Assessing Minimum, Maximum Temperature and Relative Humidity as Factors of Human Comfort of The Outdoor Environment in Port Harcourt, Rivers State, Nigeria

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Abstract: - The study assessed the minimum and maximum temperature and relative humidity as factors of human comfort of the outdoor environment in Port Harcourt, Rivers State, Nigeria. The study made use of meteorological data including minimum and maximum temperature, and relative humidity from 1985 to 2021 obtained from NiMet. Both descriptive and inferential statistics were used for the data analysis. Results showed that both minimum and maximum temperatures in Port Harcourt increased with increasing time while the monthly mean minimum and maximum temperature decreased from January to December. The total heat index continued to rise at the rate of 0.0329 in Port Harcourt and the mean total heat index was 78.78. The study can be concluded that the minimum and maximum temperature, relative humidity and heat index in Port Harcourt Metropolis from 1985 to 2021 is increasing. It is thus recommended that early warning infrastructure of preparedness should be put in place to checkmate the likely human physiological effect that might ensue due to the rise of the heat index in the recent times.

Key Words: ***Heat Index, Temperature, Relative Humidity, Descriptive, Physiological.***

I. INTRODUCTION

Since ages, human beings have been adopting different strategies to achieve the desired level of thermal comfort. Different creative ways, such as behavioral adjustment, choice of clothing and the use of fireplaces, were adopted to achieve comfort (Munonye 2020). In later years, during the 19th century, comfort research concentrated in industrial buildings and coal mines because of health and safety issues, and on vulnerable populations such as school children and hospital patients (Nicol *et al*., 2012).

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By the end of the 19th century, significant progress was made in thermal comfort research when scientists discovered the four environmental parameters (temperature, humidity, air movement and solar radiation) and personal factors that can be assessed to determine thermal comfort. In the 1920s, the American Society of Heating and Ventilation Engineers (then called ASHVE) made efforts to define the comfort zone, and the foundation for the methodological approach to adaptive thermal comfort was laid by Dr. Thomas Bedford and Nick Baker in 1930s. Considerable progress in adaptive thermal comfort was made in the 1960s when the 'focus of research shifted away from winter heating towards modelling the dynamic response of buildings in summertime, where highly glazed buildings were overheating on sunny days and during heating waves' (Humphreys, Nicol and Roaf 2015). Thermal comfort is defined by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) as the 'condition of mind that expresses satisfaction with the thermal environment' (ANSI/ASHRAE Standard 55-2013, 2013). ASHRAE's definition of thermal comfort is about a person's psychological condition of mind, whether the person feels neither 'too hot nor too cold' or thermally neutral provided that the person is healthy and wears a normal amount of clothing at the time of assessment. The latest version of the ASHRAE Standard updated the definition of thermal comfort by including the word 'subjectivity' in the definition. This psychological component in the definition is difficult to assess and to understand (Munonye 2020). Thermal comfort is influenced by personal difference, such as mood, culture and other individual, organization and social factors (Abdulkareem, 2015). As such, the definition of thermal comfort is not a state condition, but rather a state of mind. The definition of thermal comfort is meant by the condition of mind, which correctly emphasizes that, the judgment of comfort or not is a cognitive process involving many inputs influenced by physical, physiological, and other factors (Lin, 2008).

Since outdoor thermal environment may not be comfortable all the time, the various created microclimates offer individuals control in overcoming thermal discomfort. People tend to adapt to the ambient thermal conditions by modifying a clothing and activity patterns in order to continue their activities and routines (Gehl, 1987; Nasar & Yurdakul, 1990; Donaldson, Rintamaki & Nayha 2001; Nikolopoulou, Baker & Steemers, 2001; Parsons, 2002).

Comfort index refers to those hours which fall under comfortable class, where temperature, humidity and wind speed conditions are optimum for people to engage in light to moderate physical activities without the constraints of weather (excluding rainfall) (Abdulkareem, 2015). This implies that most people feel naturally comfortable without the aid of any anthropogenic support system, under the temperature conditions requisite for "comfortable" class. Consequently, when it is reported that certain months or periods of time include most hours under comfortable class, it usually means that in these months or periods one feels comfortable in natural ambient surroundings and does not require temperature altering mechanisms such as coolers, fans or air conditioners. The subject of comfort index is most applicable to people who spend a substantial time outdoors during a day. Cyclists, vendors, pedestrians, shopkeepers near roadside and most people from the lower strata of society who live in makeshift houses constitute these sets of people.

