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Evaluation of Outside Air Design Dry and Wet Bulb Temperatures for Air Conditioning Systems in Nigeria

ABSTRACT

There is increase in the ambient temperature being experienced around the world due to global warming and this has caused the energy consumption of cooling systems to increase. Statistical analysis was carried out on meteorological data obtained from Nigerian Meteorological Agency for 18 towns in Nigeria for 1994-2008 or 1995-2009. The weather variables considered in this study were hourly relative humidity and dry bulb temperature, three hourly wet bulb temperature and vapour pressure. The averages of dry bulb temperature, wet bulb temperature and vapour pressure were computed. The four warmest months were determined for each location, from which the outdoor 1%, 2.5%, and 5% design conditions of dry bulb temperature, wet bulb temperature and vapour pressure were computed using Normal Distribution tables for each town. The design month is the month with the highest average maximum temperature. The following design months were obtained from the results: February is the design month for Benin City, Calabar, Ibadan, Ondo, Owerri and Port Harcourt; March for Abuja, Enugu, Ikeja, Ilorin, Jos and Minna, April for Bauchi, Kaduna, Kano, Maiduguri, Sokoto and Yola. The 2½% outside design dry bulb and wet bulb temperatures obtained for 1951-1965 by earlier workers were compared with those obtained for 1994-2009 in this work. The percentage differences obtained were from 13-25% for dry bulb design temperature and from 2-40% for wet bulb temperature. It was concluded that climate change has caused outside design conditions for air conditioning systems to change and results obtained in this work should be used to replace the design conditions formerly used by engineers which were obtained from earlier periods. This work is useful in preparing a revised code of practice for comfort air conditioning system design for Nigeria.

Key words: air conditioning, dry bulb temperature, wet bulb temperature, relative humidity, global warming.

INTRODUCTION

Weather is the state of the atmosphere at an instant of time, with regard to temperature, humidity, cloudiness, rainfall, wind and other meteorological conditions. Climate is the average pattern of variation in temperature, humidity, atmospheric pressure, wind, precipitation, and other meteorological variables observed in a given region over long periods of time. The averaging period for defining climate normals depends on the purpose for which the data is to be used [1]. The weather variables of a place influence the cooling and heating loads of a space such as a building. In recent times, changes in weather conditions especially dry-bulb temperature have been experienced around the world and this phenomenon is known as global warming or climate change [1]. The climate variables of interest are dry bulb temperature and wet bulb temperature which can easily be measured and recorded with dry and wet bulb thermometers from which relative humidity can be easily read from Psychrometric slide rule.

Air conditioning is the treatment of air in a space with the aim of controlling the temperature, relative humidity, and air quality in that space. In the analysis of air conditioning systems, the study of mixture of dry air and water vapour is important.

Results obtained from statistical analysis of weather data are of paramount importance for design of air conditioning systems. Various works were done on weather data of different locations locally and internationally. With the recent experience of climate change, work is being intensified on weather data analysis.

Shoboyejo and Shonubi [2] worked on weather data of Nigeria for a 15-year period (1951-1965) and computed the outdoor design conditions for 28 Nigerian towns based on the data for the four warmest months for each of the locations. They determined these design conditions on the assumption that the weather data are normally distributed. They then computed the 1%, 2½% and 5% confidence values of Gaussian probability distribution. The assumption of Normal or Gaussian Distribution was convenient since statistical tables could be used once the mean and standard deviation were known.

Erbs [3] carried out statistical analysis of weather data for 20-year period for 9 cities in the United States of America from which he developed models that could be used for every city in the United States of America. The 9 cities were Madison, WI, Washington, DC, Albuquerque, NM, New York, NY, Phoenix, AZ, Seattle, WA, Miami, FL, Fort Worth, TX, and Columbia, MO. He provided the average values of dry bulb temperature and relative humidity and standard deviation from the average and several other results.

Ariyo [4] worked on dry bulb temperature of two locations in Nigeria, namely: Ikeja and Ilorin for the 15-year period 1978-1992. He calculated the design data of dry bulb temperature for both places based on the assumption that the data are normally distributed. He determined the 1%, 2½% and 5% confidence values for the four warmest months. The results so obtained were higher than those of Shoboyejo and Shonubi [2] for the two locations.

Olorunmaiye et al [5] reported that there was increase in mean temperatures for Ikeja and Ilorin in another study based on 1995-2008 data. This re-confirmed the evidence of global warming as results obtained were higher than that of Ariyo for the two places. Equally, the 1%, 2½% and 5% dry bulb temperatures for the four warmest months were higher than results obtained by the earlier workers [2, 4] for both places.

The quantity of energy needed to cool a building or space depends on the climate, the size and the design of the building or space, the interior conditions of the space being conditioned and the equipment in use [6, 7]. In buildings, the medium to be cooled is air and the occupants are made comfortable.

In an air conditioned building, the air must be conditioned and this may involve cooling to some desirable temperature (or heating as in incubator in this part of the world), dehumidification or humidification, ventilation, filtration and distribution. Human comfort standards vary with locations, climate, time of the year, life style and dressing habits and nature of physical activity engaged in at a point in time.

