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Occupational Burden of Malaria among Medical Waste Handlers in Three Tertiary Healthcare Facilities in Southeastern Nigeria: A Cross-Sectional Study

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Abstract

Background: Malaria remains a leading cause of morbidity and mortality in sub-Saharan Africa, with Nigeria bearing the highest global burden. Despite their essential role in healthcare systems, the malaria burden among medical waste handler's remains poorly documented. This study assessed the prevalence and intensity of malaria parasitaemia among medical waste handlers in three tertiary healthcare facilities in Imo State, southeastern Nigeria.

Methods: A hospital-based cross-sectional study was conducted among 500 consenting medical waste handlers from three tertiary healthcare institutions in Imo State. Venous blood samples collected in EDTA tubes were examined for *Plasmodium* parasites using 10% Giemsa-stained thick blood smears. Demographic data were obtained using structured questionnaires. Data were analyzed using SPSS version 20.0. Descriptive statistics summarized the findings, while Pearson's chi-square test compared malaria prevalence across demographic groups and hospitals at $P < 0.05$.

Results: Of the 500 participants, 371 tested positive for malaria, giving an overall prevalence of 74.2%. Prevalence was similar across the three hospitals (74.1–74.4%) with no significant difference ($P > 0.05$). Females had a slightly higher prevalence (74.6%) than males (74.1%), while participants aged 40–49 years recorded the highest prevalence (76.9%) and those aged ≥50 years the lowest (69.8%); these differences were not statistically significant. Light parasitaemia accounted for 66.6% of infections, followed by moderate (31.3%) and heavy (2.1%) parasitaemia.

Conclusions: Medical waste handlers experience a high malaria burden, indicating persistent transmission within this occupational group. The predominance of light parasitaemia suggests many workers may act as asymptomatic reservoirs. Routine malaria surveillance, strengthened vector control, improved environmental sanitation, health education, and occupational health policies should be integrated into healthcare waste management programmes.

Keywords: Malaria; Medical waste handlers; Occupational health; Parasitaemia; Healthcare waste; Nigeria.

Introduction

Malaria remains one of the most significant vector-borne diseases

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worldwide and continues to impose an enormous public health, economic, and social burden, particularly in tropical and subtropical regions. Despite decades of sustained global malaria control efforts, the disease remains endemic in many low- and middle-income countries, where environmental, socioeconomic, and health system factors continue to facilitate transmission. According to the World Malaria Report 2024, an estimated 263 million malaria cases and approximately 597,000 malaria-related deaths occurred globally in 2023, representing an increase compared with the previous year and highlighting the persistent challenges to malaria elimination. The WHO African Region accounted for approximately 94% of global malaria cases and 95% of malaria-related deaths, emphasizing the disproportionate burden borne by sub-Saharan Africa despite substantial investments in malaria prevention and control interventions (World Health Organization [WHO], 2024).

Nigeria continues to carry the largest malaria burden globally and remains central to international malaria elimination efforts. Recent estimates indicate that the country accounted for approximately 27% of global malaria cases and 31% of malaria-related deaths in 2023, making malaria one of the leading causes of outpatient attendance, hospital admission, childhood mortality, maternal anemia, adverse pregnancy outcomes, and productivity loss (WHO, 2024). The persistence of intense malaria transmission in Nigeria is attributed to a combination of favorable climatic conditions, rapid urbanization, widespread poverty, inadequate environmental sanitation, weak vector control coverage in some communities, increasing insecticide resistance among Anopheles mosquitoes, and unequal access to quality diagnosis and effective treatment. These interacting ecological, environmental, and socioeconomic factors continue to challenge progress toward achieving the objectives of the National Malaria Strategic Plan and the Global Technical Strategy for Malaria 2016–2030.

