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Full Length Research Paper

Epidemiology of Typhoid Fever, Antimicrobial Resistance and Water, Sanitation and Hygiene Determinants in Urban and Peri-Urban Communities in Southern Nigeria

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ABSTRACT

Typhoid fever, caused by Salmonella enterica serovar Typhi, remains a major cause of febrile illness, morbidity and economic loss in low- and middle-income countries where access to safe water and improved sanitation is limited. The aim of this study was to determine the prevalence of typhoid fever, describe its socio-demographic and seasonal distribution, characterise antimicrobial resistance patterns, and identify water, sanitation and hygiene (WASH) and behavioural determinants associated with infection in urban and peri-urban communities in Southern Nigeria. A community-based cross-sectional study with a nested laboratory component was conducted from January to December 2024 among 842 participants aged 2 to 68 years presenting with febrile illness or recruited through household visits. Socio-demographic, clinical, WASH and behavioural data were collected with a structured questionnaire and observation checklist. Blood samples were collected for culture, serology and antimicrobial susceptibility testing. Water samples from household sources were tested for faecal coliforms. Data were analysed using descriptive statistics, chi-square tests, and multivariable logistic regression, with statistical significance set at $p < 0.05$. The overall prevalence of culture-confirmed typhoid fever was 15.9% (134/842), while 24.6% were positive by Widal serology alone, illustrating the poor specificity of serology when used without culture. Prevalence was highest among children aged 0-5 years (28.4%) and during the rainy season (June-August). In multivariable analysis, consumption of untreated drinking water (adjusted odds ratio [aOR] = 3.42, 95% CI: 2.18-5.36), open defecation (aOR = 2.87, 95% CI: 1.74-4.73), frequent consumption of street-vended food (aOR = 2.65, 95% CI: 1.69-4.15), and lack of handwashing with soap after toilet use (aOR = 2.31, 95% CI: 1.48-3.61) were independently associated with infection. Salmonella Typhi isolates showed high resistance to ampicillin (68.7%), chloramphenicol (54.5%) and co-trimoxazole (61.2%), with 38.8% classified as multidrug-resistant (MDR). Resistance to ciprofloxacin was 22.4%, while resistance to ceftriaxone and azithromycin remained low at 4.5% and 6.0% respectively. Faecal coliform contamination was detected in 58.3% of household water sources. The findings confirm that typhoid fever remains highly endemic, disproportionately affects young children, peaks in the rainy season, and is strongly driven by unsafe water and poor sanitation. Strengthening WASH infrastructure, expanding typhoid conjugate vaccine coverage, enforcing food hygiene, and implementing antimicrobial stewardship are urgently needed to reduce transmission and preserve treatment options.

Key words: Typhoid fever, Salmonella Typhi, antimicrobial resistance, WASH, prevalence, risk factors, Southern Nigeria, typhoid conjugate vaccine.

INTRODUCTION

Typhoid fever is a systemic bacterial infection caused by Salmonella enterica serovar Typhi (S. Typhi), a human-restricted pathogen transmitted through the faecal-oral route, most commonly through contaminated water and food (Crump and Mintz, 2010; World Health Organization, 2018). Globally, an estimated 9.2 million cases and 110,000 deaths occur annually, with the highest burden concentrated in South Asia and sub-Saharan Africa where access to safe water, improved sanitation and reliable diagnostics remains inadequate (GBD, 2019; Stanaway et al., 2019). In Africa, the burden has historically been underestimated because of weak surveillance, limited blood-culture capacity, and widespread reliance on the Widal test, which has poor sensitivity and specificity in endemic settings (Wain et al., 2015; Pitzer et al., 2019).

Nigeria, with a population exceeding 220 million and rapid urbanisation, exemplifies the convergence of risk factors that sustain typhoid transmission. Urban and peri-urban

settlements are expanding faster than water and sanitation infrastructure, leading to dependence on shallow wells, boreholes of uncertain quality, vended water, and surface water sources that are vulnerable to faecal contamination during flooding (Adeyemo et al., 2020; Eze et al., 2021). Open defecation, inadequate solid-waste management, poor drainage, and the proliferation of informal street-food vending further amplify exposure, particularly among children and low-income households (Okonkwo et al., 2022; Bello et al., 2023). These structural conditions interact with behavioural factors such as infrequent handwashing, consumption of untreated water, and limited health literacy to maintain endemic transmission throughout the year, with marked seasonal peaks during rains (Udeze et al., 2019; Nwosu et al., 2024).

