



Research article

Comparative Analysis of Biophilic and Non-Biophilic Hostel Designs in a Tropical Climate: A case of University of Ibadan, Nigeria

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ABSTRACT

Various strategies have been implemented to alleviate the effects of ozone layer depletion on household comfort in both tropical and other climates. Some approaches focus on building structures, while others investigate the airspace between roofing and ceilings, and some embrace biophilic elements. However, there is a lack of research on the effectiveness of biophilic elements, particularly in tropical regions like Nigeria, which this study aims to address. This research explores a comparative analysis of biophilic and non-biophilic hostel designs in a tropical climate, specifically at the University of Ibadan. The objective is to compare environmental parameters between biophilic and non-biophilic hostels in the study area. To achieve this, indoor air temperatures for high biophilic design (IT-HBD) and non-biophilic design (IT-NBD) were measured using K-type thermometers in accordance with ASTM E1 and E77 standards. Concurrently, indoor relative humidity for high biophilic design (IRH-HBD) and non-biophilic design (IRH-NBD) was measured using a digital psychrometer based on ISO 14644-16 standards. Data were analyzed statistically using graphical representation and a t-test at $p < 0.05$. The indoor air temperatures for IT-HBD in the morning, afternoon, and evening were 29.9-27.9°C, 37.1-31.4°C, and 35.4-24.3°C, respectively, indicating high moisture content in the air, which leads to lower temperatures due to the influence of biophilic elements. In contrast, IT-NBD recorded temperatures of 32.5-30.5°C, 37.5-32.6°C, and 35.4-29.3°C, showing lower humidity and resulting in higher indoor temperatures. Similarly, IRH-HBD ranged from 60% to 77%, 55% to 65%, and 60% to 69%, indicating adequate moisture for indoor cooling. Conversely, IRH-NBD ranged from 60% to 68%, 55% to 64%, and 51% to 63%, reflecting lower humidity levels that contribute to higher temperatures. The statistical analysis revealed that the mean air temperature for NBD (Mean = 32.35, SD = 2.37) is significantly higher than that of HBD (Mean = 29.50, SD = 3.53). Comparatively, incorporating high biophilic elements in hostel design provides substantial benefits over non-biophilic designs. Therefore, designing residences with biophilic features can greatly enhance comfort in buildings. The findings of this study contribute valuable insights into how indoor comfort can be achieved through biophilic elements.

Introduction

The undeniable reality of climate change in recent times, along with the majority of studies advocating for adaptation and green lifestyles as the primary means of mitigation, underscores the necessity for building design and construction to align with nature. The rise in tree planting and the adoption of biophilic design indicate significant efforts to reconnect with the natural environment. The theory underlying biophilic design

suggests that an organism's physical and mental functions are enhanced through contact with nature (Söderlund *et al.*, 2015). This principle has led to the notable implementation of biophilic design in healthcare buildings, demonstrating significant effectiveness (Omega & Lateef, 2023). Furthermore, Assari and Tajarloo (2021) explored the impact of biophilic design on various psychological variables, finding that it positively influences stress,

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anxiety, mood, perception, cognition, and social well-being. However, there is a lack of studies examining the effectiveness of biophilic design in academic settings, particularly in terms of how it enhances learning by improving ambient temperature and humidity for educational activities. This gap is what the present study aims to address.

Empirically established, eco-friendly design is a Natural Alternative Method (NAM) of controlling air temperature, air pollution, ultraviolet radiation, and climate change in buildings. The concept of biophilic design was born out of an innovative eco-friendly approach to reducing harsh weather through the integration of nature-based materials (Davidson, 2013; Zhong *et al.*, 2015). People believed that the inclusion of nature in design improved mental health, performance, well-being, and resilience (Zhong *et al.*, 2021; Killert *et al.*, 2015). The fallout of urbanization has created environmental crises, leading to excessive heat infiltration and direct ultraviolet radiation into the space, causing overburdens on air temperature and air pollutants. However, a way out of this problem led to the integration of biophilic elements into designs as a living organism in order to sustain life from death threats (Zhong *et al.*, 2021). Similarly, Olmsted *et al.* (2014) believed that biophilic design has the tendency to reduce stress, improve our well-being, and expedite healing because of humankind's innate connection with nature.

The introduction of green environments, landscape designs, and trees to regulate the air temperature and pollutant air has been the major antidote to sick building designs and challenges. The disconnection from nature affects the way we feel inside buildings, especially when it comes to temperature and overall comfort. The temperature, humidity, air quality, and airflow all play a significant role in the well-being and productivity of those inside a building. Without access to natural elements and nature-inspired design, the thermal comfort conditions can be far from ideal. This can lead to discomfort, thermal stress, and reduced satisfaction among occupants (Frontczak *et al.*, 2012). Hence, the prevailing designs and development of the modern built environment are problematic because they deny human interaction with nature, resulting in internal discomfort.

Therefore, the influence of trees, shrubs and greenery over the indoor air temperature and relative humidity cannot be over-emphasis. These with other factors like orientation, climatic condition and the environmental conditions have proven to be a major contributor to conducive indoor thermal comfort in a tropical residential buildings. According to Chagolla *et al.*, (2012), he asserted that where effect of trees were not available or considered the temperature tend to increase by 4%. Similarly, Dekic *et al.*, (2015) believed that trees are important from the aspect of cooling through evapotranspiration and shading. He further emphasize the fact that Evapotranspiration can create oases with 2–8 °C lower air temperatures that their surroundings and a cooling effects that extends out in to the surrounding area.

The consequence of this was the reason for this research, which aimed to study the advantages of biophilic elements in ensuring internal comfort in the student hostels of the University of Ibadan.