Most designed comfort air conditioning systems are to create an interior condition within the comfort zone and not to create or produce and maintain a specified dry bulb temperature and relative humidity. Outside condition varies from one location to another and these are determined by computing the average condition that occurs over a number of years.

In recent times, the issue of climate change has contributed to the need for energy efficiency [7]. There is increased energy utilization in household refrigerators due to changes in ambient temperature of the spaces in which they are placed [6, 7], this will equally be true of air conditioning systems.

The Temperature-humidity index (THI) is a measure of the level of thermal stress that livestock or men are subjected to by the combined effect of dry-bulb temperature and the coincident relative humidity or wet bulb temperature of the ambient air. The rate at which the body of a man or an animal can lose heat by evaporative cooling through the skin and lungs reduces as the relative humidity rises and the THI is a measure of the effective temperature felt by the body [8]. When THI value is above 85 °F (29.4 °C) most people are very uncomfortable [9].

Abdulrahim et al [10] examined thermal stress caused by the weather in Maiduguri, Nigeria. They measured dry and wet bulb temperatures and wind velocity in a classroom, in the shade under a neemtree and under direct sunlight from 7.00a.m to 5.00p.m on some days in the months of October to December 2010. The mean values of THI varied from 23.58 to 31.18 °C and the classroom had the minimum THI while the location under the sun had the highest.

Sanusi et al [11] estimated temperature humidity index (THI) using monthly mean values of temperature and relative humidity data obtained from National Aeronautics and Space Administration (NASA) for 10 towns in Nigeria, namely:

- (i) Lagos, Calabar, Port Harcourt, Uyo and Sapele in southern part of Nigeria; and
- (ii) Katsina, Kano, Maiduguri, Yola and Gusau in the northern part of Nigeria.

The values of THI calculated for the 12 months for the 5 southern towns and the 5 northern towns were within the ranges 25.6-29.8 °C and 21.0-31.8 °C, respectively. Maiduguri had the highest THI value of 31.8 °C in May.

The aim of this work is to provide data for outside air condition for air conditioning system design in Nigeria, using recent weather data and thereby replace the design data generated in the work of Shoboyejo and Shonubi [2] which was based on 1951-1965 weather data, in view of global warming and climate change.

An important objective of this work is to see if comparison of results obtained from recent weather data with results of Shoboyejo and Shonubi [2] for some other locations (apart from Ikeja and Ilorin) provide evidence of global warming like was observed earlier for Ikeja and Ilorin.

SCOPE AND LIMITATIONS OF THE PRESENT WORK

This work is based on meteorological data for towns in Nigeria where these data were recorded. However, only 18 Nigerian towns for the period of 1994-2008 or 1995-2009 which covers the span of fifteen years period were considered due to incomplete recorded data for some of the stations in the country. The eighteen (18) towns considered in this study cover the six geopolitical zones and the Federal Capital Territory. The towns are spread as follows:

- (i) South- South zone: Benin-City (Lat. 6°20'06" N, Long. 5°37'38" E), Calabar (Lat. 4°57'06" N, Long. 8°19'19" E) and Port Harcourt (Lat. 4°47'21" N, Long. 6°59'54" E);
- (ii) South East zone: Enugu (Lat. 6°26'24" N, Long. 7°29'39" E) and Owerri (Lat. 5°28'59" N, Long. 7°01'49" E);
- (iii) South West zone: Ikeja (Lat. 6°40' N, Long. 3°20' E), Ondo (Lat. 7°05'59" N, Long. 4°49'59" E) and Ibadan (Lat. 7°23'16" N, Long. 3°53'47" E);
- (iv) North Central zone: Ilorin (Lat. 8°26' N, Long. 4°29' E), Minna (Lat. 9°36'50" N, Long. 6°33'24" E) and Jos (Lat. 9°55'00" N, Long. 8°54'00" E);
- (v) North East zone: Maiduguri (Lat. 11°50'47" N, Long. 13°09'36" E), Yola (Lat. 9°11'59" N, Long. 12°28'59" E) and Bauchi (Lat. 10°00' N, Long. 8°00' E);
- (vi) North West zone: Kaduna (Lat. 10°31'20" N, Long. 7°26'17" E), Kano (Lat. 11°59'39" N, Long. 8°30'49" E) and Sokoto (Lat. 13°3'5" N, Long. 5°13'53" E); and
- (vii) Federal Capital Territory: Abuja (Lat. 9°03'26" N, Long. 7°29'23" E).

METHODOLOGY

Hourly relative humidity and drybulb temperature, and three hourly wetbulb temperature data based on Greenwich Mean Time (GMT) were obtained for fifteen years (1994-2008) or (1995-2009) from Nigerian Meteorological Agency (NIMET), Oshodi, Nigeria for the eighteen (18) Nigerian towns. These data obtained on paper by making photocopies from the original documents, were keyed into the computer system using Microsoft excel office software 2007 version.

The keyed in data of hourly dry bulb temperature and three hourly wet bulb temperatures were arranged month by month for each location and for each weather variable for the 15-year period. The monthly average hourly dry-bulb temperature and monthly average hourly relative humidity were computed for 24 hours of the day for each month for each of the eighteen towns considered. The monthly average daily, standard deviation and range of the dry-bulb temperature and relative humidity were computed for each month for the eighteen towns.

