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Thermal Comfort and Occupant Behaviour in Naturally Ventilated Students' Hostel Buildings: A Case of Covenant University, Ota, Nigeria

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Abstract
The performance of a building goes a long way in affecting the productivity and heath of its occupants. Indoor thermal comfort of a building is one of the most important considerations. In warm humid tropical areas, natural ventilation has been observed to be ineffective in providing adequate thermal comfort. The study examined the thermal comfort of naturally ventilated students' hostel buildings in Covenant University, Ota, Ogun State, Nigeria, during the hot season. The study identified and assessed the physical characteristics, examined the indoor environmental conditions relating to thermal comfort, identified and examined factors that affect the thermal comfort of occupants and observed their adaptive behaviors.The study involved a subjective assessment through questionnaires and physical measurements of the prevailing indoor environmental variables. The parameters measured were air temperature, air velocity and relative humidity. This was done using a Kestrel 4500 Pocket Weather Tracker. One hundred respondents participated in the survey. A statistical analysis of the measured environmental parameters and the student's responses was carried out to determine the indoor environmental conditions and adaptive measures used. All the measured parameters fell below the comfort range prescribed by ASHRAE standard 55 and ISO 7730 standard. The study concludes that natural ventilation alone is insufficient to provide adequate thermal comfort levels for its occupants.

1.0 INTRODUCTION

One of the main functions of a building is to provide to its occupants protection against external conditions of the environment. The human body operates at optimum temperature of about 37°C; a reasonable change in this value can lead to illness or even death. According to Akande et al (2012) thermal comfort basically has to do with the temperature that the resident considers as comfortable to stay in. Indoor thermal comfort is achieved when occupants are able to pursue without any hindrance, activities for which the building is intended. ISO 7730 defined thermal comfort as that condition of mind which expresses satisfaction with the thermal environment. Heschong (1982) states that thermal comfort is primarily controlled by a building's heating, ventilating and air-conditioning systems, though the architectural design of the building may also have significant influences on thermal comfort.

The human body has several thermal adjustment mechanisms which help it to survive drastic temperature environments. According to Szokolay (2010), in a cold environment, the body uses a method called Vasoconstriction, it which reduces blood flow to the skin, skin temperature and heat dissipation. In a warm environment, Vasodilatation will increase blood flow to the skin, heat transport and skin temperature and heat dissipation. If this isn't achieved properly, an imbalance will occur and in hot environments, heat stroke may occur, in cold environments hypothermia may set in and could prove fatal. Man has a very effective temperature regulatory system, which ensures that the body's core temperature is kept at approximately 37°C. When the body becomes too warm, two processes are initiated: first the blood vessels vasodilate, increasing the blood flow through the skin and subsequently one begins to sweat. Sweating is an effective cooling tool, because the energy required for the sweat to evaporate is taken from the skin. Only a few tenths of a degrees increase in the core body temperature can stimulate a sweat

The human body continuously gives out energy which is in form of heat. Two kinds are usually given off: basal metabolism, due to biological processes which are continuous and non-conscious; and muscular metabolism, whilst carrying out work, which is consciously controllable (except in shivering) production which quadruples the body's heat loss.

If the body is getting too cold, the first reaction is for the blood vessels to vasoconstrict, reducing the blood flow through the skin. The second reaction is to increase the internal heat production by stimulating the muscles, which causes shivering. This system is also very effective, and it can increase the body's heat production dramatically. The control system which regulates the body temperature is complex, and is not yet fully understood. The two most important set of sensors for the control system are however known. They are located in the skin and in the hypothalamus. The hypothalamus-sensor is a heat sensor which starts the body's cooling function when the body's core temperature exceeds 37°C. The skin-sensors are cold sensors which start the body's defence against cooling down when the skin temperature falls below 34°C. If the hot and cold sensors output signals at the same time, our brain will inhibit one or both of the body's defence reactions.

Works by Sekhar and Goh (2011) show that unsuitable levels of thermal comfort can affect the quality of sleep and this in turn affects the daytime functionality or performance of individuals. Sleep deprivation also leads to aggressive behaviors, headaches, and tiredness. Relating this to typical student life, lack of sleep will mean, low daytime functionality, students may find it difficult to concentrate during lectures or studies. This in turn will lead to poor overall academic performance. Sleep is very vital to the human body, no matter how strong willed or disciplined a person is, he/she owes it to himself/herself to have a good amount of sleep.

Natural ventilation is seen as a great way of cutting down energy costs since they do not rely on energy powered devices. It can be seen as a risk as severe climatic conditions may mean that natural ventilation alone cannot be used especially when a building is poorly designed or constructed. Having good thermal comfort is very necessary as it promotes good living and increases building performance. Although humans tend to adapt to their environments, there is a high chance that people will prefer living in an environment that suits them rather than having to endure in one that doesn't. Thermal discomfort is not simply an unpleasant subjective sensation resulting from stress at a particular moment in time. There are cumulative effects, that either become translated into physiological response, or compensated in behavioral, or in the more extreme, adverse health effects.

Ismail et al (2009) noted that, a hostel or house design is important, as a bad thermal consideration in a hostel will influence the health and productivity of occupants. Symptoms like headache, always feeling tired and aggressiveness are common scenario that can be found due to bad thermal comfort condition.

Numerous field experiments have been performed in hot climates, but most of these have been in humid locations (e.g. de Dear and Auliciems, 1985; Auliciems and de Dear, 1986a, 1986b; Bush, 1990; de Dear et al., 1991; and de Dear and Fountain, 1994). Other hot-dry field experiments include those by Baker and Standeven (1994) in residential buildings during the summer in Athens, Greece.

Their result indicated the importance of adaptive opportunity in order for building occupants to accept temperatures warmer than 24°C. As important as these studies are, their findings have not yet emerge into comprehensive and widely accepted guideline for tropical naturally ventilated buildings (Adebamowo, 2007).

These studies were carried out in a setting where the buildings were designed to the environmental conditions, Covenant University hostels aren't. Also, being a public university, the philosophy and management of the Buildings would be different; where one is more profit oriented rather than socially inclined. The fact that Covenant University is regarded as a world class university and other activities which the school partakes in often means an influx of foreign personnel and individuals who may come from places with different climatic conditions.

There is also the fact that thermal comfort standards are not defined in Nigeria codes and there is little research on how, and what extent the performance of the buildings influence the academic performance of students.

The aim of this study is to investigate the thermal comfort levels with a view to provide information of the adequacy of naturally ventilated hostel buildings in tropical countries. In order to achieve this, this study seeks to determine the existing indoor thermal comfort parameters in the buildings, assess the thermal comfort levels in the selected hostels using PMV and PPD models, assess students' adaptive behaviour when they feel discomfort, and compare the thermal comfort level of male and female students.

2.0 LITERATURE REVIEW

Olanipekun (2014) carried out a study in Obafemi Awolowo University Ile-Ife, a location with similar climatic conditions as that of Covenant University. The results of the study showed that occupants in warm-humid climate had a wider range of thermal acceptability than that specified by the ASHRAE Standard 55. The study concludes that in warm-humid of Ile-Ife, Nigeria during hot season the desired for optimal thermal comfort in naturally ventilated hostel buildings may not be achieved. However, the availability of behavioural controls and mechanical ventilation system could help to improve thermal environmental conditions. Air-conditioners and mechanical ventilators are often used to upset thermal imbalance in a building and this often leads to soaring electric bills and increase in Ozone depletion activities.

Dhaka et al.(2013) and Dahlan et al. (2008, 2009, 2011) studied undergraduate hostel buildings in Malaysia. The studies noted that the intellectual capabilities as well as academic performance of occupants of hostel buildings was closely related to the quality of indoor environment. The electric power being supplied to Covenant University hostels is usually conserved with a scheduled "on-time" of about 5pm daily to about 9am from Mondays to Fridays and most times a 24hr "on-time" on Saturdays and Sundays. This power management system definitely plays a major role in the thermal comfort of the students as electrical devices, for example, electric fans used in adjusting thermal conditions will become unusable during these "off-times".