Several investigators have also shown that variation in the heat indices, especially temperature, have significant relations with human mortality (Kalkstein and Smoyer, 1993; Alcamo *et al*., 2007; Lin *et al*., 2011) and prevalence of certain diseases (Greenwood, 1999; Coelho *et al*., 2010). The young children (Bunyavanich *et al*., 2003), elderly and *pregnant* women are often considered to be particularly vulnerable to temperature extremes that can cause cardio-respiratory and skin diseases (Balbus and Malina, 2009). With global increase in temperature, especially from the 1960s and the tendency for further warming (Le Treut *et al*., 2007), as well as the concern for the increased urbanization in developing countries, concerns for thermal comfort have become important in the programme of the World Meteorological Organisation (WMO) (Jauregui, 1997). Studies on temperature and humidity (Arundel *et al*., 1986; Wolkoff and Kjaergaard, 2007) have showed the relevance of climate and weather to human health (Kalkstein and Valimont, 1986), migration, retirement, tourism (Mieczkowski, 1985; Jendritzky *et al*., 2001) and energy requirements, among others (Jauregui, 1993). Extreme climates can increase mortality (Hajat *et al*., 2005; Greenwood, 2006) and forced migration (Meze-Hausken, 2000). Knowledge of the thermal climate of any region is therefore vital for planning on health, urban development, tourism and migration, among other matters (De Freitas, 2003; World Health Organization, 2011).

McIntyre (1980) found that the temperature that a group prefers might correspond to a sensation above or below middle category on the warmth scale. If all neutral temperature is what a person want is debated for a long time, and from the view of related researches that neutral and preferred condition may not match (Mishra and Ramgopal, 2013). The air temperature is the major factor that controls physiological temperature. Therefore, an urgent need arises to curb this effect of air temperature so as to be tolerated by man in both high and low temperatures in Nigeria: which is thermal comfort. For instance, in Akure, Lagos, Abuja, Port-Harcourt, Kaduna there is high temperature, while in Jos and some highlands and riverine areas there prevails low temperature (Olugbenga 2011). In this study, Human comfort level therefore, is the range of temperature and humidity conditions that most people will find comfortable most times. These same thermal indices have been used to study how this relationship affects human health and activities. For example, Giles, Balafouts and Maheras (1990) analyzed how heat waves in Greece affected citizens of Athens and Thessaloniki, who experienced little relief even during the night hours. Few studies have been concerned with heat index and heat comfort in the Niger Delta cities in which the present study is looking at. The study thus assessed the minimum, maximum temperature as a factor of heat index of the outdoor environment in Port Harcourt, Rivers State, Nigeria.

II. Materials and Methods

The study was carried out in Port Harcourt, Rivers State, Nigeria. Rivers State is one of the 36 states of Nigeria. The climate of the region is an equatorial type of climate. There are two distinct seasons in the region in a year, they are called rainy and dry seasons. The rainy season begins from the month of February and gradually rises to its peak in the month of July. The major vegetation in the study area comprises of mangrove and freshwater swamp. The region is located within the lower Delta Plain believed to have been formed during the Holocene of the quaternary period by the accumulation of sedimentary deposits. Generally, region is lowland with mean elevation of between 3m and 7m above mean sea level and characterized by flood plains. Umeuduji and Aisebeogun (1999) identified that the area is within the belt of beach ridge barrier complexes generally trending in an east-west direction with height which vary between 10-25m above sea level. The net features such as lagoons are dominant relief features in the study area and are drained by many rivers and creeks among which are Epie Creek, Nun River, Orashi River, and Ekole Creek. Abam and Fubara (2022) also reported that the River Niger follows a relatively straight southwesterly trajectory after Onitsha. The flood plain is a homo-climate geomorphic structure whose trends west ward and southwards' are broken in many places by small hogback ridges and shallow swamps basic. The soil of the sandy ridges are mostly sandy or sandy barns and supports crops like Coconut, oil palm, raffia palm and cocoyam. The major geological characteristic of the state is sedimentary alluvium. The region lies on the recent coastal plain of the eastern Niger Delta.