Biophilic elements and its impact on the built environment

Zhion *et al.* (2021) define biophilia as the love of life that focuses on life and lifelike processes. Biophilia connects nature with the built environment (Messeidy, 2013). According to Killert (2015), the inherent human inclination is to affiliate with nature. Biophilia also helps to elucidate three important principles of human health and wellbeing and the natural world (Messeidy, 2019). It brings nature into humans's places and the natural world's place in human society, as in the case of city parks. This has to do with creating an urban artificial environment that satisfies human inherent intimacy with nature through the utilization of nature (Cheng *et al.*, 2023). Kellert (2008), in his contribution, defines biophilic design as having a philosophy that advocates for integrating natural systems and processes in the design of the built environment. Browler *et al.* (2015) deduced that exposure to natural environments and features has a positive impact on human health and well-being. It also maintains, improves, and restores the beneficial experience of nature in various environments, including healthcare, education, retail, the workplace, and community environments (Browning *et al.*, 2012). Meanwhile, Cox *et al.* (2017) believed that the incorporation of natural elements like vegetation reduces depression, anxiety, and stress.

However, White *et al.* (2010) alluded to the fact that the incorporation of water into the built environment helps to mitigate stress, promote satisfaction, and enhance health and performance. In addition, Nowak and Heisler (2010) buttressed that urban trees reduce air pollution by both directly removing the pollutants and by reducing air temperature and the building energy used. Similarly, Kellert (2008) asserted that biophilia acknowledges the human inclination towards nature; therefore, biophilic design is seen as a novel solution to counter the challenges presented by urban development, with the primary objective of improving the interior thermal comfort of built environments by integrating natural elements. The current study was based on the assumption that the exterior thermal comfort—measured by out-door temperature and relative humidity—of biophilic design would be more comfortable compared to that of non-biophilic design.

Hypothesis

The primary hypothesis guiding this investigation are:

H₀: There is no significant difference in external thermal comfort—specifically temperature and relative humidity—between biophilic and non-biophilic hostel designs.

H₁: Biophilic hostel design provides significantly superior external thermal comfort—specifically in terms of temperature and relative humidity—compared to non-biophilic hostel design.

Study Area

A hostel is considered among the most populated urban buildings that require good outdoor landscape design with beautiful interior greening for efficient energy, comfort, and sustainability. The research was conducted at the esteemed University of Ibadan, Ransome Kuti Hall.

Ibadan is a capital city of Oyo state Nigeria. The study area falls within the tropical climatic zone, which enjoying two different seasons annually. The rainy season (wet period) between late April to September and the dry season (sunny period) from December to March. However, this study was carried out in March 2024 during the dry season, when the sun was harsh with excessive air temperature.

The hall is located at the eastern end of Niger Road on the campus. It was formally opened in 1954, with a capacity of five hundred and fifty-four (554) beds for students. Plate 1 shows the north-south orientation of the campus layout. While Plate 2 shows the sun path location of the study hostel, the Plates 3 (a) to (f) show the sample blocks for both high-biophilic and non-biophilic designs where the study was carried out.



Plate 1: university of Ibadan Ariel view
Source: UIDLC Platform



Kuti hall

Plate 2: Sun Path diagram of the study location

The Study Samples

The study samples shared the same building orientation. They were oriented east-west direction to naturally minimize the solar gain during the day time. The east and west facing were made plain to prevent direct solar radiation into the indoor space(s). The design having double loaded terrace to act as shading device in other to reduce heat gain from the sun. There is also a central passage for circulation within the hostel, as represented in Plate 2 (c & d).

This study focus on the day time temperature within and outside of the hostel. This was done to determine the functionality and environmental impact of this hostel design on the students, during the peak period of the day when the sun will be overhead at 12 pm and till 3 pm. It is important to know how conducive and comfortable this design perform during the peak period of the dry season. And how the available passive shading device help to control and regulate environmental impact on the students living within the hostels.



(a)

(a) Kuti hostel entrance view



(b)

(b) Study sample block A



(c)

(c) north view of the sample block



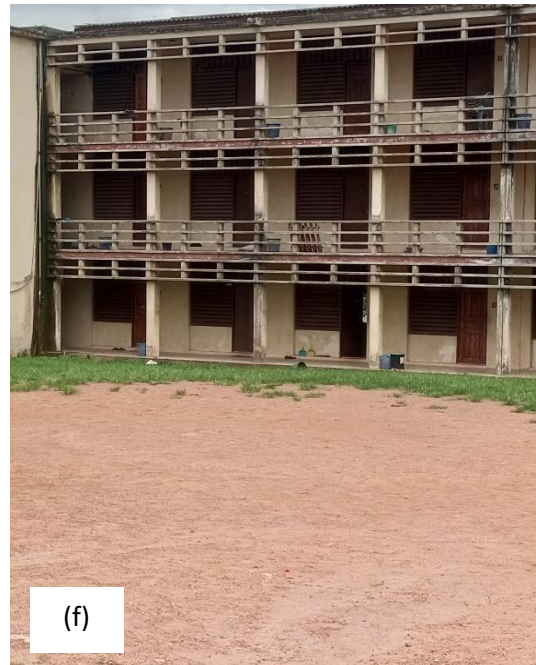
(d)

(d) south view of the sample block



(e)

(e) Study sample block E



(f)

(f) South view of the sample block E

Materials and Methodology

The research design chosen for this investigation was quantitative, as the study focuses on measuring specific environmental thermal parameters in numerical terms rather than relying on opinions.

Materials: The following equipment was employed on the field for the test: a timer, a k-type thermometer with a temperature range of -328 to 2501°F (-200 to 1372°C), fixed with a thermocouple, and used to measure the daily temperature. The digital psychrometer with a humidity range of 10 to 99% was also used to determine the relative humidity, as shown in Plates 4 and 5. Plates 6 (a) and (b) showing the biophilic elements under consideration.

Methods: The field procedure was carried out in March 2024 in the Ransom Kuti Hostel from 8 a. m. to 8 p. m. daily, towards the start of the spring period (dry season). Two rooms were selected for the experiment, one

room each from sample A and sample E. The exterior environmental design of these rooms not only exemplifies biophilic and non-biophilic environments, but they also serve as effective representations of other rooms in the sampled hostels regarding location, configuration, and size. The block A was surrounded by high-biophilic elements and the block E by less or non-biophilic elements. The k-type thermometer and the digital psychrometer were connected both on the outside and inside of the experimented rooms, where the reading took place simultaneously. The thermometer measured and recorded the amount of air temperature from the daybreak through mid-day until the twilight of the day.

