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Relationships between outdoor and indoor temperature characteristics in Yenagoa, Nigeria

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This study examined the relationships between outdoor and indoor temperature characteristics in Yenagoa, Bayelsa State, Nigeria. It adopted the quasi experimental research design; as such data on meteorological parameters, such as, outdoor and indoor temperature were collected using thermometer and hygrometer, by the researcher in the study area and at designated locations in the metropolis, baring land-use in mind. The effective temperature equation was thereafter used to determine the effectiveness of the indoor temperatures, while the Pearson's product moment correlation coefficient was used to determine the relationships between the outdoor and indoor temperature characteristics. Results indicate that the relationships between indoor and outdoor temperatures were not positive all year round. At the dry periods, outdoor temperatures showed strong correlation with that of indoor at $p<0.05$, but at rainy season temperatures outdoor showed weak association with indoor temperature at $p>0.05$. This implies that the relationships between indoor and outdoor temperatures are, to a good extent, dependent on seasons. There is, therefore, the need to design buildings based on climate. Yenagoa being a typical humid tropical area, more windows are recommended for buildings in it to help improve ventilation, and by extension, physiological comfort.

Key words: Outdoor, indoor, effective-temperature, Yenagoa.

INTRODUCTION

Buildings are designed among other things to give shelter, comfort and security of life and properties to the occupants and or the owners of them (Cheng et al., 2012; Ojeh, 2011; Oluwafemi et al., 2010; Uzuegbunam et al., 2012; Abotutu and Ojeh, 2013). Therefore, buildings are supposed to be designed in such a way that "comfort" of the occupants be paramount, while not undermining security of the properties and persons who occupy the buildings. This is because the comfort obtained by occupants of buildings, guarantee proper rest and maintenance of good health of such persons (Uzuegbunam et al., 2012).

To realise comfort in buildings, indoor temperature is very import. This is because, apart from generating

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comfort for the dwellers of such building, health benefits also arise from it (Barnett and Astrom, 2012; Mavrogianni et al., 2012; Nguyen et al., 2014; Ostro et al., 2010; Shaman et al., 2010; Shoji et al., 2011; Strand et al.,, 2011; Tamerius et al., 2013; Turner et al., 2012; van Noort et al., 2011; Ye et al., 2012). More recent researches (Barnett and Astrom, 2012; Mavrogianni et al., 2012) have shown that temperature indoor determines to a great extent the liveability of buildings. Uzuegbunam et al. (2012) and Abotutu and Ojeh (2013) also showed in their study that there is a great degree of association between the indoor temperature and the health quality of occupants. Apart from design issues, the climatological positioning of buildings is also very important. Where the sun rises and sets, the direction of wind and the ventilation capacity of the building are equally all important. As a result of the dangers that could emanate from poorly planned building structure, architects and builders in the developed world give adequate attention to not only the aesthetics of a building, but also to the capacity of such building to give comfort through proper ventilation, positioning (that is paying attention to the windward direction and the sun ray direction) (Uzuegbunam et al., 2012). All these are done to guarantee optimal comfort for inhabitants of buildings (Abotutu and Ojeh, 2013).

Nevertheless, we have a paradox of the above in the developing world in general and in Nigeria in particular (Abotutu and Ojeh, 2013), where development is never planned. Individuals build without consulting the town planning institutions. The architects are not in most cases consulted nor are the civil engineers. This is done by intending developers to evade the cost resulting from the services they render. Again, when the town planning officers discover buildings they never approved, it is marked for demolition, after payment of some bribes the ban is lifted and such buildings are yet constructed. Furthermore, the land rent issues and the quest of developers to maximise profit from housing rent, leads to the construction of substandard buildings. These buildings do not give any comfort to the occupants, which in turn, results in poor rest especially at nights (Barnett and Astrom 2012; Mavrogianni et al., 2012; Nguyen et al., 2014; Ostro et al., 2010), poor health (Shaman et al., 2010; Shoji et al., 2011; Strand et al, 2011) and even death (Tamerius et al., 2013; Turner et al., 2012; van Noort et al., 2011; Ye et al., 2012).

