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A COMPARATIVE ASSESSMENT OF THERMAL COMFORT IN RESIDENTIAL BUILDINGS IN ASABA AND IGBUZOR IN DELTA STATE

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Abstract

*Thermal comfort is a critical aspect of human well-being, particularly in relation to the built environment. It refers to the state of mind that expresses satisfaction with the surrounding thermal conditions. This study was carried out to compare the indoor/outdoor thermal comfort conditions in Asaba and Igbuzor. The quasi-experimental research design was used. Meteorological data (1983-2022) from weather station in Asaba and National Aeronautics and Space Administration (NASA) were used. Air temperature, humidity, windspeed and direction were the data collected. The historical data was complemented with measurements of weather parameters in Asaba and Igbuzor (January-December 2022). The Effective Temperature Index (ET) was used to determine the thermal conditions. The paired samples *t* test tested the difference in ET. Findings indicated that monthly average temperature for Asaba ranged between 29.9°C and 25.7°C; minimum temperature in Asaba had a range of 2.2°C. Maximum temperature was hottest in February (34.9°C). Relative humidity increased from 65% in January to 88% in June, July and August (JJA). Mean annual temperature for Igbuzor ranged between 29.4°C and 25.5°C. The annual minimum temperature in Igbuzor had a range of 2.1°C. Maximum temperature was hottest in February (34.3°C); while July (28.4°C) and August (28.4°C) were coolest. ET for Asaba was 27.6 °C, while the ET for Igbuzor was 24.5°C. The paired *t* test result showed that effective temperature in Asaba was significantly different from that of Igbuzor at, $t(364) = 10.3, p < .005$. The study recommends the need to revisit the building construction processes in Asaba, keeping in mind the findings of this study.*

Keywords: Residential buildings, Thermal comfort, Urbanization

INTRODUCTION

Thermal comfort is a critical aspect of human well-being, particularly in relation to the built environment (Adebamowo & Adeyemi, 2013). It refers to the state of mind that expresses satisfaction with the surrounding thermal conditions (Adekunle & Nikolopoulou, 2014). Achieving thermal comfort is essential for individuals to perform daily activities effectively and maintain a sense of well-being (Shaikh et al., 2014). However, thermal comfort can vary significantly based on factors such as climate, urbanization, and local environmental conditions (Oyedepo, 2014). Therefore, it is crucial to conduct comparative assessments to understand the differences in thermal comfort across different locations (Sangowawa & Adebamowo, 2012).

This study focuses on a comparative assessment of thermal comfort in Asaba and Igbuzor, which represent a city and its conurbation both located in Delta State, Nigeria.

Both Asaba (the capital city of Delta State) and Igbuzor, a rapidly developing peri-urban area (nearby Asaba), experience tropical climatic conditions. This region is characterized by high temperatures, high humidity levels, and a significant amount of rainfall throughout the year (Ozabor & Wodu, 2016). As urbanization and development continue to shape these locations, it is essential to evaluate the thermal comfort levels experienced by the residents in order to identify potential challenges and develop appropriate strategies for improvement (Shaikh et al., 2014).

The objective of this study was to compare and assess the thermal comfort levels in Asaba and Igbuzor. This assessment encompasses various aspects, including outdoor and indoor thermal conditions and the possible factors influencing thermal comfort (Nwagbara et al., 2017). The findings of this study can serve as a basis for policymakers, urban planners, architects, and engineers to design sustainable and comfortable living environments in these locations.

LITERATURE REVIEW

Generally, there has been a massive urbanization in the Asaba-Igbuzor areas of Delta State. This urbanizations and development activities are in response to the increasing demand for housing caused by the naming of Asaba as capital city of Delta State, when Delta State was created in the Year 1991. Asaba which was once a properly ordered town gradually changed nomenclature and today is a mega city with several conurbations including Okpanam and Anwai. This city has also expanded southwards to affects Igbuzor. In these places development regulations are scarcely followed, due to propensity to bribe and the cost of lands. Also, on very few occasions are experts consulted for building projects. The main focus of building developers is making money rather than creating comfort of the eventual building occupants. Therefore, window sizes, room sizes and other building characteristics are made very small, to accommodate more flats and increase the money made as Return on Investment (ROI). Sadly, such compromises affect the capacity of the buildings to ensure comfort for the building occupants (Obisesan & Famous, 2016).

A building with poor thermal conditions portrays serious challenges for the building occupants. These challenges range from poor sleep, heat rashes, heat strokes, to elevated blood pressure challenges or even death (Javed et al., 2015). Also, during the hot periods, residents are forced to seek comfort outside. This sometimes predisposes them to robbery incidences, reptile attacks. Also rodents can sneak into the buildings at night times when the doors are opened and then interact with the food which could result in laser fever concerns (Roaf et al., 2010). These are some of the reasons why the thermal comfort inventory of buildings needs to be carried out from time to time. Not only would it create awareness about the thermal comfort issues indoor for building occupants, but it will also inform the developers on the current state of air circulation

systems and then cause a change in the building design characteristics if necessary. However, while much of the existing literature on thermal comfort focuses on modern buildings and base their research on the design deficiency of the buildings, the historical changes in the thermal conditions resulting from weather patterns in urban and peri-urban areas are scant (Moon et al., 2014; Royapoor et al., 2018; Evins, 2013).

Furthermore, the urban heat island effect, characterized by elevated temperatures in urban areas, has been extensively studied (Auffenberg et al., 2017; Garnier et al., 2015). However, there is a lack of research on the long-term effects of prolonged exposure to higher temperatures in urban and peri-urban areas (Javed et al., 2014). This includes sustained hot weather and the effects on air temperature with propensity to affect the thermal comfort perception (Liang & Du, 2008). Understanding the long-term consequences of sustained temperature elevation is vital for creating sustainable and resilient urban environments to dwell (Yang et al., 2020).

More so, the interaction between the built environment and outdoor spaces in urban and peri-urban areas significantly influences thermal comfort. However, there is a lack of comprehensive studies that investigate the dynamic relationship between indoor and outdoor thermal conditions in the study area. Understanding the interaction between the microclimate within buildings and the surrounding outdoor environment can help develop integrated design strategies that maximize thermal comfort and energy efficiency. Cascading from the identified gaps, this study is poised to assess thermal comfort in Asaba and Igbuzor in Delta State.

METHODOLOGY

Study area

Asaba and Igbuzor are two prominent towns located in Delta State, Nigeria. Each town possesses unique geographical features, strategic positions, and distinctive sizes (see Figure 1). Asaba, the capital city of Delta State, is situated on the western bank of the Niger River. It lies between latitude 6°09'36" N and latitude 6°14'38"N, and longitude 6°44'05"E and longitude 6°42'30" E. The town is located in the southern part of Nigeria, near the border with Anambra State. Asaba is characterized by a relatively flat terrain with an average elevation of 56 meters above sea level. The Niger River, a major waterway in West Africa, flows along the eastern side of the city, influencing its geography and economic activities.

