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Assessment of Indoor Environments in University Student Accommodation: Evidence from Nigeria

Oluwafemi Kehinde Akande[1*], Ayuba Bassa John[2], Olufunmilola Adetayo Obakin[3], Adegbenga Adewale Oshineye[4], Henry Ogunjobi[5], Rohanna Sham[6], Lilian Chioma Obi-George[7]
**Corresponding Author*

[1] Department of Architecture, Faculty of Environmental Sciences, Nile University of Nigeria, Abuja, Nigeria,
[2] Department of Architecture, Faculty of Environmental Sciences, Baze University, Abuja, Nigeria,
[3] Department of Architecture, Faculty of Environmental Sciences, University of Ibadan, Ibadan, Nigeria,
[4] Arctuals Concepts Ltd, Suite D9 Innovation Plaza, Chioma Ejikeme Street, Wuye Abuja, Nigeria,
[5] 59 East Hill Wandsworth SW18 2QE United Kingdom,
[6] Strategic Research Institute, Asia Pacific University of Technology and Innovation, Jalan Innovasi 6, Technology Park Malaysia 57000, Kuala Lumpur,
[7] School of Built Environment, Massey University, Auckland Campus

oluwafemi.akande@nileuniversity.edu.ng; ayuba.john@bazeuniversity.edu.ng; morenifunmi@gmail.com; gbengaoshy@gmail.com; ogunjobih@googlemail.com: rohana.sham@apu.edu.my; L.ObiGeorge@massey.ac.nz
Tel: +234 7061014886

Abstract
Poor indoor environmental quality (IEQ) in Nigerian university accommodation can negatively impact students' health, comfort, and academic performance. IEQ was assessed in six (6) hostels using field measurements and surveys of 442 students. In male hostels, poor ventilation and indoor activity led to significantly higher levels of $PM_{2.5}$ and PM_{10} compared to WHO standards. Poor ventilation was seen in female accommodation, as shown by CO_2 trends. Poor IEQ was substantially related to reported symptoms such as respiratory issues, headaches, and frequent sickness. The study suggests that improved ventilation, maintenance, and statutory modifications can enhance student health and learning.

Keywords: Indoor Environmental Quality (IEQ); Student Accommodation; Occupant Health; University Hostels

1.0 Introduction

In university housing, where students spend long periods of time indoors, indoor environmental quality (IEQ) is a crucial issue for their health, comfort, and overall quality of life. Young people spend 85-90% of their time indoors, highlighting the importance of their living, studying, and social surroundings for their physical and psychological well-being (Afroz *et al.,* 2024; Ibrahim *et al.,* 2025). Poor indoor air quality (IAQ) can be caused by excessive amounts of $PM_{2.5}$, PM_{10}, CO_2, volatile organic compounds (VOCs), and microorganisms, especially in hostels (Obajulwa *et al.,* 2024). These symptoms might negatively impact students' quality of life and interfere with everyday activities. Recent research from Nigerian universities highlights the severity of these issues. Ibrahim *et al.* (2025) found that $PM_{2.5}$ and PM_{10} levels exceeded allowable criteria in hostels at southern universities, leading to respiratory problems and discomfort. Obajuluwa *et al.* (2024) found that high concentrations of microorganisms (Staphylococcus and Streptococcus species) in hostels and restaurants enhance the risk of infectious diseases in congested environments. Infrastructural deficiencies at Nigerian tertiary institutions, including poor ventilation, maintenance culture, and overcrowding, exacerbate these exposures (Ogunnaike *et al.,* 2025). While these studies provide useful evidence of indoor environmental health risks in Nigerian university hostels, they primarily focus on individual IEQ parameters or health outcomes, with little integration of architectural design variables and objective environmental measurements into a unified analytical framework.

