Malaria Transmission Hotspots in Off-Campus University Lodges: The Role of Micro-Environmental Conditions in Southeastern Nigeria

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ABSTRACT

Background: Malaria remains a major public health challenge in sub-Saharan Africa, with environmental conditions strongly influencing mosquito breeding and disease transmission. University communities represent understudied high-risk settings due to dense populations and often suboptimal residential environments.

Objective: This study assessed how key environmental factors—including ambient temperature, relative humidity, and poor sanitary conditions such as stagnant surface water and clogged drainage—contribute to malaria transmission among university students in Okofia community, Anambra State, Nigeria.

Methods: A cross-sectional descriptive and observational study was conducted among 200 students residing in 20 randomly selected private lodges. Environmental parameters, including ambient temperature, relative humidity, and the presence of stagnant water (including clogged drainage and uncovered water receptacles around student accommodations) were assessed through direct observation and measurement over seven consecutive days. Malaria occurrence data were obtained from structured questionnaires and university clinic records over a two-month period. Descriptive statistics were used to summarize socio-demographic variables, environmental parameters, and malaria occurrence.

Results: The mean ambient temperature across lodges was 28.1°C, while mean relative humidity was 84.3%, both within optimal ranges for *Anopheles* mosquito survival and *Plasmodium* parasite development. Stagnant water, including surface water, clogged drainage, and uncovered water receptacles around students' dwellings, was widely present. A total of 229 malaria cases were recorded within the two-month period.

Conclusion: Malaria transmission among university students in Okofia community is associated with favorable environmental conditions and poor environmental sanitation management. Factors such as stagnant surface water, clogged drainage, and uncovered water receptacles facilitate prolific mosquito breeding. Integrating environmental sanitation and larval source management into malaria control strategies is essential for reducing malaria burden in university residential settings.

Keywords: Malaria transmission; environmental factors; *Anopheles* mosquitoes; university students.

INTRODUCTION

Malaria is a life-threatening parasitic disease caused by protozoa of the genus *Plasmodium* and transmitted to humans through the bites of infected female *Anopheles* mosquitoes. Despite sustained global control efforts over the past decades, malaria remains a major public health challenge, particularly in sub-Saharan Africa, which accounts for more than 90% of global malaria cases and deaths (Oladipo et al., 2022; Ekhator et al., 2025; WHO, 2020). In 2022 alone, the global malaria burden was estimated at over 249 million cases, with Nigeria contributing a substantial proportion of this burden due to persistent transmission and structural vulnerabilities within the health and environmental systems (Onah et al., 2024; WHO, 2023).

The persistence of malaria transmission is strongly influenced by environmental and climatic conditions that regulate mosquito breeding, survival, and parasite development. Temperature is a critical determinant of malaria transmission, as it affects mosquito development rates, feeding behavior, and the duration of the sporogonic cycle (the developmental phase of parasites within the vector) of *Plasmodium*. Experimental and modeling studies have consistently shown that malaria transmission is optimized within temperature ranges of approximately 25–30°C, where both mosquito survival and parasite development are maximized (Paaijmans et al., 2019; Mordecai et al., 2020). Temperatures below or above this range can slow parasite development or reduce mosquito longevity, thereby limiting transmission potential.

Relative humidity is another key environmental factor influencing malaria transmission. High humidity enhances mosquito survival by reducing desiccation, thereby prolonging the lifespan of adult mosquitoes and increasing the likelihood that they survive long enough to transmit *Plasmodium* parasites. Sustained humidity levels above 60% have been associated with increased vector survival and higher malaria transmission intensity, particularly in tropical and subtropical regions (Smith et al., 2019; Paaijmans et al., 2021). Variations in humidity, often driven by rainfall patterns, can therefore significantly alter malaria risk at local and community levels.

Rainfall and the availability of water-holding structures play a central role in creating and maintaining mosquito breeding habitats. Natural and artificial water bodies, including puddles, drainage channels, and domestic water storage containers, provide suitable environments for mosquito oviposition (egg-laying) and larval development. In urban and peri-urban settings, poorly managed water receptacles such as buckets, barrels, and jerrycans have been increasingly recognized as important contributors to malaria transmission, especially where water supply is unreliable and households depend on water storage (Becker et al., 2019; Mordecai et al., 2019). These artificial breeding sites often occur in close proximity to human dwellings, increasing human-vector contact.