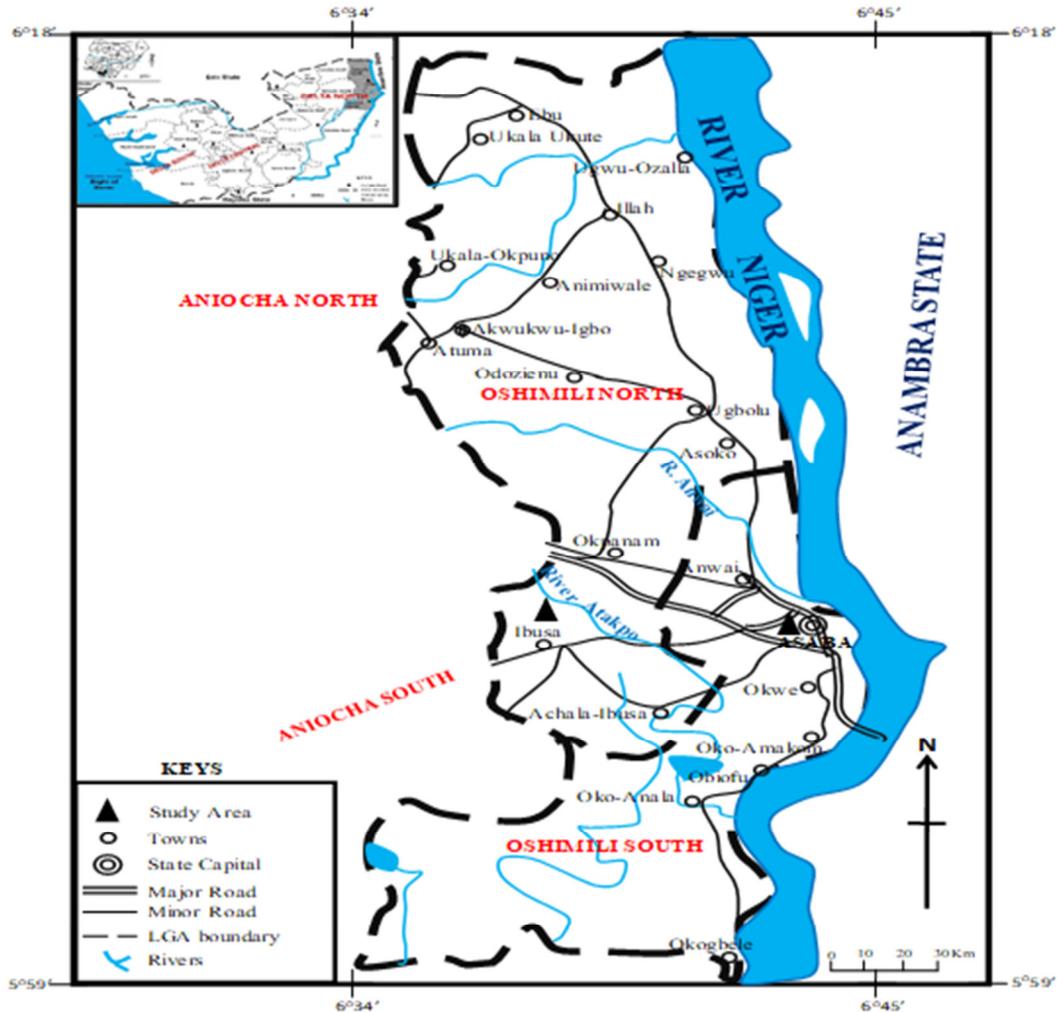


Figure 1: Location of Igbuzor (Ibusa) in Oshimili North and Asaba in Oshimili South Local Government Areas of Delta

Source: Ministry of Lands, Survey and Urban Development, Asaba, (2023)

Asaba holds a strategic position as a major commercial and administrative centre within Delta State. Its location along the Niger River provides access to inland water transportation, facilitating trade and commerce. Asaba is also well-connected to other parts of Nigeria through road networks. The Benin-Asaba Expressway links the city to Benin City, the capital of Edo State, while the Onitsha-Asaba Bridge connects it to Onitsha, a bustling commercial city in Anambra State. The strategic position of Asaba as a gateway between the eastern and western parts of Nigeria contributes to its economic significance, growth housing demand.

In terms of size, Asaba has experienced significant urban expansion over the years. The city covers an area of approximately 300 square kilometres. Its population has also witnessed substantial growth, with estimates ranging from 300,000 to 500,000 residents. The rapid

population increase is attributed to the city's economic opportunities, administrative importance, and improved transportation infrastructure. The expansion of Asaba has resulted in the development of residential, commercial, and industrial areas, transforming it into a vibrant urban centre (Samuel & Atobatele, 2019).

Similarly, Igbuzor, a town in Delta State, is located in the western part of the state. It lies at between latitude 6°09'16" N and latitude 6°11'36"N, and longitude 6°36'24"E and longitude 6°36'53" E. The town is situated on a slightly undulating terrain, with an average elevation of approximately 80 meters above sea level. Igbuzor is surrounded by lush vegetation, characteristic of the Niger Delta region. The town is part of the tropical rainforest biome, which contributes to its ecological diversity.

Igbuzor is positioned in a relatively close distance to Asaba area of Delta State. It is situated in the heartland of the Ika ethnic group and is known for its cultural heritage and traditional practices. While Igbuzor may not have the same level of economic prominence as Asaba, its strategic location within the state provides access to agricultural resources and natural landscapes. The town is well-connected to neighbouring communities through road networks, facilitating transportation and trade activities. Igbuzor is smaller in size compared to Asaba. The town covers an area of approximately 15 square kilometres. Its population is estimated to be around 100,000 to 150,000 residents. The size and population of Igbuzor reflect on the fact that it is a smaller town to Asaba.

Research design

To achieve the research the quasi experimental research design was deployed. First, meteorological data from weather station in Asaba and data from National Aeronautics and Space Administration (NASA) was used for Igbuzor (since there is no NIMET weather station there). The data set were collected for the period 1983-2022. The data were analyzed to understand the climatic patterns of the two locations and to see if there has been a departure from the existing patterns due to the changing patterns of the urbanization characteristics in the area. Parameters such as air temperature, humidity, wind speed and direction were considered to assess the outdoor thermal conditions. Analysing such historic data, provides valuable insights into the climatic differences between Asaba and Igbuzor, which can influence thermal comfort as well. Also, the researchers complemented the historical data with direct measurements. This was done to find out the current state of the indoor thermal conditions. As such, data on relative humidity, air temperature (Minimum and maximum), mean temperature, wind speed, and sun shine hours were collected in Asaba and Igbuzor for a period of one year (January 2022-December 2022). To collect the data, data loggers (Hygrochron DS1923 temperature / humidity logger iButton, 8192 8-bit readings, 512 bytes of SRAM; Acu-Rite Iris Weather Station: Wireless Display for Temperature, Humidity, Wind Speed/Direction, and Rainfall with Built-In Barometer) were used

and synchronized with the personal computer. Data were logged for the standard climatologic hours (i.e. 00:00hrs, 6:00hrs, 12:00hrs and 18:00hrs), this was done to unravel the times of the day in which thermal discomfort is experienced in both areas (Ojeh, 2011).

