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AN ASSESSMENT OF DIURNAL AIR HEAT STRESS CONDITIONS IN URBAN CORE OF KANO METROPOLIS, NIGERIA

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Abstract

The Research assessed diurnal heat stress condition in the core of urban Kano where the residents complain for a gradual increase of atmospheric temperature when compared with some years back. Nine sites were selected using cluster sampling method. The Meteorological data were collected simultaneously across the sample sites at interval of 3 hours (i.e. 3 am, 6 am, 9 am, 12 noon, 3 pm, 6 pm, 9 pm and 12 mid-night) each in the months of April, August, October and December. Heat stress condition was calculated based on Discomfort Index (D.I): 0.5Tw + 0.5Ta. The result indicates heat stress existence in the study area with hottest points found in the city centers. The out-door mean seasonal / Diurnal Heat stress condition D.I ranges revealed as follows: 16-37.5 for urban core. The patterns of the stress indicated that the industrial and densely populated axes experienced more of the stress than the sparsely populated and institutional centers. A three way Analysis of Variance revealed significant differences between seasons and hours of the day. The study recommended for Intercity Street and houses spaces for effective ventilation, massive afforestation of city streets and initiating public heat stress detecting, monitoring and disseminating system for heat stress alert to the public so as to improve the city habitat.

Keywords: *Heat Stress, Diurnal, Seasons, Ventilation, Monitoring*

Introduction

Urbanization processes and their associated outcomes were seen to be responsible for the degradation of city environmental air quality and change in the climatic condition. The cities built themselves by destroying natural green cover and replacing it with man-made covers which in most cases possess higher heat capacities. They do absorb and retain excessive amount of heat from the solar radiation and later release much of the heat to the lower atmosphere of the city. This excess heat creates urban thermal heat load and in turn impact a phenomenon called Urban Canopy Heat Island (UCHI).It is believed that urbanization has negatively impacted on the environment mainly by the production of pollution, the modification of the physical and chemical properties of the atmosphere, and the covering of the soil surface. The natural landscapes/elements in the cities are being replaced with built up areas, paved surfaces and push natural elements outside the cities. Numerous reports have indicated that, around half of the world's human population live in urban areas. It is expected that the global rate of urbanization will increase by 70% of the present world urban population by the year 2030, as urban agglomerations emerge and population migration from rural to urban/suburban areas intensifies (Camilo and Marco, 2008). More industrial, commercial and transportation services are developed to serve the growing and transforming cities. This transformation affects many physical processes in each of the cities and may result to not only Urban Heat Island (UHI), but also heat stress and pollution, which negatively impacts not only on the residents of urban-related environs, but also on humans and their associated ecosystems located far away from cities.

Balogun (2010) has reported that, Heat stress is a physiological condition of a living body, which occurs when one's body gains heat faster than it loses. When this condition persists without relief, there is the danger that worker can experience heat discomfort. Thus human health is complicated by heat stress simply by forcing the body to continue functioning as it tries to maintain core temperatures. A person's tolerance to high temperature may be limited if he or she cannot: sense temperature, lose heat by regulatory sweating and move heat by blood flow from the body core to the skin surface where cooling can occur. Thus the heart rate increases to move blood and heat from heart, lungs and other vital organs to the skin. While the sweating increases to help cool blood and body evaporate water, which is the most important way the body gets rid of the excess heat.

Studies on air heat stress were conducted in some Nigerian cities such as Balogun (2010) in Akure, Odjugu (2002) in Benin. In all the studies none of them used discomfort index (D.I) to detect heat stress condition and all the outcomes indicated that, city centers were warmer than the periphery of the metropolis.

The local communities and Kano state governments have not made serious commitment towards identifying and assessing the status of heat stress in the local government. Therefore, it's based on these facts that the researcher is prompted to undertake this research to ascertain the level of the diurnal heat stress in the city so as to inform the urban planners to improve on future planning.

MATERIALS AND METHODS

Study Area

Kano Metropolis being the capital of Kano state, was created in 1967 from the defund Northern Region is one of the nerve centers of commercial activities in Nigeria, as the famous Tran-saharan trade route, linking sub Saharan Africa with the Mediterranean coast. The old city is surrounded by a 22kms long wall, built in the 13th century and sprawl of new extensions outward around the old city, Alhaji, (2006).