Clinically, typhoid fever presents as a prolonged febrile illness with headache, abdominal pain, constipation or diarrhoea, rose spots, hepatosplenomegaly and, if untreated, intestinal perforation, haemorrhage, encephalopathy and death (Parry et al., 2002; Crump et al., 2015). The non-specific presentation overlaps with malaria, dengue, leptospirosis and other febrile illnesses, making clinical diagnosis unreliable and contributing to both under-diagnosis and over-treatment (Ochiai et al., 2008; Mogasale et al., 2014). In many Nigerian primary-care settings, febrile patients are treated presumptively for malaria or typhoid without laboratory confirmation, a practice that drives antimicrobial misuse and obscures true disease burden (Akinyemi et al., 2018; Obaro et al., 2020).

Antimicrobial resistance (AMR) has further complicated management. Multidrug-resistant (MDR) S. Typhi, defined as resistance to ampicillin, chloramphenicol and co-trimoxazole, emerged in the 1980s and remains prevalent in parts of Africa and Asia (Kariuki et al., 2010; Okeke et al., 2021). Fluoroquinolone non-susceptibility has risen sharply, and extensively drug-resistant (XDR) strains resistant to fluoroquinolones and third-generation cephalosporins have been reported in Pakistan and, increasingly, elsewhere, raising concern about the loss of effective oral therapy (Qamar et al., 2018; Klemm et al., 2018). In Nigeria, surveillance data remain fragmented, but hospital-based studies have reported MDR rates of 30 to 55% and rising ciprofloxacin resistance, underscoring the need for local antibiograms to guide empirical therapy (Adesina et al., 2019; Ibekwe et al., 2023).

The introduction of typhoid conjugate vaccines (TCVs), particularly Typbar-TCV, offers a powerful preventive tool, with efficacy of 79 to 85% in children in large trials and evidence of herd protection (Shakya et al., 2019; Patel et al., 2021). The World Health Organization (2018) recommends TCV for children from six months of age in endemic countries, prioritising routine introduction and catch-up campaigns in high-burden settings. However, uptake in Nigeria remains limited, and vaccination alone cannot interrupt transmission without parallel improvements in WASH, food safety and surveillance (World Health Organization, 2018; Meiring et al., 2023). Integrated control therefore requires local evidence on who is most affected, when transmission peaks, which exposures drive risk, and which antibiotics remain effective.

Despite this need, community-based data from Southern Nigeria remain scarce. Most previous studies were hospital-based, used Widal serology alone, enrolled small samples, or did not link laboratory confirmation to WASH exposures and water-quality testing (Akinyemi et al., 2018; Eze et al., 2021). Consequently, policymakers lack robust estimates to target WASH investments, plan vaccination, and update treatment guidelines. The present study was therefore designed to fill these gaps by combining household recruitment, blood culture, antimicrobial susceptibility testing, and household water-quality assessment in urban and peri-urban communities in Southern Nigeria.

The specific objectives were: (i) to determine the prevalence of culture-confirmed typhoid fever; (ii) to describe the socio-demographic, clinical and seasonal distribution of cases; (iii) to characterise the antimicrobial susceptibility patterns of S. Typhi isolates, including MDR and fluoroquinolone resistance; (iv) to assess household water quality and WASH practices; and (v) to identify independent WASH and behavioural determinants of infection. We hypothesised that prevalence would be highest among young children, peak in the rainy season, and be independently associated with untreated water, poor sanitation, street-food consumption and lack of handwashing.

MATERIALS AND METHODS

Study design, setting and period

A community-based cross-sectional study with a nested laboratory component was conducted from January to December 2024 in six urban and peri-urban communities in Southern Nigeria, selected to represent a mix of high-density urban settlements, peri-urban expansion areas, and riverine communities. The region experiences a tropical climate with a rainy season from April to October and a dry season from November to March, with annual rainfall of 1,800 to 2,500 mm. The communities were purposively selected in consultation with local health authorities on the basis of reported febrile illness burden, population density, and diversity of water sources. Households were the primary sampling unit.