To determine the sample sizes of Igbuzor and Asaba the locations were calibrated into neighbourhoods, as suggested by Ojeh (2011). In all 10 neighbourhoods were determined in Asaba and 5 in Igbuzor. In each of the neighbourhoods, a building with same or similar characteristics as the model the researchers calibrated in Table 1 was selected (subject to the acceptance of the head of household permission to conduct such research in their space). Thus, in each of the neighbourhoods 1 bungalow (residential apartment) was selected for the measurements (see Table 1) of daily data (air temperature, relative humidity and air flow). These data were collected for a period of 1 year. This was done to isolate the seasonal characteristics in the thermal comfort in the study area, as described by (Ku et al., 2015; Qolomany et al., 2019).

Table 1: Basic characteristics of the Bungalows investigated

BASIC BUILDING CHARACTERISTICS	PARAMETER
Types of housing Units	Bungalows only
Material used for Floor Finishing	Tiles
Material used for Wall Finishing	150 mm thick sandcrete hollow blocks
Material used for Roof Finishing	Aluminium (long span) only
Power source	Electricity (BEDC) only
Door types	Metal exterior and Wooden indoor
Window type	Sliding Aluminium only
Head room	2700mm to 3000mm
Ceiling materials	Asbestos and polyvinyl chloride (PVC)

Source: Field work (2022)

The weather parameters data for Asaba were compared with the data obtained from NIMET station domiciled in Asaba. A simple correlation matrix was deployed to compare the data measured with the instrument and that of NIMET and a correlation value (r) of 0.96 (RH), 0.97 (air temperature) and 0.93 (wind speed) were obtained. These showed that the data were similar and strengthened the decision to deploy the instruments to the field for measurements.

The Effective Temperature Index (ET) formula (see equation 1); was used to compute the thermal comfort characteristics in both localities. Usually the index recognizes that an effective temperature of 18.9⁰C-25.6⁰C is the normal effective temperature. If higher it will result in heat stress and if lower, it results in cold stress (Ayoade, 2012).

$$ET=0.4 (Td + Tw) + 4.8 \tag{equation 1}$$

In equation 1:

ET represents effective temperature

Td represents dry bulb temperature in ⁰C

Tw represents wet bulb temperature in ⁰C

0.4 & 4.8 are constants.

Since the study was about comparing thermal conditions in both localities, the paired samples t test was used to analyse the difference in effective temperature index in Asaba and Igbuzor. The choice of the paired t test rests on the fact that the data sets were two and the quest was to find the difference in the means of the data sets (Tekler et al., 2023). The paired samples t test can be used when the following data conditions are fulfilled: a) the variables were measured in interval or ratio scale; b) independent observations one to the other c) such data must be normally distributed and d) the data set must not contain outliers. These were all fulfilled in this study. The statistical package for the social sciences (SPSS) version 26 was used for data analysis.

DATA PRESENTATION AND DISCUSSION

Historical climate characteristics in Asaba and Igbuzor

The historical patterns of weather parameters in Asaba are revealed in Table 2. Monthly averages of mean temperature, minimum temperature, maximum temperature, relative humidity, and sunshine hours are presented in the Table 2. Average temperature for Asaba ranged between 29.9°C in February when the temperature is highest to 25.7°C in July. This suggests that mean temperature in Asaba is highest in the month of February when the heat wave is at its peak in the region and coolest in the peak of the rainy season. This finding agrees with that of (Ozabor, & Nwagbara, 2018) on the same region. This is also instructive for residents and occupants in the area on how to plan for thermal discomfort in the region. This also suggests that February and March are critical when planning architectural designs in the region.

Table 2: historical monthly mean temperature, minimum temperature, maximum temperature, relative humidity, and sunshine hours in Asaba

Variables	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
ATP °C	29.2	29.9	29.6	28.7	27.6	26.4	25.7	25.7	26.1	26.5	27.4	28.6	27.6
MnTP °C	23.7	24.9	25.1	24.9	24.3	23.5	23	22.9	23.2	23.4	23.8	23.8	23.9
MTP °C	34.6	34.9	34	32.4	30.8	29.2	28.4	28.4	28.9	29.5	31	33.3	31.3
RH %	65	70	78	83	86	88	88	87	88	88	82	71	81.2
SSH Hrs	8.3	7.7	7.2	6.2	6	5.6	5.3	5.2	5.2	5.5	6	7.5	6.3

ATP refers to Average temperature; MnTP refers to Minimum temperature, MTP refers to maximum temperature; RH refers to relative humidity; SSH Hrs refers to sunshine hours

Source: Field work (2022)

The mean monthly minimum temperature in Asaba is near uniform all year round with a range of 2.2°C. This is only a glitch resulting from the difference in minimum temperature for March and August. Again this represents the peak of the two seasons. Thus it is possible to conclude that the seasons play significant effect on the patterns of the temperature patterns in Asaba. As for the Maximum temperature, the month of February (34.9°C) recorded the highest; while the months of July (28.4°C) and August (28.4°C) recorded the lowest. These findings are in consonance with that of (Amasuomo & Onyia, 2014). Relative humidity increased from 65% in January to 88% in the months of peak rainfall, thereby defining the area in its climate characteristics of being a tropical region. Conversely, the sunshine hours also decreased in sympathy to the emergence of the rainy seasons where January recorded an average of 8.3 sunshine hours and the months of August and September recorded the lowest sunshine hours in the area with 5.2 sunshine hours respectively.