In reality, occupants are comfortable in wider range of conditions. This is because people are able to adapt to the environment that they are used to and also because several other factors could also contribute to the adaptation of their indoor environment.

Several studies have shown that there are some non-quantifiable elements of comfort that influence the thermal sensation. Aspects like culture, habits and traditions, mental states and expectations can vary the level of tolerance toward certain thermal conditions. (Tablada *et al*., 2005). In a Study carried out by Olanipekun (2014) in a student's residential building in Nigeria, "Profligate attitudinal disregard was observed towards the environment as occupants were found cooking in their rooms instead of the kitchenette provided for them." This places emphasis that human habits can play a major role in determining thermal comfort. The complexities involved in measuring thermal comfort levels have given rise to development of indices over the years. The first developed ones were concerned with mainly thermal sensation, with more recent ones focusing on estimating physiological responses to the a summed up effect of various factors, the range of conditions of their application and in the relative importance attributed to each of the factions and their mutual interdependence (Givoni, 1976).

The range of conditions in which thermal comfort is experienced is called comfort zone. It differs according to individuals preferences and is affected by the clothing worn, geographical location, age and sex. Although the comfort zone is defined as a subjective assessment of the environmental conditions, the limits of the zone do have a physiological basis; the range of conditions under the thermo-regulatory mechanisms of the body are in a state of minimal activity. Comfort depends on several aspects and cannot be expressed in terms of any one of these aspects as they affect the body simultaneously and influence of any aspect depends on the levels of the other factors. Several attempts have been made to evaluate the combined effects of these factors on the physiological and sensory response of the body and to express any combination of them in terms of a single parameter or "thermal index" which can be set out on a monogram (Konya, 1980).

The Equatorial Comfort Index (ECI) was developed by Webb, it was based on some 393 sets of observations. The response of the subjects who were fully acclimatized and were engaged in light sedentary work, were recorded together with other environmental variables. The index is defined as the temperature of a still, saturated atmosphere which is psychologically equivalent to the climate in question. The index is defined as the temperature of a still, saturated atmosphere which is physiologically equivalent to the climate in question. The index does not allow for activity levels or clothing different to those of the test subjects. It is claimed to be appropriate for climates beyond the 24°C WBT isotherm (i.e. in warm-humid climates) (Webb, 1960).

Materials used in building construction affect both thermal comfort and thermal performance of the building. Buildings with traditional construction materials showed a better performance in achieving thermal comfort while decreasing energy costs (Nevin, 2003). The thermal dynamics of the human body is one of the main aspects that affects health. The thermal comfort of occupants is their well- being in a particular environment for a particular climate with respect to their capacity to adapt to the thermal equilibrium, physiological, psychological and behavioral changes. The human body needs to be shielded from the external environment in order to maintain balance. Heat exchange is important, it is the thermo physical properties of the construction materials that determines the rate of this heat exchange and provides one of the aspects of thermal comfort within any building.

There are a great number of ways to estimate likely thermal comfort, including; effective temperature, equivalent temperature, Wet Bulb Globe Temperature (WBGT), resultant temperature and so on, and charts exist showing predicted comfort zones within ranges of conditions. However, BS EN ISO 7730 and BS EN ISO 10551 suggest thermal comfort can be expressed in terms of Predicted Mean Vote (PMV) and Percentage People Dissatisfied (PPD). Although two distinguishable concepts are mostly used, they are: Heat balance approach and Adaptive approach

The heat Balance approach: A model of human thermal response based on the assumption that a necessary condition for thermal comfort is a balance between the metabolic heat production and the heat loss from the body.

The adaptive approach: This approach places emphasis on the different actions which occupants can take to achieve thermal comfort, and that discomfort is caused by constraints imposed on the range of actions by social, physical or other factors. Over time this means that people are comfortable at the average temperature they have experienced. The PMV model was developed by Fanger (1970) using heat balance equations and empirical studies about human temperature to interpret comfort. The Predicted Mean Vote provides a method by which the quality of indoor environments can be rated in practice and the degree of occupant discomfort assessed. Standard Thermal Surveys require subjects to give answers concerning their thermal sensation on a seven point scale from cold (-3) to hot (+3). Some of the earliest physiological studies involved experiments on human subjects in controlled laboratory environments. Fanger (1970) argued that knowledge of thermal comfort conditions was inadequate for environmental engineers involved in the specification of heating, cooling or ventilation technologies and indoor climate. He later developed his own "comfort equation", this method took into consideration the combined conditions (air temperature, mean radiant temperature, relative air velocity and humidity level) in which the highest proportion of people are likely to be comfortable, for any specified level of activity and clothing.

Nicol (1998) points out that when Fanger (1970) realized that the vote predicted was only the mean value to be expected from a group of people, he extended PMV to predict the proportion of any population who will be dissatisfied with the environment. So PMV is defined by Fanger in terms of PPD. As PMV moves away from neutral (PMV = 0) in either direction, PPD increases. The maximum value of people dissatisfied with their comfort condition is 100%.

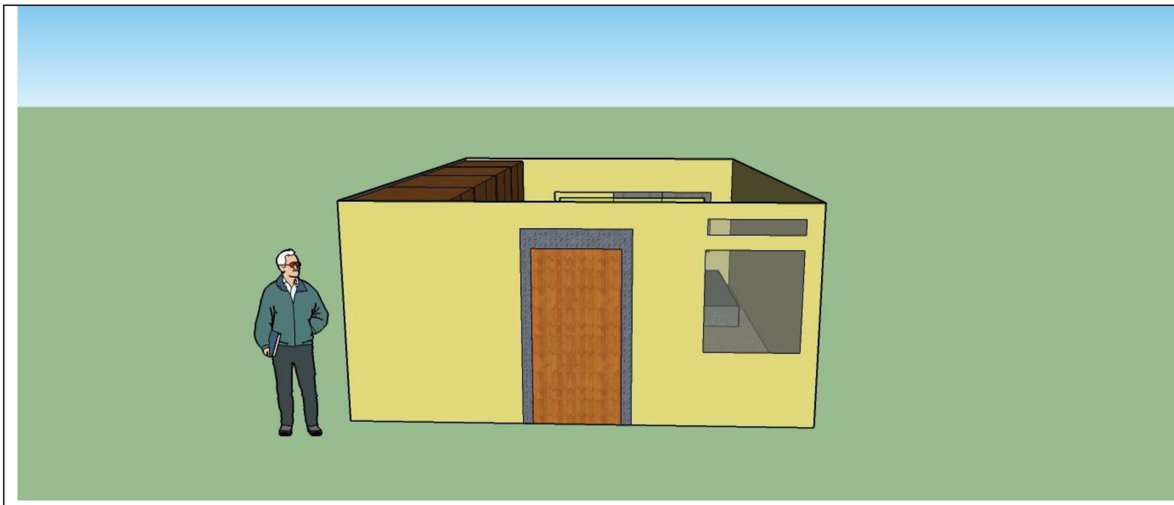
Laboratory experiments of thermal response or perception provide averaged results that have been incorporated into design codes and standards. However, they reveal little about how human beings define and experience comfort, or about how perceptions and expectations interact. Physiological and psychological research aims to account for variations in thermal comfort conditions and perceptions within buildings. Field Studies in this tradition challenge the validity of relatively 'fixed' concepts of thermal comfort, such as those based on heat-balance equations. These results have led some researchers to develop more 'adaptive' models that account for multivariate and dynamic human experiences in the real world (de Dear 1994).

Predicted Percentage Dissatisfied (PPD) is used to estimate the thermal comfort satisfaction of the occupants. It is considered that if 80% of the occupants in a building and above are satisfied, it is good; that is, PPD less than 20% is good. (Guan et al 2003).