Several studies (Akande *et al.,* 2018a; Akande *et al*, 2018b; Akande, 2021; Bawa *et al.,* 2022; Farinuola and Akande, 2023; Akande et al., 2023a; Akande *et al.,* 2023b; Akande *et al.,* 2023c; John *et al.,* 2024; Akande *et al.,* 2025) have indicated that architectural design significantly impacts IEQ. Student hostels can either promote health or worsen environmental stress, depending on factors such as space arrangement, ventilation, building materials, daylight exposure, and maintenance (Kumar *et al.,* 2025; Yang *et al.,* 2025; Fu *et al.,* 2025). Nduka *et al.* (2021) found that many Nigerian hall of residences, particularly those with traditional on-campus designs, have poor cross-ventilation, insufficient daylighting, and almost no microbiological or thermal balance in their materials.This study expands on previous research by integrating quantitative measures of $PM_{2.5}$, PM_{10}, CO_2, temperature, and humidity with an architectural analysis of student hostel design and spatial factors. Unlike previous studies, which mostly focus on environmental exceedances or health symptoms, this study directly links measured IEQ conditions to architectural design, ventilation arrangement, and spatial density in Nigerian university hostels. Furthermore, the study adds to global discussions on healthy and climate-responsive student housing by generating context-specific evidence from Nigeria and translating empirical IEQ findings into actionable architectural and policy recommendations, responding to calls for health-centered and climate-friendly design in educational environments (Fu *et al.,* 2025).

This study aims to evaluate environmental conditions in Nigerian university halls of residence, considering how IEQ impacts health, learning, and social experiences. Its objectives are to (i) identify environmental and behavioural factors that determine IEQs. (ii) Determine indoor environmental conditions; (iii) Establish links between IEQ and health, and quality of life for students; and (iv) Develop evidence-based architectural-organization treatments. The study combined objective environmental measurements ($PM_{2.5}$, PM_{10}, CO_2, temperature, humidity) with student evaluations of health, comfort, sleep quality, mental well-being, and quality of life.

2.0 Literature Review

IEQ is crucial for students who spend extended periods of time indoors for sleeping, studying, and house-sharing purposes. However, many university hostels in developing nations, such as Nigeria, have poor indoor environmental quality. Overcrowding, limited hostel capacity, and inadequate maintenance all contribute to environmental health issues, affecting not just physical health but also mental health, academic performance, and social life. Overpopulation contributes to poor IEQ in student hostels. Research by Bhyan *et al.* (2025) suggests that its use has a negative influence on both physical and psychological well-being. Overuse of a facility can lead to health issues such as higher emissions, decreased ventilation efficiency, noise levels, poor sleep quality, and psychological stress from a lack of privacy. These problems can lead to pain, sickness, vulnerability, and unhappiness. Recent studies (Benabed *et al.,* 2022) indicate that occupant activities such as cooking, mobility, cleaning, and window opening have a significant impact on pollutant emissions. More importantly, there is the presence of fine particulate particles ($PM_{2.5}$ and PM_{10}), especially in poorly ventilated environments. In communal student hall of residence with shared rooms, kitchens, and washrooms, these activities increase exposure and worsen chronic IAQ issues. However, a major limitation of existing studies is that they treat overcrowding as a uniform risk factor without considering variations in spatial layout, ventilation configuration, and building typology, which can significantly moderate its impact on IEQ outcomes (Frontczak *et al.,* 2012; Pourtangestani *et al.,* 2024).

Some studies conducted in temperate climates report that high occupancy does not always result in severe IAQ degradation when effective natural or hybrid ventilation strategies are used (Mabdeh *et al.,* 2020), implying that overcrowding alone may not be sufficient to explain poor IEQ in the absence of architectural and climatic context. This indicates a contradiction in the literature regarding whether occupancy density or building design plays the dominant role in determining IEQ performance. In communal student halls of residence with shared rooms, kitchens, and washrooms, occupant activities significantly increase exposure risks and intensify chronic IAQ problems. However, most studies focus on short-term pollutant concentrations during peak activity and fail to capture diurnal or seasonal fluctuation, especially in tropical areas where temperature and humidity greatly influence ventilation behaviour (Nibagwire *et al.,* 2025).

This methodological gap limits the applicability of findings to Nigerian hostels, which experience prolonged heat stress and variable airflow conditions. In Nigeria, there is limited research on student accommodation, the levels of pollutants, and their health effects. Most studies (Idiang *et al.,* 2022; Akoh, 2023; Ibiyeye, 2024) relied on subjective observations of overcrowding, discomfort, or poor air quality, with no simultaneous measurement of particle concentration, ventilation rates, or thermal functioning. Hence, the lack of quantitative data hinders the understanding of IEQ-related dangers in Nigerian student accommodation.This dependence on self-reported impressions contradicts previous research, as studies from other regions have found poor or inconsistent connections between perceived IAQ and objectively measured pollutant levels (Tran *et al.,* 2020; Orola *et al.,* 2020). While perception-based studies are useful for assessing occupant satisfaction, they may underestimate or exaggerate health risks when not backed by physical data, restricting evidence-based decision-making.