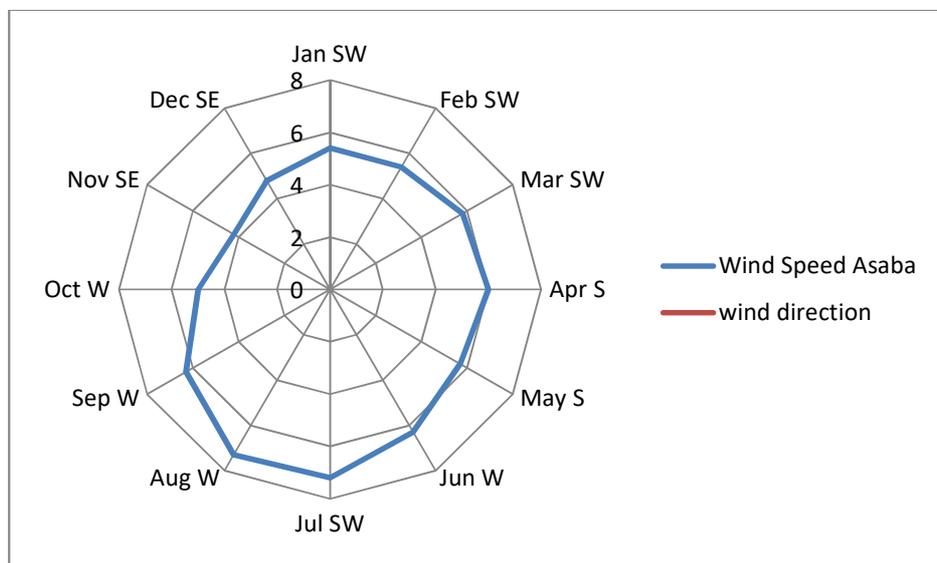


Figure 2: Wind characteristics in Asaba

The historical characteristics of wind speed and direction for the area are presented in Figure 2. In the figure the maximum wind speed occurs in the months of June, July, August and September. The preponderant wind direction is west and southwest winds.

The historical patterns of weather parameters in Igbuzor are revealed in Table 3. Monthly averages of mean temperature, minimum temperature, maximum temperature, relative humidity, and sunshine hours are presented in the Table 3. Average temperature for Igbuzor ranged between 29.4°C in March when the temperature is highest to 25.5°C in July. This suggests that mean temperature in Igbuzor is highest in the month of March when the heat wave is at its peak in the region and coolest in the peak of the rainy season. This finding agrees with that of (Onifade et al., 2013) on the same region. This is also instructive for residents and occupants in the area on

how to plan for thermal discomfort in the region. This also suggests that January, February, and March are critical months when planning architectural designs in the region.

Table 3: Historical Monthly Mean Temperature, Minimum Temperature, Maximum Temperature, Relative Humidity and Sunshine Hours in Igbuzor

Variables	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
ATP °C	28.5	29.2	29.4	28.2	27.2	26.0	25.5	25.7	25.7	26.1	27.2	28.2	27.2
MnTP °C	23	24.1	25	24.4	24	23	23	22.9	23	23	23.4	23.3	23.5
MTP °C	34	34.3	33.7	32	30.3	29	28	28.4	28.3	29.1	31	33	30.9
RH	65	70	78	83	86	88	88	87	88	88	82	71	81.2
SSH Hrs	8.3	7.7	7.2	6.2	6	5.6	5.3	5.2	5.2	5.5	6	7.5	6.3

ATP refers to Average temperature; MnTP refers to Minimum temperature, MTP refers to maximum temperature; RH refers to relative humidity; SSH Hrs refers to sunshine hours.

Source: Field work (2022)

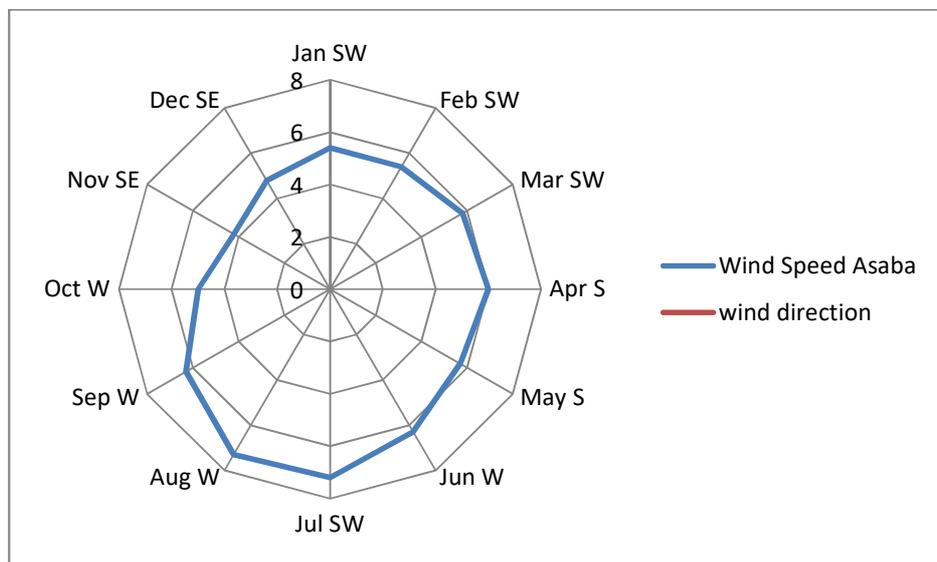


Figure 3: Wind characteristics in Igbuzor

The minimum temperature in Igbuzor is near uniform all year round with a range of 2.1°C. This is only a glitch resulting from the difference in minimum temperature for March and August. Again this represents the peak of the two seasons. Thus it is possible to conclude that the seasons play significant effect on the patterns of the temperature patterns in Igbuzor. As for the Maximum temperature, the month of February (34.3°C) recorded the highest; while the months of July

(28.4°C), and August (28.4°C) recorded the lowest. These findings are in consonance with that of (Nwagbara et al., 2017). Relative humidity increased from 65% in January to 88% in the months of peak rainfall, thereby defining the area in its climate characteristics of being a tropical region. Conversely, the sunshine hours also decreased in sympathy to the emergence of the rainy seasons where January recorded an average of 8.3 sunshine hours and the months of August and September recorded the lowest sunshine hours in the area with 5.2 sunshine hours respectively.

There exists a contrast in the temperature patterns of both localities. The values posted for maximum temperature and minimum temperature are not similar. The values recorded for Asaba were higher than that of Igbuzor. This could have been caused by local heating resulting from urbanization, congestion and proliferation of concreted surfaces highly lucid in Asaba in comparison with Igbuzor. This is as also found by Ojeh (2011) in a similar study in Warri and environs.

The historical characteristics of wind speed and direction for the area are presented in Figure 3. In the figure the maximum wind speed occurs in the months of June, July, August and September. The preponderant wind direction is west and southwest winds.