Previously, studies have looked at the interrelations, between indoor and outdoor temperature by looking at their relationships with humidity patterns (Barnett and Astrom 2012; Mavrogianni et al., 2012; Nguyen et al., 2014; Ostro et al., 2010; Arena et al., 2010). Others have looked at relationships between outdoor and indoor temperature by looking at two building types (White-Newsome et al., 2012; Arena et al., 2010). Abotutu and Ojeh (2013) attempted the characterisation of the physiologic comfort characteristics of buildings in Warri, Delta State; however the use of only the rainy periods undermines the intricate thermal comfort characteristics that may be inherent in the dry periods. More so, to the best of the researchers knowledge, there is no known work on thermal comfort in Yenagoa. This study is conducted to fill these gaps.

MATERIALS AND METHODS

The study was conducted in Yenagoa, the capital of Bayelsa State, Nigeria. It is located between latitudes 4°52' and 4°58' N and longitudes $6^0$16' and 6°20' E (Figure 1). The size of the city is about 21,110km^2 (Google Earth, 2016). At the north, the area is bordered by Kolokuma/Opokuma Local Government Area (LGA), south by Southern-Ijaw LGA, at the west by Sagbama LGA and to the east by Ogbia LGA (Iyorakpo, 2015).

The area falls within the tropical environment that enjoys the tropical rain forest climate of Koppen's (1918) and the west equatorial climate of Strahler (1965). The climate of the state is influenced by two principal air masses, namely, Tropical Maritime Air-mass (mT) and Tropical Continental Air-mass (cT). These two air masses determine the seasons of the area, which are the wet and dry seasons respectively. Although in recent times research (Efe, 2010) has shown that climatologically speaking there is no clear cut dry season in the area as all months have an average rain fall amount of 0.25 mm. However, the anthropogenic activities in the area in recent decades which is an exodus from the discovery and mining of crude oil in the area has resulted in the emission of GHGs, deforestation, and the altering of the original climate of the study area (Efe, 2010). As a result, the building comfort characteristics in the area, is already greatly affected and if nothing is done to ameliorate the conditions, the already devastating building comfort stress will persist.

The research design employed is the experimental design. The design has also been used by Ojeh (2011). Furthermore, the primary and secondary data were utilised for the research. However the primary data were sourced from the daily reading of the wet bulb and dry bulb thermometers, air temperature, doors as well as outdoor, and humidity levels of sampled points; the secondary data were temperature, solar radiation and relative humidity data for Yenagoa accessed from the archival information of the Nigerian Meteorological Agency (NIMET). The study used stratified sampling technique to delineate the study area into 5 zones using the land-use as yardstick namely:

(i) Residential areas
(ii) Industrial areas.
(iii) Commercial areas.
(iv) Government Reserved Areas (GRA)
(v) Mixed uses

This method of calibration has been used by Efe and Aruegodore (2003), and Ojeh (2011). About 20 neighbourhoods exist in the whole of Yenagoa (Table 1). Within each neighbourhood, all existing streets (598 in number) which are registered with the urban development authority were given identification numbers. Using systematic sampling technique, every 3rd street was picked to influence detailed survey.

The calibration in Table 1 implies that 33.33% of registered streets are sampled. After selecting the streets, 3 houses (Bungalows only) were selected based on predetermined classification of housing type (Table 2). Therefore a total of 597 houses were selected for the study (3 in every street). For the daily reading of the wet and dry bulb thermometers, the living rooms were the sample points. Digital thermometers were mounted at