The predominant malaria parasite in Nigeria is *Plasmodium falciparum*, which is responsible for the overwhelming majority of severe malaria cases and deaths. Transmission is maintained primarily by members of the *Anopheles gambiae* complex and the *Anopheles funestus* group, both of which thrive under the humid tropical environmental conditions that characterize much of southern Nigeria. Although the widespread deployment of insecticide-treated nets (ITNs), indoor residual spraying (IRS), rapid diagnostic tests (RDTs), artemisinin-based combination therapy (ACT), seasonal malaria chemoprevention in eligible regions, and, more recently, malaria vaccines has contributed to reductions in malaria burden in several endemic settings, progress has been heterogeneous across Nigeria. Persistent transmission hotspots continue to exist, particularly in areas characterized by inadequate drainage systems, poor waste management, stagnant surface water, dense vegetation, and limited implementation of integrated vector management strategies.

Historically, malaria prevention programmes have primarily targeted children under five years of age and pregnant women because of their increased susceptibility to severe disease and mortality. While these groups remain public health priorities, growing evidence indicates that adults living in highly endemic settings also contribute substantially to malaria transmission. Repeated exposure to *P. falciparum* throughout life results in the gradual acquisition of partial clinical immunity, allowing many infected adults to remain asymptomatic or present with only mild symptoms despite harboring malaria parasites. Consequently, asymptomatic infections often remain undiagnosed and untreated, serving as important reservoirs for continued transmission through infectious mosquito vectors. Recent systematic reviews and meta-analyses conducted in Nigeria have demonstrated that asymptomatic malaria remains common among apparently healthy individuals, underscoring the need to expand surveillance beyond traditionally recognized high-risk populations and incorporate adult populations into malaria elimination strategies.

The epidemiology of malaria is increasingly recognized as being influenced by occupation, environmental exposure, and workplace conditions. Occupational groups whose routine activities require prolonged outdoor exposure or frequent contact with environments favorable for mosquito breeding may experience an elevated risk of malaria infection compared with the general population. Such occupational risk has been reported among agricultural workers, forest workers, military personnel, miners, construction workers, and other populations whose work environments increase contact with malaria vectors. Nevertheless, healthcare support personnel have received comparatively limited attention within occupational malaria research, despite their indispensable role in maintaining healthcare systems in malaria-endemic countries.

Understanding occupational determinants of malaria has become increasingly important as countries adopt integrated approaches to disease prevention that recognize interactions between human health, occupational environments, ecological conditions, and environmental management. Identifying occupational groups that experience sustained malaria exposure can facilitate the development of targeted surveillance programmes, workplace health interventions, environmental sanitation policies, and vector control measures capable of reducing transmission while strengthening workforce productivity. Such evidence is particularly relevant in high-transmission settings such as southeastern Nigeria, where environmental conditions remain highly conducive to year-round malaria transmission.

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Materials and Methods

Study Design

A hospital-based cross-sectional study was conducted between April 2025 to November 2025 conducted to determine the prevalence and intensity of malaria parasitaemia among medical waste handlers employed in three tertiary healthcare facilities in Imo State, southeastern Nigeria. The study was designed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies.

Study Area

The study was conducted in Imo State, southeastern Nigeria, located between latitudes 4°45′N and 7°15′N and longitudes 6°50′E and 7°25′E. The state occupies approximately 5,530 km² and has an estimated population exceeding 5 million inhabitants. Imo State experiences a humid tropical climate characterized by two distinct seasons: a rainy season (April–October) and a dry season (November–March). Annual rainfall ranges from 2,000 to 2,500 mm, while mean annual temperatures vary between 24°C and 32°C, creating favorable ecological conditions for perennial malaria transmission.

Malaria transmission in the state is predominantly stable and holoendemic, with Plasmodium falciparum accounting for the vast majority of infections. The principal malaria vectors belong to the Anopheles gambiae complex and Anopheles funestus group.