Recent research suggests IEQ affects mental health, cognitive function, sleep, and academic achievement. High indoor CO_2, inadequate ventilation, temperature extremes, lack of illumination, and noise might hinder attention, impair cognitive processing speed, create fatigue, and interfere with sleep, affecting scholastic accomplishments and memory recall. While these interactions have been reported in many nations, they are not commonly examined in Nigerian hostels. Hence, there is less research on how local stressors affect students' mental health, sleep, social life, academic motivation, and long-term well-being. This results in a geographical and contextual contradiction in the literature, as findings from controlled laboratory settings or mechanically ventilated buildings in developed countries are frequently applied to naturally ventilated, high-density hostels in tropical regions without empirical validation (Mewomo *et al.,* 2023). Such broad generalisations ignore the distinct combination of climate, building design, and adaptive occupant behaviour found in Nigerian situations.

Effective building design and upkeep are crucial for improving IEQ. The internal atmosphere and occupants' comfort are influenced by architectural features such as orientation, spatial configuration, natural or mechanical ventilation, wall and roofing materials, daylight availability, temperature regulation, and maintenance practices. Traditional hostels often lack proper ventilation, daylighting, and humidity control, leading to moisture, mould contamination, thermal imbalance, and sour air. Several authors (Fu *et al.,* 2025; Kumar *et al.,* 2025) suggest that design strategies such as cross-ventilation, non-toxic material selection, improved spatial configuration, daylight provision, and proactive maintenance are crucial for improving IEQ and resident well-being. However, much of this work is prescriptive rather than empirical, providing design advice without confirming their performance through post-occupancy IEQ measures, especially in sub-Saharan African contexts (Shehata *et al.,* 2025). The divergence between design theory and measurable performance is a crucial gap in architectural and environmental health research. Hence, there is a scarcity of evidence-based architectural design options for Nigerian student housing. Thus, based on the above reviewed literature, this study identified four significant gaps: (i) Few research links objective IEQ data with student views and health. (ii) Research in Nigeria primarily overlooks the impact of IEQ on mental health, sleep, and academic achievement, in contrast to global data. (iii) Hostel design, setting, building materials, and maintenance are rarely evaluated alongside IEQ results. (iv) Little is known about the impact of overcrowding, student behaviour, and insufficient ventilation on pollution levels.

2.1 Theoretical Framework

Students' Quality of Life (QoL) at the university hall of residence is heavily influenced by the fit between their demands and the indoor environmental circumstances they encounter. This study uses four frameworks to describe how IEQ influences student well-being. First, the IEQ framework highlights measurable environmental attributes such as thermal comfort, air quality, lighting, acoustics, and hygiene. These have a significant impact on health, cognitive functioning, and comfort (Afroz *et al.,* 2023). Second, the Person-Environment Fit (P-E Fit) theory provides a behavioural and psychological perspective, arguing that well-being is determined by how effectively environmental resources fit individual needs. This approach explains why students with similar IEQ exposures may report varied satisfaction or adaptation behaviours in hostel environments, such as increased fan use or avoiding studying in their rooms (Zhang *et al.,* 2025). Third, the WHOQOL model underpins the Quality of Life (QoL) construct, which prioritises physical health, psychological status, social interactions, and environmental support. The WHOQOL-BREF instrument is still widely used in educational and public health research since it measures multidimensional well-being in addition to comfort and satisfaction (Omarov *et al.,* 2024). Post-occupancy evaluation (POE) with socio-environmental and biophilic mediators assesses objective indicators (temperature, CO_2, lighting, noise) as well as subjective perceptions (control, comfort, access to restorative elements like ventilation and green views) (Bortolini & Forcada, 2021). Hence, this study addresses critical gaps identified in recent literature by integrating objective IEQ measurements ($PM_{2.5}$, PM_{10}, CO_2, temperature, humidity), student surveys on health, mental well-being, sleep, and academic impacts, behavioural observations, and architectural assessment. The results provide actionable evidence for healthier, student-centered campus housing.