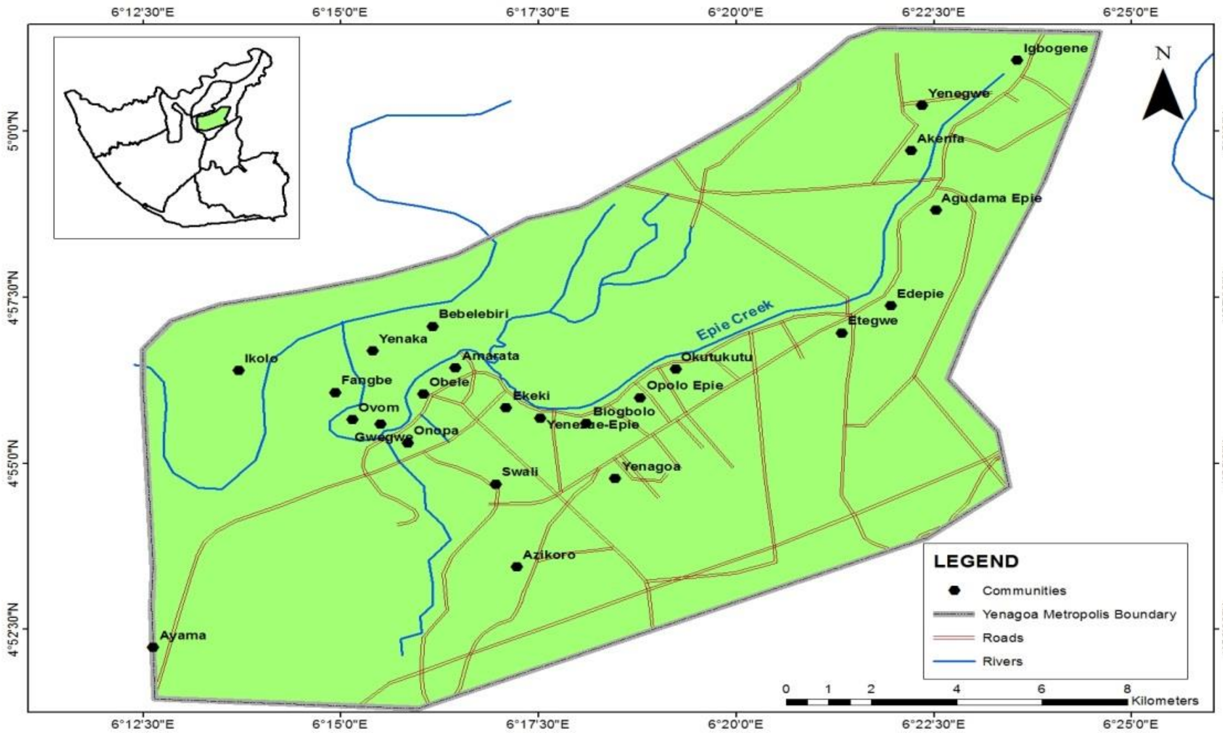

Figure 1. Yenagoa showing major communities.

Table 1. Neighborhoods in the study area and the number of streets sampled.

Zones	Areas	Number of streets	Number of sampled streets	Number of houses to be sampled
A	Agudama, Akenpai, Biogbolo, NIIT	246/3	82	246
B	Bayelsa-Palm, Gbarantoru, Imiringi	17/3	6	116
C	Tombia Round-about, Ede-Epe, Amarata, Swali, Imgbi, Ekeki 1	168/3	56	168
D	Commissioners Qurts, Opolo, G.R.A	54/3	18	54
E	Arieta-line, Kpansia, Okaka, Igbogene	113/3	37	113
Total		598	199	597

Table 2. Building types in Yenagoa.

Building type	Characteristic
1	Stone coated roof, parapet, Pop ceiling, window (casement, Single Hung, Bay, Awning, Arched), ceramic floor tiles
2	Long spam roofing sheets, PVC ceilings, sliding windows, ceramic/cement/rug/plastic carpet floors.
3	Metal zinc/Asbestos roof, louvers/wooden windows, cement/terrazzo floor, asbestos ceilings

1.5 m (5 ft) above the floor for the purpose of uniformity and a scientific approach to data acquisition. Again the standard has been suggested by World Meteorological Organization (WMO). This method has been used by Ojeh (2011) and reasonable success was realised. The dwelling units were divided into those that have air conditioning systems (AC) and naturally ventilated buildings (without fans or air conditions). The primary distinction between the building types was that the non-ventilated buildings have no mechanical air-conditioning. Thus, natural ventilation occurs through detachable windows and doors that are directly controlled by dwellers. Three types of housing units as described in Table 2, were picked from every zone (A-E) based on availability and population of households.

Hygrometer (dry bulb and wet bulb thermometer), maximum and minimum thermometer, digital anemometer (Figure 2), and wind vane (Figure 3) were used to collect primary data on climate. The

Figure 2. Digital anemometer.

