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Investigation of Indoor Thermal Comfort and Air Quality in Typical Student Residences †

Howard Njoku [1], Obiora Odugu [1,*] Elizabeth Kallstrom [2] and Nwizu Chibuike [2,*]

[1] University of Nigeria, Nsukka, Nigeria; howard.njoku@unn.edu.ng
[2] Howard Njoku;
* Correspondence: obiora.odugu.197259@unn.edu.ng (O.O.); Nwizu.chibuike.197992@unn.edu.ng (N.C.); Tel: +234-7031280804

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Abstract: This study assessed thermal and air quality conditions in student residences at the University of Nigeria, Nsukka. Indoor thermal comfort parameters such as temperature, humidity, clothing level and metabolic rate of occupants in naturally ventilated sample rooms owned by the school and private individuals were either measured or observed, and recorded. The average values were then evaluated using the CBE thermal comfort tool for comfort range plots. Next, levels of indoor $PM_{2.5}$, and HCHO were measured using on-the-spot detectors.

Keywords thermal comfort; air quality; adaptive method; predictive mean vote

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1. Introduction

Indoor thermal comfort and air quality has become a major research area since people spend between 80–90% of their time indoor (Lader, Short, & Gershuny, 2006). A number of studies show that the amount of indoor air pollution is 2–5 times higher than outdoor air, in a few cases the indoor air pollutant where about 100 times higher (Lader et al., 2006). When people are dissatisfiedwith their thermal environment, it poses health issues and reduces productivity (Mendell & Heath, 2005). For this particular reason, there is urgent concern on the survey of thermal comfort parameters and indoor air quality.

The cause of comfort sensations in student residences can be attributed to a combinatory effect of indoor thermal environmental factors, personal factors, indoor air quality, visual factors, and auditory factors (American Society of Heating, Refrigeration and Air Conditioning Engineers, 2017). Indoor thermal environment factors consist of air temperature (Ta), radiant temperature (Tr), air speed, humidity (Rh); Personal factors consist of metabolic rating (met) and clothing insulation (clo); visual factors consist of light and colors, while auditory factors consist of sound and noise.

This study investigated the indoor thermal comfort zone and air quality of typical student residences using temperature and humidity sensors as well as gas sensors. Arup (2016) in building energy efficiency Guideline for Nigeria suggests that a mean outdoor temperature of 26–28 °C provides thermal comfort. This temperature range lacks supporting evidence from any field survey provided by the ministry of works and housing, thus the need to investigate state of comfort and air quality condition of buildings. In line with this, thermal comfort parameters were measured and estimated. Results were used to evaluate the state of comfort in student residences. Common air pollutant found within indoor spaces such as particulate matters were also measured, and results presented. All measurement, estimations and comparison were in accordance with international standards such as ASHRAE (American society of Heating, Refrigeration and Air-conditioning Engineers), CBE (Centre for the Built Environment) and WHO.

2. Materials and Methods

This work was carried out in two parts- thermal comfort and air quality measurement. A total category of 3 student residences were identified as shown in Table 1. Residences were categorised according to their similarities and location. All measuring devices were placed 0.6 m–1.1 m above floor level and the average mean value were used to represent data generated. Occupants of each room are solicited as untrained personnel to help monitor and ensure proper recording of the devices. After parameters were measured and recorded, comfort data were evaluated using the adaptive method on the CBE thermal comfort web app. For air quality, the results were compared to the WHO standards.

Table 1. Population of students in each residence

Residences	Number of Students	Residence Type
Hostel 1	1230	Public
Hostel 2	750	Public
Hostel 3	300	Private

Elitech data loggers were used to measure and log room temperature and humidity levels in the room for a day. The Common gas pollutant measured were PM2:5 and HCHO.

Table 2 shows the equipment used, their measurement parameters as well as their specifications.

Table 2. Measuring equipment and specifications

Equipment	Specifications	Parameters
Elitech GSP-6	−40 °C–85 °C	Temperature
	20–80%	Relative humidity
Air quality detector	(0–0.999) ppm	PM2.5
	0–9.999 mg/m^3	HCHO

3. Results and Discussion

Data logger were portable with measurement ranges within the acceptable indoor range. Logging started at 10:00 to 18:00 WAT. The Logged values and graph were exported to an excel sheet through the Elitech desktop software. The values were then averaged and results for thermal comfort and air quality were evaluated with the CBE thermal comfort tool and WHO standard. The residents clothing and activity were recorded within the period of data collection. Table 3 shows average values of the thermal comfort data obtained from each residence and their compliance with the adaptive method recommended by ASHREA. Results are also plotted on the adaptive comfort chart to show if each building are in the line with the ASHREA standard for natural ventilated buildings.

Table 3. Thermal comfort parameters and adaptive compliance of each hostel.

Residences	Ta	Tr	To	Rh	met	clo	Adaptive Compliance
Hostel 1	31.9	32.3	31	55.4	1.1	0.36	No
Hostel 2	32.7	33.1	30.8	36.3	1	0.36	No
Hostel 3	29.5	29.9	30.7	79.3	1	0.36	Yes

In hostel 1, the average temperature (31.9 °C), mean radiant temperature (32.3 °C), mean outdoor temperature (31 °C) and relative humidity (55.4%) places the building outside the adaptive comfort zone when mean radiant temperature (operative temperature) is plotted against time. In hostel 2, a similar compliance was reached while in hostel 3, the average temperature (29.5 °C), mean radiant temperature (29.9 °C), mean outdoor temperature (30.7 °C) and relative humidity (79.3%) places the hostel within the adaptive comfort zone. Figure 1 shows a same graph plot of hostel 3 meeting the recommended standard.

