

Original Article

Applied Science

Heat Stress as A Measure of Human Level of Comfort in A Semi-Arid Zone, Maiduguri, Nigeria

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ABSTRACT [ENGLISH/ANGLAIS]

This study examined thermal stress and physiological comfort in Maiduguri, Nigeria using thermal heat stress index as a measure of human comfort. Dry-bulb temperature, Relative humidity, and Air velocity were measured in three observatory sites (class room, under neem (*azadirachta indica*) tree and under direct sunlight) within the Faculty of Engineering University of Maiduguri, Nigeria between the hours of 7.00 am and 5.00 pm on some days from October to December 2010 in order to establish the physiological responses to thermal stress and disorder. The data were analyzed using Effective Temperature (ET) and Relative Stress Index (RSI). The mean ET mean ET obtained vary from 23.58°C to 31.18°C, while the RSI values vary from 0.12 to 0.49 for the period just after the raining season. And for the hammatan period, the mean ET mean ET vary from 19.31°C to 29.09°C, while the RSI values vary from 0.01 to 0.38. The results showed that the three locations are generally comfortable during the morning hours and become uncomfortable as the day progresses. The class room was found to be the most comfortable during the period of the investigation while the location under the sun recorded the highest level of discomfort in both seasons.

Keywords: Heat stress, human comfort, temperature, humidity, air velocity heat stress, human comfort

RÉSUMÉ [FRANÇAIS/FRENCH]

Cette étude a examiné le stress thermique et confort physiologique à Maiduguri, au Nigeria en utilisant l'indice de stress thermique de la chaleur comme une mesure de confort humain. Sec ampoule température, l'humidité relative, et la vitesse de l'air ont été mesurées dans des sites d'observatoires trois (salle de classe, en vertu de neem (*Azadirachta indica*) des arbres et en plein soleil) au sein de la Faculté de génie Université de Maiduguri, au Nigeria entre les heures de 7h00 et 17h00 certains jours d'Octobre à Décembre 2010, afin d'établir les réponses physiologiques au stress thermique et le désordre. Les données ont été analysées à l'aide de la température effective (HE) et l'indice de stress relative (RSI). La moyenne HE signifie HE obtenu varient d'23.58°C à 31.18°C, tandis que les valeurs RSI varie de 0,12 à 0,49 pour la période juste après la saison des pluies. Et pour la période hammatan, la moyenne HE signifie HE varient d'19.31°C à 29.09°C, tandis que les valeurs varient d'un RSI-0.01 à 0,38. Les résultats ont montré que les trois sites sont généralement à l'aise pendant les heures de la matinée et devenir inconfortable que l'progressé de jour. La salle de classe a été jugée la plus à l'aise au cours de la période de l'enquête, alors que l'emplacement sous le soleil a enregistré le plus haut niveau d'inconfort dans les deux saisons.

Mots-clés: Le stress thermique, confort de l'homme, de la température, l'humidité, le stress de chaleur de l'air de vitesse, le confort humain

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Accepted/Accepté:
February, 2012

Citation:
Abdulrahim AT, Mshelia RB, Stephen OG, Kyauta ET. Heat stress as a measure of human level of comfort in a semi-arid zone, maiduguri, Nigeria. World Journal of Engineering and Pure and Applied Sciences 2012;2(3):107-11.

INTRODUCTION

Thermal comfort condition is regarded as being present when an individual is in an environment whose temperature, both air and radiant, humidity and air movement are within limits found acceptable by most people wearing the amount of clothing which is typically worn in that environment [1]. Four properties of the environment influence comfort. These are the Dry-bulb

temperature affecting evaporation and convection, Relative humidity affecting evaporation only, Air velocity affecting evaporation and convection, and Mean radiant temperature affecting radiation only [1]. Adelaja [2] observed that environmental temperature outdoor or indoor act on the body through the nerve receptor and activates the physiological mechanisms that reduce or increase the elimination or production of heat in relation

to the character of the stimuli. In Nigeria, a number of studies have been carried out on the relationship between human health and comfort [1,3,4,5]. The need to examine the issue of thermal stress in Maiduguri, Nigeria becomes imperative considering the fact that Maiduguri has been recording the highest temperatures in Nigeria, and falls in the North-East geo-political zone of the country which has not been considered in previous studies.