The study made use of meteorological data of the Nigerian Meteorological Agency (NiMeT) Port Harcourt International Airport, and this data included of air temperature, relative humidity, for 1985 to 2021. Also, meteorological data were obtained from Community Climate System Model which is available from https://gisclimatechange.ucar.edu/gis-data. They are in form of point grid pattern of meteorological data to validate the air temperature, relative humidity, wind speed and radiation of the unsampled points within the study area. Data were examined for spurious values and evidence of non-climatic heterogeneity and instrumental errors as advised by the World Meteorological Organization (1989). The formulae used for computation of THI have been found to be valid and generally accepted for use in Nigeria and the tropics (Eludoyin et al, 2014). The THI was calculated with the empirical Equation:

$$THI = 0.8*T + RH*(T-14.4) + 46.4 \quad \text{……………………….. Equ. 1}$$

Where T = ambient or dry-bulb temperature in °C.
RH=relative humidity expressed as a proportion i.e. 75% humidity is expressed as 0.75
An average monthly (THI) single value was derived by multiplying 0.8 with temperature value plus the total sum of relative humidity and temperature value divided by 100%. And for the average annual (THI), the monthly averages for (THI) values across twelve months were added and the total was divided by twelve months. **Mild** (68 to 71 THI) **Moderate** (72 to 79 THI) **Severe** (80 to 89 THI). Descriptive and inferential statistics were used for the data analysis.

III. Results And Discussions

3.1 Monthly and annual trends of air temperature, relative humidity, wind speed and radiation Port Harcourt

The descriptive statistics of monthly minimum temperature of Port Harcourt between 1985 and 2021 is shown in Table 1 and Figure 1 and it is shown that the highest minimum temperature is found in March (23.66 °C) and the lowest minimum is found in January (21.47°C). The maximum monthly temperature of Port Harcourt is displayed in Table 4.2 and also in Figure 4.1 whereby the highest monthly maximum temperature was found in February (34.22°C) and the lowest maximum temperature in Port Harcourt was found in August with a mean value of 28.92°C. The trend surface analysis of monthly minimum temperature of Port Harcourt from 1985 to 2021 was found in Figure 2 whereby the minimum monthly temperature was decreasing from January to December at the rate of 0.0206 °C per year and time contributed 1.47% to the variation of minim monthly temperature of Port Harcourt. Similarly, the trend surface analysis of maximum temperature of Port Harcourt displayed in Figure 3 reveals that it is reducing from January to December at the rate of 0.2427 °C with 24.48% of contribution to the variation per month.

The annual trend surface of minimum temperature of Port Harcourt displayed in Figure 4 is showing that the minimum temperature was increasing from 1985 to 2021 at the rate of

0.018 °C with 33.55% contribution to the variation in the temperature with respect to the year. Figure 4.5 displaying the trend surface of maximum temperature revealed that maximum temperature was increasing at the rate of 0.0201 °C and with 42.72% of contribution to the variation within the period considered for this study. Moreso, the highest annual temperature was found in 2009, and 2017. Table 4.4 reveals the annual minimum, maximum and average annual temperature of Port Harcourt from 1985 to 2021 whereby the mean annual temperature was 27.19 °C. The mean minimum annual temperature of Port Harcourt between 1985 and 2021 was 22.85°C, the annual maximum temperature was 31.54°C. The pairwise sample T Test in Table 5 showed that there was a significant variation in the annual minimum temperature and maximum temperature of Port Harcourt (t=179.425, p=0.000). Table 6 showing the analysis of variance in the annual temperature from 1985 to 2021 revealed that no significant variation was found among the years (F=0.005; p=1.00).

