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Analysis of human heat stress status for academic learning environment in Kano University of Science and Technology, Wudil, Kano State, Nigeria.

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Abstract

This study analysed heat stress condition and its implications on Academic activities of the KUST Wudil University. The Meteorological variables consisting of maximum and minimum wet and dry bulb temperatures data were collected from the KUST- Meteorological station from 2008 to 2011 and subjected to means simple statistic for determining heat stress condition by using Formulae of Discomfort Index (DI). The result reveals that DI values were 24.5, 26.5, 28.5 and 20 during the hot-dry, warm-wet, warm-dry and cool-dry seasons, respectively. These mean that the study area is vulnerable to severe discomfort condition, especially during the hot and humid season and during the afternoon hours when the influence of temperature and humidity elements are at their peak. This study recommends that (both passive and active mean of ventilation such as) air conditioners, surrounded with trees as well as the orientation of the building be taken into cognizance from the design stage for the effect of solar radiation on classes and rooms of the students/staff; Subjects that are mathematic based should be scheduled for morning period, while for the benefit of students the semester examinations should coincide with period around December or August when there is less risk of heat stress. The general idea presented is to illustrate the range of dimensions relevant to design and maintenance of an academic setting.

Keywords: Heat-stress, Humidity, Learning environment, Meteorology, Temperature

1. Introduction

1.1 Background: Human body is essentially a constant-temperature device. Heat is continuously produced by bodily metabolism and dissipated in an automatically regulated manner to maintain the body temperature at its correct level despite variation in ambient conditions. 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. (Epstein & Moran, 2006) reported that, heat strains can occur in arid climates, indoor office environments or in factories. In humid calm condition, it can occur above 26^0C to individual under physical work. The thermal comfort of human physiology is a function of temperature, humidity and wind. These determine his work performance and productivity. At calm condition, the optimum thermal comfort is achieved at the range of $22\text{-}28^0$C temperature and 30-50% relative humidity in a comfort chart.

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. According to Rowlinson, Jia, Li, and Ju (2013) the human body functions best within a narrow range of internal temperature. This core temperature varies from 36^0C to 38^0C. To get rid of excess heat and keep internal temperature below 38^0C, the body has to adopt two cooling mechanisms: sweating and increase in heart beat rate for faster blood circulation. When the body's cooling mechanisms work well, core temperature drops or stabilizes at a safe level (37^0C). But if too much sweat is lost through heavy labour or working under hot, humid conditions, the body doesn't have enough water left to cool itself. If the body temperature exceeds 39^0C heat stroke may developed (Bowles E. H. , 2009) and a temperature of 40.6^{0}C is life threatening (Beall & Steegmann Jr, 2000). (Ross & Altmaier, 1994) further stated that before (these) serious health effects occur, at lower heat exposures a worker may be subjected to diminished work ability , diminished mental task ability and increased accident risk which eventually lead to overall reduced work ability and lower labour productivity. Thus, reduced work ability is a function of environmental humidity, radiant heat, air movement and ambient temperature (Ramsey, 1995). Review of various literature traces the impact of heat stress disorders from minor discomforts to life threatening conditions (stroke). (Boekaerts & Corno, 2005; Hanna, Kjellstrom, Bennett, & Dear, 2011; Jones, Rock, Sawka, Modrow, & Lindsay, 1993; Kovats & Hajat, 2008; Rowlinson et al., 2013) as summarised under:

a. Heat rash: it is the most common problem in hot wet environments also known as prickly heat. The main symptom of heat rashes are red blisters and extreme itches in areas persistently dump with sweat, prickling sensation on the skin where sweating occurs

b. Heat cramps: these are spasms in larger muscles- usually back leg and arms. Cramping creates hard painful lumps within the muscles.

c. Heat exhaustion: it occurs when the body can no longer keep blood flowing to supply vital organs and at the same time send blood to the skin to reduce body temperature: weakness, head ache, breathlessness, vomiting, feeling fainting/ fainting and difficulty continuing work.

d. Heat stroke: this occurs when the body can no longer cool itself and body temperature rises to critical levels.

e. Sun burn

Educational institution is more than like a factory where both staff and students engage not only on physical activities but also subjected to serious cognitive and intellectual tasks toward achieving precisions (Siegrist, 2009). Kano University of Science and Technology Wudil is one of the earliest states University which characterised with marginal land, thousands of students and inadequate staff which signifies unfavourable teacher- students ratio. The height of complains on academic stress from the staff and students are perhaps symptoms that this study should be conducted for detecting the periods more vulnerable to heat stress and its disorders. Thus, the outcomes will be used to inform the stakeholders of the institution; for improving the Academic learning environment and for offering suggestions to adjust the subsequent academic.