Kano Metropolis is located between latitudes $11^0 40'$N and $12^0 25'$N and $8^0 30'$E and 8^0 $45'$E (see Figure I below). The boundary of Kano Metropolis keeps on changing with time due to rapid urbanization processes (Mortimore, 1989).The Metropolis is presently made up of about eight local governments and surrounded by eight rural local governments as potentially urbanized zones, Un-habitat, (2012). The Six of them: Kano Municipal, Gwale, Dala, Tarauni, Nassarawa and Fagge are fully urbanized ones. Kumbotso and Ungoggo are the partially urbanized local government areas.

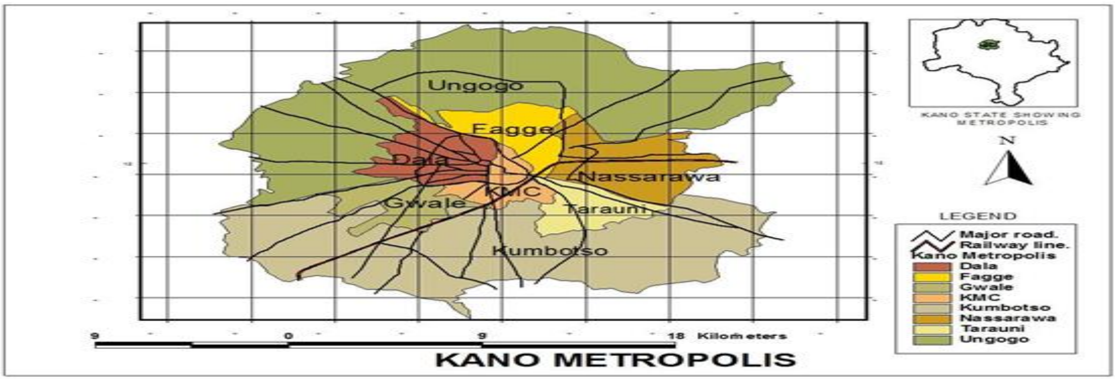

Figure I : Map of the study Area and its main Local Governments

Methods Data Collection

The data for this study were collected from primary source through measurement and observation of climatic variables (temperature and humidity) and physical observations on physiological and hydrological features. Nine sites were selected by cluster sampling method. The meteorological data were collected simultaneously across the sample sites at interval of 3 hours (i.e. 3 am, 6 am, 9 am, 12 noon, 3 pm, 6 pm, 9 pm and 12 mid-night) each in the months of April, August, October and December. This was recommended by Ayoude (2012) . Heat stress condition variables were taken through the measures of dry bulb (Ta) and wet bulb (Tw) temperature.

Both in-door and out-door temperature and humidity data of the city atmosphere were measured and recorded. The result of the values taken at different periods and locations were subjected to means and discomfort index formula as given below:

DI = 0.5tw + 0.5ta ....Eq 1

The formula was adopted from Yoram (2006) as Discomfort Index standard.
Where Tw = means wet bulb temperature
Ta = Dry bulb temperature value.
The calculated value are subjected to the ranges provided in the (DI) index below

- DI value of 22 units: means no heat stress encountered
- DI value of 23-24 units: means mild sensational heat
- DI value of 25 – 28 units: means moderate heavy heat load, people feel very hot, physical work may be performed with some difficulties.
- DI value of above 28: Indicates several heat loads.

Data Analysis

Finally, the results were subjected to Analysis of Variance for assessing differences between diurnal hours in one hand and between in-door and out-door on the other hand. The statistic aids by testing the following hypothesis:

H_0: there is no significant difference in the heat stress condition between seasons and diurnal times.

RESULTS AND DISCUSSIONS

Mean out-door Heat Stress Condition Patterns

Introduction

In this section, the diurnal out-doors heat stress characteristics based on seasons and metropolis zones were presented and discussed.

Urban-core mean diurnal heat stress condition

The result in figure1 indicates urban core mean seasonal exposures to heat stress on diurnal hours from 3:00 am to 12:00 mid night periods. The presentation is done according to various seasons of the year as indicated below.

