Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.17, 2015

Climatic Pattern and Design for Indoor Comfort in Ogbomoso, Nigeria

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Abstract
Climate is one of the basic factors for consideration in building design in Nigeria. It determine the occupants physiological conditions especially in the indoor spaces. Most climate studies in Nigeria have concentrated mainly on Agriculture and Aviation Sectors. This paper examines and analyses the climate pattern of Ogbomoso, a climatic transitional town in South West Nigeria with a view to suggesting appropriate guidelines for comfort design.Average climatic data of Ogbomoso for a period of five (5) years were examined and analysed for building design purpose using control potential zone techniques on bio-climatic chart. The climatic pattern of Ogbomoso showed that the annual mean temperature values are high for most of the years with 26.24^0C 24.69^0C, 26.21^0C, 26.43^0C and 26.64^0C respectively for the year 2004, 2005, 2006, 2007 and 2008 respectively. Annual mean minimum and maximum relative humidity are high ranging from 76.80% (2006) minimum to 81.5% (2005) as maximum. The annual mean value of solar radiation are high and constant while the average outdoor wind speed for those periods are generally low between (1.5 – 2.0 m/s). The control potential zone (CPZ) constructed on the psychometric chart of Ogbomoso showed that the length of overheated period (Lo) is greater than length of underheated (Lu) with thermal implications of hot and humid conditions. It also shows that air movement alone cannot provide adequate thermal comfort for the occupants. Other passive controls like the mass effect with night ventilation can be combined with the air movement to produce the required comfort.
Keywords: Climatic pattern, Indoor comfort, Control Potential Zone (CPZ), Bioclimatic chat, Warm humid condition.

1.0 Introduction

Climate is one of the basic properties of the atmosphere that enriches the earth. Understanding how climate occur is not a requisite for building design, but buildings should be designed to respond well to the characteristics of the climate in order to ensure adequate physiological comfort for the occupants. The World meteorological Organization defined climate as a totality of metrological elements that in their usual succession and at a given period, characterize the state of the atmosphere. Boutet (1987), on the other hand simplifies the definition of climate as the prevailing weather conditions of a given region. However, various definitions of climate available recognize climate to be a statistical composite of atmospheric conditions of a place viewed over a given period of time.

Several attempts have been made in the past by many scholars to classify climate in to different types (Oliver1980), but all these classification can be broadly divided in to three principal types: those based on climatological data, those founded on the existence of environmental conditions suitable for natural plant growth, and those which evaluate environmental conditions in terms of the ready maintenance of human comfortability. However, the classification of Koppen-Geiger which is based on monthly air temperature, humidity and the potential evaporation rate remain the most generally used classification system (Szokolay 2004)

For building design purpose, the classification must have a combined effect of temperature, relative humidity, mean radiant temperature, and wind velocity. However, most building climatologist according to Ajibola (2001), have only been able to combine one or two of the above items, notable among these scholars are Atikson (1954) and Budyko (1956) who based their classification on nature of human thermal problem in a particular location,Fagbenle (1992) who used the national index of dryness for their own classification, Oliver (1980) classification was based on air mass movement and as a result can only account for air movement. In all, the classification of Atikson in Szokolay (2004) forms the basis for other classifications: he recognized only four basic types which he based on the nature of the human thermal problem in a particular location. The climatic types identified are:-

i. Cold climate – where the main problem is the lack of heat (under heating) or excessive heat dissipation for all or most of the year.
ii. Temperate (moderate) climate, where there is a seasonal variation between under heating and overheating, but neither is very severe.
iii. Hot - dry climate, where the main problem is overheating, but the air is dry, so the evaporation cooling mechanism of the body is not restricted. There is usually a large diurnal (day-night) temperature variation.
iv. Warm humid climate, where the overheating is not as great as in hot dry areas, but is aggravated by high humidity, restricting the evaporation potential. The diurnal temperature variation is small.

The last of these four climate types describe fully the study area, however in recent times a number of scholars have focused their activities on this climatic zone, but Szololay (1982) and Ajibola (2001) asserted that climate classification is not terribly useful for building design purpose and he suggested the application of control potential zone technique. His concept however, would be adopted for the study.