Table.1. Descriptive Statistics of Monthly Minimum Temperature in Port Harcourt

Months	N	Minimum	Maximum	Mean	Std. Deviation
Jan	37	17.70	23.50	21.4730	1.20500
Feb	37	20.40	24.40	22.9351	.86962
Mar	37	22.50	24.70	23.6676	.47845
Apr	37	22.80	24.70	23.5676	.42561
May	37	22.60	24.20	23.3432	.42133
Jun	37	21.70	24.00	22.9622	.42515
Jul	37	21.90	23.30	22.7405	.37078
Aug	37	21.60	23.50	22.7676	.38948
Sep	37	22.10	24.30	22.9324	.51427
Oct	37	22.10	23.30	22.7919	.33696
Nov	37	21.60	24.60	22.9135	.53028
Dec	37	19.00	24.80	21.9649	.98748

Table.2. Descriptive Statistics of Monthly Maximum Mean Temperature

Months	N	Minimum	Maximum	Mean	Std. Deviation
Jan	37	31.70	34.90	33.1459	.72786
Feb	37	32.30	36.40	34.2162	.94649
Mar	37	32.20	35.80	33.2811	.88187
Apr	37	31.80	34.10	32.6946	.57249
May	37	31.10	33.00	31.8919	.42777
Jun	37	29.30	31.20	30.3541	.45252
Jul	37	27.90	30.50	29.1054	.58164
Aug	37	27.60	30.70	28.9162	.64140
Sep	37	28.80	30.70	29.7000	.50827
Oct	37	29.40	31.30	30.5676	.50390
Nov	37	30.80	33.20	31.8865	.61831
Dec	37	30.70	35.80	32.7676	1.03818

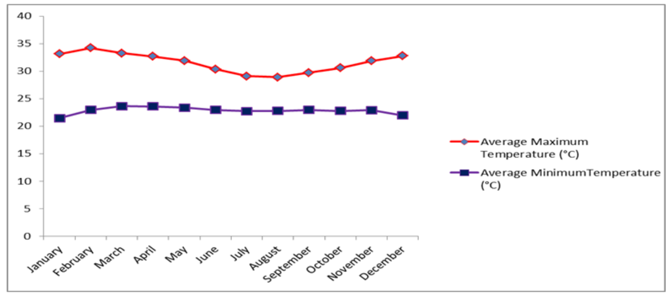

Fig.1. Monthly Minimum and Maximum Temperature

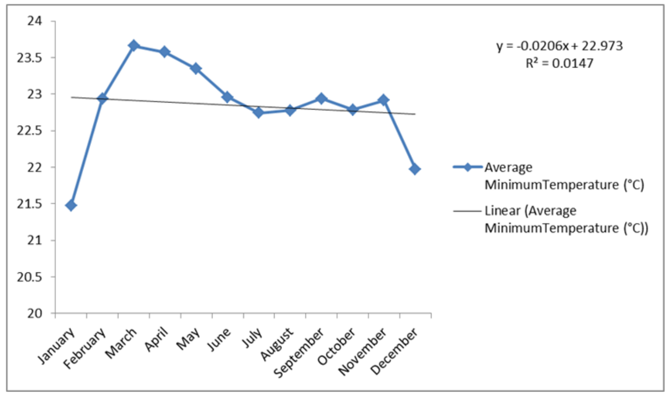

Fig.2. Trend Surface of the average Monthly Minimum Temperature of Port Harcourt from 1985 to 2021

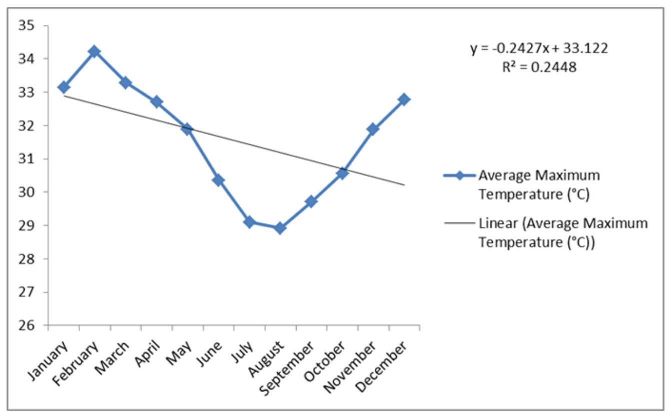

Fig.3. Trend Surface of the average Monthly Maximum Temperature of Port Harcourt from 1985 to 2021