Changes in land use and urbanization further modify malaria transmission dynamics by altering vector habitats and human exposure patterns. Rapid urban expansion, inadequate drainage infrastructure, and poor environmental sanitation can create micro-environments that favor mosquito breeding, even within densely populated residential areas (Tusting et al., 2017). While urbanization has historically been associated with reduced malaria transmission in some settings, unplanned urban growth in many low- and middle-income countries has led to heterogeneous malaria risk within cities and peri-urban communities.

University communities represent a distinct yet insufficiently explored ecological and epidemiological context for malaria transmission, particularly in off-campus student residential areas where high population density, overcrowded housing, poor drainage, inadequate waste disposal, and widespread use of water storage containers are common. These environmental and poor sanitary conditions create favorable microhabitats for *Anopheles* mosquito breeding and contribute to the formation of localized malaria transmission hotspots within densely populated settings (Robert et al., 2003; Tusting et al., 2013). Despite this risk profile, malaria research in Nigeria has predominantly focused on rural households, children under five years of age, pregnant women, and the broader urban population. Limited empirical attention has been given to environmental risk factors operating within university residential environments, thereby underscoring a critical gap in current malaria epidemiological research (NPC & ICF, 2019).

Understanding malaria transmission in university settings is particularly important, as recurrent malaria episodes among students can impair cognitive function, reduce class attendance, and negatively affect academic performance and productivity (Fernando et al., 2003). Beyond individual academic outcomes, frequent malaria

morbidity among students may also undermine overall well-being and increase demand on institutional health services. Studies show that reductions in malaria transmission are linked to improved educational outcomes, including reduced absenteeism, in endemic settings (Machila et al., 2022).

This study aims to address this gap by evaluating how key environmental factors—including ambient temperature, relative humidity, and poor sanitary conditions like stagnant surface water and clogged drainage—relate to malaria occurrence among university students in Okofia community, Anambra State, Nigeria. By integrating measured environmental parameters with clinic-confirmed malaria data, this study provides context-specific evidence to inform targeted malaria control and environmental management strategies in university residential settings.

MATERIALS AND METHODS

Study design and study area: A cross-sectional, descriptive, and observational study design was employed. The study was conducted in Okofia community, Otolo-Nnewi (Nnewi North LGA), Anambra State, Nigeria. The community hosts Nnamdi Azikiwe University's College of Health Sciences and Technology and features numerous off-campus student lodges. These facilities supplement the university's limited and oversubscribed on-campus hostels.

Study population, sample size and sampling technique: The study population comprised university students residing in private lodges within the Okofia community. Twenty (20) private lodges/hostels, representing 10% of the total number of private students' lodges/hostels in the community, were selected using simple random sampling. From each lodge, ten (10) students were selected using systematic sampling (of odd-numbered rooms), yielding a total sample size of 200 respondents.

Data collection: Data were collected using structured questionnaires (socio-demographic characteristics and malaria history), university clinic records documenting malaria diagnoses over a two-month period, and direct environmental observation using a standardized checklist. Environmental measurements, including ambient temperature (°C) using calibrated digital thermometers and relative humidity (%) using hygrometers, were recorded daily for seven consecutive days in each lodge. Additionally, the presence of stagnant water (including clogged drainage and uncovered water receptacles around student accommodations), were assessed through direct observation.

Inclusion and Exclusion Criteria: The study included only off-campus student lodges and hostels in Okofia inhabited by Nnamdi Azikiwe University students. Students residing in the on-campus university hostel were excluded. Participation was limited to students who had resided in the study location for at least one year. Furthermore, only clinic records of patients specifically diagnosed with malaria by a medical doctor were captured.

Statistical analysis: Data were analyzed using IBM SPSS Statistics (version 21). Descriptive statistics were used to summarize socio-demographic variables, environmental parameters, and malaria occurrence.

Ethical Considerations: Ethical approval was obtained from the Ethical Review Board of Nnamdi Azikiwe University's Faculty of Health Sciences and Technology. Informed consent was obtained from all participants.

RESULTS

Socio-Demographic Characteristics of Respondents

Table 1 presents the socio-demographic characteristics of respondents. Most students were aged 21–23 years (40.5%), and females constituted 57% of the respondents. All respondents resided in private off-campus lodges.