3.0 Research Methodology

This study uses a mixed-methods approach, combining objective IEQ measurements with subjective occupant-reported QoL data, to address the complex nature of student health and well-being. Recent IEQ research suggests using mixed methods to triangulate environmental exposure, user perception, and health symptoms/behavioral patterns (Afroz *et al.,* 2023; Ibrahim *et al.,* 2025). The use of structured questionnaires and architectural observations to quantify PM2.5, PM_{10}, CO_2, temperature, and humidity, and VOCs aligns with recent proposals for an integrated environmental and psychological assessment strategy (Semasinghe *et al.,* 2025; Bajc & Kerčov, 2025). The research was conducted at the Federal University of Technology (FUT) Gidan Kwano campus, Minna, Nigeria. The region is described as a naturally ventilated tropical setting with identified IEQ concerns due to high room occupancy, low ventilation rate, and ageing infrastructure. Gidan Kwano's hostel, which houses a large number of students, was chosen as a suitable environment to assess actual exposure to IEQ. The sampling frame includes all 1930 hostel occupants registered during the 2024/2025 academic year. Stratified random sampling was used, stratifying by hostel block, gender, and floor level. The study employed Cochran's algorithm to pick 442 students (22.9%) from each stratum, which is consistent with previous IEQ and student-health research by Cheung *et al.* (2025). The sample size is sufficient to discover relationships between IEQ parameters and QoL.

3.1 Research Instrumentation, Environmental Monitoring and Analysis

A structured questionnaire was constructed based on international IEQ and QoL research protocols (Ibrahim *et al.,* 2025). It had three primary parts: (i) Socio-demographic information: age, gender, level of education, length of stay in halls, room size, and number occupied. (ii) Health and QoL outcomes linked to IEQ: (a) Physical symptoms, such as headaches, 'respiratory irritation', and tiredness. (b) Psychological indicators, including stress, mood, and focus, have been linked to $PM_{2.5}$ and CO_2 levels (Higgins *et al.,* 2024). (c) An indicator of sleep and academic performance. The study indicated that both temperature discomfort and CO_2 levels have an impact on concentration and learning, with the intervention positively impacting both. (d) Measures of social well-being, such as privacy and sense of community, align with current research on IEQ and social comfort (Karimi *et al.,* 2023). (e) Behavioural and architectural factors, such as window-fan/AC use, cooking frequency, cleaning practices, perceived ventilation, and satisfaction with room design, were also considered. For quantitative analysis, responses were provided on a 5-point Likert scale. Airnode Smart IAQ Monitors were used for short-term measurements of temperature, relative humidity, and PM adsorption ($PM_{2.5}$, PM_{10}, CO_2, and VOCs). These values are consistent with international IEQ benchmarks for university accommodations (Ibrahim *et al.,* 2025).

Environmental monitoring was carried out during many short-term sample intervals spanning daylight and evening hours over several days, allowing for the capture of peak occupancy circumstances, nightly ventilation reduction, and diurnal fluctuations in temperature and pollutant levels. The sampling length was chosen to reflect realistic exposure conditions for students, especially during sleeping and study periods when windows are often closed and CO_2 accumulation is significant. Focusing on the dry season increases exposure significance because it is associated with increased dust ingress, higher temperatures, and lower natural ventilation effectiveness in northern Nigeria. Sensors were deployed in six hostel blocks throughout the dry season, characterised by dust and high temperatures. Sensors were installed at breathing level (1.1-1.5 m), in a window-free location, and away from any potential obstacles that could cause measurement bias. Statistical analysis was conducted on (i) IEQ sensor data, comparisons with WHO and ASHRAE criteria, and time-series to capture overnight thermal variations and pollution occurrences. (ii) Survey data: descriptive statistics, chi-square between IEQ and QoL outcomes, Spearman correlations between IEQ perceptions and academic performance and mental health, and regression models predicting QoL from environmental variables, all in line with recent African and global IEQ studies (Ibrahim *et al.,* 2025). (iii) Building: On-site inspection includes architectural observations such as cross-ventilation, window area-to-floor size ratio, building orientation, materials used, occupant count, and maintenance condition. To account for potential confounding factors, regression models included key covariates such as socioeconomic status proxies (e.g., year of study, scholarship/employment status, room occupancy density), pre-existing health conditions (self-reported respiratory or allergic symptoms), and ventilation-related behaviours such as window opening frequency, fan/AC use, and length of room occupancy. These changes improve estimates of the independent impacts of IEQ parameters ($PM_{2.5}$, PM_{10}, CO_2, temperature, and humidity) on health, sleep, and academic results. By accounting for behavioural, demographic, and architectural confounders, the analytical framework eliminates bias and enhances causal inference in accordance with best practices in IEQ and environmental health research.