Table.3. Analysis of Variance in the Monthly Temperature

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	699.816	11	63.620	3.108	0.000
Within Groups	17931.423	876	20.470		
Total	18631.240	887			

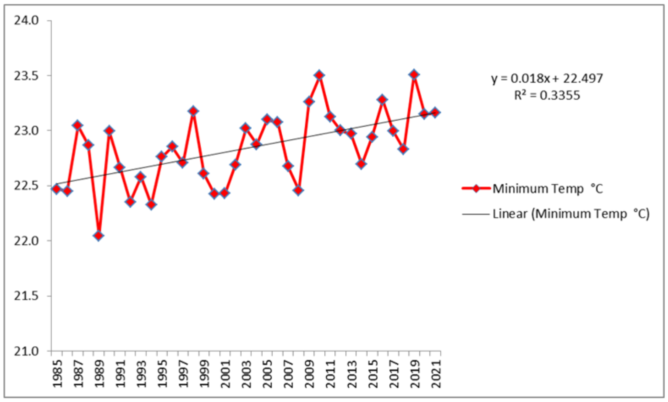

Fig.4. Trend Surface of Minimum Temperature in Port Harcourt from 1985 to 2021

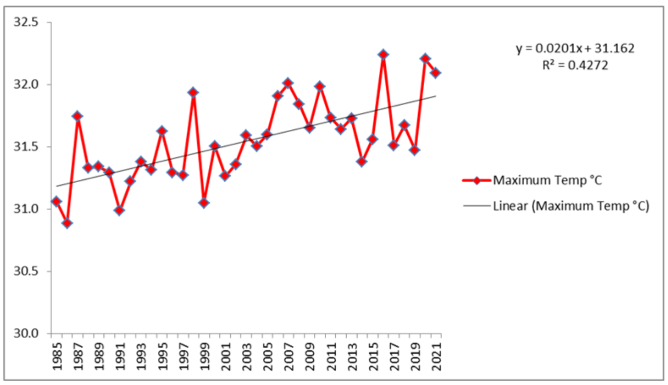

Fig.5. Trend Surface of Maximum Temperature in Port Harcourt from 1985 to 2021

Table.4. Descriptive Statistics of Annual Minimum, Maximum and Average Temperature of Port Harcourt from 1985 to 2021

	N	Minimum	Maximum	Mean	Std. Deviation
Annual Minimum	37	22.00	23.50	22.8459	.33878
Annual Maximum	37	30.90	32.20	31.5432	.32706
Average Annual Temp	37	26.67	27.76	27.1921	.30016

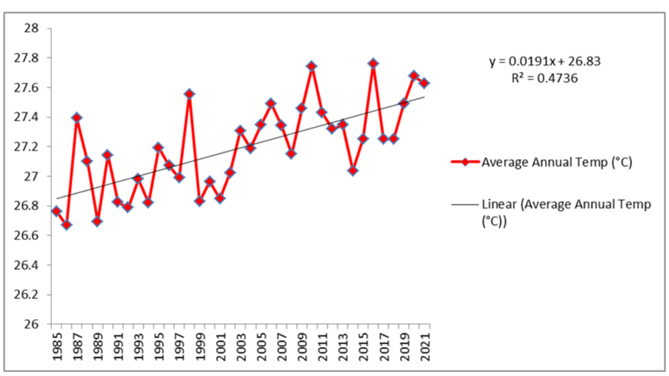

Fig.6. Trend Surface of Average Annual Temperature in Port Harcourt from 1985 to 2021

Table.5. Paired Samples Test between Minimum and Maximum Temperature in Port Harcourt from 1985 to 2021

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Annual Minimum Temperature - Annual Maximum Temperature	-8.69730	.29485	.04847	-8.79561	-8.59899	-179.425	36	.000

Table.6. Analysis of Variance in the Annual Temperature from 1985 to 2021

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6.418	36	.178	.005	1.000
Within Groups	1400.960	37	37.864		
Total	1407.378	73			