Table 1: Socio-Demographic Characteristics of the Respondents

Variable	Category	Frequency (*n*)	Percentage (%)
Age (years)	18–20	34	17.0
	21–23	81	40.5
	24–26	53	26.5
	≥27	32	16.0
	Total	**200**	**100.0**
Gender	Male	86	43.0
	Female	114	57.0
	Total	**200**	**100.0**
Accommodation type	On-campus	0	0.0
	Off-campus (private lodge)	200	100.0
	Total	**200**	**100.0**

Malaria Occurrence Based on University Clinical Records

Table 2 shows data collected from the university clinic records. A total of 229 malaria cases, among all the students of the university, were recorded over the two-month period. Female students accounted for 55.02% of cases, while males accounted for 44.98%.

Table 2. Malaria Cases Recorded at the University Clinic Over Two Months

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	103	45.0
	Female	126	55.0
	Total	**229**	**100.0**
Department	Medical Rehabilitation	36	15.7
	Medicine	33	14.4
	Medical Laboratory Science	33	14.4
	Nursing Science	30	13.1
	Radiography & Radiological Sciences	29	12.7
	Environmental Health Science	17	7.4
	Nutrition & Dietetics	9	3.9
	*Other/Not Specified	42	18.3
	Total	**229**	**100.0**

*Other/Not Specified: The clinic records did not specify a university department for these patients.

Environmental Conditions in Student Lodges

The mean ambient temperature across lodges was 28.1°C (range: 26.2–29.5°C), while the mean relative humidity was 84.3% (range: 69.3–92.1%) (Table 3). Additionally, stagnant water, including surface water, clogged drainage, and uncovered water receptacles, was widely present around the students' dwellings.

Table 3: Temperature and Humidity Measurements in Student Lodges

Lodge/Hostel Name		Average Temperature (°C)	Average Humidity (%)
1	Unchangeable God Lodge	28.2	89.4
2	New York Lodge	27.3	81.3
3	New Haven Lodge	26.2	85.7
4	Nkonyelu Lodge	27.1	79.4

5	Madonna Lodge	29.5	83.7
6	Exotic Lodge	28.0	92.1
7	St Raphael Hostel	28.5	90.3
8	Apple Lodge	26.9	69.3
9	Our Lady of Perpetual Help Hostel	27.5	80.2
10	SunCity Lodge	28.8	84.5
11	Omata Lodge	29.2	87.1
12	Royal cottage Lodge	27.9	82.3
13	Emmanuel Lodge	28.4	91.5
14	Fidelity Lodge	27.7	78.9
15	Gelaviv Lodge	29.1	86.2
16	Snow Lodge	28.6	90.9
17	Mega Lodge	27.4	80.5
18	Graceland Lodge	29.3	88.5
19	St Joseph Hostel	28.1	81.9
20	God of Abraham Lodge	27.8	83.2
Mean		**28.1**	**84.3**

DISCUSSION

This study provides empirical evidence that environmental conditions within university residential environments are significantly associated with malaria transmission dynamics. The observed mean ambient temperature (28.1°C) and relative humidity (84.3%) fall squarely within the ecological thresholds known to optimize *Anopheles* mosquito survival, feeding activity, and *Plasmodium* parasite development. These findings are consistent with experimental and modeling studies demonstrating that malaria transmission efficiency peaks between 25–30°C, where mosquito longevity and the sporogonic cycle are optimally synchronized (Eke et al., 2025; Ekpa et al., 2023; Paaijmans et al., 2019; Mordecai et al., 2020).

Higher temperatures accelerate larval development, increase adult mosquito biting frequency, and shorten the extrinsic incubation period of *Plasmodium*, thereby increasing the likelihood of successful transmission (Ryan et al., 2015; Mordecai et al., 2019). Additionally, high humidity reduces mosquito desiccation, prolongs adult lifespan, and enhances nocturnal activity, increasing the probability that mosquitoes survive long enough to transmit infection (Paaijmans et al., 2021; Smith et al., 2019). In southeastern Nigeria, where humidity levels remain persistently high for much of the year, humidity may therefore be associated with continuous malaria transmission rather than seasonal outbreaks (Ezihe et al., 2017). The ambient temperature and high relative humidity recorded in this study highlight the critical role of tropical temperature and atmospheric moisture in sustaining malaria transmission within the study area, which is a typical humid tropical environment.