A total of 26 measurements were taken repeatedly in each of the two hostels for both biophilic and non-biophilic design, which constitutes the data used for the analysis in this study.



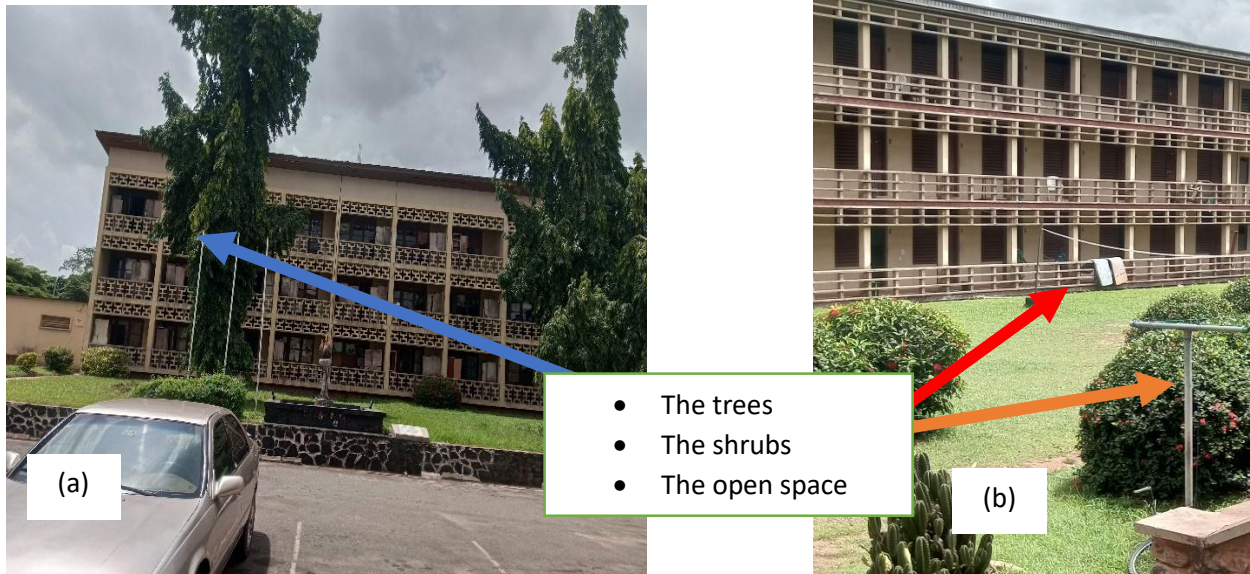
Plate 4: k-type thermometer



Plate 5: digital psychrometer

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Results and Discussion

Figures 1 and 2 shown the maximum, minimum and average indoor air temperature for high biophilic design IT-HBD and indoor relative humidity for high biophilic design IRH-HBD, meanwhile Figure 3 shows the combined average relative humidity and air temperature level in a High Biophilic Design (HBD). The result revealed that the air moisture level in HBD is relatively high, causing the air temperature level to be reduced. This is because the air velocity is higher, which helps to neutralize warm air in the room and thereby ensure a cool air inlet. The presence of biophilic elements, especially the

outdoor greenery with trees, contributed in absorbing the direct solar radiation from the sun, thereby reducing the air temperature and ultraviolet (UV) radiation and consequently releasing the water through the trans-photosynthesis (transpiration + photosynthesis) process. This in turn helps to improve air intake, reduce air pollution, and ensure conducive internal ambient air. This is in tandem with Nowak's (2016) submission that trees alter microclimate and cool air temperature through tree transpiration.

