 have stayed in their various houses for over 10 years. Similarly, 16.9% respondents in Ogbomoso have lived in their various houses for between 2- 5 years, 17.8% have lived for between 6-10 years and 56.8% have stayed in their various houses for over 10 years. This implies that 95.4% and 91.5% of respondents in Ibadan and Ogbomoso respectively have lived in their various houses for over two (2) years which makes them suitable for the study.

Table 9. Residents tenure status and length of stay characteristics

Cities	Socio-economic characteristics	Attributes	Frequency (%)	Percentage (%)
Ibadan	**Tenure Status**	Owner Occupier	28	21.4
		Renter	50	38.2
		Free Houser	52	39.7
		Others	1	0.8
		Total	131	100
Ogbomoso		Owner Occupier	34	28.8
		Renter	37	31.4
		Free Houser	40	33.9
		Others	7	5.9
		Total	118	100
Ibadan	**Length of Stay in the House**	Less than 2 years	05	3.8
		2 years - 5 years	56	42.7
		6 years - 10 years	44	33.6
		Over 10 years	25	19.1
		No Response	01	0.8
		Total	131	100
Ogbomoso		Less than 2 years	10	8.5
		2 years - 5 years	20	16.9
		6 years - 10 years	21	17.8
		Over 10 years	67	56.8
		Total	118	100

Source: Authors field work.

4.5 Respondents' subjective Feelings of Thermal Stress in the Study Areas (Thermal Comfort Sensations)

The subjective feelings of respondents towards thermal stress in the two study areas at different times of the day (morning, afternoon and evening) were assessed on a likert 5 point scale ranging from cold, cool, Neutral, warm and hot. Data obtained in Ibadan indicated that 21.4% respondents feel cold in the morning, 11.5% feel cool, 64.1% feel comfortable, 2.3% feel warm and 0.8% feels hot. However, 2.3% feel cool in the afternoon, 9.2% feel comfortable, 44.3% feel warm and 44.3% feel hot while 37.4% feel cool in the evening, 45% feel comfortable, 16.8% feel warm and 0.8% feels hot.

Data obtained from Ogbomoso on the other hand indicated that no respondent feels cold discomfort in the morning, 15.3% feel cool, 38.1% feel comfortable, 25.4% feel warm and 21.2% feel hot discomfort. 2.5% respondent indicated that they feel cold discomfort in the afternoon, 0.8% feels cool, 1.7% feels comfortable, 0.8%

DOI: https://doi.org/10.30564/jaeser.v4i1.2229

feels warm and 94.1% feel hot discomfort. 4.2% respondents also indicated that they feel cold discomfort in the evening, 40.7% feel cool, 18.6% feel comfortable, 19.5% feel warm and 16.9% feel cold discomfort.

It can be inferred from this result that while 64.1% respondents in Ibadan feel comfortable in the morning period, only 38.1% respondents feel comfortable in Ogbomoso.

Whereas only 3.1% respondents feel either warm or hot in Ibadan in the morning, 46.6% respondents in Ogbomoso either feels warm or hot discomfort.

Data obtained also revealed that while 9.2% respondents feel comfortable in Ibadan in the afternoon period, only 1.7% respondents feel comfortable in Ogbomoso. Also, 88.6% respondents feel either warm or hot discomfort in Ibadan in the afternoon period as against 94.9% who feel either warm or cold discomfort in Ogbomoso. This period of the day however offers the greatest hot discomfort conditions in the two cities.

45% respondent indicated that they feel comfortable in Ibadan during the evening periods while only 18.6% feel comfortable in Ogbomoso. Similarly, while 17.6% respondents feel either warm or hot discomfort in Ibadan in the evening period, 36.4% feels either warm or hot discomfort in Ogbomoso.

This result has however shown that the climate of Ibadan is more comfortable than that of Ogbomoso and this is in line with the objective findings presented by the Evans scale.

4.6 Residents' Response to Thermal Stress through Window Openings

Data obtained from the respondents attitudinal response to thermal stress at these periods of the day shows that 98.5% respondents in Ibadan prefer to leave their windows opened in the morning while 1.5% prefers to leave them closed. Similarly, 94.7% prefer to leave their windows opened in the afternoon as against the 5.3% that prefer leaving them closed and 74% prefer leaving them opened in the evening as against 26% who prefer leaving them closed.

However, 94.1% respondents in Ogbomoso prefer to leave their windows opened both in the morning and afternoon periods as against 5.9% who prefer closing their windows at both periods of the day. However, 66.9% respondents prefer leaving their windows opened in the evening as against 33.1% who prefer leaving them closed.

Chi-square analysis was used to determine whether there is a significant relationship between residents' response to thermal stress through window openings and periods of the day or not. Result obtained indicated that their relationship is significant at 0.05 significant level in the two cities (x^2= 46.43, df = 2 and p value = 0.000 in Ibadan and x^2= 45.45, df = 2 and p value = 0.000 in Ogbomoso).