Figure 3. Digital wind vane.

traditional way to measure humidity is a two-step process: both wet bulb and dry bulb temperatures are obtained, and then converted to relative humidity using a psychometric chart. The maximum and minimum thermometers measure the air temperature. The measurement techniques involved mounting the thermometers at 5 feet (1.5 m) above the floor level on the north facing wall of living rooms in all the sampling areas. Before the readings of the hygrometer and the maximum and minimum thermometer were done in all sample points, the instruments were made to stay for 5 min, a time-frame within which the instruments adapts to the climatic condition (s) of the particular sample point. This condition is known as the process of standardization of the instrument. This process has been applied by Efe (2006) and was effective. The outdoor temperature reading were taken outside the dwelling premises with the same instrument used for taking the indoor readings also observing the standardization process to get accurate records without any direct contact with the radiation of the sun (by constructing a lookalike of Stevenson screen). The measurement of weather parameters for both indoor and outdoor records was carried out at climatological hours (00:00 h, 6:00 h, 12:00 h, and 18:00 h) as also specified below and for a period of one year. The effective temperature index (ET) (see equation 1) was used to determine the comfort level of the dwelling units as suggested by Ayoade (2004).

$$ET=0.4\,(Td + Tw) + 4.8 \quad (1)$$

Hence, an ET value of 18.9°C or below indicates cold stress, while an ET value of above 25.6°C indicate heat stress (Ayoade, 2004; Ojeh, 2011). The temperature data were analysed using Pearson's product moment correlation coefficient (PPMC). The PPMC is given by the following formula (Ware et al., 2013):

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[\,n\Sigma x^2 - (\Sigma x)^2\,]\,[\,n\Sigma y^2 - (\Sigma y)^2\,]}} \quad (2)$$

Where n is number of observation,
∑ is summation,
X is independent variable 1 (indoor temperature)
Y is dependent variable 2 (outdoor temperature)
The PPMC analysis was carried out in the IBM/SPSS v 22 environment.

Table 3. Average annual weather characteristics in Yenagoa.

DB	WB	RH	WD	WSP	Temp	Rainfall
32.2	23.8	83.3	195	3.5	27.9	208.25

DB: Dry bulb temperature; WB, Wet bulb temperature; RH, Relative humidity; WD, Wind direction; WSP, Wind speed; temp, Mean temperature.

Table 4. Relationships between indoor and outdoor temperatures.

Land-use types	Indoor/outdoor temperature correlations				
	Annual	Dry period	Wet period	With Air cooling units	Without Air cooling units
Residential (r)	0.60	0.81	0.32	0.26	0.75
Sig	0.00	0.00	0.18	0.32	0.00
Industrial (r)	0.56	0.76	0.39	0.17	0.91
Sig	0.00	0.00	0.14	0.10	0.00
Commercial (r)	0.78	0.79	0.25	0.41	0.82
Sig	0.00	0.00	0.11	0.03	0.00
GRA (r)	0.59	0.76	0.34	0.23	0.68
Sig	0.00	0.00	0.06	0.08	0.00
Mixed (r)	0.64	0.81	0.44	0.18	0.83
Sig	0.00	0.00	0.05	0.17	0.00

RESULTS

Table 3 presents the average annual weather characteristics in the study area. The average dry bulb temperature in the table is 32.2°C, while the wet bulb temperature is 23.8°C. The relative humidity is seen to be 83.3% while the wind direction is 195° (South west in orientation). Mean temperature is 27.9°C and rainfall is 208.25 mm. The reflection of the data is that the environment is a tropical type.

In Table 4, the relationships between the indoor and outdoor temperature is displayed. In the table, the relationship between the indoor and outdoor temperature for the whole period of investigation shows that there is generally significant relationships between the indoor and outdoor temperature characteristics in the area at $p<0.05$, although the commercial environment showed a higher relationship with an r value of 0.78. This is misleading, considering what happened in the wet period where all the correlation values for the indoor and outdoor temperatures in the land-uses were generally low and did not reach significance at $p<0.05$ except that of the mixed land use that was r - 0.44 at $p \leq 0.05$.

However, in the dry period the relationships between the outdoor and indoor temperature were significant at $p<0.05$ for all land uses. Nevertheless, the mixed land-use and the residential land use posted higher r values of 0.81 respectively. Conversely, indoor and outdoor temperature in the dwelling units with air conditioner did not have significant relationships at $p<0.05$ in all the land uses, except for the commercial land use which had an r value of 0.41 at $p<0.05$. Furthermore, the dwelling units without air conditioner, all showed significant correlation between the indoor and outdoor temperatures for all land uses, although at varying magnitudes. Characteristically, the industrial area posted higher correlation value of r, 0.91 at $p<0.05$; which is followed by the commercial and mixed land uses with r values of 0.82 and 0.83 respectively.