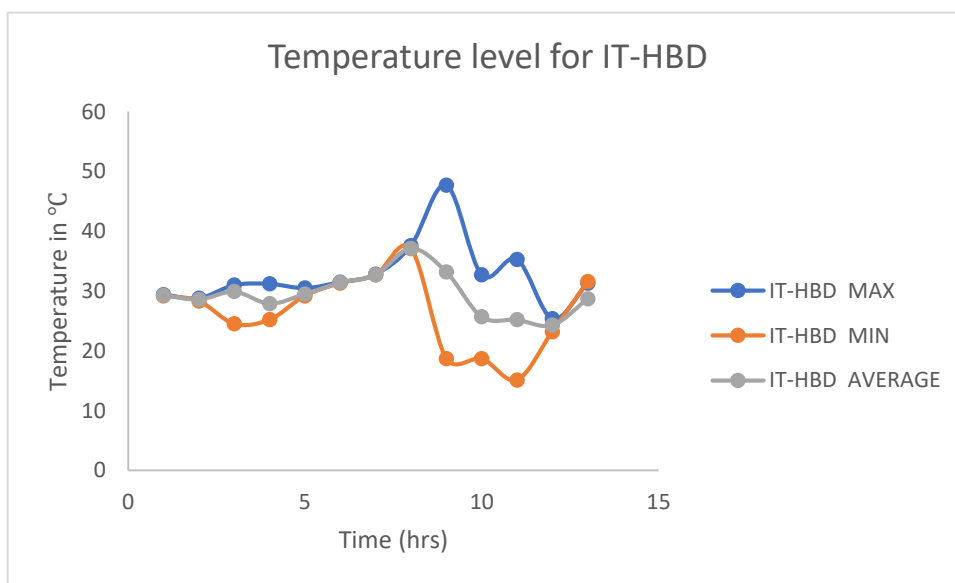


Figure 1: Showing max., min., & average air Temperature level in HBD

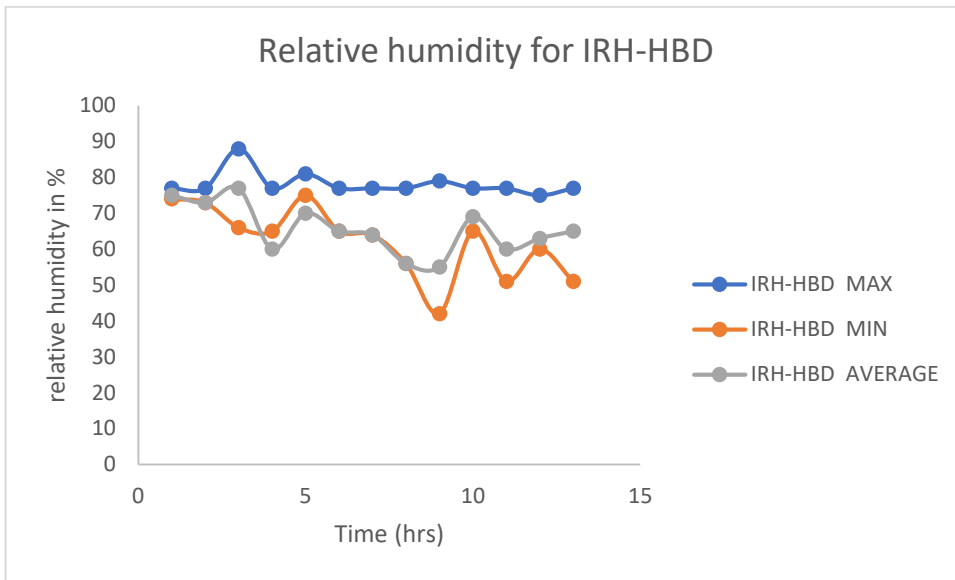


Figure 2: Showing max., min., & average Relative Humidity level in HBD

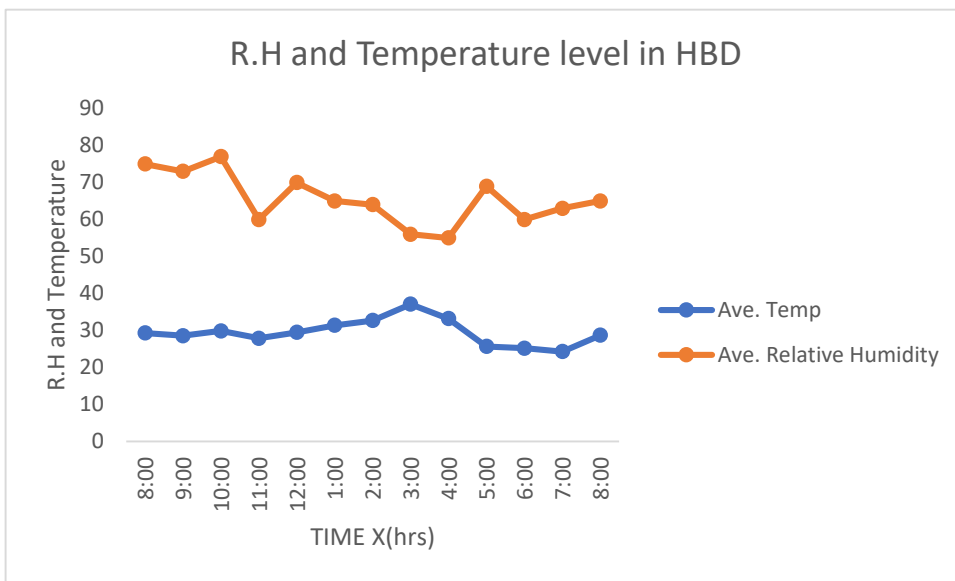


Figure 3: Showing Combination of Relative Humidity and Temperature level in HBD

Figures 4 and 5 show the maximum, minimum and average relative and air temperature level for non-biophilic design. The air moisture level in these rooms considerably low, causing the rise in air temperature. This is because the air velocity rate is low, and also due to lack or inadequacy of biophilic elements in and around the design, which affected the air moisture content level within the space. Figure 6 shows a combination of average relative humidity

and average air temperature. This result implies absence of biophilia causes the rise in air temperature during the evening because of direct exposure of the design to intense sun-ray with nothing to shade, repel, or absorb the air temperature, air pollutant, and excess ultraviolet radiation comes into the building, as in the case of a high biophilic design. This sometimes resulted in the sick building syndrome, a situation where people fall ill regularly as a result of poor designs.