4.0 Findings

This study's occupant questionnaire scales had reliable internal consistency (Cronbach's Alpha ≥ 0.70), indicating that students' reports on environment, health, comfort, and habits were reliable. The demographic statistics indicate high levels of congestion in hostels. Over 80% of students sleep in hall of residence with up to 12 people, exceeding the stated limit of 5-6 per room. The average student stays at the Hall for 4-9 months, indicating prolonged exposure to unhealthy indoor settings. Crowding can lead to poor ventilation, high CO_2 levels, dust emissions, discomfort, and noise. These situations can lead to stress, poor sleep, decreased attention span, and increased transmission of infectious diseases, all of which have a severe influence on academic performance and quality of life. Instrument-based observation in Rooms A-C (Table 1) has shown that contaminants frequently exceed acceptable levels.

Table 1. Hourly average pollutant concentrations (Rooms A, B, C; 6pm–6am monitoring)

Parameter (12-hr mean)	Room A (mean)	Room B (mean)	Room C (mean)
PM2.5 (µg/m³)	68.47	72.23	50.94
PM10 (µg/m³)	97.56	99.36	67.11
CO_2 (ppm)	676.68	757.65	827.33
Temperature (°C)	28.12	27.78	28.59
RH (%)	21.11	27.39	27.35
AQI (US) — mean	134.94	158.96	130.31

Note: Summary 12-hour averages (6pm–6am) for the three monitored rooms. Rooms B and C show higher CO_2 and PM levels, associated with indoor cooking and higher occupant activity.

CO_2 levels were within a reasonable range in Room A, but exceeded 1000 ppm in Rooms B and C, especially during cooking, indicating inadequate ventilation and excessive occupancy. Particulate matter ($PM_{2.5}$ and PM_{10}) levels increased significantly in rooms B and C during cooking, with some observations reaching 100 µg/m³. These quantities have been linked to ocular and respiratory irritation, asthma aggravation, headache, and cognitive tiredness. Late-night PM_{10} increases were detected in room A, indicating the presence of outside dust. Temperatures reached 30°C, while relative humidity ranged from 20% to 44% in male hostels and up to 71% in female hostels (Table 2), contributing to environmental stress. High heat can disrupt sleep and concentration, while low humidity might dry out and make one more prone to disease. Elevated humidity in rooms, such as Female Room E, can lead to mould formation, posing health risks. AQI scores above 100 in all tracked rooms are considered "Unhealthy for Sensitive Groups," indicating potential respiratory, immunological, and cognitive impairment. These findings support data linking PM exposure to long-term cardiovascular and respiratory risks.

Table 2. Female hostel rooms D – G (summary)

Parameter (12-hr mean)	Room D	Room E	Room F	Room G
PM2.5 (µg/m³)	32.28	43.98	37.12	43.96
PM10 (µg/m³)	37.49	53.03	44.88	53.55
CO_2 (ppm)	973.30	1063.79	1035.05	948.83
Temp (°C)	26.80	27.83	28.22	27.93
RH (%)	54.95	47.84	47.46	51.11
AQI (US) — mean	93.90	115.76	102.49	117.88

Note: Female hostel rooms show higher mean CO_2 (near/above 1000 ppm) and AQI values—Room E & G present the highest AQI and CO_2, indicating both poor ventilation and higher particulate/microbial risks in parts of the female hostels.