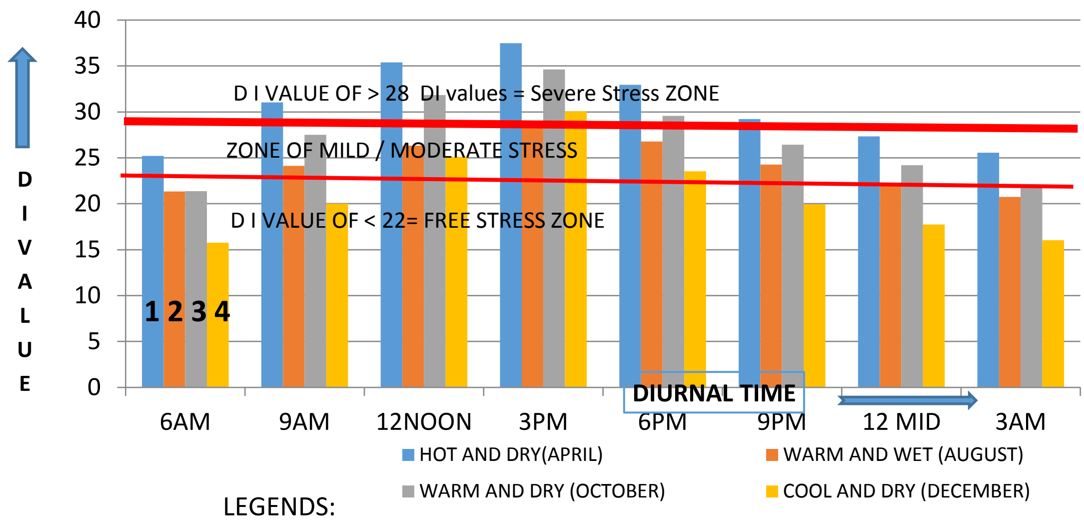

FIG. 1.1 Urban core mean seasonal / diurnal heat stress condition (outdoor)

SOURCE:FIELD WORK.2013

Hot and dry season (April)

For instance during hot and dry season the figure shown that there is no heat stress free hours in the zone. The periods around from 9:00am to 9:00pm marked the time when the zone is exposed to the severe heat stress condition. The period around early day hours and late night hours are the only hours when the zone was subjected to moderate stress condition. The 6am hour is the period around which the urban core has the lowest Discomfort index; while 3:00pm the severest hours of vulnerability to heat stress problems. This is not surprising if one considers the agglomeration of urban industrialization and anthropogenic sources of heat and coupled with compacted settlements and heat absorbent building. The result has resembles that of Akure and Benin cities in Southern Nigeria they belong to tropical cities of the world.

Warm and wet season (August)

The figure displays that the urban core witnessed free stress condition in the period of earliest day and late night hours. This may be due to absence of the sunlight and industrial operations in the city. The 3:00 pm is the only hour around which the zone came under severe heat stress condition. The remaining hours had stress exposure from mild to moderate levels but with 3:00 pm having the severest vulnerability while 6 am with lowest D.I value.

Warm and dry season (October)

During this season, it is observed that the early hour (6:00 am) was the only period with lowest D.I value and stress free condition. The 9:00 am, 9:00 pm and 12:00 mid night are hours around which the zone came under mild to moderate stress condition. The period when the urban inhabitants came under heat stress condition coincided with period around 12:00 noon, 3:00 pm, and 6:00 pm. Thus the lowest D.I value is recorded around 6 am while the highest was recorded around 3 pm.

Cool and dry season (December)

The figure reveals that most of the early day and latest night hours' workers are free from stress problems. But for the 12:00 noon and 6:00 pm the core-urban people are prone to mild or moderate heat stress condition. The severe stress period is only observed at the period by 3:00 pm hour. Unlike in the case of the southern Nigerian cities of Akure and Benin, Kano city been closer to Hamattan wind turns to be cooler than the afore mentioned cities.

Statistical Analysis

The result of two-way ANOVA has indicated that there is significant differences between seasons and diurnal times. Seasons were divided into cool and dry, warm and wet, warm and dry and hot and dry. The result revealed that there was statistically significant main effect for seasons {F (3, 99.033), P= 0.0001) and diurnal {F: (7, 52.504), P= 0.0001}. see table1

Table 1: Tests of Between-Subjects

Dependent Variable: Heat Stress Condition

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	887.080[a]	10	88.708	66.463	.000
Intercept	21213.288	1	21213.288	15893.732	.000
Diunal	490.542	7	70.077	52.504	.000
Season	396.538	3	132.179	99.033	.000
Error	28.029	21	1.335		
Total	22128.397	32			
Corrected Total	915.109	31			

a. R Squared = .969 (Adjusted R Squared = .955)