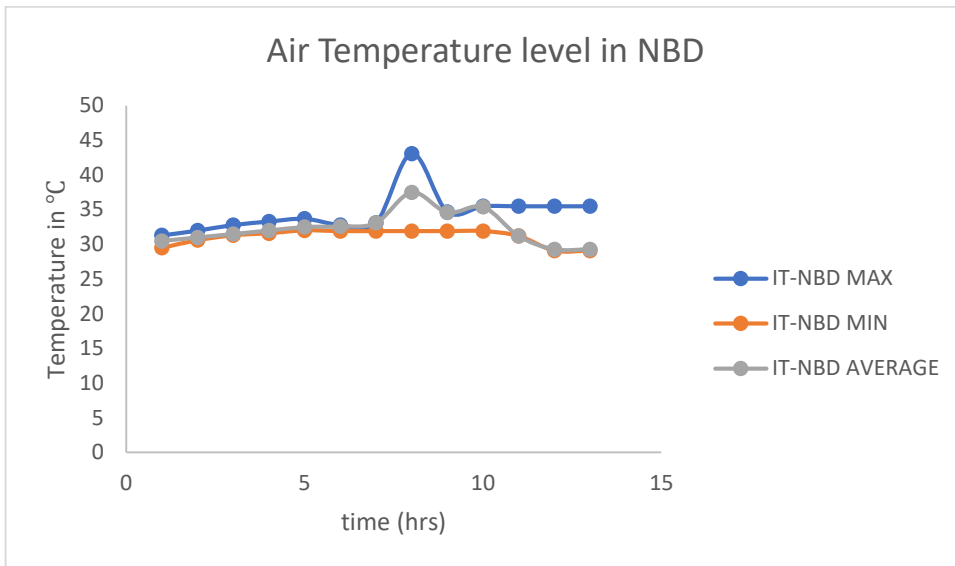


Figure 4: Showing max., min., & average air Temperature level in °C for NBD

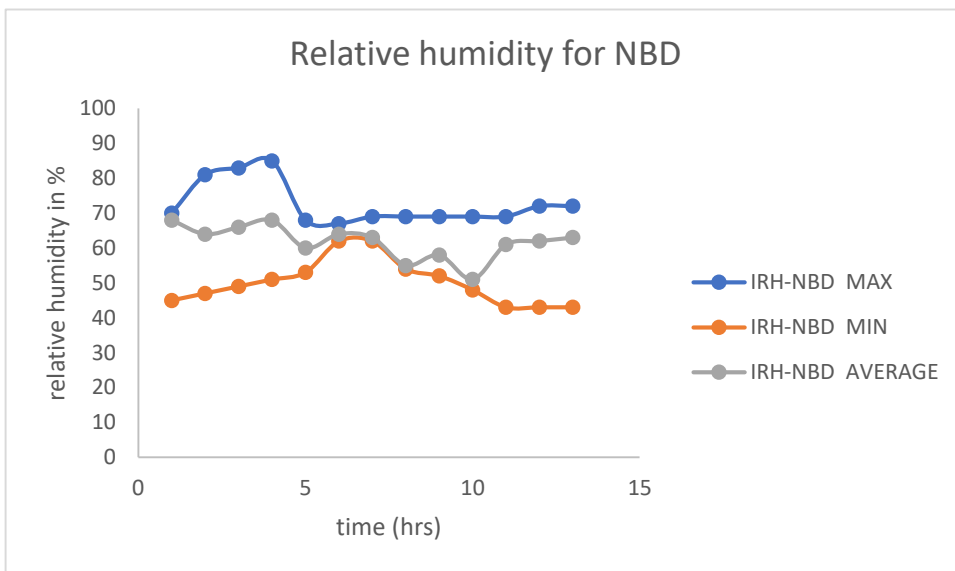


Figure 5: Showing max., min., & average relative humidity level in % for NBD

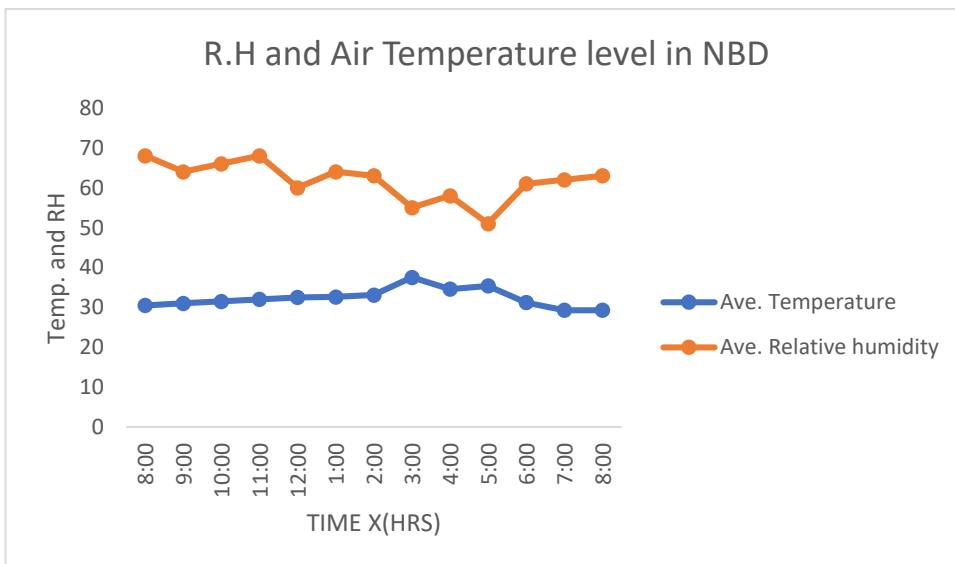


Figure 6: Showing Relative Humidity in % and Temperature level in °C for NBD

Furthermore, Figure 7 reveals the air temperature level in both high-biophilic and non-biophilic designs when the two samples were compared together. The result shows that there is a relatively cool air temperature within the HBD throughout the day when compared with the NBD. The air temperature in NBD was high all through the day,

subjecting the occupant to a certain level of discomfort. This implies that the rate of air velocity in the HBD design is high and faster due to the high air moisture saturation in this design. Unlike the NBD, where the air velocity is low and slow owing to low air moisture due to insufficient biophilic elements around the design.

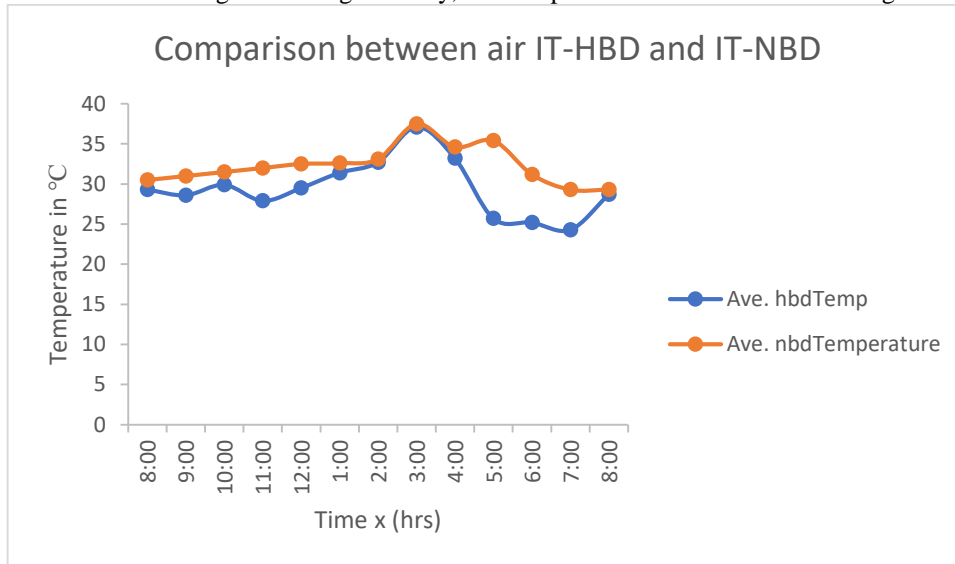


Figure 7: Showing the air temperature level between IT-HBD and IT-NBD

Figure 8 shows the comparison between the relative humidity in high-biophilic and non-biophilic designs. The RH was high in HBD between 55 and 75 from morning until night, while for NBD it was between 51 and 68. It is implied that RH is consistently high and saturated in HBD design when compared with NBD design. Although their