The maximum and the minimum values of the monthly mean of the hourly dry bulb temperatures were computed and the differences of the maximum and minimum values were calculated as the range for the month. Using the monthly average dry bulb temperature which were also calculated, the four warmest months of the year for each of the locations were determined. The design month, which is the month with the highest average maximum temperature of the four warmest months, was determined for each location. The distribution of the dry-bulb temperature data was assumed to be Gaussian or Normal distribution. Then the 1%, 2½% and 5% confidence values for dry bulb and wet bulb temperatures were obtained from normal distribution table using the monthly mean values, and standard deviations for the four warmest months. The coincident relative humidity values of the 1%, 2½% and 5% confidence values of dry bulb temperature were determined by finding the averages of relative humidities that coincided with the dry bulb temperature in the range of $\pm 0.1^\circ\text{C}$ of the confidence values during the four warmest months.

RESULTS

The 1%, 2½% and 5% confidence values for the four warmest months of the dry bulb temperature, wet bulb temperature and vapour pressure for each of the eighteen towns in this study are presented in Tables 1-3, while Tables 4-6 show outside design conditions for dry bulb temperature, wet bulb temperature and vapour pressure obtained by Shoboyejo and Shonubi [2] for the sixteen towns that their work had in common with the present work. The coincident relative humidity values of the 1%, 2½%, and 5% confidence values of dry bulb temperature of the four warmest months are also shown in Table 1.

TABLE 1: CITIES WITH DESIGN MONTH, DESIGN DRY BULB TEMPERATURE VALUES FOR 1%, 2½% AND 5% CONFIDENCE VALUES AND COINCIDENT RELATIVE HUMIDITY VALUES, MEAN DRY BULB TEMPERATURE AND STANDARD DEVIATION.

S/No	Station	Elevation (m)	Design Month	Design T _{DB} °C						Mean T _{DB} , °C	STD of T _{DB}
				1% T _{DB} , °C	Coincident RH (%)	2½% T _{DB} , °C	Coincident RH (%)	5% T _{DB} , °C	Coincident RH (%)		
1	Abuja	536.0	March	39.30	29.50	37.70	26.97	36.33	31.64	29.16	4.36
2	Bauchi	609.3	April	41.29	21.67	39.46	25.60	37.90	19.71	29.72	4.95
3	Benin City	77.7	February	35.86	38.40	34.61	46.46	33.54	52.54	27.95	3.40
4	Calabar	61.9	February	34.70	56.41	33.58	67.86	32.63	60.33	27.63	3.04
5	Enugu	141.4	March	37.29	29.70	35.92	39.35	34.76	43.68	28.64	3.72
6	Ibadan	227.1	February	36.21	42.60	34.93	49.41	33.84	47.64	28.12	3.48
7	Ikeja	39.3	March	35.29	47.59	34.19	55.13	33.26	71.35	28.34	2.99
8	Ilorin	305.4	March	38.09	28.80	36.56	32.33	35.25	51.41	28.37	4.35
9	Jos	1284.7	March	34.39	9.00	32.62	17.40	31.10	21.60	24.02	5.10
10	Kaduna	645.0	April	39.38	16.70	37.53	18.10	35.95	18.20	27.70	5.02
11	Kano	472.1	April	42.00	15.45	40.13	15.25	38.52	20.50	30.14	5.10
12	Maiduguri	353.6	April	44.76	14.33	42.65	14.70	40.85	14.80	31.41	5.74
13	Minna	258.5	March	40.43	20.80	38.84	26.20	37.48	32.00	30.38	4.32
14	Ondo	286.5	February	35.87	43.20	34.53	42.80	33.38	46.23	27.44	4.29
15	Owerri	159.0	February	36.95	35.19	35.67	44.46	34.49	45.57	28.86	3.54
16	Port-Harcourt	19.5	February	35.85	36.40	34.52	49.41	33.38	55.45	27.44	3.64
17	Sokoto	350.5	April	44.03	19.50	42.20	15.80	40.62	19.50	32.84	5.20
18	Yola	185.9	April	43.74	18.00	41.81	18.00	40.16	22.41	31.53	5.25

The design conditions of dry bulb and wet bulb temperatures for the eighteen Nigerian towns were compared with the results obtained by Shoboyejo&Shonubi [2] based on 1951-1965 meteorological data. The comparisons are presented in the following figures: Figures 1 to 3 are the bar charts for 1%, 2½% and 5% confidence values for dry bulb temperature while Figures 4 to 6 are the bar charts for 1%, 2½% and 5% confidence values for wet bulb temperature. The mean values in Tables 1 to 3 are the averages of dry bulb temperature, wet bulb temperature and vapour pressure for the four warmest months. The Daily range values in Table 3 were obtained from the differences of the maximum and minimum average hourly dry bulb temperature of the design months. Figures 7 – 9 give the comparison of results obtained from 1951 – 1965 data with results obtained in this work from 1995 – 2009 data for daily range, mean and standard deviation of dry bulb temperature, respectively, for sixteen Nigerian towns.