In Table 5, the thermal comfort characteristics of the dwelling units were computed using the effective temperature equation. In the table for the residential land use, the annual value showed that the effective temperature was normal for the residential area with *ET* value of 24.5°C, the dry period posted *ET* value of 26.01°C which signifies heat stress. The wet period was normal for the residential area with *ET* value of 18.9°C and the dwelling units with AC posted *ET* value of 19.2°C which is normal effective temperature. The same cannot be said for the dwelling units without AC in the area which had an effective temperature value of 26.1°C implying that there is heat stress in the residential area.

In the industrial land use, the annual value showed that the effective temperature was not normal for the industrial area with *ET* value of 26.2°C, the dry period posted *ET* value of 27.9°C which signifies heat stress. The wet period was normal for the industrial area with *ET* value of 20.1°C and the dwelling units with AC posted *ET* value of 19.3°C which is normal effective temperature. The same cannot be said for the dwelling units without AC in the industrial land use which had an effective temperature value of 28.1°C, implying that there is heat stress in the

Table 5. The effective temperature characteristics in the different land-uses of the study area.

Land-use types	Indoor effective temperatures (°C)				
	Annual	**Dry period**	**Wet period**	**With Air cooling units**	**Without air cooling units**
Residential (ET)	24.51	26.01	18.92	19.26	26.12
Industrial (ET)	26.26	27.90	20.15	19.39	28.1
Commercial (ET)	27.02	27.31	19.50	20.01	27.52
GRA (ET)	25.68	25.78	18.73	19.75	25.83
Mixed (ET)	26.05	26.91	20.64	20.64	26.64

ET signifies effective temperature.

Table 6. Relationships between indoor and outdoor temperatures and the effect temperature characteristic based on building types.

Periods in the year		Building types		
		1	**2**	**3**
Annual	RI&O	0.89	0.84	0.91
	ET	28.91	27.34	26.01
Dry period	RI&O	0.71	0.83	0.87
	ET	29.04	27.08	26.95
Wet period	RI&O	0.54	0.49	0.63
	ET	27.08	26.2	25.34

Type 1: Stone coated roof, parapet, Pop ceiling, window (casement, Single Hung, Bay, Awning, Arched), ceramic floor tiles; Type 2: Long spam roofing sheets, Polyvivyl chloride (PVC) ceilings, sliding windows, ceramic/cement/rug/plastic carpet floors. Type 3: Metal zinc/Asbestos roof, louvers/wooden windows, cement/terrazzo floor, asbestos ceilings; ET signifies Effective temperature; RI&O implies relationship between indoor and outdoor temperature.

industrial area. As for the commercial land use, the annual value showed that the effective temperature was not normal for the with *ET* value of 27.0°C, the dry period posted *ET* value of 27.3°C which signifies heat stress. The wet period was normal for the industrial area with *ET* value of 19.5°C and the dwelling units with AC posted *ET* value of 20.0°C which is normal effective temperature. The same cannot be said for the dwelling units without AC in the commercial land use which had an effective temperature value of 27.5°C implying that there is heat stress in the commercial area.

In the government reservation area, the annual value showed that the effective temperature was not normal for the with *ET* value of 25.68°C, the dry period posted *ET* value of 25.78°C which signifies heat stress. The wet period was normal for the area with *ET* value of 18.7°C and the dwelling units with AC posted *ET* value of 19.75°C which is normal effective temperature. The same cannot be said for the dwelling units without AC in the GRA land use which had an effective temperature value of 25.8°C, implying that there is heat stress in the GRA.

Furthermore, in the mixed land uses, the annual value showed that the effective temperature was not normal with *ET* value of 26.05°C, the dry period posted *ET* value of 26.91°C which signifies heat stress. The wet period was normal for the area with *ET* value of 20.64°C and the dwelling units with AC posted *ET* value of 20.64°C which is normal effective temperature. The same cannot be said for the dwelling units without AC in the mixed land use which had an effective temperature value of 26.64°C implying that there is heat stress in the mixed land use.