2.0 The Study Area Ogbomoso.

Ogbomoso is the second largest city in Oyo State, South Western part of Nigeria. It lies on $8^{0}10^{1}$ north of the equator and longitude $4^{0}10^{1}$ east of the Greenwich Meridian within the derived savannah region of Nigeria. It is on important trunk A (Ibadan-Ilorin) road and serves as the gateway to the northern part of Nigeria from south-west (Ayinla, 2012)

Climatically, Ogbomoso is in warm humid zone; however this is the climatic context for the study. The warm humid climate is found close to the equator and extends 15^{0} latitude of north and south (Ayinla, 2012). The dominant features is lack of seasonal variation in temperature, it is characterised by high humidity, high rainfall and high temperature with relative low wind velocity. The seasonal pattern is dominated by diurnal and annual variations of temperature and little seasonal variations. The climate is largely independent of the topographical features but varies with interactions between two principal wind currents: *The Harmattan* (often appears as a dense fog and covers everything with a layer of fine particles), from the northeast, which is hot and dry and carries a reddish dust from the desert; it causes high temperatures during the day and cools at nights. Also, the moist, *South-West Wind* coming off, of the Atlantic Ocean, which brings cloudy and rainy weather. The interactions between these two air masses play a distinct role in the country's seasons and temperatures (Nationsencyclopedia, 2012).

3.0 Methodology

3.1 THE CLIMATE OF OGBOMOSO

The relevant climatic data for Ogbomoso were obtained from Oyo State Water Corporation, Ogbomoso. The data obtained were for a period of five years in line with the recommendation ofOgunsote (1988), Marsh (2001) and Liu Yang (2003) that averages of climate data for a period of between five to ten years is adequate for building design purpose. The data included values of the following climatic elements on a monthly basis from January to December for the years 2004, 2005, 2006, 2007 and 2008 maximum and minimum temperature, maximum and minimum relative humidity, solar radiation, wind speed, and rainfall. Averages of these data were presented in Table1 and figure1 below.

Table 1*Average Climatic data of years for Ogbomoso (2004 - 2008)*.

Month	*Temp. oC (Max.)*	*Temp. oC (Min.)*	*Temp. ^{o}C*	*RH(AM) %*	*RH(PM) %*	*Rainfall (mm)*	*Radiation (mj/m2/day)*	*Wind Speed(m/s)*
January	33.36	19.53	26.445	65.91	40.43	11.76	11.68	1.62
February	34.73	20.7	27.715	68.164	37.2	20.79	12.42	1.68
March	34.16	22.86	28.51	73.27	46.75	82.14	13.34	1.74
April	32.94	22.38	27.66	77.11	60.78	128.51	12.54	1.76
May	31.96	22.23	27.095	80.76	66.03	167.02	11.56	1.68
June	30.77	21.74	26.255	84.66	69.6	187.58	9.72	1.68
July	29.31	21.44	25.375	89.16	72.76	171.87	7.22	1.6
August	28.55	20.87	24.71	85.85	73.27	137.58	7.86	1.52
September	29.41	20.85	25.13	85.51	73.33	237.652	9.1	1.72
October	31.28	19.88	25.58	86.04	68.54	198.03	11.06	1.74
November	32.82	20.69	26.755	83.06	54.26	79.19	13.28	1.92
December	33.16	18.94	26.05	74.23	44.6	13.21	10.9	2
Average	31.87	21.01	26.44	79.48	58.96	119.61	10.89	1.72

Source: Adapted from Oyo State Water Corporation, Ogbomoso. (2004 - 2008.)