Table 10. Residents subjective feelings ofthermal stress in the study area at different periods of the day

City	Periods of the Day	Indoor Temperature Feeling					
		Cold	Cool	comfortable	Warm	Hot	Total
Ibadan	Morning	28 (21.4)	15 (11.5)	84 (64.1)	03 (2.3)	01 (0.8)	131 (100)
	Afternoon	00 (00)	03 (2.3)	12 (9.2)	58 (44.3)	58 (44.3)	131 (100)
	Evening	00 (00)	49 (37.4)	59 (45.0)	22 (16.8)	01 (0.8)	131 (100)
Ogbomoso	Morning	00 (00)	18 (15.3)	45 (38.1)	30 (25.4)	25 (21.2)	118 (100)
	Afternoon	03 (2.5)	01 (0.8)	02 (1.7)	01 (0.8)	111 (94.1)	118 (100)
	Evening	05 (4.2)	48 (40.7)	22 (18.6)	23 (19.5)	20 (16.9)	118 (100)

Note: Figures outside brackets represents frequencies; Figures in brackets represents percentages.

Source: Authors fieldwork.

Table 11. Residents' response and attitude to thermal stress through window openings for indoor comfort in the study areas

Cities	Window Opening conditions	Periods of the Day		
		Morning Freq. (%)	Afternoon Freq. (%)	Evening Freq. (%)
Ibadan	Opened	129 (98.5)	124 (94.7)	97 (74.0)
	Closed	02 (1.5)	07 (5.3)	34 (26.0)
	Total	131 (100)	131 (100)	131 (100)
Ogbomoso	Opened	111 (94.1)	111 (94.1)	79 (66.9)
	Closed	07 (5.9)	07 (5.9)	39 (33.1)
	Total	118(100)	118(100)	118(100)

Note: Figures outside brackets represents frequencies; Figures in brackets represents percentages.

Source: Authors fieldwork.

 DOI: https://doi.org/10.30564/jaeser.v4i1.2229

Table 12. Chi-square result

Cities	Variables	Chi-square X^2	Degree of Freedom (df)	P value	Significance
Ibadan	Window opening condition and periods of the day.	46.43	2	0.0000	Sig.
Ogbomoso		45.45	2	0.0000	Sig.

Note: (α = 0.05) Source: Authors analysis.

4. Conclusion

The results from the Evans scale revealed that hot or very hot discomfort is experienced in most of the months in the two cities (8 months in Ibadan and 11 months in Ogbomoso) and cold or very cold nights is experienced in the two cities throughout the year. Through the subjective assessment, the study found that occupants' experiences a more comfortable condition in the morning periods in the two cities (64.1% and 38.1% in Ibadan and Ogbomoso respectively), the afternoon periods presents the highest hot discomfort condition in the two cities (88.3% and 94.9% in Ibadan and Ogbomoso respectively) and cold discomfort is mostly felt in the evening periods in the two cities (37.4% and 44.9% in Ibadan and Ogbomoso respectively). This result however aligns with the results of the Evans scale.

The study however realised that over 90% of occupants in the two cities prefer to keep their windows opened in the morning and afternoon periods when comfortable and hot discomfort conditions are mostly experienced and only less than 10% prefers keeping their windows closed during those periods. Findings also revealed that there is a rise in the number of occupants who prefer to keep their windows closed in the evening periods (26.0% and 33.1% in Ibadan and Ogbomoso respectively) this is owing to the fact that the evening periods present the highest cold discomfort condition.

The outcome of the study has clearly shown that occupants in the two study areas respond actively to thermal stress in their various buildings by keeping their windows either opened or closed depending on the thermal condition of the environment and periods of the day. This is also in line with the results obtained from the chi-square analysis which found a significant relationship between residents' response to thermal stress through window openings and periods of the day in the two cities.

The study has further proven that building occupants effectively use window openings to moderate indoor climates in achieving balanced thermal conditions and hence, the study is in line with the findings of Authors [11] and [12] who both found window opening behaviours of occupants as the most effective, efficient and economical way of achieving comfort in buildings. Architects should hence come to the awareness that window opening is one of the most effective ways IC can be maintained with or without active driven devices and should:

(1) Concentrate more on window opening systems and designs vis-a-vis Type, number and sizes which would be capable of achieving comfort in their proposed design.

(2) Ensure good window positions and orientations in order to maximize their effectiveness.

(3) Take decisions on window designs right from design inception with special attention to construction and operation, details and specifications.

If possible, future researches should look further into the effect of privacy, persisting cultural practices, the organization of buildings in relation to density and use of thermal indices and window openings behaviours or operations in various places.

Abbreviations

The following is the list of abbreviations used in the study

IC - Indoor comfort
TI - Thermal (heat) Index
AOT - Ambient Outdoor temperature (°c)
ORH - Outdoor Relative Humidity (%)
TS - Thermal Stress

Conflict of Interest

The authors have not declared any conflict of interest.