TABLE 2: CITIES WITH DESIGN MONTH, DESIGN WET BULB TEMPERATURE VALUES FOR 1%, 2½% AND 5% CONFIDENCE VALUES, MEAN WET BULB TEMPERATURE, AND STANDARD DEVIATION.

S/No	Station	Elevation (m)	Design Month	Design Twb °C				
				1%	2 ½%	5%	Mean	STD
1	Abuja	536.0	March	38.71	36.14	33.94	22.26	4.33
2	Bauchi	609.3	April	36.41	33.65	31.29	21.21	4.28
3	Benin City	77.7	February	41.07	39.12	37.45	24.71	2.4
4	Calabar	61.9	February	38.00	36.60	35.41	24.77	2.05
5	Enugu	141.4	March	39.39	37.37	35.64	24.09	2.65
6	Ibadan	227.1	February	39.20	37.33	35.72	24.27	2.63
7	Ikeja	39.3	March	39.71	38.32	37.13	25.84	2.70
8	Ilorin	305.4	March	39.57	37.14	35.07	23.03	3.45
9	Jos	1284.7	March	31.21	28.49	26.17	16.41	4.23
10	Kaduna	645.0	April	34.21	31.26	28.75	18.92	4.37
11	Kano	472.1	April	35.81	32.86	30.35	20.59	3.92
12	Maiduguri	353.6	April	33.98	31.07	28.59	19.85	4.95
13	Minna	258.5	March	38.51	35.82	33.53	22.48	3.41
14	Ondo	286.5	February	39.16	37.03	35.21	23.38	4.08
15	Owerri	159.0	February	40.52	38.35	36.50	24.19	2.66
16	Port-Harcourt	19.5	February	40.85	38.90	37.23	24.39	2.37
17	Sokoto	350.5	April	36.28	33.33	30.82	21.57	3.76
18	Yola	185.9	April	37.71	34.65	32.05	21.48	4.13

TABLE 3: CITIES WITH DAILY RANGE OF DRY BULB TEMPERATURE, VAPOUR PRESSURE VALUES FOR 1%, 2½% AND 5% CONFIDENCE VALUES, MEAN AND STANDARD DEVIATION OF VAPOUR PRESSURE

S/No	Station	Daily Range °C	Vapour Pressure mb				
			1%	2 ½%	5%	Mean	STD
1	Abuja	11.68	4.36	39.30	37.70	22.43	7.00
2	Bauchi	12.63	4.96	41.29	39.46	18.96	7.50
3	Benin City	9.15	3.41	35.88	34.63	28.74	5.30
4	Calabar	8.79	3.04	34.70	33.58	29.16	3.80
5	Enugu	9.21	3.72	37.32	35.95	26.60	5.50
6	Ibadan	10.35	3.39	36.00	34.75	27.34	5.10
7	Ikeja	7.15	2.99	35.29	34.19	30.92	3.78
8	Ilorin	11.26	4.35	38.49	36.89	24.22	6.60
9	Jos	13.45	5.10	35.88	34.01	14.00	7.40
10	Kaduna	11.27	5.02	39.37	37.52	15.60	8.00
11	Kano	13.49	5.10	42.00	40.13	17.20	8.00
12	Maiduguri	14.96	5.74	44.76	42.65	15.60	7.90
13	Minna	11.28	4.32	40.43	38.84	21.53	7.30
14	Ondo	10.69	4.29	37.42	35.84	25.67	5.80
15	Owerri	9.46	3.54	37.09	35.79	26.80	5.90
16	Port-Harcourt	9.69	3.64	35.91	34.57	28.52	5.30
17	Sokoto	13.06	5.20	44.94	43.02	17.67	8.00
18	Yola	11.28	5.25	43.74	41.81	18.40	8.30

TABLE 4: RESULTS OBTAINED FOR 16 OF THE TOWNS FOR DRY BULB TEMPERATURE FROM 1951-1965 DATA BY SHOBOYEJO & SHONUBI [2]

S/No	Station	Elevation (m)	Design Month	Design T _{DB} °C				
				1%	2 ½%	5%	Mean	STD
1	Bauchi	609.3	April	38.33	36.60	35.00	27.22	5.00
2	Benin City	77.7	March	32.20	31.11	30.00	25.56	2.78
3	Calabar	61.9	March	31.11	30.00	29.44	25.56	2.22
4	Enugu	141.4	March	33.88	32.22	31.67	26.11	3.33
5	Ibadan	227.1	February	32.78	31.67	30.56	25.56	3.33
6	Ikeja	39.3	March	31.67	30.56	30.00	25.56	2.78
7	Ilorin	305.4	March	35.00	33.33	32.22	25.56	3.89
8	Jos	1284.7	March	29.44	28.33	27.22	21.11	3.33
9	Kaduna	645.0	March	34.44	32.78	31.67	23.89	4.44
10	Kano	472.1	April	38.33	36.11	34.44	25.56	5.00
11	Maiduguri	353.6	April	40.56	38.33	36.67	26.67	6.11
12	Minna	258.5	March	35.56	34.44	32.78	26.67	3.89
13	Ondo	286.5	February	32.22	31.67	30.56	26.11	2.78
14	Port-Harcourt	19.5	February	31.11	30.56	29.44	25.56	2.78
15	Sokoto	350.5	April	41.67	39.44	37.78	29.44	5.56
16	Yola	185.9	March	38.33	36.66	35.00	27.22	5.00