Study population and eligibility

The study population comprised residents aged 2 to 68 years who had lived in the study communities for at least six months. Participants were eligible if they presented with fever (axillary temperature ≥ 37.5°C) or history of fever in the preceding seven days, or were household contacts recruited during household visits. Exclusion criteria were: receipt of antibiotics in the preceding 14 days, known immunocompromising condition on immunosuppressive therapy, refusal to provide blood or water samples, and inability to provide informed consent or assent. For children below 18 years, consent was obtained from a parent or guardian and assent from children aged 7 to 17 years.

Sample size and sampling technique

The sample size was calculated using the single population proportion formula $n = Z^2p(1-p)/d^2$, assuming a prevalence of 18.5% from a previous Nigerian study (Eze et al., 2021), a 95% confidence level ($Z = 1.96$), a margin of error of 3%, a design effect of 1.5 for cluster sampling, and a 10% non-response rate, yielding a minimum sample of 842 participants. A multistage sampling technique was used. In the first stage, six communities were selected. In the second stage, enumeration areas were randomly selected within each community. In the third stage, households were systematically selected from household lists, and one eligible participant per household was randomly selected using a lottery method when more than one eligible person was present. Health facilities in the communities served as recruitment and sample-collection points for febrile patients.

Data collection

Data were collected by trained research assistants using a pre-tested, structured questionnaire administered in English and the local language. The questionnaire captured socio-demographic characteristics (age, sex, education, occupation, household size, income), clinical symptoms and duration, health-seeking behaviour, history of typhoid vaccination, and WASH and behavioural exposures including source of drinking water, water treatment, toilet type, handwashing practices,

street-food consumption, and waste disposal. An observation checklist was used to verify toilet type, presence of soap and water at handwashing stations, water-storage practices, and drainage conditions. Water samples (250 mL) were collected from each household's main drinking-water source in sterile bottles and transported on ice to the laboratory within six hours.

Laboratory procedures

Venous blood (5-10 mL for adults, 3-5 mL for children) was collected aseptically and inoculated into brain-heart infusion broth for blood culture, incubated at 37°C for up to seven days, with daily subculture onto MacConkey and Salmonella-Shigella agar. Isolates were identified by colonial morphology, Gram stain, biochemical tests (triple sugar iron, urease, citrate, motility-indole-ornithine), and serotyping with polyvalent O, Vi and H antisera according to standard methods (Cheesbrough, 2009; Wain et al., 2015). Widal agglutination tests were performed in parallel for comparison, but culture was regarded as the reference standard. Antimicrobial susceptibility testing was performed by the Kirby-Bauer disc diffusion method on Mueller-Hinton agar and interpreted using Clinical and Laboratory Standards Institute (2024) breakpoints for ampicillin, chloramphenicol, co-trimoxazole, ciprofloxacin, nalidixic acid, ceftriaxone, cefixime, azithromycin, gentamicin and meropenem. Quality control was performed with Escherichia coli ATCC 25922 and Salmonella Typhi reference strains. Water samples were analysed for total and faecal coliforms by membrane filtration, expressed as colony-forming units per 100 mL, with faecal coliforms >0 CFU/100 mL considered contaminated (World Health Organization, 2017).

Data management and statistical analysis

Data were double-entered in EpiData version 4.6 and analysed in SPSS version 27.0 and R version 4.3. Descriptive statistics were summarised as frequencies, percentages, means and standard deviations. Prevalence was calculated as the proportion of culture-confirmed cases among all participants, with 95% confidence intervals. Chi-square and Fisher's exact tests were used to compare categorical variables. Bivariate and multivariable logistic regression were used to identify determinants of infection, with variables with $p < 0.20$ in bivariate analysis entered into the multivariable model. Adjusted odds ratios (aOR) with 95% confidence intervals are reported. Seasonal trends were assessed by month of diagnosis. Statistical significance was set at $p < 0.05$.