1.2. Aim and Objectives

The aim of this paper is to analyse the heat stress status based on the meteorological measures (Gibilisco, 2006) and its potential implications for academic learning atmosphere in the study area. The aim is planned to be achieved through the following objectives:

a. To identify and calculate the relevant meteorological elements for human heat stress condition analysis.

b. To proper suggestions to the University for improving condition for conducive academic calendar.

1.3: Study Area

Kano University of Science and Technology Wudil, the study area is approximately located on latitude 11, 8.2127N and longitude 8.5E in Wudil town. The campus is located along Wudil-Gaya Road about 3 KM from the main Wudil River that flows toward Lake Chad basin. Tropical wet and dry climate is typical condition with mean monthly Temperature above 18^{0}c throughout the year and rainfall of around 80cm/annum. The temperature is generally worm throughout the year with exception of December when the temperature is slightly cool. But no month with mean temperature less than 18^{0}C. While for humidity is determined by temperature factor, with more humidity in wet season than dry period. The campus serves as residence to staff and Students as well as Educational and administrative land uses. The campus accommodates and provides services to more than 5000 people.

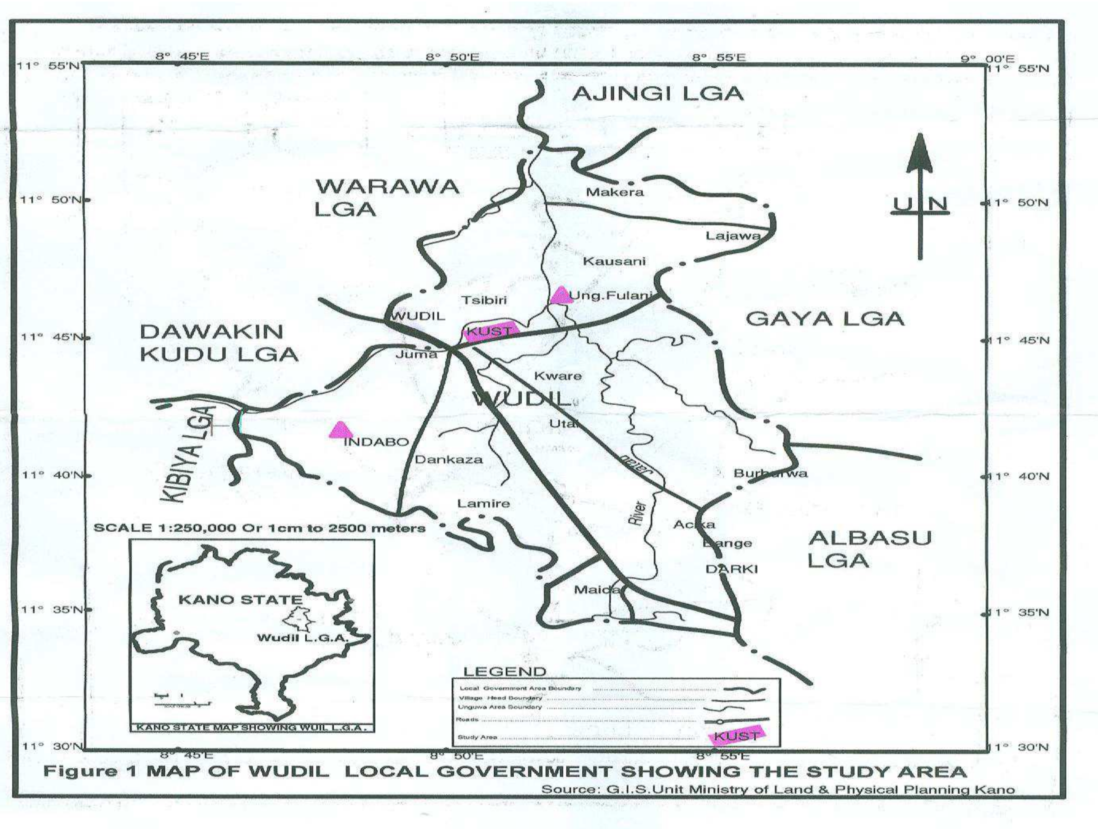

Figure 1 MAP OF WUDIL LOCAL GOVERNMENT SHOWING THE STUDY AREA
Source: G.I.S.Unit Ministry of Land & Physical Planning Kano