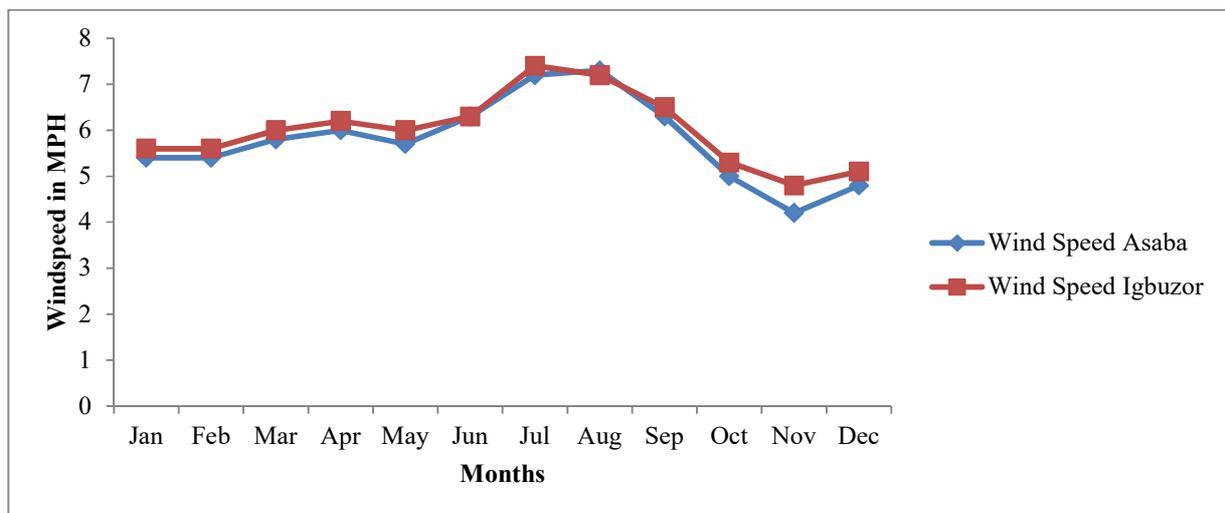


Figure 4: Wind speed plots for Asaba and Igbuzor

Figure 4 presented a graphical comparison of wind speed characteristics in both localities (Asaba and Igbuzor). The wind speed in Igbuzor ranged from 5.6 Mph in January to peak at July at 7.5Mph. Contrarily, the wind speed in Asaba recorded 7Mmph in July. During the months of November and December the wind speed is at its lowest. This partly explains the thermal discomfort experienced in Asaba at these times of the Year. Another factor responsible for lower wind speed in Asaba is the development of urban canyons resulting from high buildings (Samson

& Olorunnimbe-Rafiu, 2011). These have serious deflective capacity on wind and also its buoyancy (Adaramola et al., 2014).

The decadal temperature characteristics for Asaba and Igbuzor are as presented in Figure 5. In all four decades were examined (1983-1992; 1993-2002; 2003-2012; 2013-2022). Also in Figure 5 are 3 diagrams. Graph A showed the mean decadal temperature dissimilarities in Igbuzor and Asaba. Graph B presented the differences in maximum temperature in Asaba and Igbuzor; while graph C revealed the decadal dissimilarities in minimum temperature characteristics in Asaba and Igbuzor. For decadal mean temperature, the first decade showed that Asaba posted a mean temperature of 27.5°C whereas Igbuzor was 27°C. In the next decade (1993-2002) Asaba recorded a mean temperature of 27.8°C while Igbuzor recorded 27.2°C. In the third decade (2002-2012), mean decadal temperature in Asaba was 28.1°C while that of Igbuzor was 27.3°C. In the last decade (2013-2022), mean temperature in Asaba was 28.5°C and that of Igbuzor was 27.4°C.

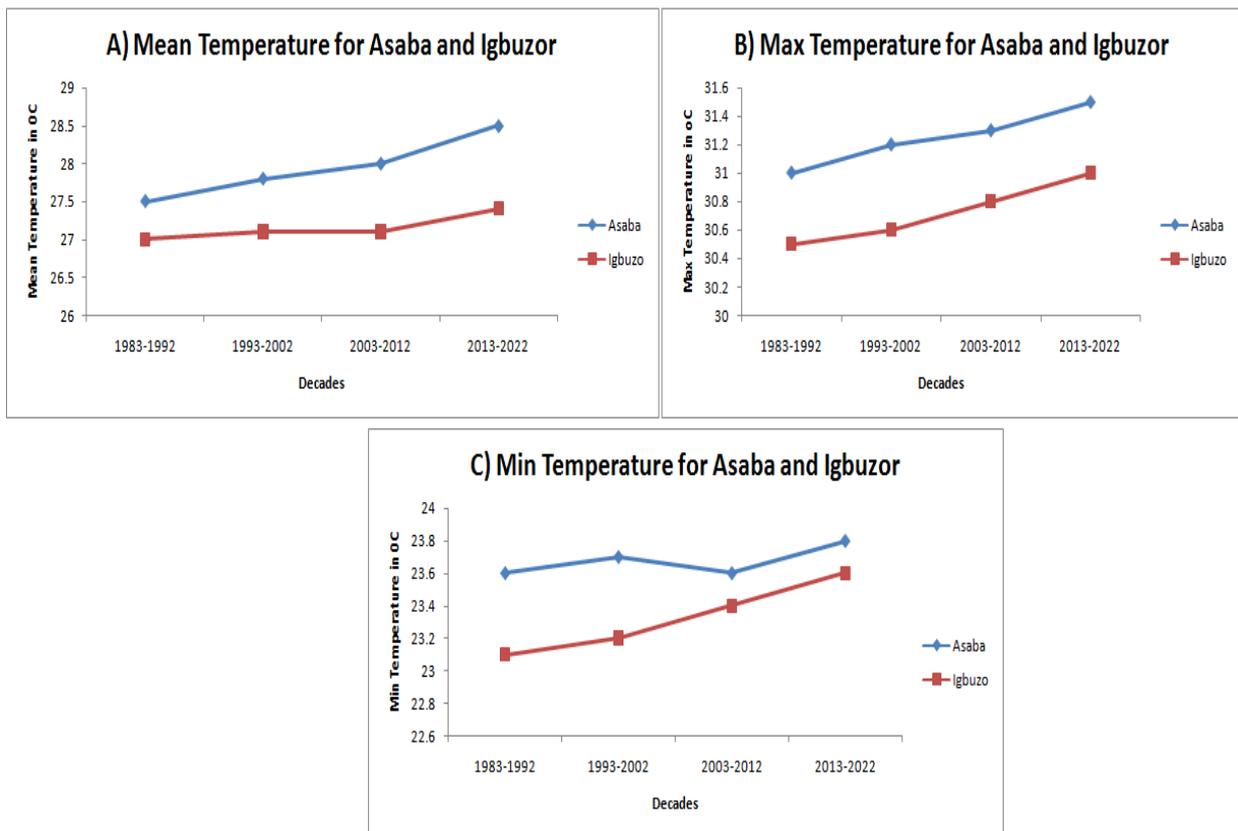


Figure 5: Decadal temperature patterns in Asaba and Igbuzor

For decadal maximum temperature, the first decade showed that Asaba posted a maximum temperature of 31°C whereas Igbuzor was 30.5°C. In the next decade (1993-2002) Asaba

recorded a maximum temperature of 31.2°C while Igbuzor recorded 30.7°C. In the third decade (2002-2012), maximum decadal temperature in Asaba was 31.4°C while that of Igbuzor was 30.7°C. In the last decade (2013-2022), maximum temperature in Asaba was 31.6°C and that of Igbuzor was 30.8°C. An examination of decadal minimum temperatures showed that in the first decade Asaba posted a minimum temperature of 23.6°C, whereas Igbuzor was 23.1°C. In the next decade (1993-2002) Asaba recorded a minimum temperature of 23.7°C while Igbuzor recorded 23.3°C. In the third decade (2002-2012), minimum decadal temperature in Asaba was 23.5°C while that of Igbuzor was 23.4°C. In the last decade (2013-2022), minimum temperature in Asaba was 23.8°C and that of Igbuzor was 23.6°C.