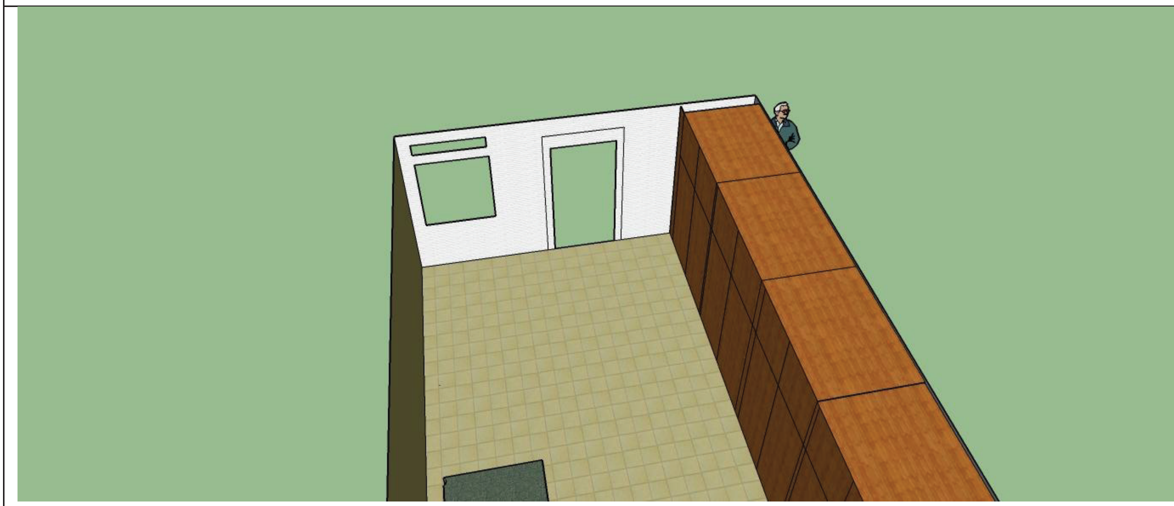
3.0 METHODOLOGY

The field study focused on four student's residential halls in Covenant University Ota, Nigeria, which is in the tropical area of Southwest Nigeria (see Figure 1 and 2). Its geographical coordinates are Longitude 6.6699˚ N, 3.1574˚ E. It has a warm-humid climate characterized by two seasons (rainy and dry). It experiences constant high temperatures and relative humidity and low air movement throughout the year. The zone in which the case study falls is characterized by seasonal variations through the year. The seasonal variations include; long raining season which starts by March and lasts till July ending having its peak in June. This period is characterized by thick cloud and excessively wet, humidity not less than 85%. Short wet periods around August.

The estimated total population of the students was about 5000. The students are normally distributed into 4, 3 and sometimes 2 to a room. They normally have lectures in their different lectures halls within the 8:00am and 5:00pm. Objective and subjective methods were used for data collection, this ensures balance in the strengths and weaknesses of individual methods.



Front view



Interior view

Figure 1: Sketch of front view and interior of a typical room in the hostel building.


Dorcas Hall


Esther Hall


Peter Hall

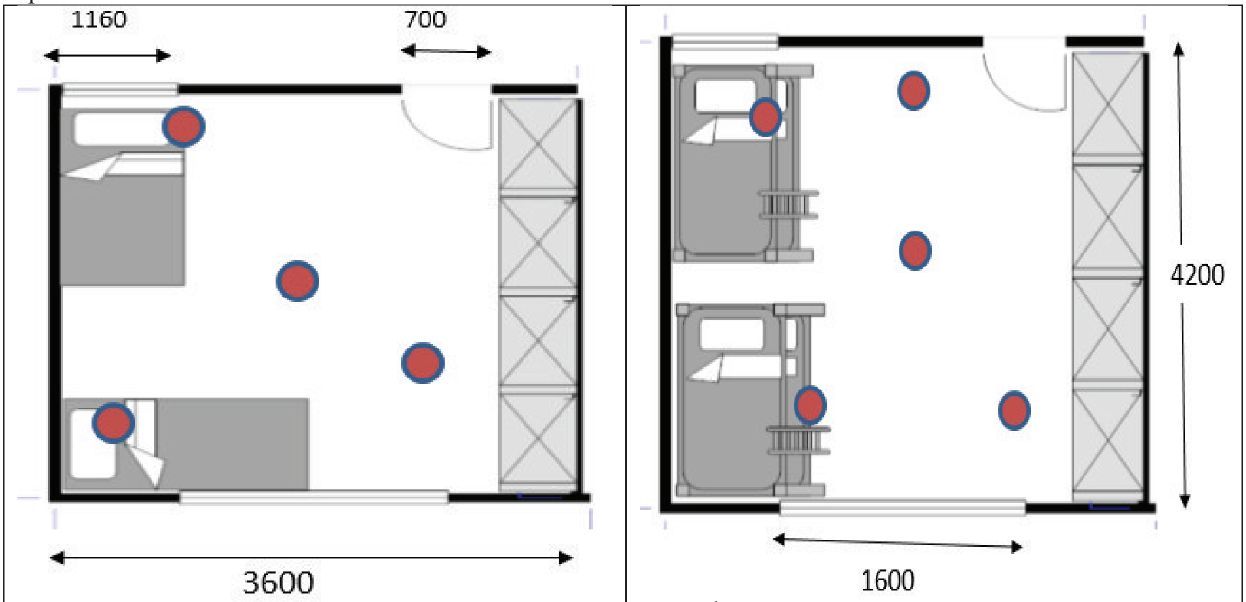

Daniel Hall

Figure 2: Hostel buildings used for the study

The field experiments were conducted from 7th February to 30th March 2015. Daily measurements were taken from 8 am till 12 midnight. The parameters measured were humidity, wind velocity and air temperature. The measurement of each hostel lasted for a week in each of the two months of the study. Each sample room was measured on different floors with the purpose of identifying the environmental effect on the hostel occupants (see Figure 3). The ruling indoor environmental parameters of the hostels were measured internally and externally. The equipment used for the field measurement was the Kestrel 4500 Pocket Weather tracker. The device was used in measuring the air temperature, air velocity and relative humidity. Uniformity of readings were almost hard to achieve in most rooms, hence the measurement of the parameters was conducted at various points in the occupied area. When taking the measurements, a distance of not less than 1m was observed from wall or window location to avoid any unnecessary interference with the readings. The measurements were taken at 1.1 m from the floor closed to the subjects to record the thermal comfort variables simultaneously, as the subjects filled in the subjective thermal comfort questionnaire.

Questionnaire surveys were conducted during the period of the environmental parameter measurements. The subjective assessments were based on the occupant's vote on the thermal sensation, thermal preference, thermal acceptance, air velocity and humidity in the occupied zone. The scales used were ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) scale, air flow scale and Humidity scale.

In each room questionnaires were given to the occupants while the environmental parameters were being recorded. The questionnaires were designed according to ISO 7710 standards. The questionnaires contained information about the occupant's socio-economic characteristics and thermal comfort perception of their room spaces. The ASHRAE thermal sensation scale and seven scale of BEDFORD were used.



Room layout type A

Room layout type B

Figure 3: Floor plan of room showing points were measurements were taken.

4.0 RESULTS AND DISCUSSION

The residential halls consist of 10 hostel buildings; 5 male, 5 female each. Two different designs are generally noticed. This is as explained in Table 1.

Table 1: Physical description of hostel buildings

Hostel buildings	Physical description
	Male hostel buildings
Peter hall	Mainly for 100 Level male students. It comprises of 7 wings with four floors each .It has a total of 792 rooms and has a capacity of about 792. It has the same design with Esther hall
Daniel hall	Normally occupied by 400 and 500 Level male students. It comprises of 8 wings and four floors. It also has base floors in some of the wings due to the topography of the land. It has 327 rooms and has a capacity of about 1308.
	Female hostel buildings
Esther hall	Mainly for 100 Level female students. It comprises of 7 wings with four floors each. It has a total of 198 rooms with a capacity of about 792. It has a similar design to Dorcas hall
Dorcas hall	Normally occupied by 400 and 500 Level female students. It comprises of 8 wings and four floors. It has a capacity of about 1208.