Beyond climatic variables, the study highlights the association between environmental sanitation, water holding structures, and malaria risk within university communities. The widespread presence of stagnant surface water, clogged drainage and uncovered water receptacles around student residences provides ideal breeding habitats for *Anopheles* mosquitoes. Similar studies in urban and peri-urban African settings have demonstrated that artificial water containers can significantly contribute to vector proliferation, particularly in areas with unreliable water supply and inadequate drainage infrastructure (Becker et al., 2019; Tusting et al., 2017). The proximity of these breeding sites to student living spaces increases human–vector contact and sustains localized transmission hotspots.

The significance of stagnant surface water, clogged drainage and uncovered water receptacles in this study reinforces the importance of larval source management as a complementary malaria control strategy. While malaria interventions in Nigeria have largely focused on use of insecticide-treated nets and case management, environmental control measures (such as covering water containers, improving drainage, and regular environmental sanitation) remain underutilized, particularly in institutional residential settings. The findings

suggest that targeted environmental interventions within university communities may be associated with reduced malaria risk and could be implemented with relatively low cost and high sustainability.

A key strength and novelty of this study lie in its focus on a university student population, an understudied group in malaria epidemiology. Most malaria research in Nigeria has concentrated on rural households, children under five, pregnant women, or the general urban population, often overlooking institutional residential environments (Isiko, 2024; Ibinaiye et al., 2023; Oladimeji et al., 2019). University communities represent unique ecological systems characterized by high population density, shared facilities, transient populations, and distinct behavioral patterns that may influence exposure risk (Bolanos et al., 2025). By demonstrating malaria occurrence among students, including recent diagnoses, this study highlights that malaria transmission within university environments may be ongoing.

Furthermore, the integration of measured environmental parameters with clinic-confirmed malaria data provides context-specific evidence that strengthens the validity of the observed associations. The relationship between environmental variables, sanitation, and malaria cases further supports the biological plausibility of the findings and aligns with established malaria transmission frameworks.

The study identifies micro-environmental factors that facilitate mosquito breeding and the endemicity of the malaria parasite. These include ambient temperature and high humidity, alongside conditions linked to human activity such as open or clogged drainage. Furthermore, the problems posed by stagnant surface water and clogged drainage are exacerbated by the use of open receptacles for water storage, a necessity driven by the university residential community's unreliable water infrastructure.

Overall, this study extends the current understanding of malaria ecology by demonstrating that micro-environmental conditions within university residential settings are associated with malaria transmission in endemic regions, thus achieving the objectives of the study. The findings underscore the need to incorporate environmental management strategies into malaria control programs targeting institutional communities and provide a foundation for future longitudinal and intervention-based studies aimed at reducing malaria burden among university populations.

CONCLUSION

This study provides compelling evidence that malaria transmission within university residential environments is significantly associated with local environmental conditions. Elevated ambient temperature and high relative humidity—conditions that enhance *Anopheles* mosquito survival and *Plasmodium* development—were associated with malaria occurrence among university students in Okofia community. In addition, the widespread presence of stagnant surface water, clogged drainage and uncovered water receptacles around student residences was identified as an important environmental factor associated with mosquito breeding and malaria transmission. These findings suggest that university settings with similar micro-environmental conditions may experience comparable malaria transmission patterns.

By focusing on a university student population, this study addresses an important gap in malaria epidemiology and demonstrates that institutional residential settings can serve as malaria transmission micro-environments in endemic regions. The integration of measured environmental parameters with clinic-confirmed malaria data strengthens the biological plausibility and public health relevance of the findings.

These results underscore the need to complement conventional malaria control strategies, such as case management and use of insecticide-treated nets, with targeted environmental sanitation and larval source management interventions within university communities. Improving water storage practices, drainage systems, and environmental hygiene in off-campus student residences could substantially reduce malaria risk and improve student health and academic productivity. Overall, this study provides evidence-based insights to inform context-specific malaria control policies and highlights the importance of incorporating environmental management into malaria prevention strategies in institutional settings.

To address the limitations of this research, future studies should adopt a prospective longitudinal design across multiple geographical sites to establish causality and enhance the generalizability of findings. Furthermore, integrating objective clinical testing alongside entomological surveillance (such as larval indices and mosquito density) is essential to eliminate recall bias and provide a comprehensive understanding of malaria transmission.

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