relative humidity ranges fall within the required standard of 30 and 60 for indoor RH, However, there is a high air moisture content in the HBD temperature, which ensures cool ambient air and a comfortable temperature internally. This is also responsible for the low air temperature throughout the day.

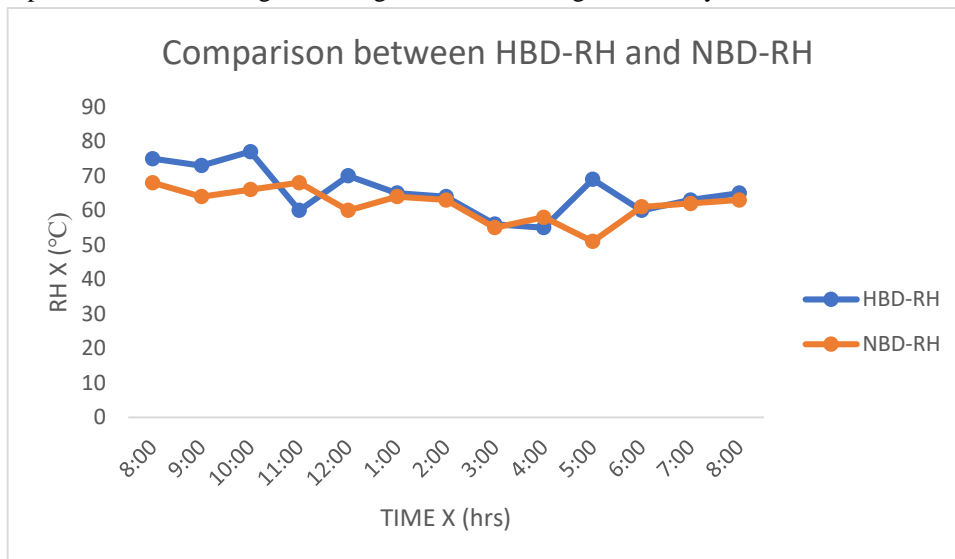


Figure 8: Showing the relative humidity level between HBD and NBD

Figures 9, 10, 11 and 12, show the exterior maximum, minimum and average air temperature and relative humidity for the sampled high-biophilic and non-biophilic designs. The finding in Figures 9 & 10 showed high level of comfort in both interior IT-HBD and exterior ET-HBD, high biophilic design. This revealed that air temperature data on this design from minimum to maximum fall within the comfort range of 22 – 29 °C for a tropical region, which ensure a conducive environmental condition with cool air moisture, induced by the presence of high biophilic and

greenery compared with interior and exterior of NBD, as represented in Figure 11 and 12. This is in tandem with Fuad 1996, T. Safikhani et al., (2014) and Eludoyin et al., (2014) that comfort temperature for tropical climates falls within 21.9 - 29°C. This trend is also similar in Figures 13 and 14, where the combination of average air temperature and relative humidity for the two samples were relatively compared together. The findings implies a consistent high RH with considerable low air temperature in HBD design when compared with NBD design.

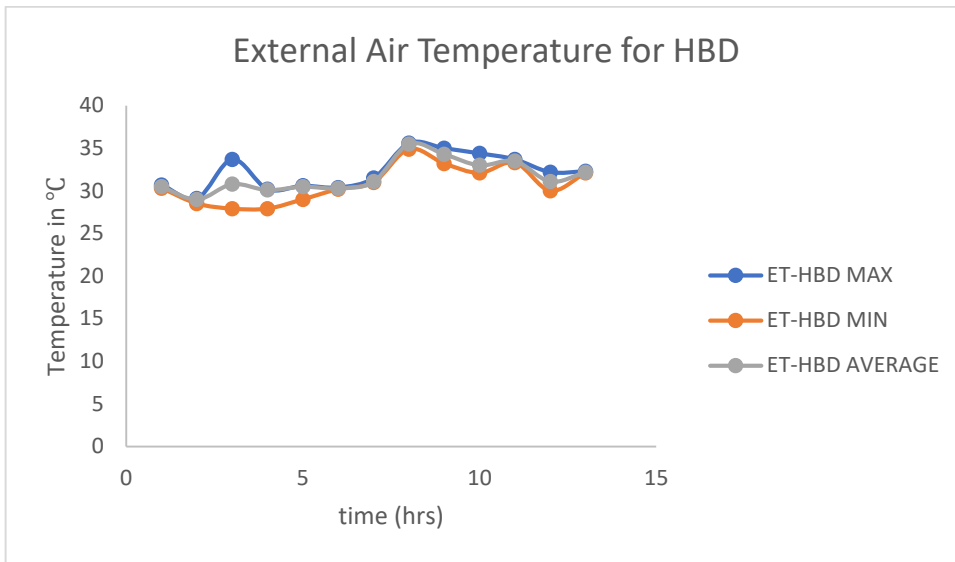


Figure 9: Showing the max., min., & average external air Temperature level in HBD