A total of 100 subjects participated in this study, they were occupants of different rooms randomly selected from 4 of the 10 halls in the campus. Amongst the 100 students that participated in the study, 50 (50%) were male and 50 (50%) were female. This showed an equal distribution amongst them. The total sample chosen represented about 2% of the schools total population. The subjects were between 15-25 years of age. The occupants usually engaged in light work (1.2met). Therefore, the activity level of all the subjects involved in the study was taken as 1.2met (70W/m²). This was done in accordance with the value recommended by the Manual

Book of Thermal Comfort Meter for the light office activity (BruelandKjer, 1982) and International Standard Organization (ISO-7730, 1994). The clothing value (clo) of subjects during the measurements were estimated to be about 0.6 clo (90% subjects), 0.9 (7%), 1.0 clo (2%) and 1.2 clo (1%). Table 2 and 3 show the demographic data of respondents and features of the hostel buildings. In Table 2, , the mean average age of the respondents was 19years, the lowest was 16.5years and highest average age was 22years. Also an average height of 1.61m and an average weight of 65kg was derived. The respondents were all Nigerians.

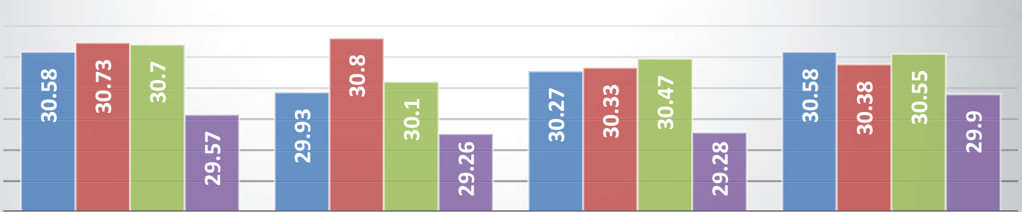
Table 2. Demographic data of respondents

S/N	Demographic data	Esther hall	Dorcas hall	Peter hall	Daniel hall
1	Age (years)	16.5	21	17	22
2	Height (m)	1.6	1.6	1.6	1.65
3	Weight (kg)	60	68	64	68

Table 3 Features of the hostel buildings

Structure system	**Esther hall**	**Dorcas hall**	**Peter hall**	**Daniel hall**
Shape of hostel	Finger	Cross	Finger	Cross
Material of wall	225mm sandcrete blocks & concrete	225mm sandcrete blocks & concrete	225mm sandcrete blocks & concrete	225mm sandcrete blocks & concrete
Number of doors	1	1	1	1
Number of windows	3	3	3	3
Type of window	Sliding	Sliding	Sliding	Sliding
Size of door (m)	0.74 x 1.90	2.10 x 0.85	0.74 x 1.90	2.10 x 0.85
Size of windows (m)	1.16 x1.16 1.60 x 1.15 0.70 x 1.16	1.16 x 1.16 1.60 x 1.15 0.40 x 1.16	1.16 x1.16 1.60 x 1.15 0.70 x 1.16	1.16 x 1.16 1.60 x 1.15 0.40 x 1.16
Average number of occupants per room	3	2	3	3

Environmental parameters such as air temperature, relative humidity and air velocity were measured. This are as presented in Figure 4, 5, 6, 7, Table 4 and 5. From Figure 4, the average temperatures of rooms on different floors in Esther hall can be seen at different periods of the day. The peak highest average temperature reading (30.73˚C) was observed at the ground floor in the afternoon. Figure 5 shows the average temperatures of rooms on different floors in Dorcas hall can be seen at different periods of the day. The highest average temperature reading (30.42˚C) was observed at the second floor during the afternoon, while the lowest average temperature reading (29.00 ˚C) was observed at the ground floor at night. In Figure 6, the highest temperature readings were found to have occurred in the evening, with an average of 30.80˚C, while lower temperatures were found to have in during the morning and night periods. In Figure 4, high temperatures were observed during the afternoon periods, while cooler temperatures were observed at night. The mean air temperature of the hall in the afternoon was about 30.76 ˚C and 28.68 ˚C at night.



	Ground	First	second	Third
Moring	30.58	29.93	30.27	30.58
Afternoon	30.73	30.8	30.33	30.38
Evening	30.7	30.1	30.47	30.55
Night	29.57	29.26	29.28	29.9

Figure 4: Average temperature in Ester hall per floor (^{0} C)

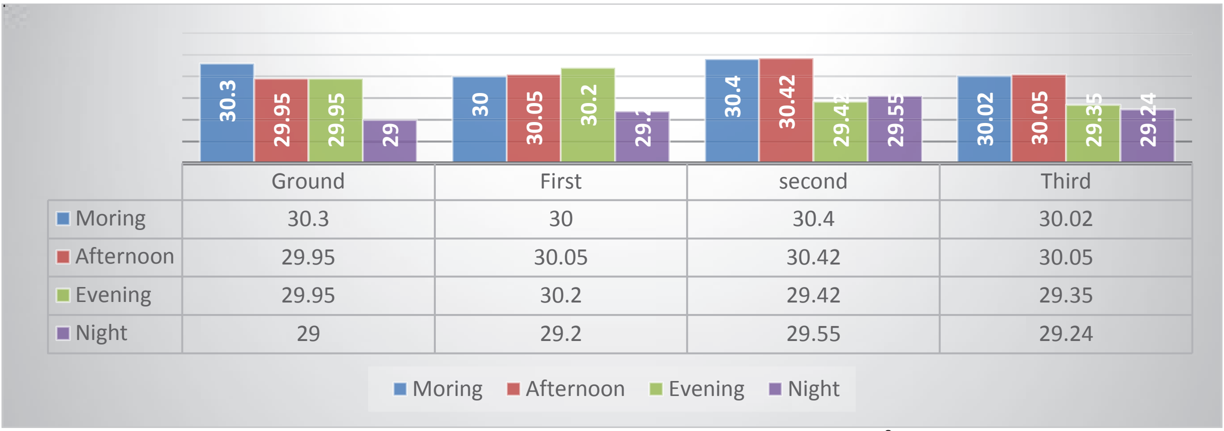


Figure 5: Average temperature in Dorcas hall per floor (^{0} C)

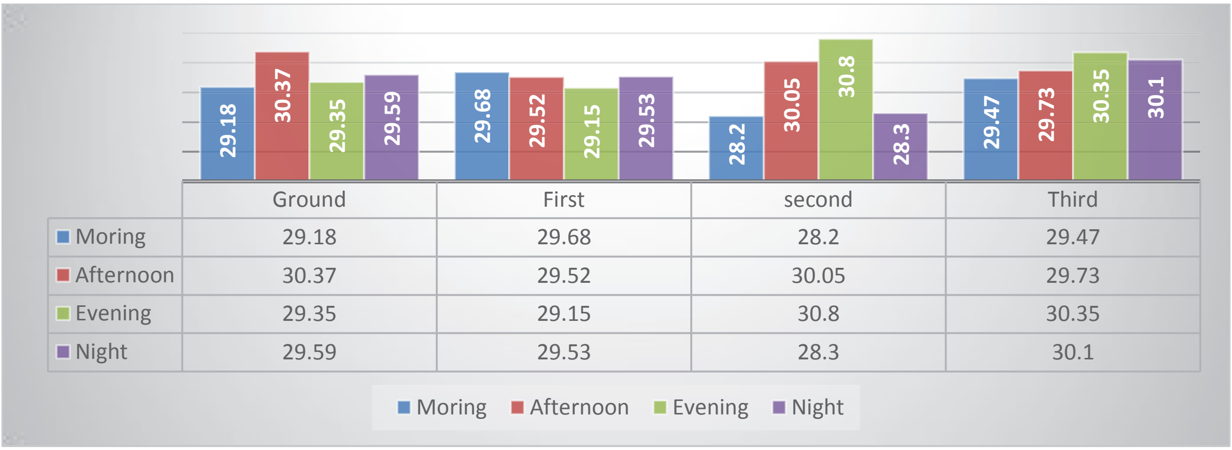


Figure 6: Average temperature in Peter hall per floor (^{0} C)