The study was undertaken in three tertiary healthcare institutions that provide specialist healthcare services and generate substantial quantities of healthcare waste: Federal University Teaching Hospital (FUTH), Owerri, Imo State University Teaching Hospital (IMSUTH), Orlu, and Umuguma Specialists Hospital, Owerri

Each institution operates healthcare waste collection, segregation, transportation, and disposal systems, although the level of implementation and environmental management practices varies across facilities.

Study Population

The study population comprised all medical waste handlers employed within the selected healthcare institutions. Medical waste handlers included personnel directly involved in the collection, segregation, transportation, temporary storage, treatment, and disposal of healthcare waste generated during routine hospital activities.

Eligibility Criteria

Inclusion Criteria

Participants were eligible if they:

- were employed as medical waste handlers in one of the participating hospitals;
- had worked in the facility for at least six months;
- were aged 18 years or older;
- Voluntarily provided written informed consent.

Exclusion Criteria

Individuals were excluded if they:

- declined participation;
- were receiving ant malarial treatment during sample collection;
- had severe illness requiring immediate medical attention;
- Submitted inadequate blood samples for laboratory analysis.

Sample Size Determination

The minimum sample size was estimated using the single-population proportion formula described by Cochran:

$$n=Z^2 P(1-P)d^2$$

Where:

- **n** = minimum sample size;
- **Z** = standard normal deviate corresponding to the 95% confidence level (1.96);
- **P** = estimated prevalence of malaria based on previous Nigerian studies;
- **d** = margin of error (5%).

To improve statistical power and compensate for possible non-response, a total of **500 medical waste handlers** were recruited across the three participating hospitals.

Sampling Technique

A proportionate stratified sampling technique was adopted. Each healthcare institution represented a sampling stratum, while eligible medical waste handlers constituted the sampling units. The number of participants recruited from each hospital was proportional to the size of its waste management workforce. Eligible participants were selected using simple random sampling from staff lists provided by hospital management.

Data Collection

Data collection was conducted by trained research personnel using a structured interviewer-administered questionnaire. Information obtained included: age, sex, educational level, years of employment, occupational responsibilities, history of malaria episodes, and use of insecticide-treated nets, previous ant malarial treatment, and selected environmental and occupational exposure characteristics.

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Questionnaires were pre-tested among medical waste handlers in a comparable healthcare facility outside the study sites to improve clarity and reliability.

Blood Sample Collection

Approximately **2 ml of venous blood** was aseptically collected from each participant by trained laboratory scientists using sterile disposable syringes. Blood samples were transferred immediately into sterile ethylenediaminetetraacetic acid (EDTA) anticoagulant tubes and transported under appropriate conditions to the hospital laboratory for microscopic examination.

Laboratory Diagnosis of Malaria

Malaria diagnosis was performed using conventional light microscopy, the reference standard for malaria parasite detection in epidemiological surveys.

Thick blood films were prepared according to standard WHO laboratory procedures. Air-dried smears were stained with **10% Giemsa solution for 10 minutes**, rinsed with buffered water (pH 7.2), air dried, and examined under oil immersion (×100 objective lens) using a binocular light microscope.

Each slide was independently examined by two experienced microscopists who were blinded to participants' demographic information. Discordant findings were reviewed by a third senior microscopist, whose interpretation served as the final result.

Parasite density was estimated by counting the number of asexual *Plasmodium* parasites against **200 leukocytes** and expressed as parasites per microlitre (parasites/µL) of blood using the WHO standard assumption of **8,000 white blood cells/µL**

Parasitaemia was categorized as:

- **Light infection:** <1,000 parasites/µL
- **Moderate infection:** 1,000–9,999 parasites/µL
- **Heavy infection:** ≥10,000 parasites/µL

Quality Assurance

Several quality control measures were implemented throughout the study. Laboratory personnel received refresher training before commencement of the study. All microscope slides were independently read by two qualified microscopists, with discrepancies resolved by a third expert reader. Giemsa stain solutions were prepared fresh daily using buffered distilled water. Microscopes were calibrated before use, and laboratory procedures strictly followed WHO standard operating procedures for malaria microscopy.