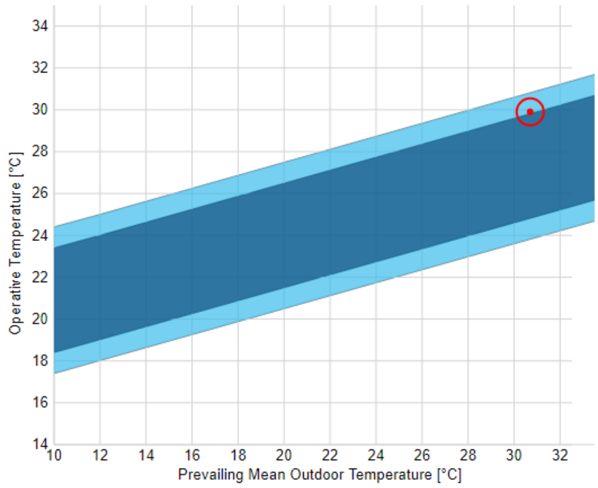
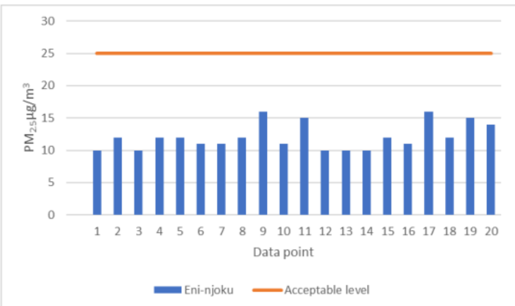
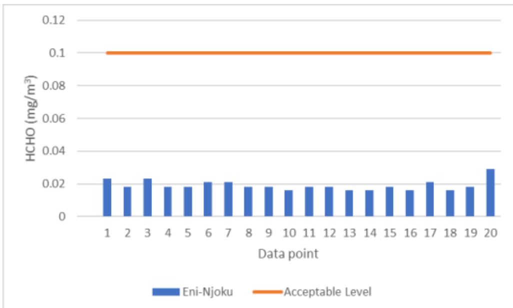


Figure 1. Sample plot of comfort zone in hostel 3 on the adaptive comfort chart.

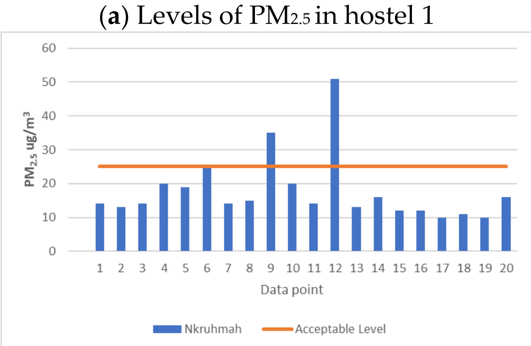
Figure 2 shows the air quality conditions for $PM_{2.5}$ and HCHO. Each data point represents a single room in a building. The histogram shows the level of particle and gases in the rooms while the straight line is the recommended standard by WHO. In hostel 1, all rooms are seen to be with the range of good air quality conditions. In hostel 2, 3 out of the 20 rooms surveyed is seen to be above 25 μg/m^3 while 1 out of the 20 room is above 0.1mg/m^3 which is the maximum limit set by the WHO for HCHO. In hostel 3, 14 out of 20 rooms were above the set limit for $PM_{2.5}$ while all the rooms were within the limit for HCHO.



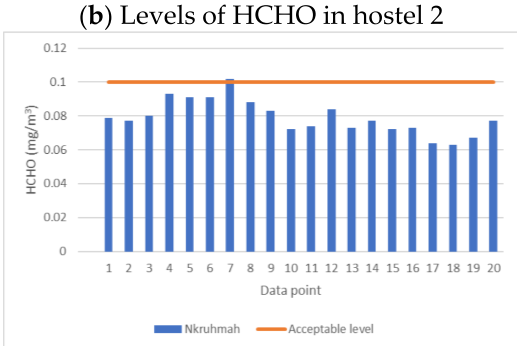
(**a**) Levels of $PM_{2.5}$ in hostel 1



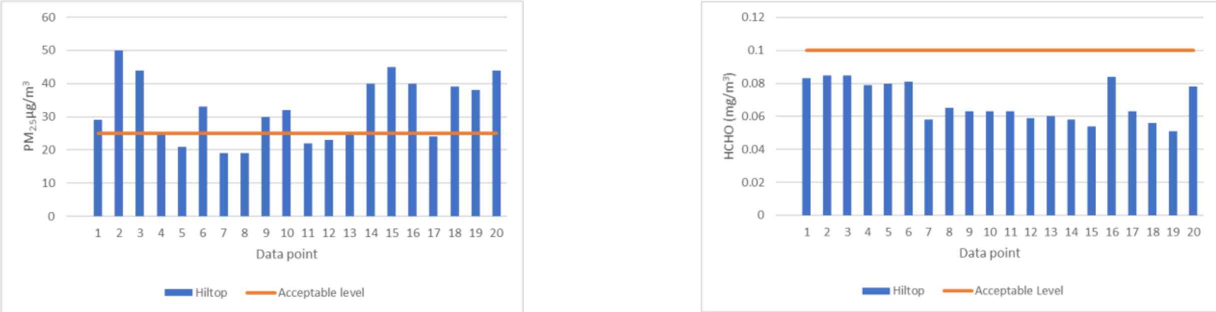
(**b**) Levels of HCHO in hostel 2



(**c**) Levels of $PM_{2.5}$ in hostel 2



(**d**) Levels of HCHO in hostel 2



(**e**) Levels of PM2.5 in hostel 3

(**f**) Levels of HCHO in hostel 3

Figure 2. Comparison of $PM_{2.5}$ and HCHO to WHO standard.

Institutional Review Board Statement:

Informed Consent Statement:

Data Availability Statement:

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