The descriptive statistics of monthly relative humidity of Port Harcourt is displayed in Table 7 whereby it is found that the month with the lowest relative humidity was January with a mean value of 76.62% and the month with highest relative humidity was July with 88.32%. The trend surface analysis of monthly relative humidity of Port Harcourt revealed an increasing rate of 0.5121% per month from January to December with the 21.01% of contribution (Figure 6). Table 8 displays the descriptive statistics of the annual relative humidity of Port Harcourt from 1985 to 2021 and it is revealed that the mean relative humidity was 83.09%. The analysis of variance for the monthly relative humidity in Table 9 reveals of no significant variation in the relative humidity in Port Harcourt (F=1.203, p=0.283). The trend surface analysis of relative humidity in Port Harcourt reveals that the highest relative humidity was found around 1995 and the minimum was found around 1999. The annual trend of relative humidity was slightly increasing at the rate of 0.0131%. The analysis of variance of yearly relative humidity in Port Harcourt from 1985 to 2021 showed that there was a significant variation in the relative humidity across the years considered for this study (F=30.328, p=0.000).

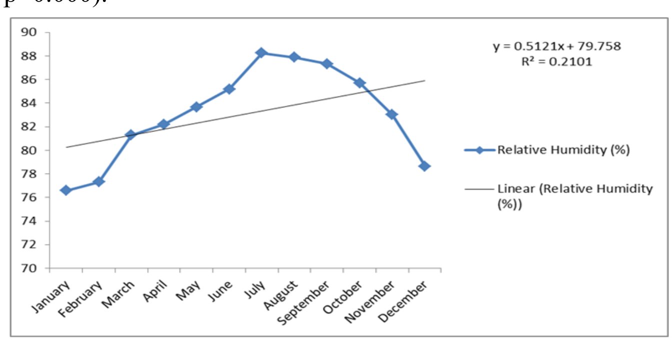

Fig.7. Trend surface analysis of the Average Monthly analysis of Relative Humidity

Table.7. Descriptive Analysis of monthly Relative Humidity

Months	N	Minimum	Maximum	Mean	Std. Deviation
January	37	51.00	90.00	76.6216	8.06347
Feb	37	41.00	85.00	77.3243	8.91645
March	37	74.00	86.00	81.2703	3.07904
April	37	78.00	88.00	82.2162	1.70188
May	37	74.00	88.00	83.7027	2.25912
June	37	56.00	88.00	85.2973	5.04350
July	37	80.00	94.00	88.3243	2.28588
August	37	82.00	91.00	87.8649	1.85835
October	37	82.00	88.00	85.7027	1.50674
September	37	84.00	90.00	87.3514	1.27402
November	37	75.00	88.00	83.0541	2.79827
December	37	57.00	86.00	78.7027	5.49174

Table.8. Descriptive Statistics of the Annual Relative Humidity

	N	Minimum	Maximum	Mean	Std. Deviation
Annual Relative Humidity	37	78.17	85.83	83.0861	1.43910

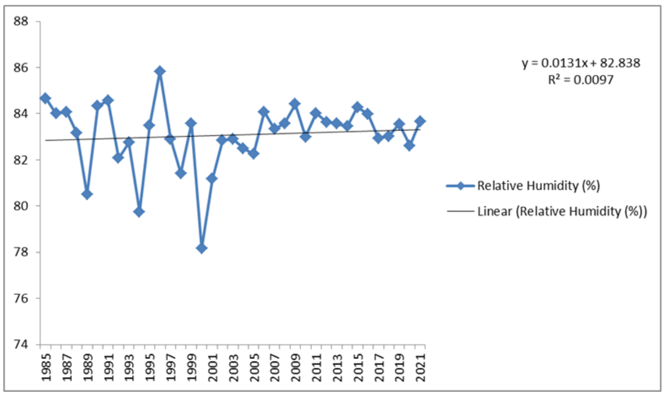

Fig.8. Trend surface analysis of the Average Annual Distribution of Relative Humidity in Port Harcourt