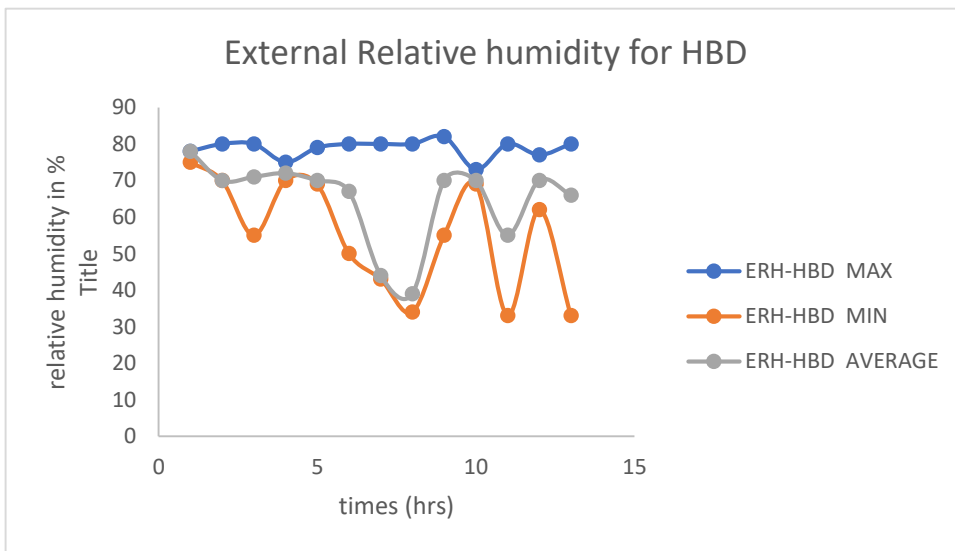


Figure 10: Showing the max., min., & average external relative humidity level in HBD

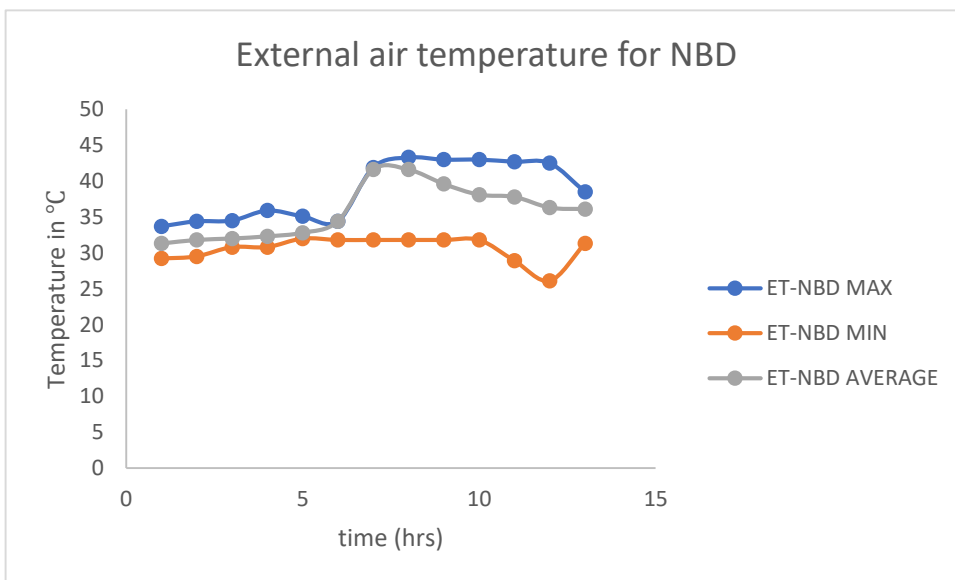


Figure 11: Showing the max., min., & average external air temperature level in NBD

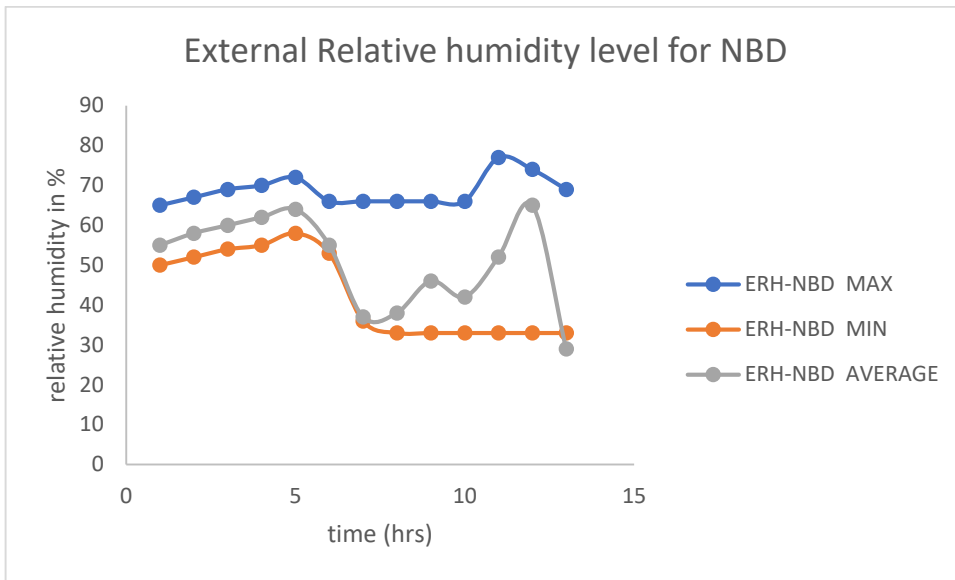


Figure 12: Showing the max., min., & average external relative humidity level in NBD