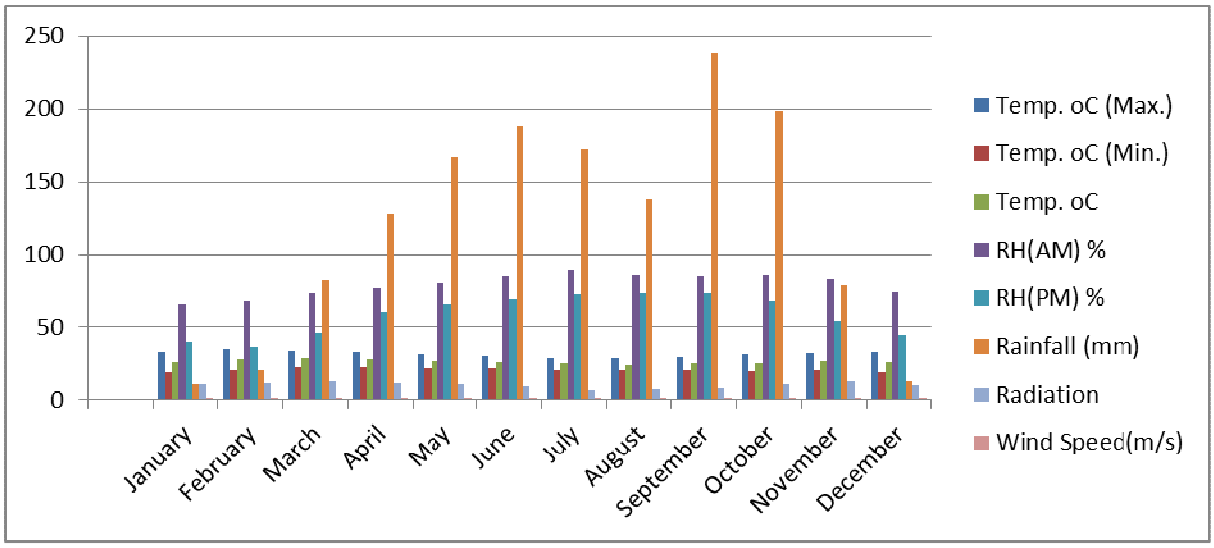

Fig. 1 Average Climatic data of Ogbomoso, (2004 - 2008).
Source: Author's analysis, November 2009

3.2 CLIMATIC PATTERNS AND THEIR EFFECTS ON DESIGN COMFORT

3.2.1. Temperature**.**

Temperature pattern of Ogbomoso over a period of five years (2004 to 2008) is presented in table 2. The maximum temperature was highest in February for almost all the years under review (fig. 2) with values of 33^0C, 34.5^0C, 35.05^0C and 35.70^0C respectively for the years 2004, 2005, 2006 and 2007, for 2008. The highest maximum temperature occurs in March. The minimum temperature is highest in March with values 23.70^0C, $24.0,^0$C 22.7^0C, 22.60^0C and 22.10^0C respectively for the years of 2004, 2005, 2006, 2007 and 2008. However, for the year 2008, the highest value of the minimum temperature occurs in April. The months of maximum high temperature (temperature values above 30^0C) would impose discomfort for the occupants. These months include January, February, March, April, May, June, October, November and December for all the five years under review. The months of July, August and September however, for all the five years under review, offer a mild comfort compared to other months.

Table 2 Temperature pattern of Ogbomoso (2004 – 2008)

Month	*Temp.(oC) 2004*		*Temp.(oC) 2005*		*Temp.(oC) 2006*		*Temp.(oC) 2007*		*Temp.(oC) 2008*	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	32.90	19.35	33.00	20.80	33.00	19.00	34.00	18.80	33.90	19.7
February	33.00	20.30	34.50	21.75	35.05	20.65	35.70	20.50	35.40	20.30
March	32.30	23.70	32.20	24.00	34.90	22.70	35.60	22.60	35.80	2.1.30
April	31.10	22.10	32.10	22.90	33.10	22.30	34.10	22.50	34.30	22.10
May	31.00	23.00	31.60	22.60	31.90	21.85	32.60	21.80	32.70	21.90
June	30.80	23.60	30.30	21.20	30.45	21.30	31.00	21.20	31.30	21.40
July	29.60	23.20	30.00	21.30	28.55	20.90	29.20	20.90	29.20	20.90
August	28.40	21.40	29.10	21.20	28.00	20.65	28.70	20.60	28.55	20.50
September	28.00	20.50	30.40	21.10	28.85	20.85	29.80	20.80	30.00	21.00
October	31.10	20.10	31.30	21.20	30.70	19.40	31.40	18.00	31.90	20.70
November	32.30	20.00	31.80	22.20	32.40	20.65	33.60	20.00	34.00	20.60
December	32.90	19.00	32.90	21.00	32.90	18.90	33.90	17.00	33.20	18.80
Annual Mean value	31.12	21.35	31.60	21.77	31.65	20.76	32.46	20.39	32.52	20.77