Table.9. Analysis of Variance for Monthly Relative Humidity in Port Harcourt from 1985 to 2021

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	451.214	11	41.019	1.203	.283
Within Groups	14733.459	432	34.105		
Total	15184.673	443			

Table.10. Analysis of Variance for Yearly Relative Humidity in Port Harcourt from 1985 to 2021

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6616.619	11	601.511	30.328	.000
Within Groups	8568.054	432	19.833		
Total	15184.673	443			

3.2 Heat Index Analysis in Port Harcourt

The trend analysis of heat index in Port Harcourt from 1985 to 2021 is displayed in Figure 8 whereby an increase trend was discovered. The heat index in Port Harcourt increased at the rate of 0.0329 with 40.28% contribution to the variation of heat index across the years. THI in Port Harcourt was 78.78 from 1985 to 2021.

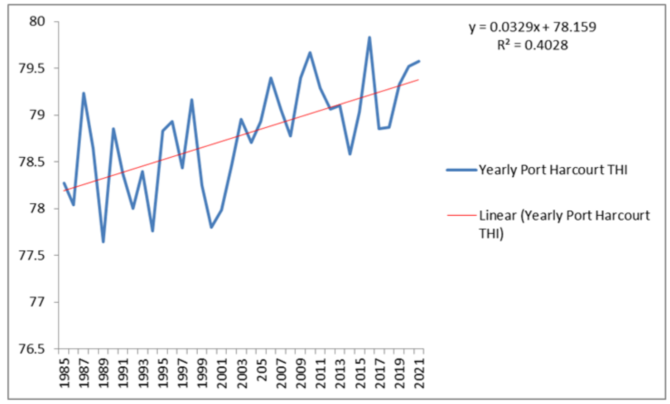

Fig.9. Total Heat Index of Port Harcourt from 1985 to 2021

3.3 Relationship between THI and Air Temperature, Relative Humidity

The correlation statistics among the THI, air temperature, and relative humidity in Port Harcourt is displayed in Table 11. It is shown that THI was significantly correlated with relative humidity ($r=0.700$, $p<0.05$) and temperature ($r=0.859$, $p<0.05$). The analysis in Table 12 shows that the multiple regression analysis between THI and other meteorological parameters (Temperature, Relative Humidity) had the regression coefficient of 1 suggesting a perfect relationship. The coefficient of the relationship shown in Table 13 is used to generate the regression model for the relationship in Port Harcourt.

$Y_{THI} = -2195.192 + 12.581_{Rel\ Hum} + 83.798_{Temp} + 5.661$ (Equ 2)

Table.11. Correlation between THI, Relative Humidity and Temperature in Port Harcourt

		Annual THI	Wind Speed	Solar Radiation	Relative Humidity	Average Temperature
THI	Pearson Correlation	1	.122	.450**	.700**	.859**
	Sig. (2-tailed)		.471	.005	.000	.000
	N	37	37	37	37	37
Relative Humidity	Pearson Correlation	.700**	-.006	.208	1	.235
	Sig. (2-tailed)	.000	.974	.218		.161
	N	37	37	37	37	37
Average Temperature	Pearson Correlation	.859**	.171	.460**	.235	1
	Sig. (2-tailed)	.000	.312	.004	.161	
	N	37	37	37	37	37

**. Correlation is significant at the 0.01 level (2-tailed).

Table.12. Model Summary of Regression in Port Harcourt

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000a	1.000	1.000	.33477

a. Predictors: (Constant), Temperature, Relative Humidity

Table.13. Coefficient of Relative Humidity, and Temperature in Port Harcourt

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2195.192	5.661		-387.770	.000
	Relative Humidity	12.581	.040	.527	312.176	.000
	Average Temperature	83.798	.212	.733	394.773	.000

a. Dependent Variable: THI

IV. CONCLUSION

The study can be concluded that the minimum and maximum temperature, relative humidity and heat index in Port Harcourt Metropolis from 1985 to 2021 is increasing. It is thus recommended that early warning infrastructure of preparedness should be put in place to checkmate the likely human physiological effect that might ensue due to the rise of the heat index in the recent times.

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