TABLE 5: RESULTS OBTAINED FOR 16 OF THE TOWNS FOR WET BULB TEMPERATURE FROM 1951-1965 DATA BY SHOBOYEJO & SHONUBI [2]

S/No	Station	Elevation (m)	Design Month	Design T _{wb} °C				
				1%	2 ½%	5%	Mean	STD
1	Bauchi	609.3	April	27.78	26.11	25.00	18.89	3.89
2	Benin City	77.7	March	26.11	26.11	25.56	23.33	1.11
3	Calabar	61.9	March	26.11	25.56	25.56	23.89	1.11
4	Enugu	141.4	March	26.11	25.56	25.00	22.78	1.67
5	Ibadan	227.1	February	32.78	31.67	26.11	25.56	3.33
6	Ikeja	39.3	March	26.67	26.67	26.11	23.89	1.11
7	Ilorin	305.4	March	26.11	25.56	25.00	22.22	1.67
8	Jos	1284.7	March	22.78	21.67	21.11	15.56	3.33
9	Kaduna	645.0	March	27.22	25.56	24.44	18.33	3.88
10	Kano	472.1	April	28.33	27.22	25.56	18.33	4.44
11	Maiduguri	353.6	April	29.44	27.78	26.67	18.89	4.44
12	Minna	258.5	March	27.78	26.67	25.56	21.67	2.78
13	Ondo	286.5	February	25.56	25.56	25.00	23.33	1.11
14	Port-Harcourt	19.5	February	26.11	26.11	25.56	23.89	1.11
15	Sokoto	350.5	April	30.00	28.33	27.22	21.67	4.44
16	Yola	185.9	March	29.44	28.33	27.22	21.11	3.33

TABLE 6: RESULTS OBTAINED FOR 16 OF THE TOWNS FOR VAPOUR PRESSURE FROM 1951-1965 DATA BY SHOBOYEJO & SHONUBI [2]

S/No	Station	Daily Range °C	Vapour Pressure mb				
			1%	2 ½%	5%	Mean	STD
1	Bauchi	14.44	33	30	28	16	7
2	Benin City	11.11	31	30	30	28	1
3	Calabar	9.44	30	30	30	28	1
4	Enugu	11.11	31	30	29	26	2
5	Ibadan	11.11	29	29	28	26	1
6	Ikeja	9.44	32	31	31	29	1
7	Ilorin	13.33	31	30	29	24	2
8	Jos	12.78	28	25	23	14	6
9	Kaduna	14.44	33	31	28	17	7
10	Kano	15.56	33	31	28	16	7
11	Maiduguri	17.22	34	31	29	17	7
12	Minna	12.77	35	33	31	22	6
13	Ondo	10.56	29	29	28	26	1
14	Port-Harcourt	11.11	31	30	30	28	1
15	Sokoto	15.00	35	32	30	16	8
16	Yola	15.56	37	35	32	21	7