References

[1] Ayinla, A.K. Assessment of Indoor Environmental Quality of Houses in Selected Cities in Oyo State. An Unpublished Ph.D Thesis in the Department of Architecture, Ladoke Akintola University of Technology, Ogbomoso, Nigeria, 2018.

[2] Adunola A.O. A study of thermal Comfort in Naturally Ventilated residential Buildings in Olubadan Estate Ibadan. An Unpublished Master of Philosophy Thesis at the Obafemi Awolowo University, (OAU), Ile - Ife Nigeria, 2006.

[3] Ajibola, K. Ventilation of spaces in warm - humid climate - case study of some house types. Journal of Renewable Energy, 1997, 10(1): 61-70. DOI: 10.1016/0960-1481(95)00128-X

[4] Ogunsote, O.O, Prucnal-Ogunsote, B. Choice of Thermal Index for Architectural Design with Climate in Nigeria. Habitat International, 2003, 27: 63-81. DOI: https://doi.org/10.1016/S0197-3975(02)00035-8

[5] Lai, A.C.K, Mui, K.W, Wong, L.T, Law, L.Y. An

DOI: https://doi.org/10.30564/jaeser.v4i1.2229

Evaluation Model for Indoor Environmental Quality (IEQ) acceptance in residential buildings". Energy Built, 2009, 41(9): 930-936.
DOI: https://doi.org/10.1016/j.enbuild.2009.03.016

[6] ASHRAE. Standard 55. Thermal environmental conditions for human occupancy. Atlanta: American Society of heating, refrigerating and air conditioning engineers, 2004.
www.ashrae.org/techical-resources/bookstore/standard-55-thermal-environmental-conditions-for-human-occupancy

[7] Institute of Medicine of the National Academics. Climate Change, the Indoor Comfort and Health. The National Academics press, 2011. Retrieved from:
https://www.nap.edu/read/13115/chapter/9#188

[8] SKAT. Climate Responsive Building- Appropriate Building Construction in Tropical and Subtropical Regions. 1993.

[9] Adebisi, I.I, Ayinla, A.k, Okeyinka Y.R. Energy Efficient Buildings in Tropical Climate through Passive-Techniques- An Overview. Journal of Environment and Earth Science, 2018, 8(4): 45-50.
www.iiste.org/journals/index.php/JEES/article/view/41910

[10] Ogunsote, O. O., Prucnal-Ogunsote, B., Adegbie M. Optimizing Passive Cooling Systems in Residential Buildings: A Case Study of Akure, Nigeria. 2011. Retrieved from:
www.academia.edu/2951280

[11] Rijal, H.B, Humphreys, M.A., Nicol, J.F. Development of a window opening algorithm based on adaptive thermal comfort to predict occupant behavior in Japanese dwellings. Japan, Architecture, 2018.
DOI: https://doi.org/10.1002/2475-8876.12043

[12] Amy, K., Shuoqi, W., Ji-Eun, K., Dorothy, R. Indoor/Outdoor Environmental Parameters and Window-Opening Behavior: A Structural Equation Modelling Analysis. MDPI Publishers, 2019, 9(94).
DOI: https://doi.org/10.3390/buildings9040094

[13] Okeyinka, Y.R. Socio-Economic Characteristics of Residents of Multi-habited Houses in Ogbomoso, South West Nigeria. Global Journal of Human Social Science: Sociology and Culture. 2016, 16(6).
https://globaljournals.org/GJHSS_volume16/9-Socio-Economic-Characteristic-of-Resisents.pdf

[14] Ayinla, A.K., Olaniyan, S.A., Okeyinka, Y.R. Bio Climatic Characteristics of Residential Building Types in the Traditional Core of Ogbomoso Southwest Nigeria. International Journal of Science, Environment and Technology, 2013, 2(1462-1478).
www.ijset.net/journal/223.pdf

[15] Adebisi, I.I, Okeyinka Y.R. Ayinla, A.k. Evaluating the Appropriateness of Passive Techniques Used in Achieving Thermal Comfort in Buildings: A Case of Lautech College of Health Sciences, Ogbomoso. World Academy of Science, Engineering and Technology, International Journal of Civil and Architectural Engineering, 2018a, 12(1).
http://publications.waset.org/pdf/10009060

[16] National Bureau of Statistics (NBS). Annual Abstract of Statistics, 2009. Abuja: National Bureau of Statistics, Nigeria.
www.nigerianstat.gov.ng

[17] Adebisi I.I, Okeyinka Y.R, Ayinla A.K. Appraisal of the Impact of the Gender of Household head on Housing Condition in Egbeda, Iragbiji, Osun State. Journal of African Studies and Development, 2018b, 10(2): 19-28.
DOI: 10.5897/JASD2016.0429

 DOI: https://doi.org/10.30564/jaeser.v4i1.2229