Table 6 reveals the relationships between the outdoor and indoor temperature and the effective temperatures reached in relation to the calibrated building types. For the annual epoch, the r value between the indoor outdoor temperatures for the building type 1 is 0.89 and an effective temperature for the building type is 28.9°C which is higher than that of building type 2, with r value of 0.84 and an *ET* value 27.34°C. In the building type 3, r value is 0.91 and the *ET* value of 26.1°C was realised.

In the dry period, the r value between the indoor outdoor temperatures for the building type 1 is 0.71 and an effective temperature for the building type is 29.04°C which is higher than that of building type 2, with r value of 0.83 and an *ET* value 27.08°C. In building type 3, r value is 0.87 and the *ET* value of 26.95°C was realised.

However, wet epoch, the r value between the indoor outdoor temperatures for building type 1 is 0.54 and an effective temperature for the building type is 27.08°C which is higher than that of building type 2, with r value of 0.49 and an *ET* value 27.08°C. In the building type 3, r value is 0.63 and the *ET* value of 25.34°C was realised.

DISCUSSION

The relationships between the indoor and outdoor temperature characteristics for the whole period investigated revealed that there is generally significant relationship at $p<0.05$, although the commercial environment showed a higher relationship with an r value of 0.78. The reason for this is not farfetched, as the commercial environment is expected to be hotter as a result of the anthropogenic activities which are constantly carried out in the area. Therefore, outdoor temperatures are expected to affect the indoor temperature in such environment. However, in the wet period the rains encourage the locking of windows and the use of indoor gadgets that could increase the indoor temperature and alter relationships between the outdoor and indoor temperatures. This finding corresponds with that of Uzuegbunam et al. (2012) and Abotutu and Ojeh (2013); that also observed that the relationships between outdoor and indoor temperature were poorly relates in the rainy periods and highly related at the dry periods of the year. However, the study finding varies with that of Arena et al. (2010), who observed a high and significant relationship between indoor and outdoor temperatures even in the rainy period.

However, in the dry period the relationships between the outdoor and indoor temperature were significant at $p<0.05$ for all land uses. Nevertheless, the mixed land-use and the residential land use posted higher r values of 0.81 respectively. This may be as a result of altered temperature due to anthropogenic activities there and the presence of few vegetal covers. Not only that, the openings (windows, doors) in the dwelling units are so small due to space constrain and the quest to make more money from land rent. Conversely, indoor and outdoor temperature in the dwelling units with air conditioner did not have significant relationships at $p<0.05$ in all the land uses, except for the commercial land use which had an r value of 0.41 at $p<0.05$. It is a known fact that, the air conditioning units actually ameliorate hot conditions. However, whether that influences the outdoor temperature of the houses without AC is a phenomenon this current study has not ascertained. Nevertheless, Ojeh (2011) identified in his study that, the use of AC, as coolant in indoor environments does not only consume energy but also releases GHGs into the environment, thereby raising temperatures. He further emphasized that, in the developing environments, there is no power, and dwellers are therefore forced to use generating sets which releases GHGs into the environment, while making outdoor temperatures hotter. This partly explains the case in the study area.

Again the thermal comfort characteristics of the dwelling units were computed using the effective temperature equation revealed that the residential land use, effective temperature was normal for the residential area with *ET* value of 24.5°C, the dry period posted *ET* value of 26.01°C which signifies heat stress. The wet period was normal for the residential area with *ET* value of 18.9°C and the dwelling units with AC posted *ET* value of 19.2°C which is normal effective temperature. The same cannot be said for the dwelling units without AC in the area which had an effective temperature value of 26.1°C implying that there is heat stress in the residential area. This is particularly, not so good for the residents. This is because the mere fact that the indoor thermal comfort characteristics is higher than normal, signifies that the residents would have stressful rest time, leading to shortened sleep, and heat related diseases. This has been corroborated by Cheng et al. (2012). Nevertheless, there is need to look into the actual effect of these high thermal comfort characteristics on the residents. This is an area this current study has not examined, but Ostro et al. (2010) and Shaman et al. (2010) ascertained in their studies that, high indoor thermal comfort characteristics, causes heat stress, leads to skin rashes, blood pressure imbalance, or even deaths.