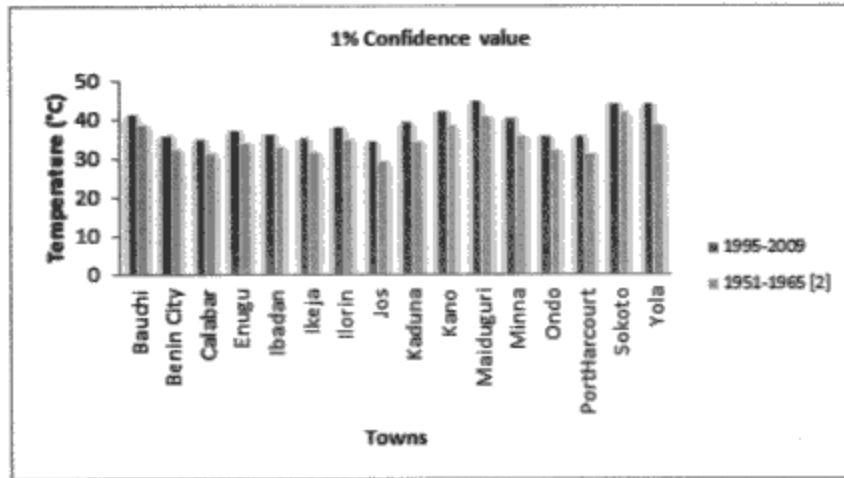


FIGURE1: COMPARISON OF 1995-2009 AND 1951-1965 DRY BULB TEMPERATURES DATA AT 1% CONFIDENCE VALUE FOR 16 NIGERIAN TOWNS

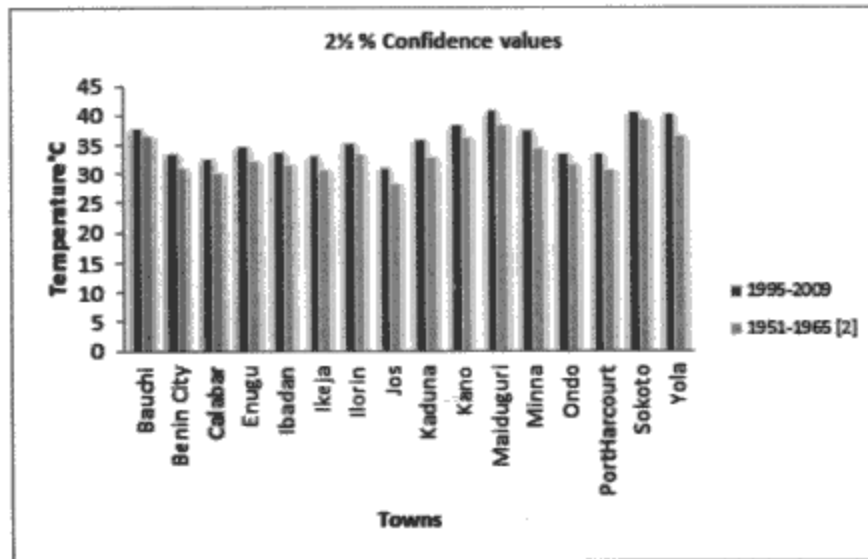


FIGURE2: COMPARISON OF 1995-2009 AND 1951-1965 DRY BULB TEMPERATURES DATA AT 2% CONFIDENCE VALUE FOR 16 NIGERIAN TOWNS

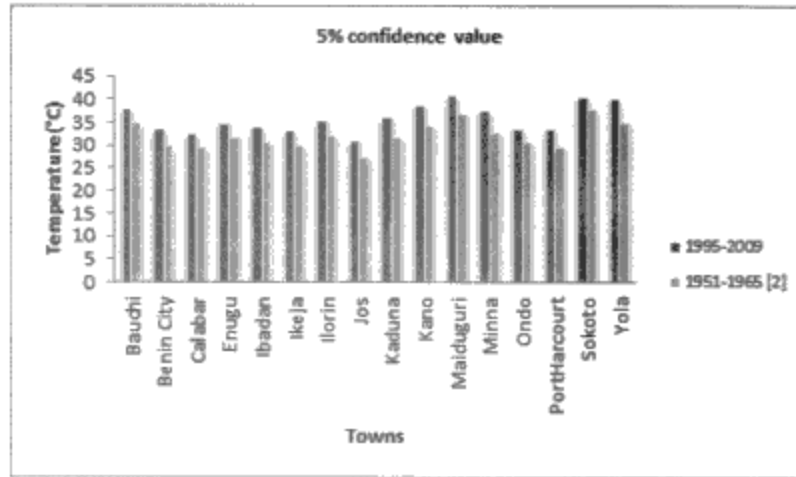


FIGURE 3:
COMPARISON OF 1995-2009 AND 1951-1965 DRY BULB TEMPERATURES
DATA AT 5% CONFIDENCE VALUE FOR 16 NIGERIAN TOWNS

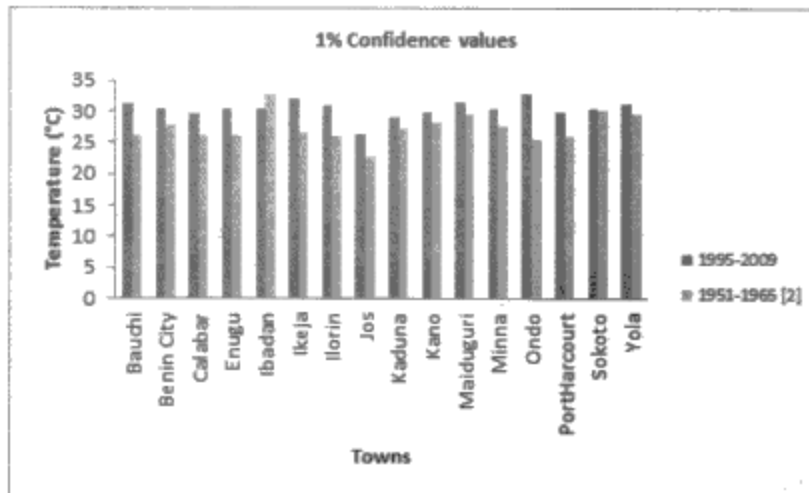


FIGURE 4:
COMPARISON OF 1995-2009 AND 1951-1965 WET BULB TEMPERATURES
DATA AT 1% CONFIDENCE VALUE FOR 16 NIGERIAN TOWNS

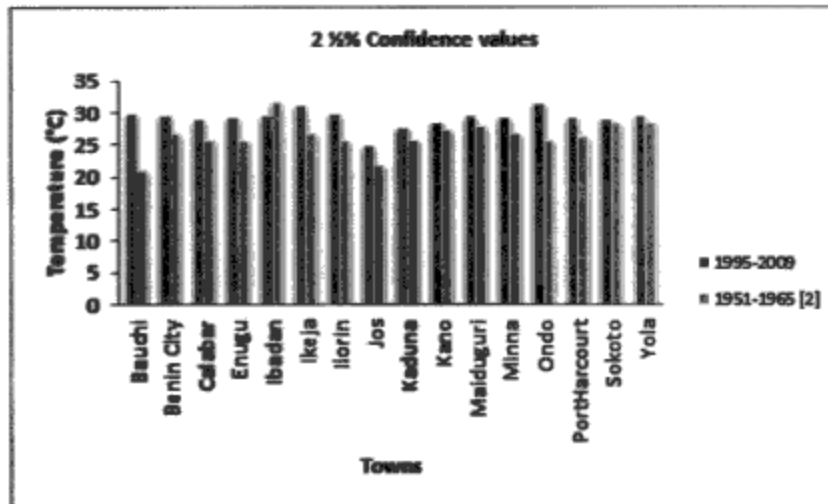


FIGURE 5:
COMPARISON OF 1995-2009 AND 1951-1965 WET BULB TEMPERATURES
DATA AT 2% CONFIDENCE VALUE FOR 16 NIGERIAN TOWNS

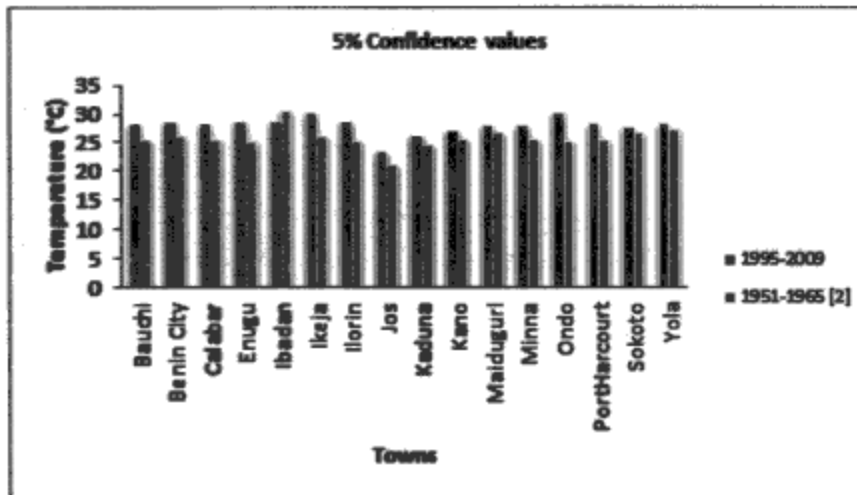


FIGURE 6:
COMPARISON OF 1995-2009 AND 1951-1965 WET BULB TEMPERATURES DATA
AT 5% CONFIDENCE VALUE FOR 16 NIGERIAN TOWNS

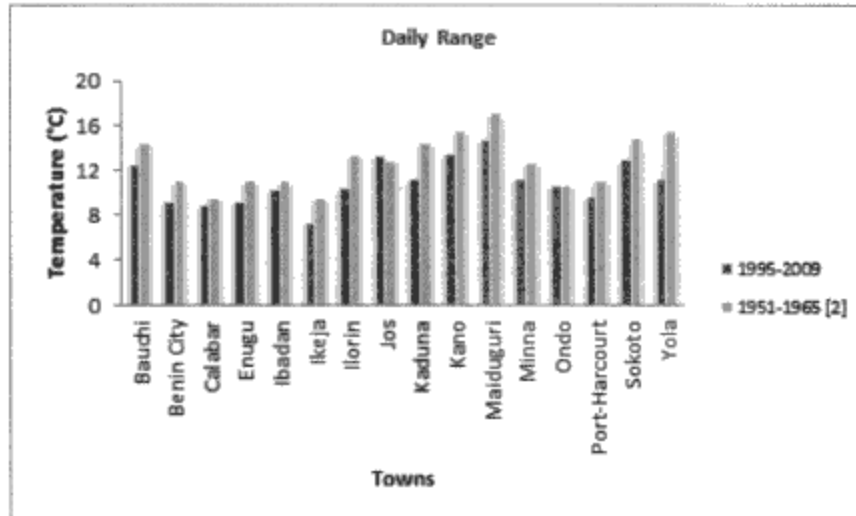


FIGURE 7:
COMPARISON OF 1995-2009 AND 1951-1965 DAILY RANGE OF DRY BULB TEMPERATURES DATA FOR 16 NIGERIAN TOWNS

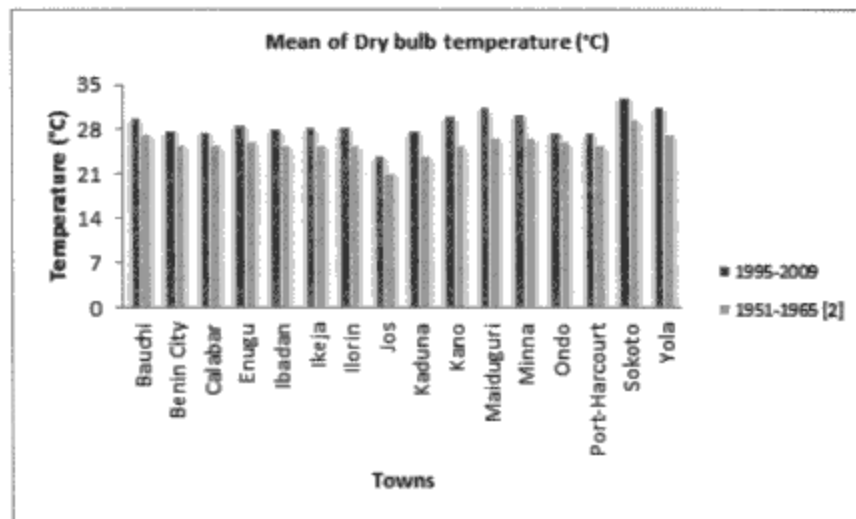


FIGURE 8:
COMPARISON OF 1995-2009 AND 1951-1965 MEAN OF DRY BULB TEMPERATURES DATA FOR 16 NIGERIAN TOWNS

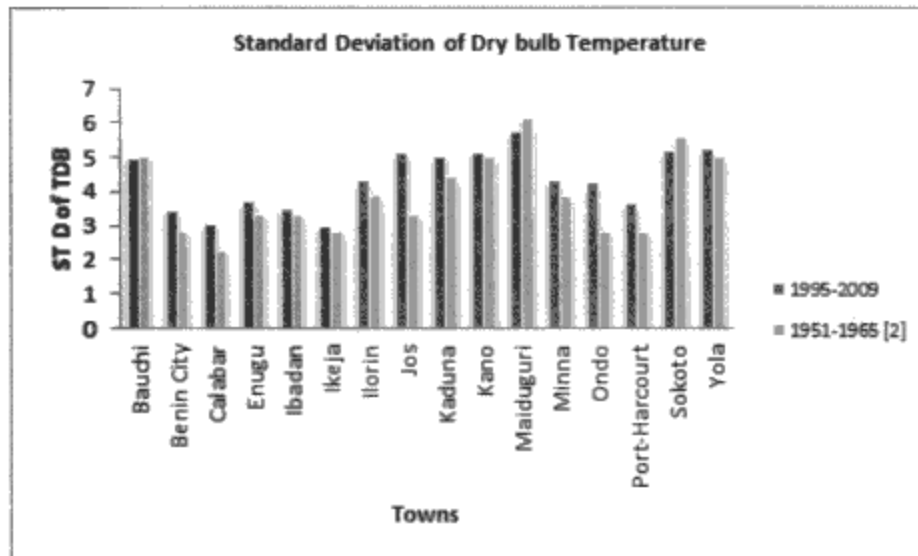


FIGURE 9:
COMPARISON OF 1995-2009 AND 1951-1965 STANDARD DEVIATION
OF DRY BULB TEMPERATURES DATA FOR 16 NIGERIAN TOWNS