MATERIALS AND METHODS

Study Area

The study area is the Faculty of Engineering University of Maiduguri, Maiduguri, Nigeria. Maiduguri is located on latitude 11.85° north and longitude 13.08° east with an altitude 345m above sea level [6,7] Maiduguri falls within the semi-arid zone of West Africa geographically. It experiences little of rainfall and more of dry season. The average annual rainfall for a period of 12 years has been 50.03 mm. High temperature of upto 47°C is commonly recorded between March and May [4] Three different locations within the study area were selected namely; inside a class room, under a neem tree (*azadirachta indica*) and directly under the sun Inside a Classroom (FE 114), Under a Neem Tree and Directly Under the Sun within the Faculty of Engineering premises.

Materials

For this study, the instruments used for the collection of data are the Wet and Dry bulb thermometers (alcohol in glass type) for measuring Temperatures and Anemometers (hand-held digital anemometer, vane-prop type model AM-4812) for measuring wind velocity and Psychrometry Charts for determining the relative humidity.

METHODS

Procedure for Data Collection

The data used for this study were collected from three different locations (class room, under neem tree and under direct sunlight) Class room, Underneem tree and Under direct sunlight) simultaneously. The survey stretches over normal lecture hours i.e. from 7:00am to 5:00pm and twice a week for a period of two months. The first part of readings were taken from third week of October to second week of November, 2010 to represent period just after the raining season and Raining season, and the second parts of readings were taken from the third week of November to third week of December,

2010 which represented the Dry harmattan period. Wet and Dry bulb thermometers were used to measure the wet and dry bulb temperatures of the study areas, Psychrometric chart was used to estimate the relative humidity at a pressure of 1 atmosphere and the wind velocity was measured using a hand-held digital anemometer.

Method for Data Analysis

A widely used measure of comfort of thermal sensation is the Effective Temperature (ET) index which is calculated from an empirical formula [4]:

$$ET = 0.4(T_d + T_w) + 4.8 \dots\dots\dots (1)$$

Where T_d and T_w are dry and wet bulb temperature respectively in °C. The resulting values are related to a subjective scale on sensation of people within the areas covered. Another measure of comfort is Relative Stress Index (RSI) which was to account for insulating effects of the body. The formula is given as [4]:

$$RSI = \frac{10.7 + 0.74(T_d - 35)}{44 - e_a} \dots\dots\dots (2)$$

Where T_d is the dry bulb temperature and e_a is the vapour pressure of air.

Vapour pressure can be calculated as [4]:

$$VP = \frac{RH \times SVP}{100} \dots\dots\dots (3)$$

OR

$$P_a = \rho R_a T \dots\dots\dots (4)$$

Where VP or P_a is the vapour pressure of air, SVP is the saturated vapour pressure, R_a is the gas constant = 0.2871 kJ/(kg.K) KJ/kgk, T is the dry bulb temperature, RH is the relative humidity and ρ is density.

For a healthy person, the scale of sensation indicates comfort condition for the people when RSI is less than 0.2, discomfort conditions when RSI is more than 0.3, distress conditions when RSI is more than 0.4 and complete failure when RSI is more than 0.5 [4]. Hobbs [8] stated that when body temperature exceeds 40°C and ET above 33°C with RSI more than 0.3, a critical point of discomfort is observed. Also, for indoors a wind speed of under 0.1m/s is likely to raise a feeling of stiffness. Up to 1.0m/s one will feel comfortable but above that threshold, certain inconveniences will be experienced. Such inconveniences include movement of papers and rising of dust. At outdoors, higher speeds are necessary to induce discomfort; speeds of up to 2.0m/s are comfortable in very hot condition. Ground speed of up to 5.0m/s or 10.0m/s is positively unpleasant and above 20m/s can be dangerous [9].

RESULTS AND DISCUSSION

The results of the data collected and analyzed are presented in two ways namely; the period when the rainy season just ceased and the dry harmattan season. Figures 1 and 2 show the variation of RSI and ET with time of the day respectively for the period just after the rainy season, while figures 3 and 4 show the variation of RSI and ET for the period of harmattan season respectively.