The Industrial land use, annual value effective temperature was not normal with *ET* value of 26.2°C, the dry period posted *ET* value of 27.9^0C which signifies heat stress. The wet period was normal for the industrial area with *ET* value of 20.1^0C and the dwelling units with AC posted *ET* value of 19.3°C which is normal effective temperature. The same cannot be said for the dwelling units without AC in the industrial land use which had an effective temperature value of 28.1°C, implying that there is heat stress in the industrial area. As for the commercial land use, the annual value showed that the effective temperature was not normal for the with *ET* value of 27.0°C, the dry period posted *ET* value of 27.3°C which signifies heat stress. The wet period was normal for the industrial area with *ET* value of 19.5°C and the dwelling units with AC posted *ET* value of 20.0°C which is normal effective temperature. The same cannot be said for the dwelling units without AC in the commercial land use which had an effective temperature value of 27.5°C, implying that there is heat stress in the commercial area. In the government reservation area, the annual value showed that the effective temperature was not normal for the with *ET* value of 25.68°C, the dry period posted *ET* value of 25.78°C which signifies heat stress. The wet period was normal for the area with *ET* value of 18.7°C and the dwelling units with AC posted *ET* value of 19.75°C which is normal effective temperature. The same cannot be said for the dwelling units without AC in the GRA land use which had an effective temperature value of 25.8°C implying that there is heat stress in the GRA area. Furthermore, in the mixed land uses, the annual value showed that the effective temperature was not normal with *ET* value of 26.05°C, the dry period posted *ET* value of 26.91°C which signifies heat stress.

The wet period was normal for the area with *ET* value of 20.64°C and the dwelling units with AC posted *ET* value of 20.64°C which is normal effective temperature. The same cannot be said for the dwelling units without AC in the mixed land use which had an effective temperature value of 26.64°C, implying that there is heat stress in the mixed land use. Looking at the findings shows that, the rainy periods have considerable influence on effective temperature characteristics in the study area, because the rains carry along with it cool and moist air that have considerable cooling effects on not only the indoor temperature but also on humans (Barnett and Astrom 2012; Mavrogianni et al., 2012; Nguyen et al., 2014; Ostro et al., 2010; Shaman et al., 2010; Shoji et al., 2011; Strand et al, 2011).

Nevertheless, the relationships between the outdoor and indoor temperature characteristics and the effective temperatures reached in relation to the calibrated building types showed that building type one (Stone coated roof, parapet, Pop ceiling, window (casement, Single Hung, Bay, Awning, Arched), ceramic floor tiles) was generally higher in the study area. This is followed by type two (Long spam roofing sheets, PVC ceilings, sliding windows, ceramic/cement/rug/plastic carpet floors) and the next is the type 3 (Metal zinc/Asbestos roof, louvers/wooden windows, cement/terrazzo floor, asbestos ceilings). This indicates that the materials used for building the dwelling units have some role to play in the effective temperature reached. Of course, the wooden windows and louvers are designed in such a way that there are openings even when they are locked. This causes wind exchange when air blows into the building and also allows the evacuation of hot indoor air. The same cannot be said of the other building types. Some of the paraphernalia used in those types of buildings, such as the windows and the roof types (parapets, PVC ceiling, etc.) do not allow exchange of indoor winds. This affects the thermal comfort characteristics in such building in the study area. This idea has also been established by Ojeh (2011) and Abotutu and Ojeh (2013).

CONCLUSION AND RECOMMENDATIONS

From the study it can be concluded that, the indoor thermal comfort characteristics in the study area were affected not only by land use but also by outdoor temperature and building characteristics. This therefore means that, there is need to apply some adaptive and palliative measures as suggested below:

(i) There is need to create more windows and doors in buildings to improve ventilation in already built houses. Also, in buildings that such adjustments are not possible, windows and doors should be opened often to improve ventilation, especially in the dry periods.
(ii) Buildings should be constructed baring the meteorological controls of the area in mind. That is, there is need to put in mind the windward direction so that the windows be placed towards it to facilitate ventilation in the buildings.
(iii) The standards for building constructions, which entails, the sizes of windows, doors, number of windows, fence size and building material types, should be followed in the area.
(iv) There is need to model out building designs that suits the type of climate characteristics prevalent in the study area, as against the current borrowed building designs in the area. This will allow the creation of building designs with better ventilation.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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