Source: Adapted from Oyo State Water Corporation, Ogbomoso. (2004 - 2008.)

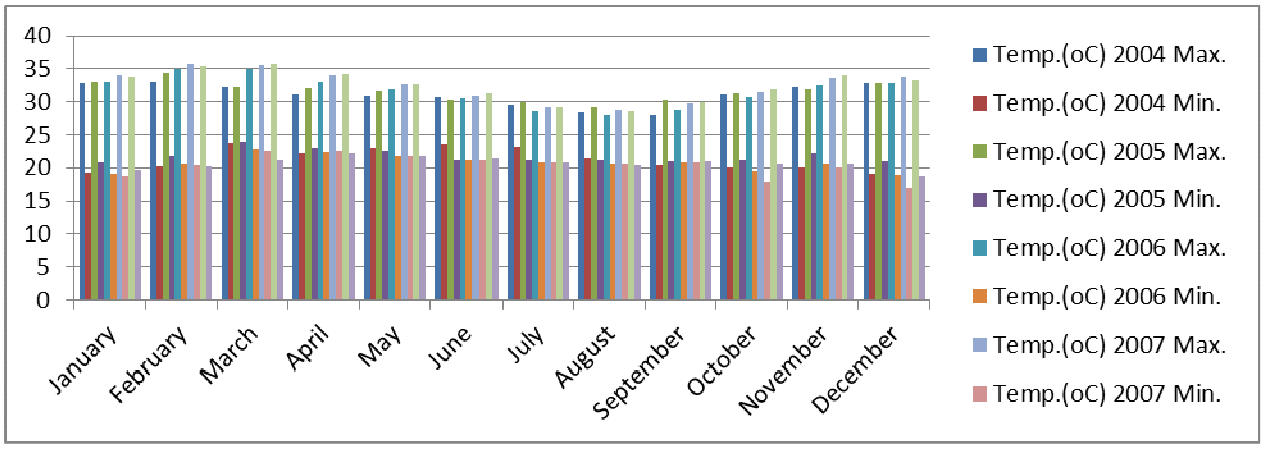

Fig. 2 Temperature pattern of Ogbomoso. (2004 -2008)
Source: Author's analysis, November 2009

3.2.2 Relative Humidity

Relative humidity in figure 3 for most of the months of the years under review is high (above 60%). The highest being 97% in July, 2008 (Table 3). The implication is that the rate of evaporation of sweat from the skin would be low, thereby causing discomfort especially with the months of high temperature. This was the case for the months of January, February, March, April, May, June, October, November and December for all the five years under review.

Table 3 Relative Humidity pattern of Ogbomoso (2004-2008)

Month	*2004*		*2005*		*2006*		*2007*		*2008*	
	Max. (AM)	Min. (PM)	Max. (AM)	Min. (PM)	Max. (AM)	Min. (PM)	Max. (AM)	Min. (PM)	Max. (AM)	Min. (PM)
January	70.30	45.50	73.10	36.00	67.25	43.35	68.40	33.80	50.50	43.50
February	67.35	40.10	70.76	43.60	65.75	36.50	73.65	29.30	63.50	36.50
March	70.30	48.40	76.60	50.55	69.95	47.00	74.25	40.50	75.25	47.30
April	79.50	65.90	76.50	60.00	75.45	62.75	75.80	53.00	78.30	62.25
May	80.50	68.00	80.65	68.40	79.95	66.20	82.30	61.30	80.40	66.25
June	85.30	73.00	84.55	70.25	83.50	69.35	86.25	66.40	83.70	69.00
July	86.30	71.30	89.55	78.60	83.63	69.95	89.30	70.40	97.00	73.55
August	80.40	78.40	91.25	70.90	84.50	74.45	87.40	70.20	85.70	72.40
September	87.50	75.00	76.80	82.20	86.75	72.50	86.30	68.40	90.20	68.55
October	86.45	68.60	90.00	72.75	81.00	68.10	83.25	64.50	89.50	68.75
November	80.90	58.50	88.75	51.00	75.40	58.20	74.35	45.30	95.90	58.30
December	71.50	48.20	79.80	45.15	68.50	48.35	77.85	32.50	73.50	48.80
Annual Mean value	**78.86**	**61.74**	**81.51**	**60.78**	**76.80**	**59.73**	**79.93**	**52.97**	**80.29**	**59.60**