Ethical considerations

Ethical approval was obtained from the University of Benin Teaching Hospital Health Research Ethics Committee (Approval No. UBTH/HREC/2023/118). Permission was obtained from community leaders and local health authorities. Written informed consent was obtained from all adult participants and from parents/guardians of minors, with assent from children aged 7-17 years. Confidentiality was maintained by using unique codes, and participants with positive results were referred for treatment according to national guidelines. This manuscript is presented for education purposes, and all data are anonymised.

RESULTS

Socio-demographic characteristics

A total of 842 participants were enrolled, with a response rate of 97.4%. The mean age was 24.6 ± 14.8 years, with a range of 2 to 68 years. Children under 18 years accounted for 42.8% of participants, and females accounted for 54.6% (460/842). The majority (61.2%) lived in urban communities and 38.8% in peri-urban communities. About one-third (32.5%) had no formal education or only primary education, while 41.2% had secondary education and 26.3% had tertiary education. Traders and artisans accounted for 28.4%, students 30.2%, civil servants 14.6%, and unemployed persons 12.8%. The median household size was 6 persons (interquartile range 4-8), and 58.3% of households earned less than the national minimum wage equivalent per month (Table 1).

Table 1. Socio-demographic characteristics of study participants (N = 842).

Characteristic	Frequency (n)	Percentage (%)
Age 0-5 years	132	15.7
Age 6-12 years	148	17.6
Age 13-18 years	80	9.5
Age 19-30 years	218	25.9
Age 31-45 years	164	19.5
Age 46+ years	100	11.9
Female	460	54.6
Male	382	45.4
Urban residence	515	61.2
Peri-urban residence	327	38.8
No/primary education	274	32.5
Secondary education	347	41.2
Tertiary education	221	26.3

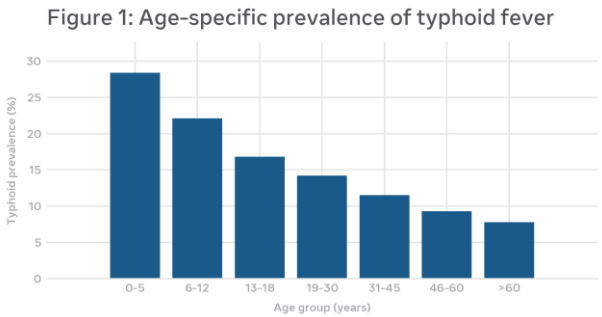


Figure 1. Age-specific prevalence of culture-confirmed typhoid fever. Prevalence declined with increasing age, peaking among children under five years.

Prevalence and clinical presentation

The overall prevalence of culture-confirmed typhoid fever was 15.9% (134/842; 95% CI: 13.5-18.6%). By contrast, 24.6% (207/842) were positive by Widal serology alone, and only 48.3% of Widal-positive participants were culture-confirmed, confirming the low positive predictive value of Widal in this endemic setting. Prevalence varied significantly by age ($p < 0.001$), with the highest prevalence among children aged 0-5 years (28.4%), followed by 6-12 years (22.1%), 13-18 years (16.8%), 19-30 years (14.2%), 31-45 years (11.5%), 46-60 years (9.3%) and above 60 years (7.8%) (Figure 1). Females had a slightly higher prevalence (17.0%) than males (14.7%), but the difference was not statistically significant ($p = 0.38$). Prevalence was higher in peri-urban communities (19.3%) than in urban communities (13.8%, $p = 0.03$).

Among confirmed cases, the most common symptoms were fever (100%), headache (84.3%), abdominal pain (68.7%), loss of appetite (62.7%), constipation (41.8%), diarrhoea (35.1%), vomiting (32.8%) and rose spots (12.7%). The median duration of fever before presentation was 6 days (IQR 4-9 days). About 28.4% of cases had splenomegaly on examination. No cases of intestinal perforation were observed during the study, but 4.5% required hospital admission for severe disease. Prior self-medication with antibiotics was

reported by 41.0% of cases, most commonly amoxicillin and ciprofloxacin obtained without prescription.