Behavioural study highlights typical activities that negatively affect IEQ. Approximately 35 - 45% of students cook indoors in their rooms or corridors, with 61-86% using kerosene burners (Table 3). These activities are significant emitters of CO_2 and particulates. Other practices, such as keeping windows open in dusty circumstances and using blinds, might allow external pollutants to enter. Behavioural patterns can be influenced by architectural constraints such as cooking location, room size, and lack of numbered compartments. Health data support the environmental consequences.

Table 3. Occupant behaviours (selected items)

Behaviour / variable	Male (%)	Female (%)
Use kerosene for cooking	61.4	85.5
Cook inside room	44.6	35.5
Cook along corridor	32.5	41.9
Use electric cooker	36.1	12.9
Smoke indoors (yes)	7.2	3.2

Note: High reliance on kerosene and indoor/corridor cooking practices are major pollutant sources (PM and CO_2); these behaviours interact with architectural features to elevate pollutant exposure.

Students reported high rates of malaria, influenza, chicken pox, asthma, and pneumonia (Table 4). Respiratory and viral disorders are linked to high PM and CO_2 concentrations, as well as overcrowding and extended close-contact exposure. These circumstances negatively impact academic performance, emotional well-being, and quality of life.

Table 4: Reported illnesses (ranked by weighted mean)

Condition	Weighted Mean	Rank
Malaria	3.50	1
Influenza	2.10	2
Chicken pox	2.06	3
Asthma	2.05	4
Pneumonia	2.03	5
Measles	1.95	6
Tuberculosis	1.92	7
Meningitis	1.92	7

Note: Self-reported illnesses suggest both vector-borne diseases (malaria) and respiratory/infectious illnesses (influenza, pneumonia, asthma) are prevalent — respiratory conditions plausibly linked to IEQ exposures.

Overall, the hostels' indoor living conditions fall below basic standards. Overcrowding, inadequate ventilation, poor behaviour, and architectural flaws all lead to sick students who are less comfortable and academically effective. To preserve student health, modifications in design, lower occupancy loads, and proper cooking and ventilation equipment are necessary.

5.0 Discussion

The monitored IEQ conditions in student hostels consistently meet comfort and health standards. Monitored rooms with a mean AQI of >100, CO_2 levels between 800 and 1100 ppm, and $PM_{2.5}$ spikes over 100 µg/m³ at cooking times suggest conditions that are "unhealthy for sensitive groups" and unhealthy closer to a/c peak (especially in Rooms B and E). This finding aligns with recent Nigerian university studies by Ode *et al.* (2023) and Abdulmalik *et al.* (2023), who identified similar levels of PM and CO2 overexposure in hall of residence, attributed to crowds and combustion-based cooking. Over 80% of the rooms have 5 to 12 students, exceeding the planned capacity. This causes high levels of CO_2, temperature discomfort, and increased microbial burdens. Sensors show that high use of kerosene stoves, indoor/corridor cooking, and incorrect window operation correlate with pollution peaking in the evening. Recent sensor-based campus IEQ surveys in Africa and Asia (Yu *et al.,* 2024; Igiebor *et al.,* 2025) have found a correlation between design and behaviour, including small room sizes, poor cross-ventilation, open cooking facilities, and other behavioural issues. Students' self-reported discomforts and illnesses correlate with measured IEQ decline. High levels of CO_2, PM exposure, and heat strain can cause headaches, respiratory problems, poor sleep, and difficulty concentrating.CO_2 levels decreased cognitive speed, accuracy, and sustained attention in visual primary assessments (Sharma *et al.,* 2025; Khalil *et al.,* 2024) in control education settings. Bennett (2025) and Grasso-Cladera *et al.* (2025) found that exposure to levels above 1000 ppm alters brain oscillations related to alertness and cognitive processing, resulting in drowsiness and study fatigue in students. The conclusions are supported by three theoretical lenses. According to PE Fit, the mismatch between students' environmental needs (silent, ventilated space) and their hostel environment can negatively impact study and sleep, resulting in a lower quality of life (QoL). According to the Environmental Stress Theory, students' persistent exposure to temperature extremes, air pollution, and crowding during school activities can cause physiological and psychological stress, resulting in headaches and sleep difficulties. The SBS paradigm aligns with non-specific symptoms (e.g., annoyance, fatigue, malaise) linked to prolonged indoor exposure and poor indoor air quality, as measured quantitatively and reported by students.