Fig. 1 Map of Wudil Local Government Showing KUST

1.4: Climatic considerations in design of learning environment

In addition to comfort and energy saving architectural design should be made with climatic considerations in order to preserve to preserve important resources in the world (Rowlinson et al., 2013). However most buildings were not designed with such objectives of utilizing and conserving natural resources which leads to their poor thermal performance (Wong & Jan, 2003) and the fact that no stable electricity is yet to be seen in Nigeria, passive means of air conditioning will be difficult to manage economically. Thus, climatic considerations at the design stage of the buildings may provide a great benefit to the society. To maximize natural ventilation in KUST, building orientations should be placed in in such a way as to encourage passive cooling (Santamouris & Asimakopoulos, 1996) such that the longer exterior face of the building envelope with maximum penetration faces the North-South orientation so as to utilize the South-West trade wind which is cool and comfortable and avoid direct solar radiation of the sun which rises from the East to West. While the shorter side of the building should be orientated to face East-West direction in order to limits the direct effect of solar radiation and curtail the effect of North east trade wind (which is hot, dry and dusty). Sun shading devices should also be incorporated in the design to reduce the effect of heat stress on the building users (Tzempelikos & Athienitis, 2007). In addition to colour absorption studies by Kontoleon and Bikas (2007) measure the effects of material absorptions on the exterior walls. While area ratio of the exterior glazing according to (Al-Tamimi, Fadzil, & Harun, 2011) accounts for 25-28% in addition infiltration of the total heat gain in the tropics.

2. Methods and Procedures

Quantitative data were collected for this study. The quantitative data include the measures of “mean” monthly dry (Ta) and wet (Tw) bulbs temperature and mean minimum and maximum temperature values. These were obtained from hygrometer and thermometer instruments from the university Meteorological station. The values of the temperatures were recorded by 6:00am and 3:30pm when the lowest and highest diurnal temperatures are recorded, respectively. The values were recorded in April, August, October and December months which coincided with peak periods of hot-dry, warm-wet, warm-dry, and cool-dry seasons, respectively. Mean values of four years were computed (2008 to 2011 years). The results were later subjected to Discomfort index formulae for calculating the heat stress condition in the study area for the analysis. Epstein and Moran (2006) Method was used as Discomfort Index (DI) standard:

Dis comfort index (DI) = 0.5Tw + 0.5Ta-------------------------------------EQ.

Where Tw means wet bulb Temperature and Ta = dry bulb Temperature value.
The calculated values are subjected to the ranges provided in the DI index below

- DI value of 22 units: means no heat stress encounter
- DI value of 23-24 units: means mild sensation of 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 severe heats loads, people engage in physical work are at increased risk for heat stress illness (heat exhaustion and heat stroke).

Mean statistic was used for analysing the data using tables.

3. Results and discussion of the findings

The study revealed that dry bulb temperature was in the morning (6:00am) generally below 26^0c in all the seasons, with April and October recording 25^0c. This indicates that minimum temperatures of the seasons were within comfort level. Table 1 shows the heat stress free DI level as none of the morning values exceeds 22. But October minimum temperature and DI level approach the mild heat stress load.

Table 1: Mean monthly values of dry (Ta) and wet (Tw) bulb temperature in 0c and Discomfort index (DI) values

TIME	KEY	APRIL	AUGUST	OCTOBER	DECEMBER	MEAN
6:00AM	TA ==	25	21	25	14	21
6:00AM	TW ==	14	19	18	10	15.5
6:00AM	DI=	19.5	20	21.5	12	

Source: Field work 2011

While, the maximum temperature (3:30pm) analysis across the seasons has clearly indicated that the study area is severely vulnerable to heat stress danger for none of the dry bulb temperatures is below 26^0c. This is especially looking at its April, October and the mean seasonal values. For the DI values, the results on Table 2 have generally indicated severe heat loads which may result to serious heat stress disorders especially in October which records the highest DI Value.

Table 2: Mean Monthly values of dry (Ta) and wet (Tw) bulb temperature in 0c and Discomfort index (DI) values

TIME	KEY	APRIL	AUGUST	OCTOBER	DECEMBER	MEAN
3:30PM	TA ===	44	34	40	32	38.25
3:30PM	TW ===	32	32	31	24	29.5
3:30PM	DI==	29.5	33	35.5	28	

Source: Field work 2011

3.1 Analysis of heat stress exposure for academic planning

Table 3 (below) has revealed the ranges of DI values across the seasons of the year in the study area as represented also in fig. 2. The mean values of the two extreme temperatures range from heat stress free (18.25) in the morning to severe heat load value (30.5) in the afternoon. While considering the four seasons, warm-wet and warm-dry are the most dangerous seasons of heat stress exposure as result of the combine impact of humidity and temperature elements as result of the intensity of the apparent overhead sun. The cool-dry season is almost free from the vulnerability. However, the general mean suggests that the Kust-Campus is throughout the year vulnerable to heat stress exposure.

In general, the result indicates that although hot and dry condition has higher ambient temperature than the warm wet and warm dry seasons, yet, it is physiologically much better than the later seasons due to the combination of temperature and humidity influence around August and October months. Thus, the community of the institution is exposed to the risk of the stress and stress disorders during the hot and humid condition.