Source: Adapted from Oyo State Water Corporation ,Ogbomoso. (2004 - 2008.

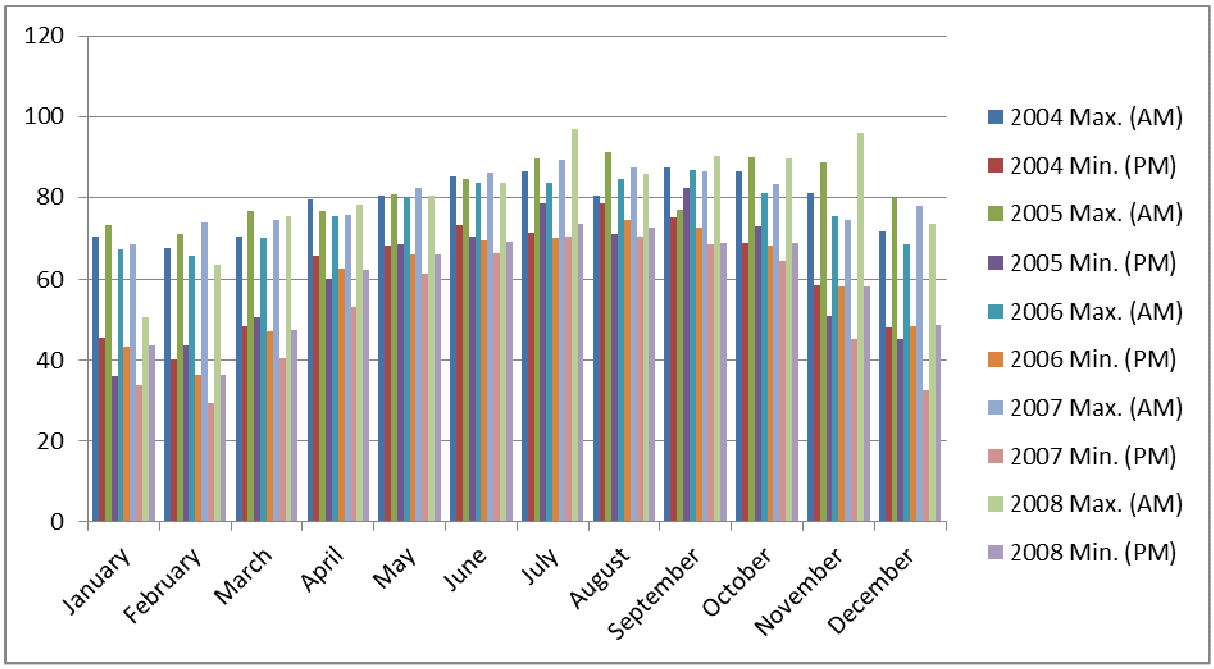

Fig.3 Relative Humidity pattern of Ogbomoso (2004- 2008).
Source: Author's analysis, November 2009

3.2.3 Solar Radiation.

Table 4. shows the months with high solar radiation (radiation value above 10KJ/m^2/day) including January, February, March, April, May, June, November and December for years 2004, 2006, 2007 and 2008, the highest value of 16.8 KJ/m^2/day occurs in march 2006. For year 2005, all the months except June, July, August and September were months of high solar radiation. The months of July, August, September, and October were months of lowest solar radiation for all the years under review. The lowest value of 6.2 KJ/m^2/day occurred in July 2007. However, the summary is presented in figure 4 below. Solar radiation is usually associated with thermal discomfort; therefore, months of high solar radiation will be critical in terms of discomfort. However, majority of the buildings in the core area of Ogbomoso were built with Mud and galvanized iron roofing sheets. The walling material (building fabric) used in this area serves as thermal mass which regulates the effect of solar radiation in indoor spaces by moderating the indoor temperature swings.