Data collection instruments were pre-tested, while completed questionnaires were checked daily for completeness and consistency before data entry.

Statistical Analysis

Data were entered into Microsoft Excel, cleaned, and analyzed using **IBM SPSS Statistics version 29.0** (IBM Corp., Armonk, NY, USA). Continuous variables were summarized as means and standard deviations (SD) or medians and interquartile ranges (IQR), depending on data distribution, whereas categorical variables were presented as frequencies and percentages.

Overall malaria prevalence was calculated as the proportion of participants with microscopically confirmed malaria parasitaemia. Differences in prevalence across hospitals, sex, age groups, and other categorical variables were assessed using Pearson's chi-square test or Fisher's exact test where appropriate.

To identify factors independently associated with malaria infection, **multivariable binary logistic regression analysis** was performed. Variables with **P < 0.20** during bivariate analysis were entered into the multivariable model. Adjusted odds ratios (AORs) with corresponding **95% confidence intervals (95% CI)** were reported. Model fitness was assessed using the Hosmer–Lemeshow goodness-of-fit test, and multicollinearity among predictor variables was evaluated using variance inflation factors (VIFs). A two-sided **p-value < 0.05** was considered statistically significant.

Ethical Considerations

Ethical approval for the study was obtained from the **Research Ethics Committee of Imo State University, Owerri.** Additional administrative approvals were obtained from the management of the three participating healthcare institutions.

The objectives, procedures, potential benefits, and minimal risks associated with the study were clearly explained to all eligible participants. Written informed consent was obtained before enrolment. Participation was entirely voluntary, and participants were free to withdraw from the study at any stage without consequences. Confidentiality was maintained by assigning unique identification codes rather than personal identifiers. Participants diagnosed with malaria were referred to the hospital's outpatient clinic for appropriate management according to the Nigerian National Malaria Treatment Guidelines.

Results

Participant Socio-demographic Characteristics

A total of 500 medical waste handlers participated in the study, comprising 370 (74.0%) males and 130 (26.0%) females, yielding a response rate of 100%. Participants were recruited from three tertiary healthcare facilities in Imo State, namely the Federal Teaching Hospital Owerri (FUTH), Owerri (n = 168), Umuguma Specialists Hospital,

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Owerri (UGHO; n = 166), and Imo State University Teaching Hospital (IMSUTH), Orlu (n = 166).

Participants ranged in age from 20 to over 50 years. The largest proportion belonged to the 40–49-year age group (36.4%), followed by those aged 30–39 years (30.8%), ≥50 years (21.2%), and 20–29 years (11.6%) (Table1).

Table1: Socio-demographic characteristics of the study participants (N = 500)

Variable	Frequency (n)	Percentage (%)
Sex		
Male	370	74
Female	130	26
Age group (years)		
20–29	58	11.6
30–39	154	30.8
40–49	182	36.4
≥50	106	21.2

Overall Prevalence of Malaria

Of the 500 medical waste handlers examined, 371 tested positive for malaria parasites by Giemsa-stained thick blood microscopy, giving an overall prevalence of 74.2% (95% CI: 70.2%–77.8%).

Malaria prevalence was remarkably similar across the three participating healthcare facilities. The highest prevalence was observed at Federal Teaching Hosipital, (FUTH), Owerri (74.4%; 125/168), and while identical prevalence estimates were recorded at Umuguma Specialists Hospital (74.1%; 123/166) and Imo State University Teaching Hospital (74.1%; 123/166).

Pearson's chi-square analysis demonstrated no statistically significant difference in malaria prevalence among the three hospitals ($\chi^2 = 0.006$, df = 2, P = 0.997) (Table 2).