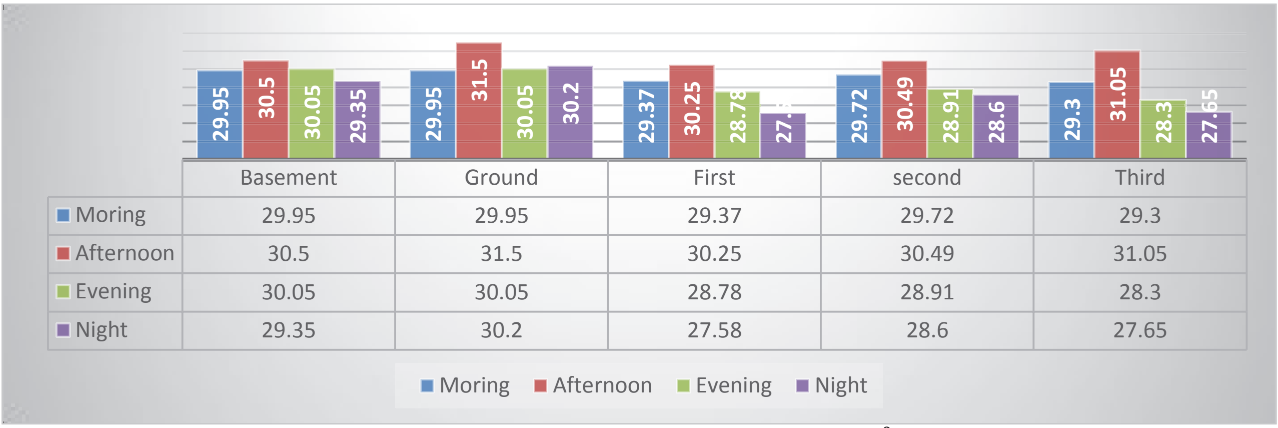


Figure 7: Average temperature in Daniel hall per floor (^{0} C)

Table 4 shows the average air velocity readings of the hostel buildings at different periods of the day. Air movement during the off periods (9am-5pm) during weekdays were very low, the air movement increased in the evening and at night. Also the electric fans which were installed in the rooms played resulted in huge differences; some fans were noticed to have been faulty, so readings were relatively lower compared to those with good working condition fans. It was also observed that rooms in external blocks and higher floors experienced more natural air flow than those in the inner blocks and lower floors. The average relative humidity for the hostel buildings are as presented in Table 5. High humidity values were observe at the night and lower value in the afternoon.

Table 4: Average Air Velocity readings of the hostel buildings at different periods of the day

Hostel	Average air velocity (m/s)			
buildings	Morning	Afternoon	Evening	Night
Esther hall	0.17	0.04	0.97	1.06
Dorcas hall	0.10	0.00	0.08	1.28
Peter hall	0.29	0.00	0.93	1.10
Daniel hall	0.29	0.02	0.35	1.34

Table 5: Relative Humidity reading of the hostel buildings at different periods of the day

Hostel	Average relative humidity (%)			
buildings	Morning	Afternoon	Evening	Night
Esther hall	80.19	74.00	80.03	81.77
Dorcas hall	77.80	74.90	82.27	80.64
Peter hall	78.37	73.45	77.69	80.43
Daniel hall	72.3	71.48	78.01	79.13

The results of subjective responses to temperature (thermal sensation) are presented in Figure 8 below. The result shows that the majority of the respondents indicated hot sensations in all hostel buildings. The ASHRAE Standard 55 -20004 specified that an acceptable thermal environment should have 80% of occupants vote for the central three categories (-1, 0, 1). Only 80.75% indicated outside the central three categories showing that all 4 hostel buildings were not in thermal acceptable conditions. This assessment uses the subjective scale of -3 (very dissatisfied), -2 (dissatisfied), -1 (slightly dissatisfied), 0 (Neutral), -1 (slightly satisfied), -2 (satisfied) and -3 (very satisfied).

Figure 9 shows the thermal satisfaction of the hostel buildings, it can be observed from the figure that majority of the occupants (77.25%) were very dissatisfied with the temperature levels with Daniel hall reporting the highest percentage of very dissatisfied occupants. This high level of dissatisfaction is expected since many of the halls experienced average temperatures of about 30˚C which is clearly out of the comfort zone

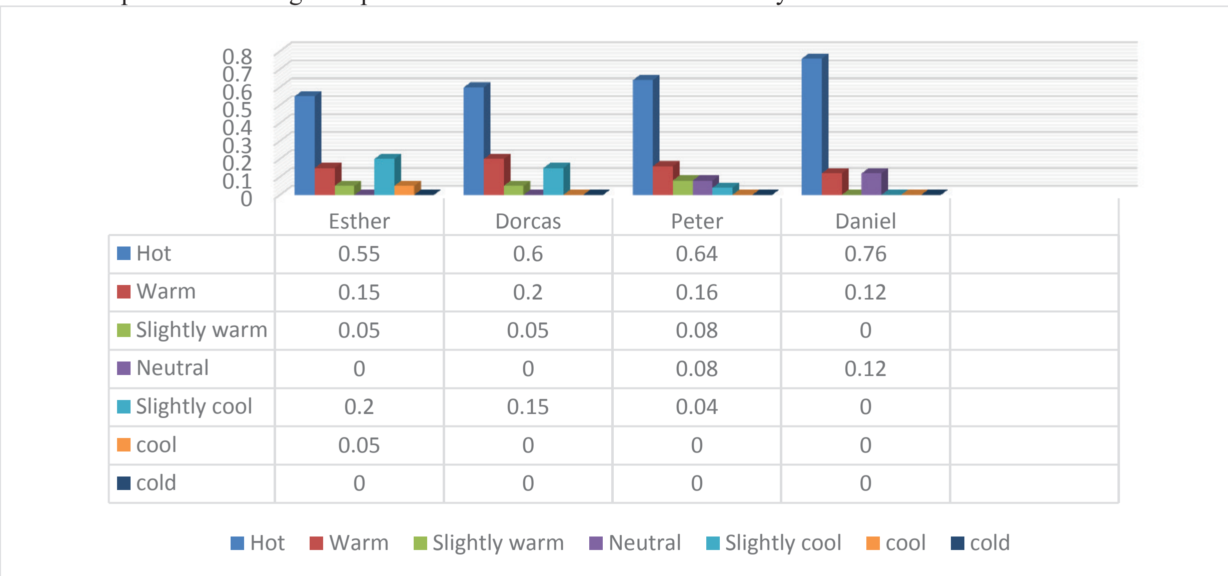
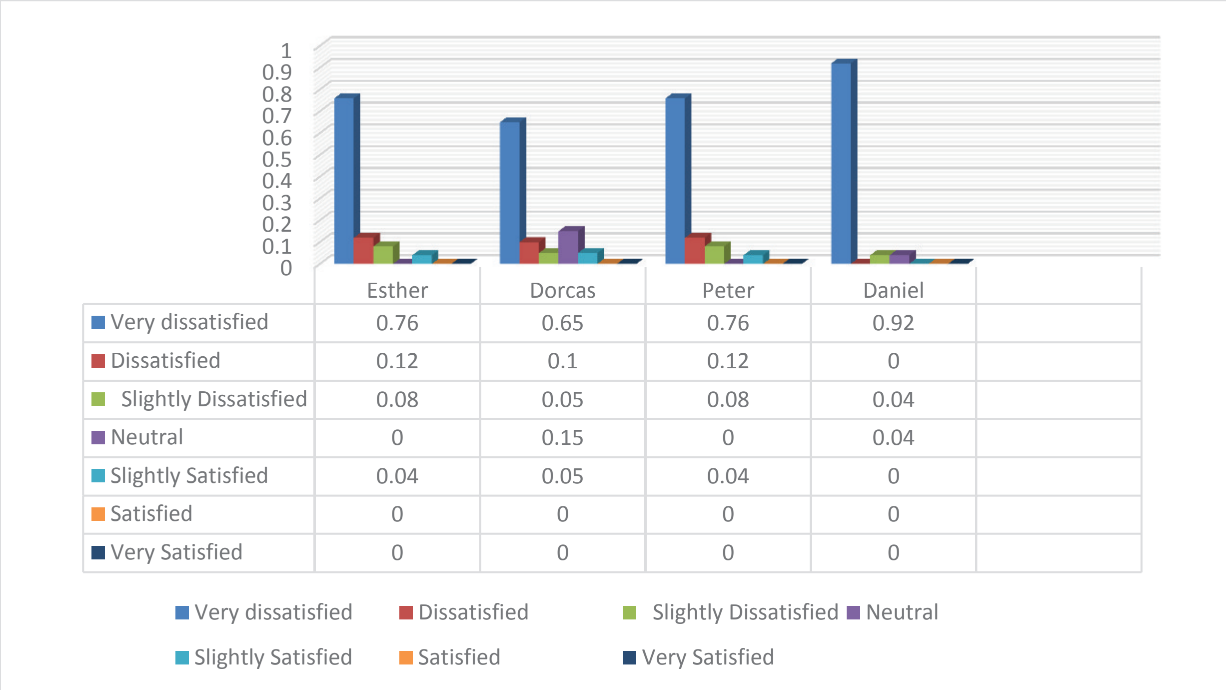