Table 4 : Solar Radiation pattern of Ogbomoso.(2004-2008)

Month	***2004 Radiation (mj/m2/day)***	***2005 Radiation (mj/m2/day)***	***2006 Radiation (mj/m2/day)***	***2007 Radiation (mj/m2/day)***	***2008 Radiation (mj/m2/day)***
January	12.10	13.70	14.90	11.50	12.10
February	13.40	14.00	15.60	11.70	13.20
March	13.60	15.20	16.80	13.60	12.80
April	12.90	14.40	14.20	13.00	12.80
May	12.21	12.90	12.10	12.00	12.60
June	11.00	9.40	10.20	10.40	10.60
July	9.21	8.10	9.60	6.20	7.80
August	8.42	7.70	8.20	8.50	7.60
September	8.62	9.50	9.10	9.20	8.20
October	9.41	10.70	9.80	9.80	9.30
November	12.40	11.20	13.10	10.20	12.30
December	12.00	12.50	14.10	10.62	11.80
Annual Mean value			14.60	11.24	

Source: Adapted from Oyo State Water Corporation, Ogbomoso. (2004 - 2008.)

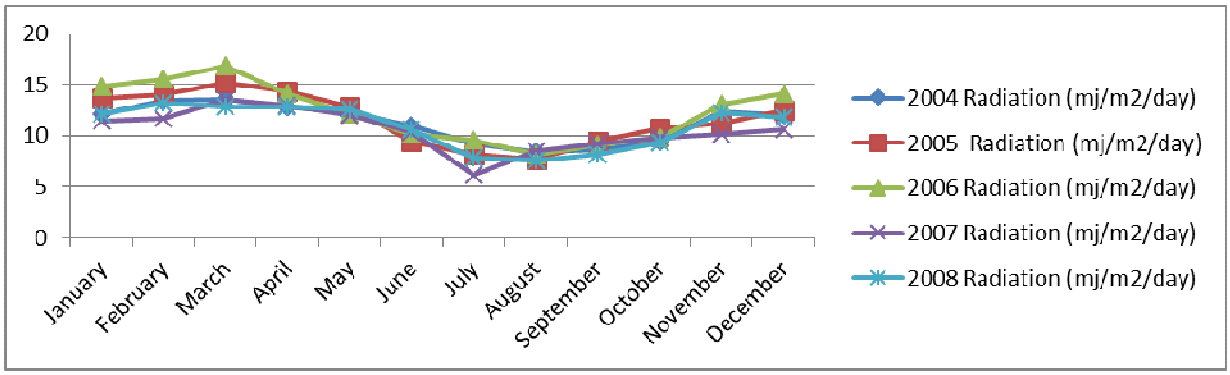

Fig. 4 Solar Radiation pattern of Ogbomoso.
Source: Author's analysis, November 2009.

3.2.4 Average Wind Speed.

Average Outdoor wind speed in (m/s) for the five years under review is presented in figure 5 below. The graph is almost uniform for all the months; the value is generally low between 1.5 and 2.0 (m/s), with the highest in December and the lowest in August. The month of December is always associated with Harmattan wind which is dry, dusty with desiccating effects, while the month of August is cool, chill with low temperature and rainfall (''August break''). However none of these months is comfortable climatically especially when other climatic elements were combined.