Generally, it is evident that the temperature in Asaba is rising faster than is the case in Igbuzor, although the maximum temperatures in Igbuzor increased remarkably in the last decade, indicating the increase in development in Igbuzor. The urbanization characteristics in Asaba and Igbuzor are not same. More interesting is that the urban expansion has continued without abating. This partly explains the differences in the thermal comfort conditions observed in this study. However, the rising temperatures in Igbuzor can be explained by the conurbation effects of the Asaba metropolis, so that in more recent times developers have preferred to build in Igbuzor and other peri-urban areas such as Ogbolu, Okpanam and Illah. This also explains the rising cost of land rent in Igbuzor (Olanrele & Agbato, 2014; Indraganti et al., 2015).

Weather characteristics in Asaba and Igbuzor

As stated, weather parameters at the indoor and outdoor levels were also measured. Mean outdoor temperature, minimum temperature, maximum temperature, relative humidity and sunshine hours in Asaba and Igbuzor are presented in Table 4. The interest herein is to show the observed differences in the weather characteristics. Average (mean) temperature for Asaba and Igbuzor showed a difference of 0.5°C.

Table 4: mean annual outdoor temperature, minimum temperature, maximum temperature, relative humidity and sunshine hours in Asaba and Igbuzor

Variables	Asaba (Mean)	Igbuzor (Mean)	Difference
ATP °C	27.8	27.3	0.5
MnTP °C	24	23.6	0.4
MTP °C	31.5	31	0.5
RH	81.5	81.3	0.2
SSH Hrs	6.5	6.5	0

ATP refers to Average temperature; MnTP refers to Minimum temperature, MTP refers to maximum temperature; RH refers to relative humidity; SSH Hrs refers to sunshine hours

Source: Field work (2022)

As for the minimum temperature 0.4°C difference was recorded for both localities. As for Maximum temperature a difference of 0.5°C was recorded. For relative humidity, outdoor values were only different with 0.2% and as for sun shine hours both localities posted same values.

Data on mean indoor temperature, minimum temperature, maximum temperature, relative humidity and sunshine hours in Asaba and Igbuzor are presented in Table 5. The interest herein is to show the observed differences in the weather characteristics at the indoor levels. Average (mean) indoor temperature for Asaba and Igbuzor showed a difference of 0.7°C, while a minimum temperature 0.8°C difference was recorded for both localities. A maximum temperature a difference of 0.6°C was recorded, while an indoor relative humidity difference of 0.8% was also noted.

Table 5: Mean Indoor Temperature, Minimum Temperature, Maximum Temperature, Relative Humidity and Sunshine Hours in Asaba and Igbuzor

Variables	Asaba (Mean)	Igbuzor (Mean)	Difference
ATP °C	28.1	27.4	0.7
MnTP °C	24.1	23.3	0.8
MTP °C	32.1	31.5	0.6
RH	76.5	77.3	0.8

ATP refers to Average temperature; MnTP refers to Minimum temperature, MTP refers to maximum temperature; RH refers to relative humidity; SSH Hrs refers to sunshine hours

Source: Field work (2022)

The mean monthly indoor and outdoor temperature characteristics in Asaba and the differences observed are presented in Table 6. Asaba recorded the highest differences in indoor-outdoor temperatures in the dry months of the year such as February (0.4°C), November (0.6°C) and December (0.5°C). However, October posted a high difference due to the erratic nature of weather at the period of the year due to transition from the rainy season to the dry season.

Table 6: Mean monthly indoor and outdoor temperature characteristics in Asaba

Mean indoor-outdoor Temperature in Asaba (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Indoor	28.1	28.2	28.3	28	28.2	26.5	26.4	26.3	27	27.6	27.8	28
Outdoor	27.8	27.8	27.9	27.6	27.9	26.7	26.2	26	26.7	26.9	27.2	27.5
Difference	0.3	0.4	0.4	0.4	0.3	-0.2	0.2	0.3	0.3	0.7	0.6	0.5
Max indoor-outdoor Air Temperature in Asaba (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Indoor	31.5	31.7	31.8	31.4	31.9	30.5	30.3	30.1	31.2	31.3	31.4	31.5
Outdoor	32.1	32.1	32.2	32	32.3	31.5	31.4	31.3	32	32.1	32.4	32.4
Difference	-0.6	-0.4	-0.4	-0.6	-0.4	-1	-1.1	-1.2	-0.8	-0.8	-1	-0.9

Min indoor-outdoor air Temperature in Asaba (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Indoor	24.1	24.1	24.2	24	24	23.8	23.6	23.5	23.8	23.9	24	24.1
Outdoor	24	23.9	23.8	23.7	23.6	23	23	23.1	23.5	23.6	23.8	24
Difference	0.1	0.2	0.4	0.3	0.4	0.8	0.6	0.4	0.3	0.3	0.2	0.1

Source: Field work (2022)

As for maximum temperature, the indoor temperatures were lower than the outdoor maximums. However, January and December posted higher differences due to the impact of harmattan during that period of the year (Sanusi, 2012). The minimum indoor temperature was higher than the outdoor minimum temperatures in Asaba throughout all the months of the year. The main reason for this is that the personal effects of the persons living within the building and the fact that most fenestrations are closed in the night times partly explains the higher indoor temperatures compared to the outdoor ones. The months of June (0.8°C), and July (0.6°C) had higher differentials in the indoor-outdoor minimum temperature across all months of the year.

The mean monthly indoor and outdoor temperature characteristics in Igbuzor and the differences observed are presented in Table 7. Mean indoor and outdoor in Igbuzor recorded the highest differences in indoor-outdoor temperatures in the dry months of the year such as November(0.6°C), December (0.5°C) and December (0.5°C).