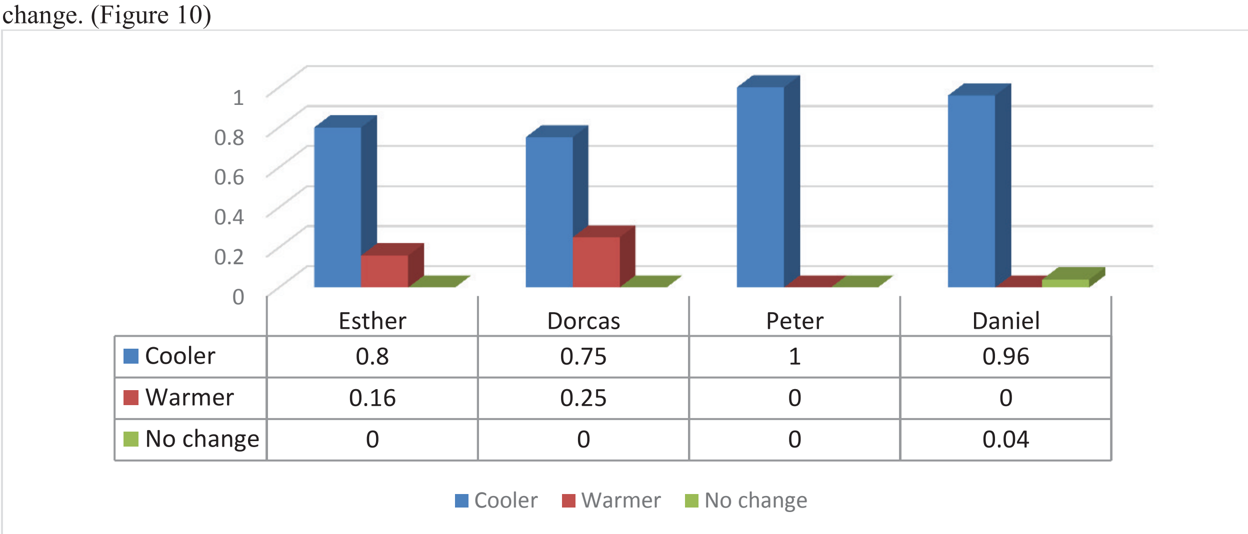
Figure 8: Thermal sensation of the hostel building



	Esther	Dorcas	Peter	Daniel
Very dissatisfied	0.76	0.65	0.76	0.92
Dissatisfied	0.12	0.1	0.12	0
Slightly Dissatisfied	0.08	0.05	0.08	0.04
Neutral	0	0.15	0	0.04
Slightly Satisfied	0.04	0.05	0.04	0
Satisfied	0	0	0	0
Very Satisfied	0	0	0	0

Figure 9: Thermal satisfaction of the hostel buildings

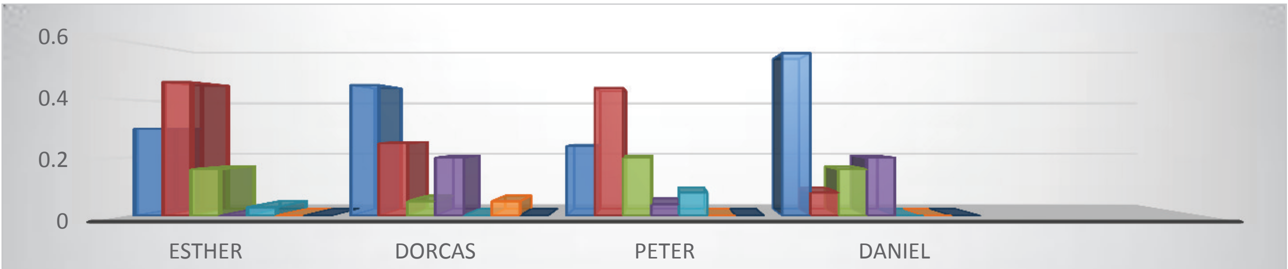
The subjective scale used for thermal preference was the McIntyre scale (1980). In the scale, -1 represents ‘’cooler’, 0 represents ‘no change’, and +1 means ‘warmer’. It can be observed that respondents in all halls of residence, majority of occupants (87.75%) preferred to be cooler, 10.25% indicated warmer and 20% wanted no change. (Figure 10)



	Esther	Dorcas	Peter	Daniel
Cooler	0.8	0.75	1	0.96
Warmer	0.16	0.25	0	0
No change	0	0	0	0.04

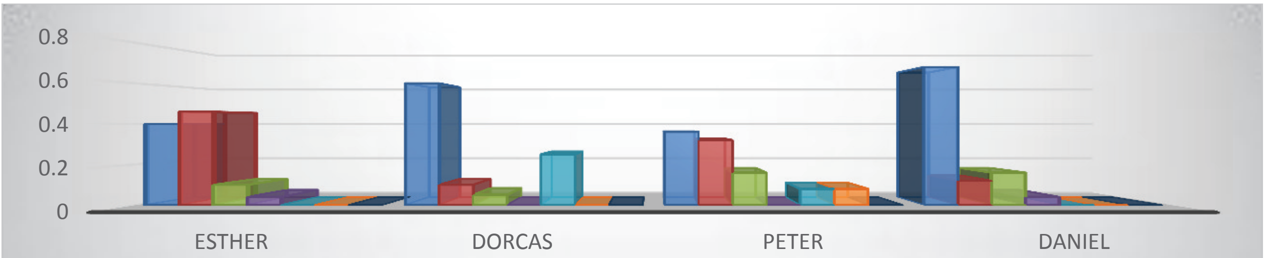
Figure 10: Thermal preference in the hostel buildings

Figure 11, 12 and 13 show the air movement sensation, air movement satisfaction and air movement preferences in the hostel buildings. In Esther hall, about 30% of the respondents indicated that the air was much too still. Less than 30% of the respondents indicated the same in Peter hall; while more than 40% indicated ‘much too still’ in Dorcas and Daniel halls. Air movement sensation was indicated as ‘just right’ only in Dorcas and Daniel halls; while air movement sensation was not too breezy in all the hostel buildings, as indicated by the respondents. More than 30% of the respondents were very dissatisfied with air movement in all the hostel buildings; while none of the respondents were satisfied with air movement in all the hostel buildings. The result shown in Figure 13 shows that more than 80% of the respondents preferred more air movement in all the halls of reside



	Esther	Dorcas	Peter	Daniel
Much too still	0.3	0.45	0.24	0.56
Too still	0.46	0.25	0.44	0.08
Slightly still	0.16	0.05	0.2	0.16
Just right	0	0.2	0.04	0.2
Slightly breezy	0.03	0	0.08	0
Too breezy	0	0.05	0	0
Much too breezy	0	0	0	0

Figure 11: Air movement in the hostel buildings



	Esther	Dorcas	Peter	Daniel
Very dissatisfied	0.4	0.6	0.36	0.68
Dissatisfied	0.46	0.1	0.32	0.12
Slightly Dissatisfied	0.1	0.05	0.16	0.16
Neutral	0.04	0	0	0.04
Slightly Satisfied	0	0.25	0.08	0
Satisfied	0	0	0.08	0
Very Satisfied	0	0	0	0