Table 3: Mean Seasonal Analysis of Heat Stress Exposure (DI Value Ranges)

SEASONS	6:00 AM	3:30 PM	MEAN	HEAT STRESS EXPOSURE
(MONTH)	MIN. DI VALUE	MAXIMUM	DI VALUE	
		DI VALUE		
HOT-DRY(April)	19.5	29.5	24.5	MODERATE SENSATION
WARM-WET (AUGUST)	20	33	26.5	EXTREMELY SEVERE
WARM-DRY (OCTOBER)	21.5	35.5	28.5	EXTREMELY SEVERE
COOL-DRY (DECEMBER)	12	28	20	NO EXPOSURE
MEAN	18.25	31.5	24.88	SEVERE
HEAT STRESS EXPOSURE	NIL	EXTREMELY SEVERE	MODERATE	

Source: Field work, 2011

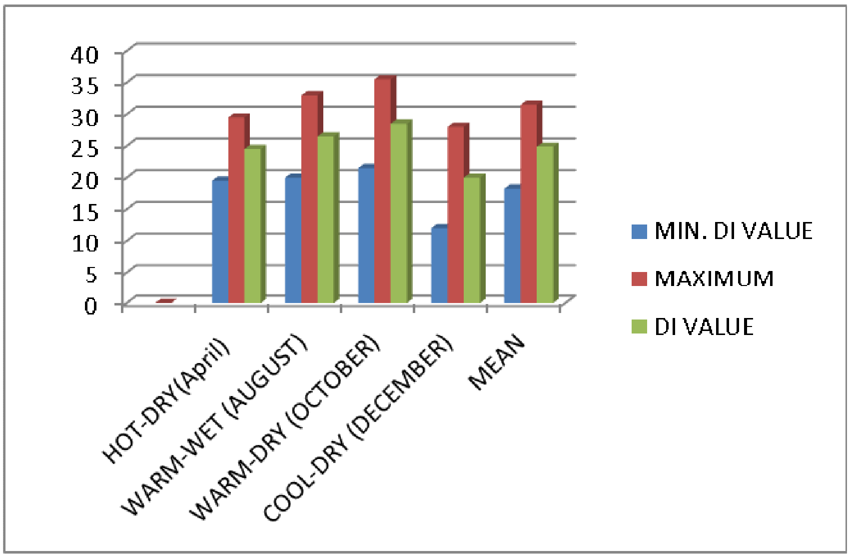

Fig.2 Mean seasonal analysis of heat stress exposure (di value ranges)

3.2 Implications of results to KUST environment

Having discovered that the University atmosphere is exposed to the danger of heat stress, it is pertinent to note that the staff labour productivity and students' academic performances would be impaired as result of the discomfort. But at the same time, the liability of the strain is determined by the following factors:

I. Personal risk factors like weight, poor physical condition, previous heat illness, age of >65 and < 4years, high blood pressure, medication and lack of acclimatization.
II. Environmental factors: radiant heat (temperature), humidity, air movement (wind)
III. Job factors: workloads, clothing types and personal protective equipment (PPE) Uniforms.
IV. Periods of the day and year as revealed by the tables above.

4. Conclusion and Recommendations

4.1 Conclusion

The result revealed the DI values of 24.5, 26.5, 28.5 and 20 during the hot-dry, warm-wet, warm-dry and cool-dry seasons, respectively. These mean that the study area is vulnerable to severe discomfort condition, especially during the hot and humid season and during the afternoon hours when temperature and humidity elements are at their peak influence.

4.2 Recommendations

Although human body comfort is affected by health, age, sex, activities, clothing, food and acclimatization, there is need for improving the Academic activities, general room and office shelter and improve upon the available social amenities in the entire campus under which majority of the occupants will feel comfortable. The study also recommends that, all classes and rooms/offices of the students and staff should be furnished with air conditioners, surrounded with trees, if the university atmospheric shelter is to be improved for sound academic activities. Subjects that are mathematic-based should be scheduled for morning period, while semester ending should coincide with period around December or August when there is less risk of heat stress. The sports Directorate should also be careful and in accordance with this findings so as to reduce liable causalities during sporting activities.

4.3 Limitations

The study is limited to the measurement of heat stress and its effects on the comfort but does not proposed ways to curtail or limits its dangers, but it is not the only variable that causes discomfort. Passive and active means needs to be employed to prevent the effect of heat gains but more importantly is the need to prevent the effect of the heat gains with architectural design made with climatic consideration. These present the needs for further studies on the effect of colour, building orientation, as well as size ratio of the glazed windows on the exterior of building envelope on heat gains and the learning comfort of the students and the staff.

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