Figure 1: This figure shows graph of mean RSI against time for the season just after the rainy season

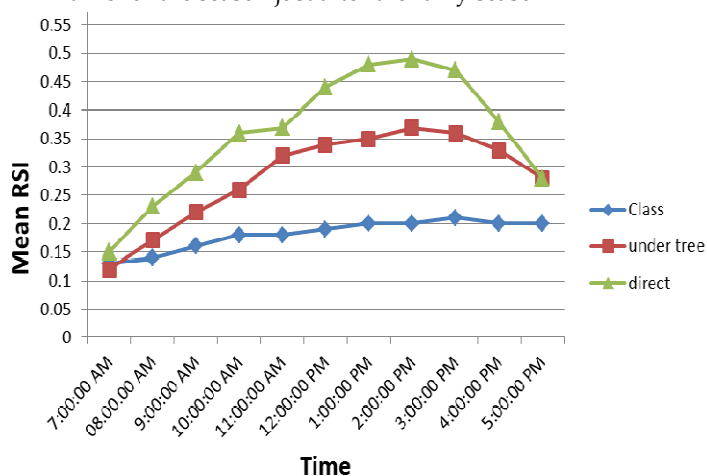
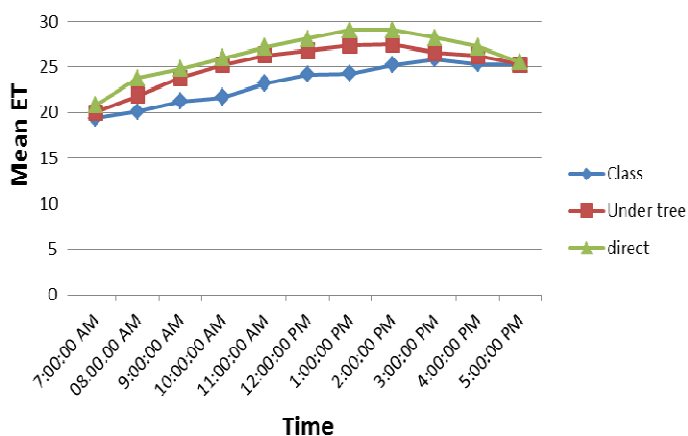


Figure 2: This figure shows graph of mean ET for the period just after the rainy season



Period just after Rainy Season

The minimum and maximum values of ET obtained in the class were 23.58°C and 26.53°C respectively, that for under the tree varies from 24.38°C as at 7.00 am to a maximum of 29.23°C and under the sun, the values varies from 25.18°C to 31.18 at 1.00 pm and 2.00pm.

Based on ET values obtained, both the class and under tree location can be classified as comfortable at the period under study because their value falls within the comfort values of ET of between 26 and 32°C [8]. The ET values for the class location were lower than those of the directly under the sun and under tree locations. The reason why the ET value shows that some locations are comfortable and others are not may be attributed to the availability of shades and structures that have created a micro-climate within that environment during this period.

Figure 3: This figure shows graph of mean RSI against time for the harmattan season

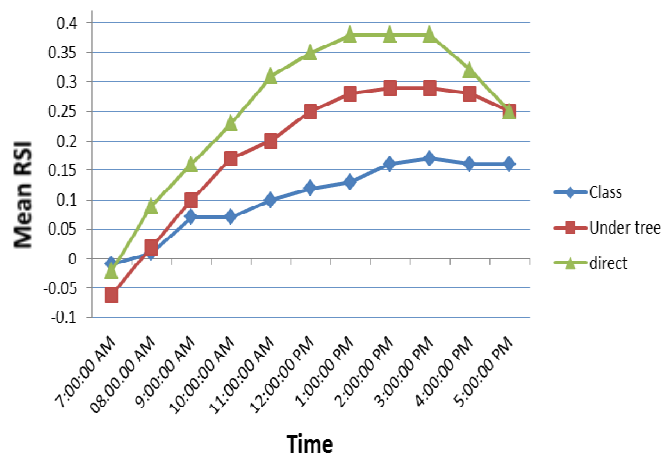
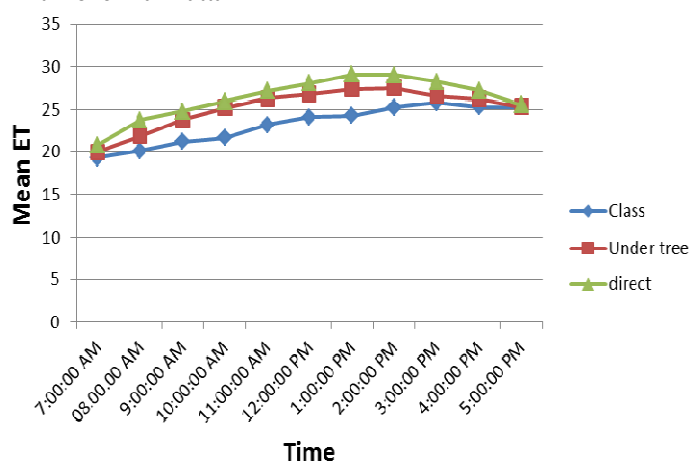