Figure 12: Air movement satisfaction in the hostel buildings

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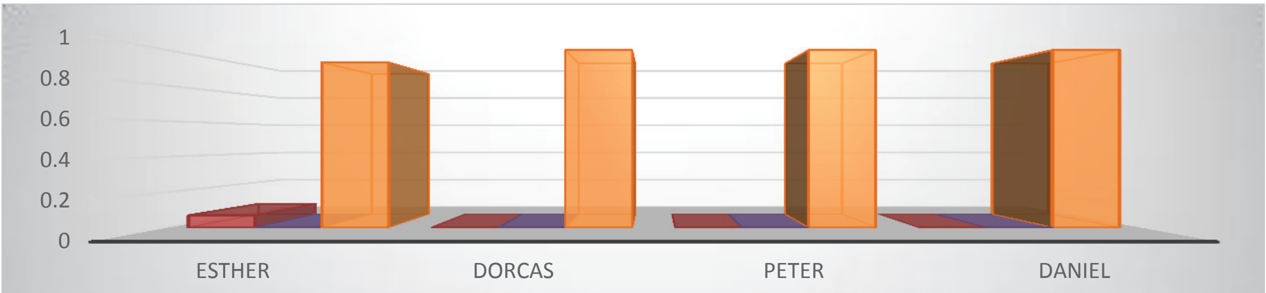
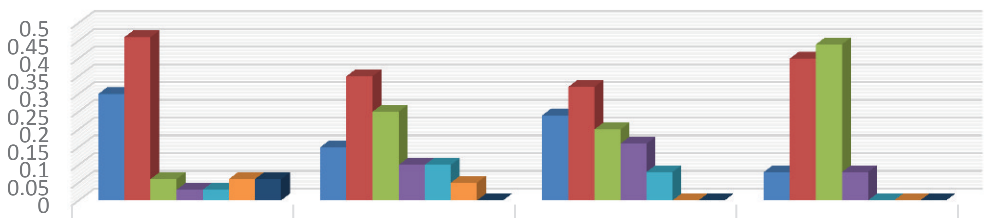


	Esther	Dorcas	Peter	Daniel
less air movement	0.07	0	0	0
No change	0	0	0	0
More air movement	0.93	1	1	1

less air movement No change More air movement

Figure 13: air movement preference in the hostel buildings

The relative humidity for the hostel buildings was assessed using subjective scale of -3 (much too dry), -2 (too dry), -1 (slightly dry), 0 (just right), 1 (slightly humid), 2 (too humid) and 3 (much too humid). The subjective responses on humidity are presented in Figure 14. The results show that more than 30% of the respondents indicated that air was too dry in the halls of residence. The air in Esther and Peter halls was much too dry as indicated by over 20% of the respondents. As presented in Figure 15, more than 80% of the respondents were dissatisfied with the humidity levels in their rooms and preferred the air to be fresher. In Figure 16, more than 20% indicated that they were always in discomfort throughout the day in all the halls of residence. More than 40% of the respondents indicated afternoon period as their period of discomfort in all the halls of residence; while morning and evening periods posed no or low level of discomfort to the occupants in all the halls of residence. As already been established as the period with the hottest temperatures of the day, discomfort is reinforced with that fact that ceiling fans cannot be used during this periods except weekends to control cooling since the afternoon falls within the “off times”.



	Esther	Dorcas	Peter	Daniel
Much too dry	0.3	0.15	0.24	0.08
Too dry	0.46	0.35	0.32	0.4
Slightly dry	0.06	0.25	0.2	0.44
just right	0.03	0.1	0.16	0.08
Slightly humid	0.03	0.1	0.08	0
Too humid	0.06	0.05	0	0
Much too humid	0.06	0	0	0

Much too dry Too dry Slightly dry just right Slightly humid Too humid Much too humid