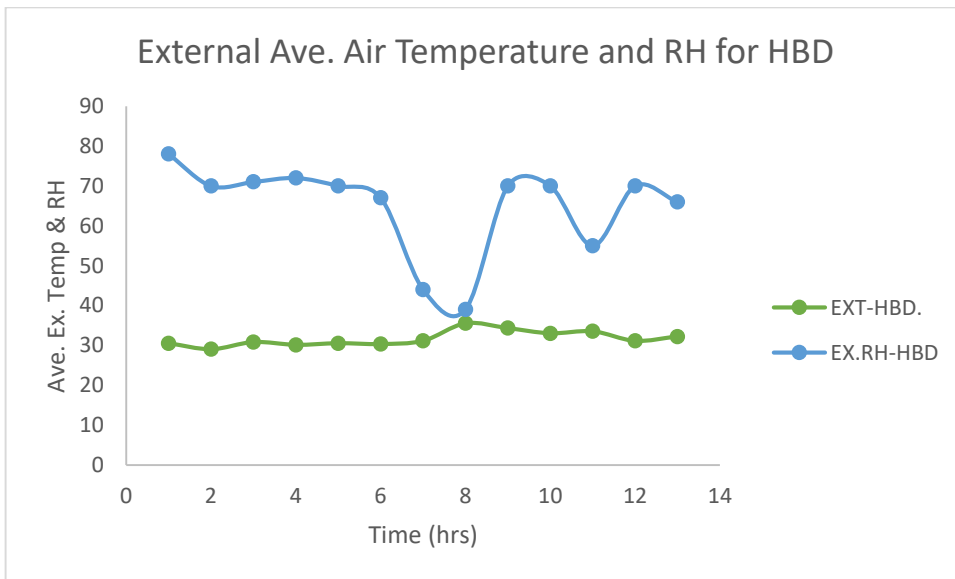


Figure 13: Showing the Ave. Temp., and relative humidity level in Ex-HBD

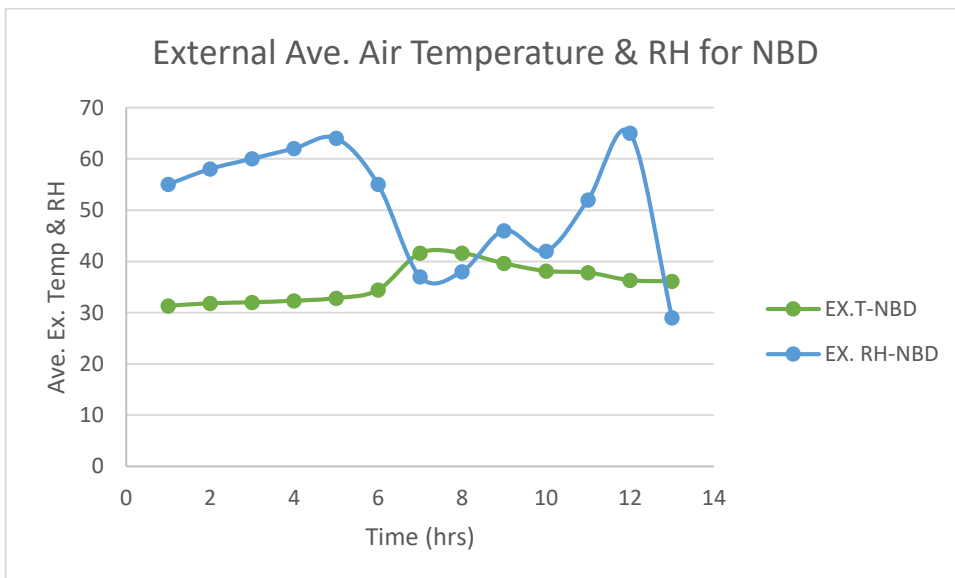


Figure 14: Showing the Ave. Temp., and relative humidity level in Ex-NBD

The Statistical analysis of HBD and NBD

Table 1 shows that the independent t-test was used to examine whether there is a difference in temperature between HBD and NBD. The result revealed a significant difference in mean ($t = -2.413$, $df = 24$, $p < 0.05$). Which implies that the mean temperature of NBD (mean = 32.35,

$SD = 2.37$), is significantly higher than the mean temperature of HBD (mean = 29.50, $SD = 3.53$). This suggests that there is no statistical basis for accepting the null hypothesis concerning the temperature differences between biophilic and non-biophilic designs.

Table 1: Statistical analysis of different between HBD and NBD Temperature

Variable	Mean	Std. Deviation	df	t	Sig
HBD	29.50	3.53	24	-2.413	0.024
NBD	32.35	2.37			

Table 2 shows that the independent t-test was used to assess whether the difference in relative humidity between HBD and NBD is significant. The result revealed that there is no significant difference between the two values ($t =$

1.59 , $df = 24$, $p > 0.05$). The mean relative humidity for HBD (mean = 65.54, $SD = 6.96$) is not significantly higher than the mean relative humidity for NBD (mean = 61.77, $SD = 4.90$).

Table 2: Statistical analysis different between HBD and NBD Relative Humidity

Variable	Mean	Std. Deviation	df	t	Sig
HBD	65.54	6.96	24	1.59	0.123
NBD	61.77	4.90			

The results indicate that there is a statistical basis for rejecting the alternative hypothesis regarding the differences in humidity between biophilic and non-

biophilic designs. Consequently, the alternative hypothesis was not accepted.

Conclusion

The paper presents a study carried out on the biophilic design integration for tropical buildings as an eco-friendly alternative for hostel building design at the University of Ibadan. The study explores a comparative analysis of biophilic and non-biophilic hostel designs in a tropical climate, specifically at the University of Ibadan. This aim is to evaluate the effectiveness of biophilic elements in aiding internal thermal comfort in hostel designs.

temperature at every period of the day. However, this was not the case with a less or non-biophilic design, resulting in an increase in air temperature and causing internal discomfort, especially at the twilight of the day.

Therefore, the incorporation of high biophilic elements in hostel design holds significant advantages over non-biophilic design. The findings established that designing residences with biophilic features can greatly enhance comfort in buildings.

The results revealed that the integration of biophilic elements has helped to reduce the amount of air temperature, air pollutants, and shading in the building from direct ultraviolet radiation. There is also an increase in the air moisture in the room due to the photo-transpiration process coming from the trees, shrubs, and other elements, leading to an increase in the rate of air velocity in the room, resulting in a cool internal

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Conflict of Interest

The author declares no conflict of interest.

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