Table 7: Mean monthly indoor and outdoor temperature characteristics in Igbuzor

Mean indoor-outdoor Temperature in Igbuzor (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Indoor	27.4	27.35	27.35	27.15	27.45	26.5	25.8	25.65	25.9	26.45	27.05	27.25
Outdoor	27.3	27.35	27.4	26.7	27.2	26.55	25.5	25.5	25.85	26.25	26.45	26.75
Difference	0.1	0	-0.05	0.45	0.25	-0.05	0.3	0.15	0.05	0.2	0.6	0.5
Max indoor-outdoor Air Temperature in Igbuzor (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Indoor	31.5	31.5	31.6	31.3	31.5	30	29	28.8	29	30	31	31.3
Outdoor	31	31	31.2	30	30.8	30	28	28.5	29	29.7	30	30.4
Difference	0.5	0.5	0.4	1.3	0.7	0	1	0.3	0	0.3	1	0.9
Min indoor-outdoor air Temperature in Igbuzor (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Indoor	23.3	23.2	23.1	23	23.4	23	22.6	22.5	22.8	22.9	23.1	23.2
Outdoor	23.6	23.7	23.6	23.4	23.6	23.1	23	22.5	22.7	22.8	22.9	23.1
Difference	-0.3	-0.5	-0.5	-0.4	-0.2	-0.1	-0.4	0	0.1	0.1	0.2	0.1

Source: Field work (2022)

As for maximum temperature, the indoor temperatures were lower than the outdoor maximums. However, April November and December posted higher differences due to the impact of harmattan during that period of the year (Sanusi, 2012) and the transition from dry season to

rainy season in April. The minimum indoor temperatures were lower than the outdoor minimum temperatures in Igbuzor throughout all the months of the year.

The mean indoor-outdoor temperature, minimum temperature, maximum temperature, relative humidity and wind speed in Asaba and Igbuzor, at the climatological hours of the day, are shown in Table 8. The interest herein was to compare the observed differences in the weather characteristics at the indoor and outdoor levels. Generally at all times of the day, temperatures in Asaba were hotter than in Igbuzor. However, temperature graduated from the morning hours and peaked at the 18:00 hrs. For instance the outdoor mean temperature for 00:00hrs in Asaba was 25.8°C compared to that of Igbuzor for same hour that was 25.6°C. From this point the mean temperature increases to peak at 27.8 °C for Asaba and 26.6°C for Igbuzor. Same can be said of the minimum and the maximum temperature in the Asaba and Igbuzor. However, maximum temperature appeared to be same for Asaba and Igbuzor at the 12:00 hrs. The reason for this is that this is the peak of sun shine in the day. Relative humidity and the wind speed are similar in both locations. This is expected as these weather variables are large scale ones having pervasive influence on the regional climates (Ozabor & Nwagbara, 2018).

Table 8: Mean indoor and outdoor weather characteristics in Asaba and Igbuzor during different times of the day

		Time of day weather characteristics							
Time	Location	Outdoor				Indoor			
		0:00	6:00	12:00	18:00	0:00	6:00	12:00	18:00
AaTP (°C)	Asaba	25.8	26.4	27.6	27.8	26.8	26.9	28.1	28.5
	Igbuzor	25.6	25.8	27.1	27.3	26.6	26.3	27.6	28
MnTP(°C)	Asaba	21.5	21.8	23.1	24.2	22.5	22.3	23.6	24.9
	Igbuzor	20.8	21.6	22.1	23.6	21.8	22.1	22.6	24.3
MTP(°C)	Asaba	28.5	28.9	30.5	31.6	29.5	29.4	31	32.3
	Igbuzor	28	28.3	30.5	31	29	28.8	31	31.7
RH (%)	Asaba	80.5	81	81	81.3	78.5	78.9	81.5	82
	Igbuzor	80	80.1	80.6	80	78	77.5	81.1	80.7
wind speed (MPH)	Asaba	7.3	7.1	6.8	6.5	3.8	3.9	3.1	3
	Igbuzor	7.2	7.2	7	6.9	4	4	4.1	4.3

ATP refers to Average temperature; MnTP refers to Minimum temperature, MTP refers to maximum temperature; RH refers to relative humidity; SSH Hrs refers to sunshine hours

Source: Field work (2022)

On the other hand, the indoor temperatures were higher than the outdoor ones whether in Asaba or at Igbuzor. This is a clear indication of the fact that the weather system outdoor is not directly proportional to the indoor thermal environment. A close look at the outdoor wind speed and the indoor ones show that the wind speed is lower indoor than it is with the outdoor wind speed. This is a clear indication of building fenestrations faults, household sizes and the space constraint created indoor and the use of some gadgets which could be influencing the indoor thermal

conditions negatively. This finding agrees with that of Wodu et al., (2020), but disagrees with van der Linden et al., (2002) where the indoor temperature was found to be directly proportional to the outdoor ones.

Table 9 revealed the mean seasonal temperature for Asaba and Igbuzor at both the dry and wet seasons. Indoor temperatures were higher than outdoor ones for all the temperature characteristics, in Asaba and Igbuzor, except for maximum temperature, which was higher outdoors than indoor in Asaba and Igbuzor.

Table 9: Mean seasonal indoor and outdoor weather characteristics in Asaba and Igbuzor

Weather elements	Locations	Asaba		Igbuzor	
		Dry Season	Rainy Season	Dry Season	Rainy Season
Mean Temperature (°C)	Indoor	27.9	27.1	27.1	26.4
	Outdoor	27.4	26.9	26.9	26.2
Max Temperature (°C)	Indoor	31.5	30.8	31.2	29.9
	Outdoor	32.2	31.7	30.6	29.4
Min temperature (°C)	Indoor	24.1	23.8	23.2	22.8
	Outdoor	23.9	23.3	23.4	22.8
Wind Speed (MPH)	Indoor	3.4	3.5	3.6	4.2
	Outdoor	6.5	7	6.8	7.3
RH (%)	Indoor	72.5	81.9	80.1	80.6
	Outdoor	77.8	85	81	88

Source: Field work (2022)

The indoor-outdoor wind speed and RH were dissimilar whether in Asaba or Igbuzor. The rainy seasons wind speed in Igbuzor at the indoor levels was closer to the outdoor ones in the rainy seasons compared to the one of Asaba. This is a clear indication that the indoor thermal condition in Igbuzor would be cooler than that of Asaba in the rainy periods.

Figure 6 showed the effective temperature characteristics for Asaba and Igbuzor respectively. Figure 6A described the effective temperature characteristics for the study area. Whereas, ET for Asaba was determined to be 27.6 °C, ET for Igbuzor was 24.5°C. This shows that the Asaba mean ET is higher than that of Igbuzor. The factors responsible for this include congestion (Araújo et al., 2006), congested indoor apartments (Van Heesch et al., 2020) and building surrounding characteristics such as concreted surfaces, poor setbacks and poor building orientation (Al-Homoud, 2005), which is rampant in Asaba and less rampant in Igbuzor.