Table 2: Malaria prevalence according to healthcare facility

Healthcare facility	Examined	Positive	Prevalence (%)
Federal Teaching Hospital, Owerri	168	125	74.4
Umuguma Specialists Hospital	166	123	74.1
Imo State University Teaching Hospital	166	123	74.1
Total	**500**	**371**	**74.2**

Sex-specific Prevalence of Malaria

Among the 370 male participants, 274 were positive for malaria parasites, corresponding to a prevalence of 74.1%. Among the 130 female medical waste handlers, **97** were infected, representing a prevalence of 74.6%.

Although females exhibited a marginally higher prevalence than males, the difference **was** not statistically significant **(χ^2** = 0.0001, df = 1, P = 0.993) (Table 3).

Table 3: Sex-specific prevalence of malaria among medical waste handlers

Sex	Examined	Positive	Prevalence (%)
Male	370	274	74.1
Female	130	97	74.6
Total	**500**	**371**	**74.2**

Age-specific Prevalence of Malaria

Age-specific analysis revealed that malaria prevalence ranged from 69.8% to 76.9%. Participants aged 40–49 years recorded the highest prevalence (76.9%; 140/182), followed by those aged 20–29 years (74.1%; 43/58) and 30–39 years (74.0%; 114/154). Participants aged 50 years and above had the lowest prevalence (69.8%; 74/106).

Despite these numerical differences, there was no statistically significant association between age group and malaria infection ($\chi^2 = 1.774$, **df** = 3, P = 0.621) (Table 4).

Table 4: Age-specific prevalence of malaria

Age group (years)	Examined	Positive	Prevalence (%)
20–29	370	274	74.1
30–39	130	97	74.6
40–49	182	140	76.9
≥50	106	74	69.8
Total	**500**	**371**	**74.2**

Distribution of Malaria Parasitaemia

Among the 371 participants with microscopically confirmed malaria infection, 247 (66.6%) had light parasitaemia, 116 (31.3%) had moderate parasitaemia, and 8 (2.1%) had heavy parasitaemia (Table5).

Light parasitaemia constituted approximately two-thirds of all infections and was therefore the predominant infection category among medical waste handlers. Heavy parasitaemia was uncommon, accounting for only 2.1% of infected participants.

Overall, malaria parasitaemia was detected in nearly three-quarters of medical waste handlers across the three tertiary healthcare facilities. Malaria prevalence was

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Table 5: Distribution of malaria parasite density among infected participants (n = 371)

Parasitaemia category	Frequency	Percentage (%)
Light	247	66.6
Moderate	116	31.3
Heavy	8	2.1
Total	371	100

consistently high irrespective of healthcare facility, sex, or age group, with no statistically significant differences observed across these demographic strata. The predominance of light parasitaemia indicates that most infections were of low parasite density, suggesting that many infected workers may have been asymptomatic carriers capable of sustaining malaria transmission within endemic communities.

Discussion

This study investigated the prevalence and intensity of malaria parasitaemia among medical waste handlers employed in three tertiary healthcare institutions in Imo State, southeastern Nigeria. The findings revealed an exceptionally high malaria prevalence of **74.2%,** with no statistically significant differences across healthcare facilities, sex, or age groups. Furthermore, light parasitaemia accounted for approximately two-thirds of all infections, indicating that most infected workers harbored relatively low parasite densities. Collectively, these findings suggest that malaria remains highly endemic among healthcare support personnel and underscore the need to incorporate occupationally exposed workers into malaria surveillance and prevention programmes.

The overall prevalence observed in this study is substantially higher than recent national estimates reported for the general Nigerian population but is consistent with Nigeria's continued position as the country with the greatest malaria burden worldwide. According to the **World Malaria Report 2024**, Nigeria accounted for more than one-quarter of global malaria cases and nearly one-third of malaria-related deaths in 2023, despite considerable investments in vector control, improved diagnostics, and effective antimalarial therapy. The persistently high prevalence observed among medical waste handlers therefore reflects the intense malaria transmission that continues to characterize many parts of southern Nigeria, where favorable climatic conditions, prolonged rainy seasons, poor drainage systems, rapid urbanization, and environmental degradation support year-round breeding of *Anopheles* mosquitoes.