Table : 2 Multiple Comparisons

Dependent Variable: Heat Stress Condition

Tukey HSD

(I) Season	(J) Season	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Hot and Dry	Warm and Wet	6.2880*	.57765	.000	4.6779	7.8980
	Warm and Dry	3.3212*	.57765	.000	1.7111	4.9313
	Cool and Dry	9.5041*	.57765	.000	7.8940	11.1142
Warm and Wet	Hot and Dry	-6.2880*	.57765	.000	-7.8980	-4.6779
	Warm and Dry	-2.9667*	.57765	.000	-4.5768	-1.3566
	Cool and Dry	3.2161*	.57765	.000	1.6060	4.8262
Warm and Dry	Hot and Dry	-3.3212*	.57765	.000	-4.9313	-1.7111
	Warm and Wet	2.9667*	.57765	.000	1.3566	4.5768
	Cool and Dry	6.1829*	.57765	.000	4.5728	7.7929
Cool and Dry	Hot and Dry	-9.5041*	.57765	.000	-11.1142	-7.8940
	Warm and Wet	-3.2161*	.57765	.000	-4.8262	-1.6060
	Warm and Dry	-6.1829*	.57765	.000	-7.7929	-4.5728

Source: field work, 2016
Based on observed means.
The error term is Mean Square(Error) = 1.335.
*. The mean difference is significant at the 0.05 .

The estimated marginal Means of heat stress condition among four seasons i.e hot and dry, warm and wet, warm and dry and cool and dry show significant interaction effects. see figure 2.

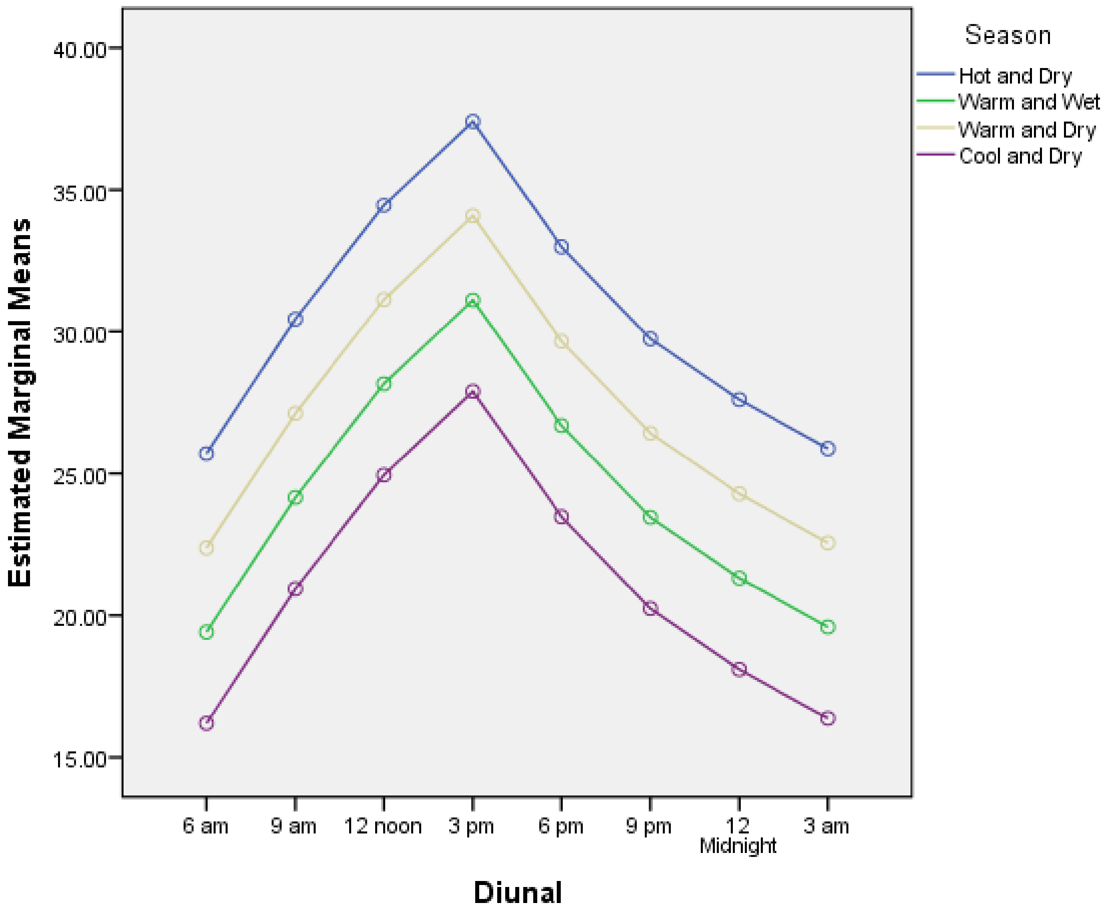

Figure 2: Estimated Marginal means of diurnal Heat stress condition

CONCLUSION AND RECOMMENDATION

The study focused on the assessment of spatio-temporal air heat stress condition and associated implications to mankind in Kano Metropolis. It began with assessment of temperature pattern and mapping of the urban heat island before it fundamentally assessed the Heat stress condition across the metropolis zones. The following findings are deduced from the study:

The metropolis heat stress conditions in out-door have revealed the following D I ranges: 14.2 – 37.5c^0, 14.4 – 34.9C^0 and 12-34.7C^0 Discomfort index values for Urban Core, suburban and rural surrounding, respectively. While for seasons, the D.I Values ranges of 24.9-37.5 C^0, 18.1-28.3 C^0, 18.6-34.6 C^0 and 12-30.1 C^0 during hot-dry, warm-wet, warm-dry and cool-dry season, respectively.

Thus, the inhabitants of the urban core are more liable to heat stress disorder than any of the metropolitan zones even though all the zones values exceed 28c^0 (severe stress limit). While the rural sites and airport outlier are the coolest of all the sites in the study area.
In the study area, the business nerves (CBD), industrial clusters (Bompai and Sharada) and densely populated axes (Dala and Shahuci) are the warmest of all the metropolitan sites. These were attributed to numerous automobiles and anthropogenic sources of heat and tall congested built-up. Statistical analysis indicates significant difference of heat stress condition between seasons, time of the day and across the metropolitan zones.

Conclusion

It can be emphatically concluded that, the heat stress exists at Kano metropolitan zones as was established in temperate area of Europe and other tropical localities. Its existence with spatio-temporal variations is the functions of meteorological and non-meteorological factors as lamented by Ayoade (2008).

The phenomenon was found to be severe in the city down town than at the rural zone, during the mid-day/evening hours and more serious during the hot-dry and warm-wet seasons. Thus, the rural sites and airport outlier are the coolest of all the sites in the study area.
The phenomenon has impacted the inhabitants of the metropolis to be potentially subjected to heat stress disorders especially at the urban core and during the noon hours and hot-dry and warm-wet seasons of the year.
The population of the study area, its demographic characteristics, land use types, mode of buildings, city technology and inhabitants body responses are fundamental to the assessment of future trend of the heat stress in the city under study especially if global warming and rapid population growth are also put into consideration.

Recommendations

The following are recommended for curbing the heat stress escalation and the potential solutions on how to make the metropolitan environment sustainable and comfortable for habitation.
The governments in collaboration with urban planners are to imbibe and implement climatic aspects in designing and execution of city/town planning and sensitized them to bridge the communication gaps existing between them and beneficiaries as opined by Christina (2004) and Ayoade (2012, 2008 and 2004). By this the planners should also ensure adequate ventilation with hazard free plan, maintain air quality (reduce pollution) and improve thermal situation in an in-door environment. In addition to that, planners should be making a composite design and plan according to the expected future climate (by combining traditional and modern architecture and civil engineering) in building technology.
Intercity street spacing and inter housing spaces should be encourage and ensured by the town planners for maintaining ventilation with the view to providing effective fresh air circulations especially in the densely populated areas of the city. Massive planting of flowers and tall economic

trees (for not intercepting room ventilation system) in available city spaces: streets, parks, back/front yards of houses and institutional lands as the carbon sinks of the city as opined (Aliyu, 2005).

Households should construct/paint with light coloured materials, green-roof (eco-friendly) for increasing heat absorption and reflectivity of solar energy on one hand and, on the other, to discourage flooring of city spaces and compound with concrete, tar and asphalts materials which are heat retentive in nature.

Governments should ensure the establishment of advance automated weather system in various urban land use clusters, in the tertiary institutions and other strategic suburban and rural local governments' centres. This serves as a bench-mark for subsequent establishment of heat-wave detection, monitoring, preparedness and public awareness system unit in the various states ministry of environments for weather predictions and heat alert to the public. Subsequently this is to be followed by establishing heat stress disorders specialized hospitals at the areas potentially vulnerable to severe heat stress condition.

Governments and local community should embark on mass media sensitization about heat stress effects and prompt severe heat alert to the public on emergency, especially in the rural and densely populated areas. Finally, there is vehement need for Non-Governmental Organizations to link up with governments and Community Based Organizations for establishing Pollution detection and controls, drainages and infrastructures Boards for supplementing Government efforts.

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