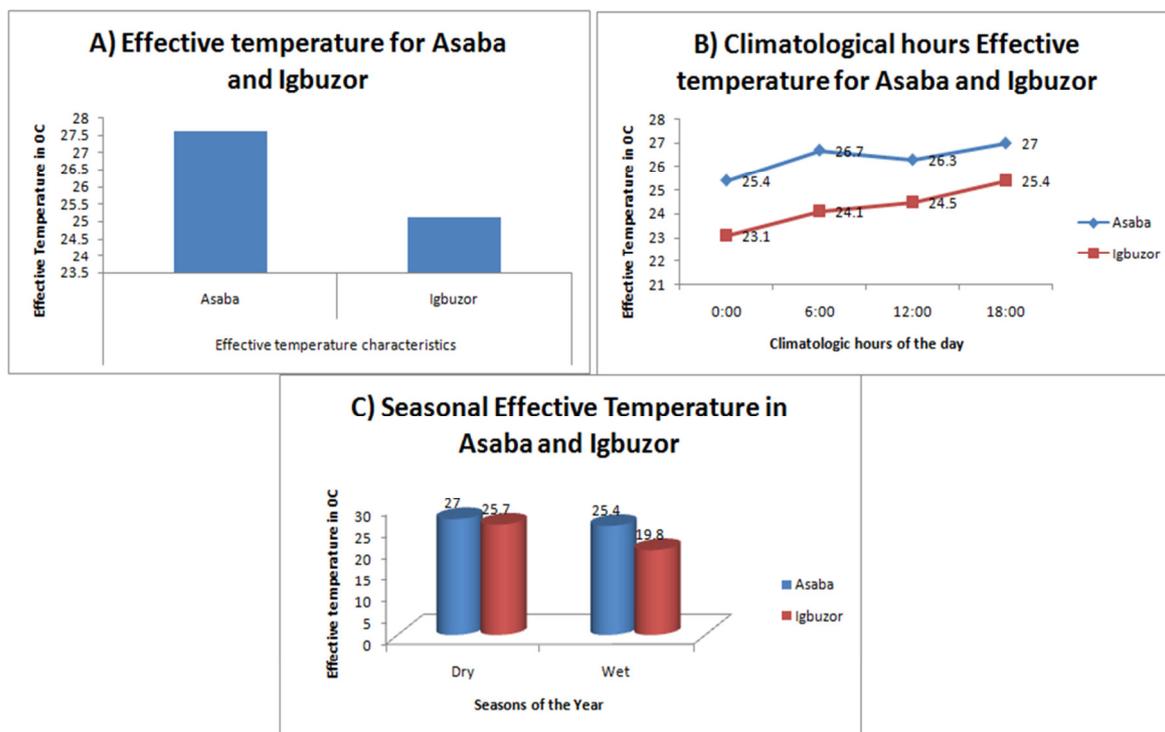


Figure 6: Effective temperature characteristics in Asaba and Igbuzor

Also, ET for the climatologic hours as presented in figure 6B indicated that the temperatures in Igbuzor and Asaba were coolest at 0:00hrs with ET value of 23.3 °C and 25.4 °C respectively. From that point the ET increases and peaks at 18:00 hrs. As for the seasonal ET characteristics, Dry seasons ET for both locations were higher than the wet periods. For example Asaba posted ET 27(°C) in the dry season, while the wet season corresponding ET was 25.4(°C). In Igbuzor, dry seasons ET was 25.7(°C) and the wet season corresponding value was 19.8 (°C). These are clear indications that given the same building design and characteristics Igbuzor is cooler than Asaba and possess better effective temperature at the indoor levels. This is not unconnected with the amount of green vegetation still available in Igbuzor and lacking in Asaba due to development (Benjankar et al., 2011), on one hand, and on the other, the rates of congestions and the building characteristics in Asaba relative to Igbuzor.

Table 10: Differences in effective temperature in Asaba and Igbuzor

Variables	Std div	mean	Std err	t	Df	Sig
ET Asaba - ET Igbuzor	1.0021	1.7123	0.0341	10.3	364	0.0312

Source: Field work (2022)

The comparison between the effective temperature characteristics in both localities (Asaba and Igbuzor) is presented in Table 10. The paired samples t test was used to carry out the comparison. The model turned out significant at $p < 0.05$ (stdv 1.0; means diff 1.7; t 10.3; df 364; sig 0.03). This indicates that the ET in Asaba is significantly different from that of Igbuzor. More so, that the mean difference has no negative sign shows that the ET Asaba is higher than that of Igbuzor.

CONCLUSION AND RECOMMENDATIONS

The quest of the current study was to investigate the thermal comfort similarities or dissimilarities in Asaba and Igbuzor at the indoor-outdoor levels. To be able to do this the historical information of the two localities were investigated to see if there has been a change in their patterns of occurrence over the years. It is common to trace the changes in thermal conditions to climate change resulting mostly from anthropogenic activities and actions. Also, the study measured the weather conditions locally to find out the indoor/outdoor thermal conditions and in addition compare the difference in the thermal conditions.

Findings indicated that monthly average temperature for Asaba is highest in the month of February when the heat wave is at its peak in the region and coolest in the peak of the rainy season. Compared to that of Igbuzor that ranged between 29.4°C in March when the temperature was highest to 25.5°C in July. The mean monthly minimum temperature in Asaba was near uniform all year round with a range of 2.2°C; compared to that of Igbuzor which was near uniform all year round but with a range of 2.1°C. The mean monthly maximum temperature revealed that the month of February (34.9°C) was highest; while the months of July (28.4°C) and August (28.4°C) recorded the lowest. In Igbuzor, the mean monthly maximum temperature showed that the month of February (34.3°C) recorded the highest; while the months of July (28.4°C) and August (28.4°C) recorded the lowest. In Asaba, the mean monthly relative humidity increased from 65% in January to 88% in the months of peak rainfall; and was relatively same for Igbuzor. Mean monthly sunshine hours also decreased in sympathy to the emergence of the rainy seasons where January recorded an average of 8.3 sunshine hours and the months of August and September recorded the lowest sunshine hours in the area with 5.2 sunshine hours. The mean maximum wind speed occurred in the months of June, July, August and September; the same was recorded for Igbuzor. The preponderant wind direction for both locations was west and southwest winds.

The study is not without some limitations such as the lack of enquiry from the occupants of the buildings what their thermal perceptions are. Also, the current attempt did not find out the cost of thermal cooling in both localities. Thirdly, the building design failures that could be responsible for the poor thermal conditions in both localities were not ascertained. These all fell outside the scope of the current study and as such form areas for further investigation. Notwithstanding this, the findings of the current study suffice to conclude the following;

- i. The temperature characteristics in Asaba are different from that of Igbuzor even though they are geographically close to each other.
- ii. The effective temperatures in Asaba were grossly negative in the dry seasons, though they fell within the permissible limits in the cool periods. On the other hand the ET for Igbuzor fell within the thermal range throughout the year.

In general, based on the findings of this study for Asaba and Igbuzor, it is recommended that there be the revisiting of the building construction processes and planning in these localities. Also, there is the need to carry out further studies in the region, to find out the conditions being experienced by residents as a result of thermal discomfort in these locations.

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