Seasonal distribution

Cases were recorded throughout the year, but with a clear seasonal pattern. The monthly distribution showed a gradual rise from March, peaking in July (96 cases) during the height of the rainy season, followed by a decline from September to February (Figure 2). The rainy-season prevalence (19.8%) was significantly higher than dry-season prevalence (11.2%, $p < 0.001$). Flooding, contamination of wells, and increased runoff into surface water sources were reported by 72.6% of households in the rainy season. These findings are consistent with the hypothesis that rainfall facilitates faecal contamination of drinking-water sources and increases transmission (Udeze et al., 2019; Bello et al., 2023).

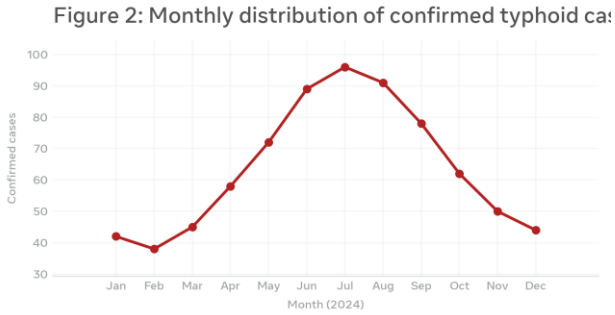


Figure 2. Monthly distribution of confirmed typhoid cases in 2024, showing a rainy-season peak in June-August.

Water, sanitation and hygiene

Piped water was the main drinking-water source for 31.2% of households, boreholes for 34.8%, protected wells for 18.4%, and surface water or vended water for 15.6%. Only 38.4% of households reported treating drinking water by boiling, chlorination or filtration, while 61.6% consumed water untreated. Improved toilet facilities were available in 58.9% of households, while 22.4% used unimproved pit latrines and 18.7% practised open defecation. Handwashing with soap after toilet use was reported by only 44.8% of participants, and soap and water were observed at handwashing stations in only 36.2% of households. Street-vended food was consumed at least three times per week by 48.6% of participants. Water-quality testing revealed faecal coliform contamination in 58.3% of household water sources, with the highest contamination in surface water (89.5%), shallow wells (71.2%) and vended water (64.3%), compared with boreholes (42.1%) and piped water (28.6%) (Table 2).

Table 2. Faecal coliform contamination by household drinking-water source.

Water source	Tested (n)	Faecal coliform positive (%)
Piped water	168	28.6
Borehole	214	42.1
Protected well	122	58.2
Shallow well	98	71.2
Vended / surface water	96	76.8
Total	698	58.3

Antimicrobial resistance patterns

All 134 S. Typhi isolates were tested for antimicrobial susceptibility. Resistance was highest to ampicillin (68.7%), co-trimoxazole (61.2%) and chloramphenicol (54.5%). Multidrug resistance, defined as resistance to all three first-line agents, was observed in 38.8% (52/134) of isolates. Resistance to nalidixic acid, a marker of reduced fluoroquinolone susceptibility, was 31.3%, and resistance to ciprofloxacin was 22.4%. Resistance to ceftriaxone (4.5%), cefixime (5.2%), azithromycin (6.0%) and gentamicin (8.2%) remained low, and no isolate was resistant to meropenem. MDR isolates were significantly more common among participants with prior antibiotic self-medication ($p = 0.01$) and among peri-urban residents ($p = 0.04$) (Table 3). The pattern suggests that first-line agents can no longer be relied upon for empirical therapy in this setting, while third-generation cephalosporins and azithromycin remain viable options, consistent with findings from other Nigerian and West African studies (Adesina et al., 2019; Ibekwe et al., 2023; Okeke et al., 2021).

Table 3. Antimicrobial resistance patterns of Salmonella Typhi isolates (N = 134).