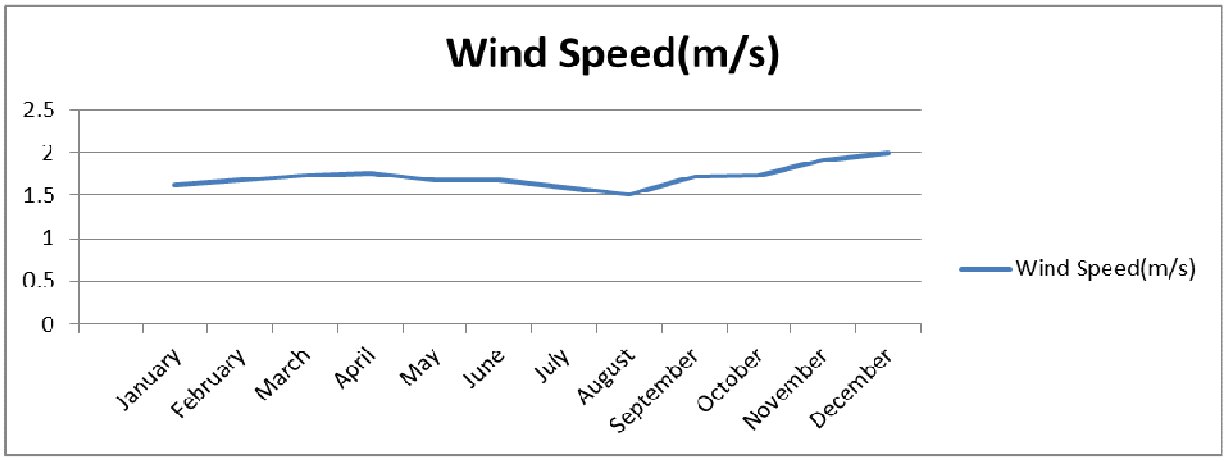

Fig.5 Average wind speed pattern of Ogbomoso (2004- 2008).
Source: Author's analysis, November 2009.

Comparing the climate of the five years under review, the annual mean temperature values in ^{0}c for most of the years are high and fairly uniform with values of 26.24, 24.69, 26.21, 26.43 and 26.64 respectively for years 2004, 2005, 2006, 2007 and 2008. Annual mean minimum and maximum relative humidity are relatively high and uniform ranging from76.80% (2006) minimum to 81.51% (2005) as maximum. Other values are 78.86% (2004), 79.93% (2007) and 80.29% (2008). The annual mean value of solar radiation was almost high and constant throughout the five years under review. However, the average outdoor wind speed for the period is generally low between 1.5 to 2.0(m/s).

3.3 CLIMATIC ANALYSIS USING BIO-CLIMATIC CHART.

Averages of climatic data for a period of five years (2004 to 2008) as suggested byOgunsote (1988),Marsh (2001) and Liu Yang (2003) were used for this analysis. The averages are presented in table1 above. These data were analyzed using Control Potential Zone (CPZ) technique which, according to Szokolay (1992), is the range of outdoor conditions within which indoor comfort can be achieved by one of the passive control techniques. The monthly maximum and minimum temperatures with corresponding relative humidities were plotted on Psychometric chart as climate plot; the comfort zone for Ogbomoso was determined and super imposed on the graph. The Control Potential Zones are then constructed on the Psychometric chart in form of overlays. These are then compared with the climate plot and the comfort zone (fig.6) The extent of these lines in relation to comfort zone, that is, the aggregate length below (to the left), within or above (to the right of) the comfort zone gives an indication of the climatic problems. The overheated and under heated periods were determined (fig.6). The length of overheated dry (Lod) and overheated humid (Loh) were also calculated.

From the analysis, the annual mean maximum temperature (To) was found to be 31.84^{0}C (table 5),

thermal neutrality (Tn) was 27.5°C. Length of overheated (Lo) was 46.5, length of under heated (Lu) was 13, length overheated humid (Loh) was136.5, length of overheated dry (Lod) was 9.5. These results are summarized below in table 5.

Table 5 Interpretation of Bio-climatic chat of Ogbomoso.