6.0 The Implications of the study for Quality of Life (QoL)

The implications of the findings from this study are multifaceted. The Physical: High levels of PM and CO_2 can aggravate asthma, lead to more respiratory infections, and cause exhaustion. Cognitively, sleep impairment and lower emotional well-being are both associated with cognitive performance decrements, heat stress (30°C over ambient), and high CO_2 concentrations. Academically, exposure between 6pm and 6am during peak study or sleep times might negatively impact focus, memory consolidation, and exam preparation. Crowding in a social setting can lead to less privacy, interpersonal disputes, and the use of in-room cooking methods that increase exposure to pollutants. Some architectural and operational improvements are urgently needed. Recent studies (Li, 2023; Afroz *et al.,* 2023) suggest that interventions such as ventilation-first retrofits, shared ventilated cooking spaces, occupancy management, and IEQ-aware maintenance can significantly reduce pollutants when combined with behavioural modifications. These expenditures can improve the design of student housing, leading to safer and healthier conditions.

7.0 Conclusion & Recommendations

The study evaluates environmental conditions in Nigerian university halls of residence and found that the IEQ in the analysed hostels does not reach acceptable standards, with peaks of particulate matter during cooking.CO_2 levels are over tolerable limits, and constantly result in heat stress. Overcrowding and cooking in the room are the primary culprits. It concludes that environmental stressors can negatively impact physical health, sleep, mental well-being, cognitive performance, and social satisfaction, highlighting the need for inclusive institutional interventions. Recommendations are based on improving the IEQ in the student hall of residence. This requires coordinated architectural, operational, and behavioural interventions. Hostels should prioritise cross-ventilation by repairing or expanding window apertures, removing airflow blockages, constructing vents, and installing energy-efficient fans or mechanical ventilation systems. These would minimise CO_2 levels, heat stress, and humidity-related discomfort. To improve lighting quality, room designs should be changed to maximise natural light and provide adequate artificial illumination. Using newer, properly operating luminaires can improve visual comfort and reduce eye strain. Third, noise reduction measures in overcrowded buildings, such as putting sound-insulating materials around walls and doors, should be implemented. Fourth, improving air quality requires addressing both polluting sources and the surrounding environment. Overcrowding reduces CO_2 and airborne contaminants, while routine maintenance will prevent mould formation. Finally, strategic infrastructure investment is needed to restore ageing hostel blocks, monitor IEQ-centered design standards, and implement sustainable building systems suitable for a tropical climate.

8.0 Paper Contribution to Related Field of Study, Limitations and Future Research

This study adds to existing knowledge about student housing and environmental health. It provides detailed monitoring of key IEQ factors such as PM_2, PM_{10}, CO_2, temperature, and humidity within specific hostels. The study links environmental measurements to people's physical, emotional, and educational well-being, highlighting the importance of buildings, customs, and upkeep in determining quality of life. The mixed-methods technique combines sensor readings, questionnaires, and architectural inspection for contemporaneous triangulation, aligning with best practices in contemporary IEQ literature. One of the key features is the concentration on nighttime (6 pm-6 am), which is crucial for study and sleep. However, there are several limitations to consider. The study's scope is limited, as it only covers one university hostel and may not include other Nigerian campuses. Survey self-reporting may rely on recall or transient circumstances. Environmental monitoring was limited to a 12-hour window per room, making it difficult to detect long-term trends or seasonal change. Sensor-based studies advocate longer durations for better characterisation. Microbiological sampling was not conducted, but similar Nigerian research highlights the microbiological hazard of overcrowding in poorly ventilated halls of residence. The cross-sectional design may not account for dynamic factors like weather or semester patterns, as the results only cover a single time point. Future studies should include long-term, multi-seasonal monitoring of sensors, cross-regional comparisons, and further examination into mental health conduits via which climate change's impact on IEQ may have an effect. Post-occupancy assessments of retrofitted buildings to prevent informal settlements from being trapped in low-quality housing are recommended. Cost-benefit analyses of increasing indoor air quality in relation to changes that could be made to improve thermal comfort and overall indoor environmental quality should be prioritised in future research plans. These recommendations can promote healthier student living environments nationwide.

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