Figure 4: This figure shows graph of mean ET against time for harmattan



On the other hand, the relative stress index (RSI) values of the class varies from 0.13 at 7.00 am to 0.21 at 3.00 pm, while that of under tree fall between 0.12 and 0.37 and the location under the sun varies from 0.15 to 0.49. The RSI values clearly shows that people undertaking activities directly under the sun go through extreme body stress compared to people under the tree and inside a building.

The micro-climatic conditions created by the class room can attributed to the favourable RSI values when compared to other study sites.

The speed for wind in the class varies from 0 to 0.9m/s, that for under tree varies from 0 to 2.3m /s while for directly under the sun, it varied from 0 to 3.5m/s. It will be noted that the most comfortable location is under the tree while the wind speed of the class and that taken directly under the sun is either too low for that of the class or too high for that under the sun.

The relative humidity is also considered in evaluating thermal stress. It was found that the relative humidity of class varies from 42 to 88%, under the tree it varied from 12 to 92%, while directly under the sun it varied from 10 to 92%. It was also noted that the relative humidity in the class increases gradually from morning period to the evening time while that of the location under the tree and inside the sun experiences a higher relative humidity in the morning which starts to decrease drastically until the evening hours.

Harmattan Period

The Mean Effective Temperature (ET) used to determine thermal sensation varies from 19.31°C occurring at 7a.m. to 29.09°C at 12noon and 2p.m. For the class room, ET varies from 19.31°C at 7am to 25.84°C at 3pm, under the tree it varies from 20°C at 7am to 27.51°C at 2.00 pm, directly under the sun, ET varies from 20.79 °C at 7a.m. to 29.07 °C at 1.00 pm. It can be inferred from Tyubee [10] that the general temperature range which people feel comfortable is between 26°C and 32°C, the morning periods for the all locations are generally uncomfortable since the temperatures recorded for these hours are usually below 26°C while the under tree location is the most comfortable location in the afternoon since it records the highest occurrence of temperature within the comfort range.

The RSI values of the class room vary from -0.01 at 7am to 0.17 at 3.00 pm, under the tree it varied from -0.06 at 7am to 0.29 at 2.00 pm and 3.00 pm and for the direct sun location it varied from -0.02 at 7.00 am to 0.38 at 1.00 pm until 3.00 pm. The values shows that the class is not within the range of comfort at this period, it also indicated that the most favourable location in the afternoon is under the tree because its RSI values are within the range of comfort while in the direct sun exposure, there is extreme cold temperature in the morning which later becomes uncomfortably hot at midday.

High wind speed is one of the most outstanding features of this season. The speed of wind in the class varies from 0 in the morning to 1.8m/s, that for under the tree varies from 0 to 3.8m/s while that recorded directly under the sun ranges from 0 to 5.0m/s. Based on the analysis done by Boutet [9], it was found that there is a range of speed that will be comfortable for indoors: 0.1 to 1.0m/s and 0.1-2.0m/s for outdoors, upon comparison it was noted that the speed of the speed of wind is unpleasant in these three locations during these periods. The relative humidity was also considered in this study, for the class it varied from 12 to 88%, under the tree it varied from 7 to 74% while that for the location directly under the sun varied from 8 to 90%.

CONCLUSION

This study concludes that the three locations are generally comfortable during the morning hours. The class room was found to be the most comfortable during the period of the investigation while the location under the sun recorded the highest level of discomfort in both seasons.

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ACKNOWLEDGEMENT / SOURCE OF SUPPORT

The authors wish to acknowledge the support of the Faculty of Engineering, University of Maiduguri, Nigeria for providing the sites and some of the measuring equipment for this study.

CONFLICT OF INTEREST

Nil

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