Figure 14: Humidity sensation in the hostel buildings

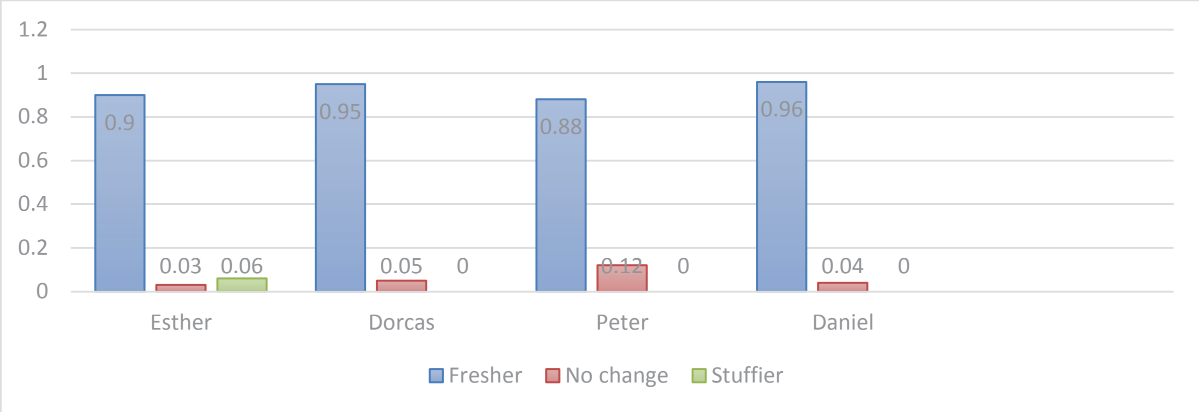


Figure 15: Humidity preference in the hostel building

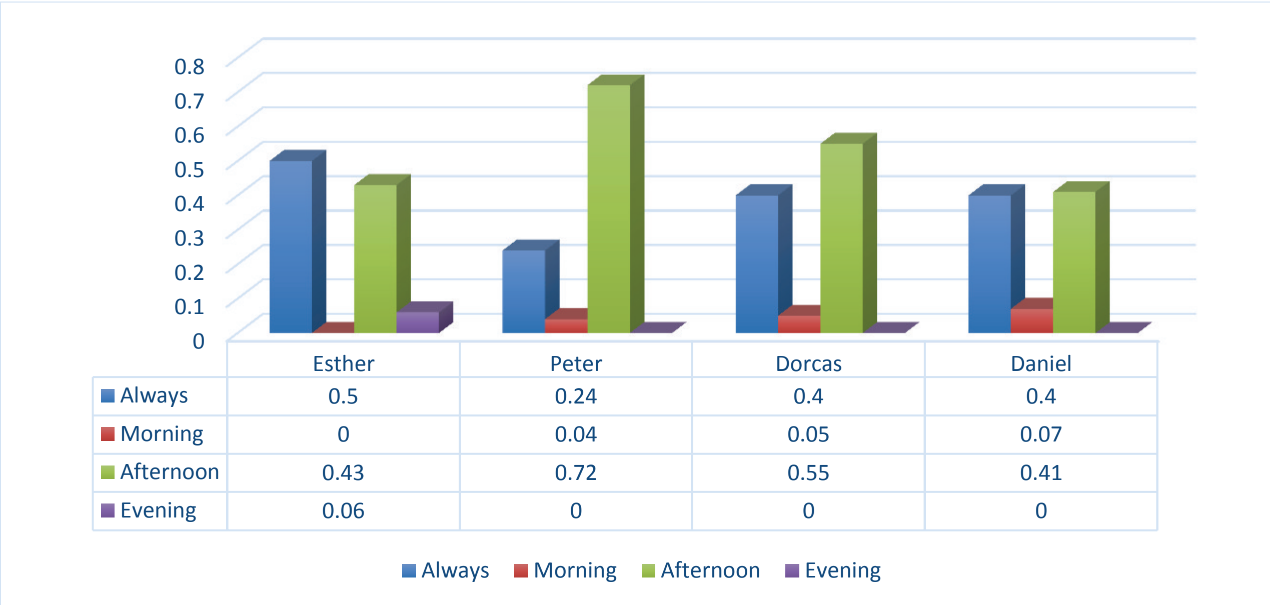
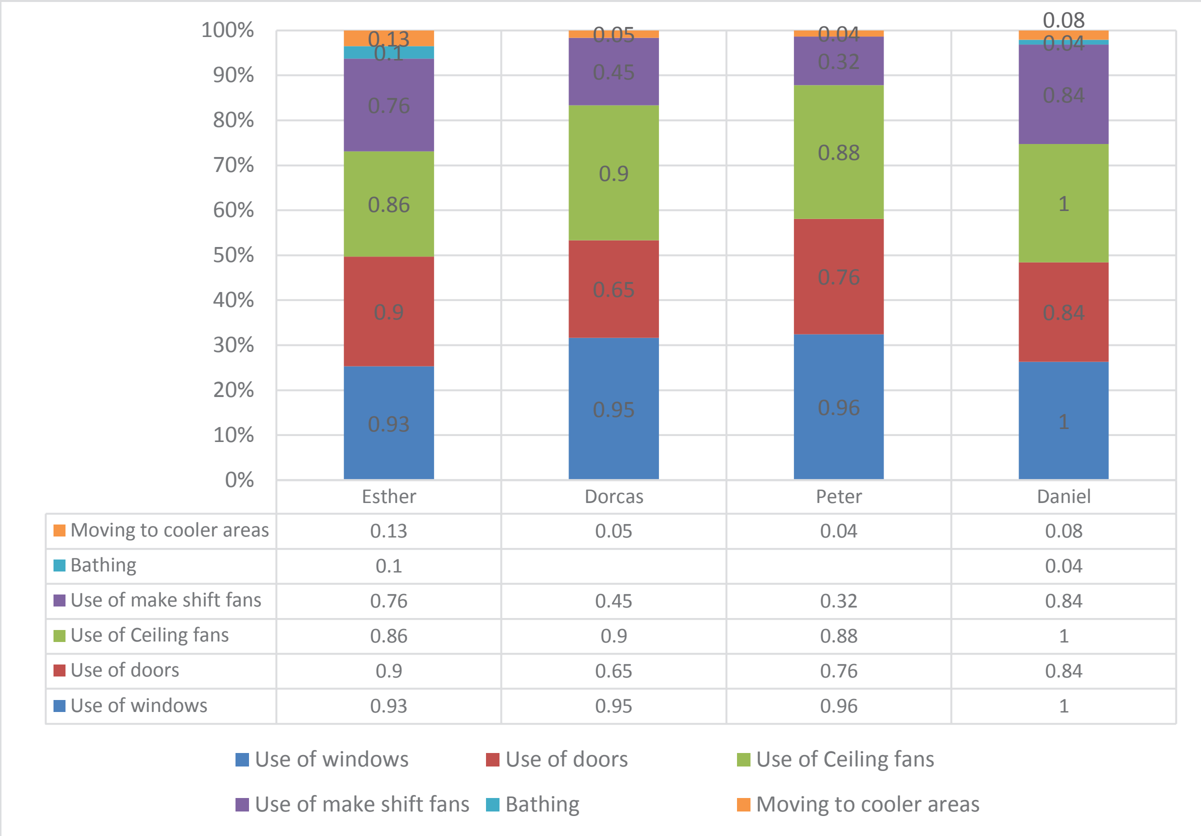


Figure 16: Period of discomfort in the hostel buildings

The adaptive behavior of the occupants of the hostel buildings was investigated. The results is as presented in Figure 17. No less than 93% of the respondents indicated that they use windows to control their comfort levels in the halls of residence. More than 65% use doors and more than 86% use ceiling fans to control the level of comfort in the halls of residence. Use of make shift fans, bathing, and moving to cooler areas were not commonly used as adaptive behavior by the respondents.



	Esther	Dorcas	Peter	Daniel
Moving to cooler areas	0.13	0.05	0.04	0.08
Bathing	0.1			0.04
Use of make shift fans	0.76	0.45	0.32	0.84
Use of Ceiling fans	0.86	0.9	0.88	1
Use of doors	0.9	0.65	0.76	0.84
Use of windows	0.93	0.95	0.96	1

Figure 17: Adaptive behavior of the occupants in the hostel buildings

For a building to be thermally comfortable, its PMV value should conform to this expression (-1 ≥ PMV +1). PPD and PMV values of the hostel buildings were determined. The following assumptions were made while computing the data for the PMV calculator: MRT=AT (Mean Radiant Temperature = Air Temperature); Value of clo = 0.6, Metabolic rate = 1.0. The results are as shown in table 6. The results show PPD and PMV values higher than the expected value for comfort. With exception of Dorcas hall (0.95) and Daniel hall (0.52) where values fell within the accepted comfort values It can be observed that the values for PPD and were significantly high during the afternoon period in the different halls, and much lesser during the night period. The results showed that only Daniel hall was thermally comfortable, during the night period with a PPD value of about 10.7%. PPD values for other halls fell above 20% at every other period. Also, results from the four halls indicated that the halls were not thermally comfortable at all periods of the day. Only Daniel hall was found to be thermally comfortable, and this was achieved at night.

Table 6: PPD and MV values for the hostel buildings

Hostel buildings	Air Temperature [℃]	Mean Radiant Temperature [℃]	Air Velocity [m/s]	Humidity [%]	Clothing [clo]	Metabolic Rate [met]	PMV	PPD [%]
			Morning					
Esther	30.30	30.30	0.17	80.17	0.60	1.00	1.95	74.40
Dorcas	29.84	29.84	0.10	77.80	0.60	1.00	1.83	68.90
Peter	29.17	29.17	0.29	78.37	0.60	1.00	1.34	42.80
Daniel	29.60	29.60	0.29	72.30	0.60	1.00	1.46	49.00
			Afternoon					
Esther	30.59	30.59	0.04	74.00	0.60	1.00	2.15	83.10
Dorcas	29.95	29.95	0.00	74.90	0.60	1.00	1.92	73.20
Peter	29.59	29.59	0.00	73.45	0.60	1.00	1.77	65.60
Daniel	30.48	30.48	0.02	71.48	0.60	1.00	2.08	80.30
			Evening					
Esther	30.43	30.43	0.97	80.03	0.60	1.00	1.65	59.40
Dorcas	29.55	29.55	0.08	82.27	0.60	1.00	1.81	67.60
Peter	29.60	29.60	0.93	77.69	0.60	1.00	1.23	36.70
Daniel	28.97	28.97	0.35	78.01	0.60	1.00	1.21	35.70
			Night					
Esther	29.43	29.43	1.06	81.77	0.60	1.00	1.15	33.10
Dorcas	29.17	29.17	1.28	80.64	0.60	1.00	0.95	24.30
Peter	29.55	29.55	1.10	80.43	0.60	1.00	1.19	34.80
Daniel	28.38	28.38	1.34	79.13	0.60	1.00	0.52	10.70

5.0 CONCLUSION

The study showed that the occupants in that majority of the occupants in the selected halls were not comfortable with their immediate thermal environment. With average temperature values of about 30˚C, and which is outside the comfort range which was suggested by Evans (1980), who suggested that comfort range should be 22.5° to 27.5°C during daytime and 20°C to 26°C during night-time. For a higher relative humidity of 70% to 100% the recommended range is between 22.5°C to 27°C during daytime and 20°C to 25.5°C during night-time. According to Paul (1993), comfort zone however, should have an indoor temperature of not more than 25°C or fall below 15°C and the relative humidity should range between 40% to 75%.Based on the above statements regarding the range of thermal comfort as suggested by Koenigsberger (1973) and Evans (1980), comparing it to the summarized findings gathered, it can be said that thermal comfort cannot be achieved by natural ventilation alone in these halls.

Although thermal environment is very hard to achieve in tropical climatic regions by passive cooling design, the simplest and most effective solution for achieving thermal environment which had been done by many designers is to use active cooling methods like air conditioners. Nonetheless, air conditioning system will lead to huge electric bills in the hostels or other type of building as well as increase the emission of CO2 to the environment. Also cooler temperatures were observed in areas where tree vegetation was planted around the hostel buildings. The occupants found their thermal conditions unacceptable. The study also revealed that the thermal levels of males compared to their female counterparts were quite similar.

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