Symbol	*Interpretation*	*Reference*	*Value*
To	Annual mean maximum Temperature	Table 4.1	31.87 oC
Tn	Thermal neutrality	Fig. 4.1	27.5 oC
Lo	Length of over heated	Fig. 4.1	46.5
Lu	Length of under heated	Fig. 4.1	13
Loh	Length of overheated humid	Fig. 4.1	136.5
Lud	Length of under heated dry	Fig. 4.1	9.5

Source: Author's analysis, November 2009.

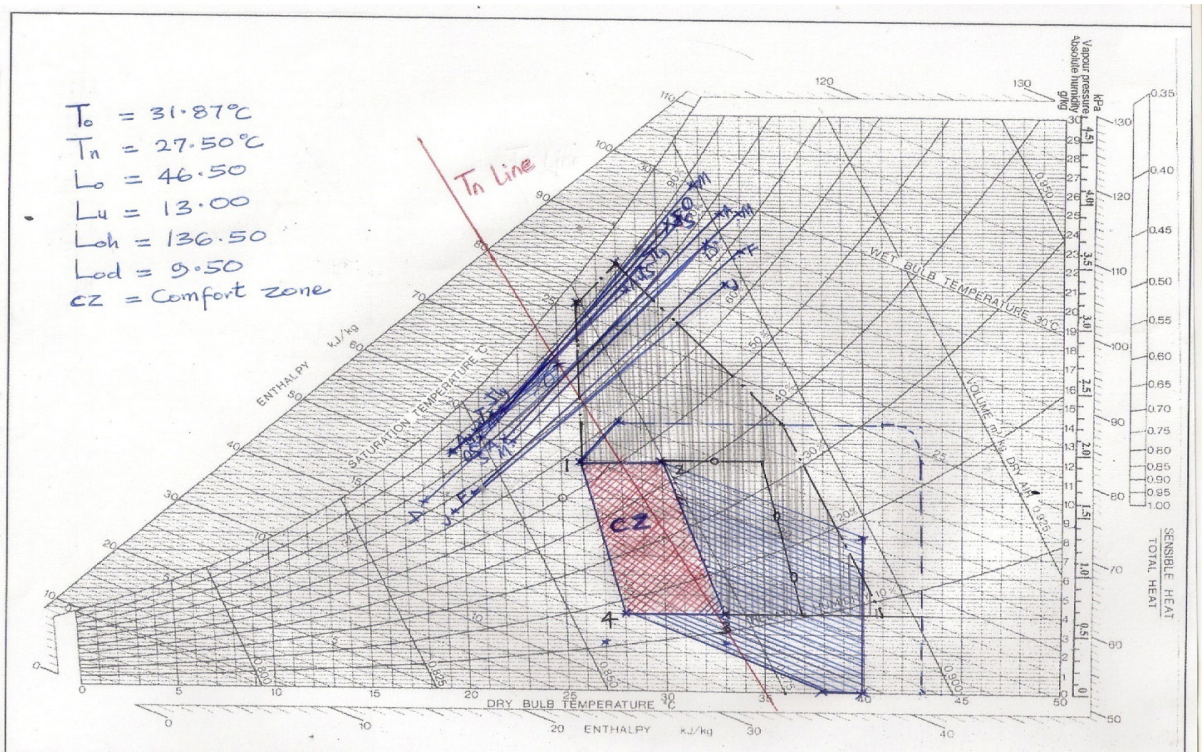

Fig. 6: Bio-climatic chat of Ogbomoso. (2004-2008)
Source: Author's analysis, November 2009.

It can be seen from table 5 that the length of overheated period (Lo) is greater than length of under heated (Lu). This has implication of thermal stress for indoor spaces in Ogbomoso. Also the length of overheated humid (Loh) is greater than the length of overheated dry (Lod). The implication of this is that Ogbomoso is hot and humid and falls under the climate type which Szokolay (1992) described as the most difficult to deal with design wise.

4. Conclusion and Recommendation.

The climate of Ogbomoso from analysis is too warm for comfort by days and some nights, and that air movement is highly essential to reduce discomfort. However, the amount of air movement available in the area cannot provide adequate comfort for the occupants. In these regards, other passive control techniques like the thermal mass with night ventilation can be combined with the air movement to produce the required comfort.

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