Several environmental and occupational factors may explain the high burden of malaria identified in this study. Medical waste handlers routinely work around refuse collection points, waste storage facilities, drainage channels, sewage systems, and poorly maintained environments that may accumulate stagnant water following rainfall. Such conditions provide ideal breeding habitats for *Anopheles* mosquitoes, thereby increasing opportunities for repeated mosquito exposure during routine occupational activities. Unlike clinical personnel who spend most of their working hours indoors, waste handlers frequently undertake outdoor duties during the early morning and evening periods when malaria vectors are most active. In addition, irregular use of insecticide-treated nets, inadequate workplace vector control, limited access to occupational health services, and socioeconomic disadvantages may further increase susceptibility to malaria infection. Although these factors were not directly measured in the present study, they provide biologically plausible explanations for the high prevalence observed and warrant investigation in future analytical studies.

An important finding of this study was the absence of statistically significant differences in malaria prevalence among the three participating hospitals. This observation suggests relatively homogeneous malaria transmission across the study area despite differences in institutional management structures. All three hospitals are located within the humid rainforest ecological zone of southeastern Nigeria, where consistently high rainfall, favorable temperatures, dense vegetation, and abundant mosquito breeding habitats promote perennial malaria transmission. Comparable environmental sanitation practices, waste management infrastructure, and surrounding ecological conditions may therefore contribute to the similar prevalence estimates observed across institutions. These findings imply that occupational malaria prevention should be implemented uniformly across tertiary healthcare facilities rather than being limited to individual institutions.

Sex-specific analysis demonstrated no statistically significant difference in malaria prevalence between male and female medical waste handlers, although females exhibited a marginally higher prevalence. Similar findings have been reported in several epidemiological studies conducted among adult populations in malaria-endemic settings, where infection risk is largely determined by environmental exposure, behavioral practices, and local transmission intensity rather than biological sex. The slight numerical difference observed in this study is therefore unlikely to represent a meaningful biological disparity and may instead reflect sampling variability resulting from the relatively smaller number of female participants. From an occupational health perspective, these findings indicate that malaria prevention strategies should target all healthcare waste handlers irrespective of sex.

Likewise, malaria prevalence did not differ significantly across age groups, although workers aged 40–49 years

recorded the highest prevalence. In areas of stable malaria transmission, repeated exposure to *Plasmodium falciparum* results in the gradual acquisition of partial immunity that protects against severe clinical disease but does not necessarily prevent infection. Consequently, adults frequently harbor asymptomatic or mildly symptomatic infections while remaining capable of infecting mosquito vectors. This pattern is consistent with recent systematic reviews demonstrating that asymptomatic malaria is common among adults living in endemic regions of Nigeria and other sub-Saharan African countries. These hidden infections constitute an important parasite reservoir that can sustain community transmission even where symptomatic cases are effectively diagnosed and treated. The findings therefore reinforce growing recommendations that adult populations, including occupational groups, should be incorporated into malaria surveillance and elimination programmes.

Conclusions

The predominance of light parasitaemia observed in this study has important epidemiological implications. Although individuals with low parasite densities often remain clinically asymptomatic, increasing evidence indicates that they contribute substantially to malaria transmission because they frequently remain untreated while maintaining sufficient parasite densities to infect mosquito vectors. The high proportion of light infections observed among medical waste handlers therefore suggests that this occupational group may represent an under-recognized reservoir of malaria parasites within healthcare settings and surrounding communities. Strengthening routine malaria screening, particularly during periods of peak transmission, may facilitate earlier detection and treatment of asymptomatic infections, thereby reducing onward transmission.

Review Board Statement

Ethical approval for the study was obtained from the Research Ethics Committee of Imo State University, Owerri.

Informed Consent Statement

Written and verbal informed consent was obtained from all participants involved in the study.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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Conflict of Interest

The author declares no conflict of interest

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