DISCUSSION OF RESULTS

For Bauchi, Enugu, Ibadan, Ikeja, Ilorin, Jos, Maiduguri, Minna, Ondo, Port Harcourt and Sokoto the design months observed in this work using 1995 – 2009 data were the same as the design months obtained by Shoboyejo and Shonubi [2] from 1951-1965 data.

For Benin City, Calabar, Kaduna, Kano and Yola the design months observed in this work using 1995 – 2009 data differs from those obtained by Shoboyejo and Shonubi [2]. See Tables 1 and 4.

In Figures 1 to 6, there are no bars for Abuja and Owerri because Abuja and Owerri were not considered in the work of Shoboyejo and Shonubi [2] since there were no meteorological stations in the two places at that time. Infact Abuja did not exist as a city as at that time.

In the case of dry bulb charts of Figures 1 to 3 and 8, the bars of 1995-2009 are higher than those of 1951-1965 for each location. This is a strong evidence of global warming in the sixteen towns. This phenomenon is as a result of human activities that generate green house gases. This is equally evident in the case of wet bulb charts. Figures 4 to 6 show that the bars of 1995-2009 are higher than those of 1951-1965 for each location except Ibadan. This result shows that the ambient air at Ibadan was on the average drier (lower relative humidity) in the period 1995-2009 than the earlier period (1951-1965).

In Figure 7, there is higher daily range of dry bulb temperature for 1951-1965 data than in the present work which indicates that diurnal variation of dry bulb temperature are higher for the design months in the 1951-1965 data. The variations of the standard deviation in Figure 9 shows that there is higher standard deviation in this present work compared with the work of Shoboyejo and Shonubi [2] in thirteen (13) places (Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin, Jos, Kaduna, Kano, Minna, Ondo, Port Harcourt and Yola) which shows that there is higher dispersion of the hourly measured temperature from the mean in the 1995-2009 data than that of 1951-1965 data of Shoboyejo and Shonubi.

CONCLUSION AND RECOMMENDATION

Having computed 1%, 2½% and 5% confidence values for dry bulb and wet bulb temperatures for the four warmest months, it can be concluded that the results of this recent data of 1995-2009 in comparison with those of Shoboyejo and Shonubi [2] (1951-1965) shows clear evidence of global warming in other locations besides Ikeja and Ilorin for which this was reported in an earlier work(5).

It is recommended that this research should be extended to the other towns not considered in this study but which were considered in Shoboyejo and Shonubi's work to come up with current results in view of the trend of global warming.

Therefore, this work will be useful in preparing a revised code of practice for comfort Air conditioning system design for Nigeria.

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