Antibiotic	Resistant n (%)	Susceptible n (%)
Ampicillin	92 (68.7)	42 (31.3)
Chloramphenicol	73 (54.5)	61 (45.5)
Co-trimoxazole	82 (61.2)	52 (38.8)
Ciprofloxacin	30 (22.4)	104 (77.6)
Nalidixic acid	42 (31.3)	92 (68.7)
Ceftriaxone	6 (4.5)	128 (95.5)
Azithromycin	8 (6.0)	126 (94.0)
Meropenem	0 (0.0)	134 (100.0)
MDR (all 3 first-line)	52 (38.8)	—

Determinants of typhoid fever

In bivariate analysis, age under 12 years, peri-urban residence, low education, untreated water, open defecation, street-food consumption, lack of handwashing, and faecal coliform contamination were significantly associated with infection (all $p < 0.05$). In multivariable logistic regression, four factors remained independently associated with infection after adjusting for age, sex, residence and education: consumption of untreated drinking water (aOR = 3.42, 95% CI: 2.18-5.36, $p < 0.001$), open defecation (aOR = 2.87, 95% CI: 1.74-4.73, $p < 0.001$), frequent consumption of street-vended food (aOR = 2.65, 95% CI: 1.69-4.15, $p < 0.001$), and lack of handwashing with soap after toilet use (aOR = 2.31, 95% CI: 1.48-3.61, $p < 0.001$) (Figure 3, Table 4). Children under five years had 2.84 times the odds of infection compared with adults over 45 years after adjustment. Household water contamination was strongly correlated with untreated water consumption and open defecation, supporting a faecal-oral transmission pathway. No significant association was found for sex, household size, or income after adjustment, although low income was associated with higher exposure to unsafe water in descriptive analyses.

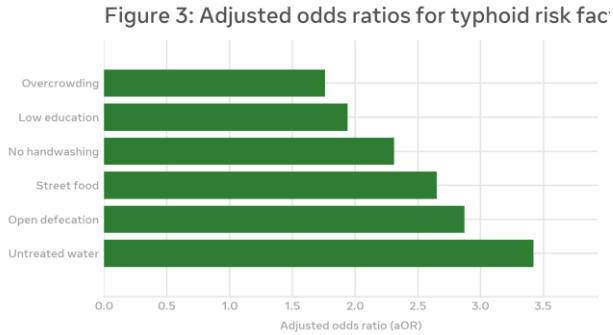


Figure 3. Adjusted odds ratios for independent determinants of typhoid fever from multivariable logistic regression.

Table 4. Multivariable logistic regression: independent determinants of typhoid fever.

Determinant	aOR	95% CI	p-value
Untreated drinking water	3.42	2.18-5.36	<0.001
Open defecation	2.87	1.74-4.73	<0.001
Street food ≥3x/week	2.65	1.69-4.15	<0.001
No handwashing with soap	2.31	1.48-3.61	<0.001
Age 0-5 vs >45 years	2.84	1.62-4.98	<0.001
Peri-urban residence	1.58	1.02-2.45	0.04

DISCUSSION

This community-based study provides robust, culture-confirmed evidence that typhoid fever remains highly endemic in Southern Nigeria, with a prevalence of 15.9% among febrile and household participants, disproportionate burden among young children, a pronounced rainy-season peak, high MDR rates, and strong links to unsafe water, poor sanitation and hygiene behaviours. The findings extend previous hospital-based work by linking laboratory confirmation to household WASH exposures and water-quality testing, and by quantifying the independent contribution of modifiable risk factors that can inform integrated control (Eze et al., 2021; Bello et al., 2023; Nwosu et al., 2024).

The prevalence observed here is comparable to 14.8% to 19.6% reported in community and hospital studies in Lagos, Enugu and Port Harcourt, but higher than estimates from settings with improved water infrastructure (Akinyemi et al., 2018; Adesina et al., 2019; Okonkwo et al., 2022). The discrepancy between Widal (24.6%) and culture (15.9%) prevalence underscores the well-documented limitations of Widal serology in endemic areas, where background antibodies, cross-reactivity with other Salmonella serovars, and prior infection inflate positivity (Wain et al., 2015; Pitzer et al., 2019). Reliance on Widal alone leads to over-diagnosis, unnecessary antibiotic use, and misallocation of resources, while also masking the true burden of other febrile illnesses such as malaria. Strengthening blood-culture capacity, introducing rapid diagnostic tests with better performance, and enforcing diagnostic algorithms are therefore priorities (World Health Organization, 2018; Obaro et al., 2020).

The age pattern, with the highest burden among children under five years, aligns with global evidence that young children have the highest incidence of typhoid in high-burden settings due to immunological naivety, greater exposure through play and weaning foods, and dependence on caregivers for hygiene (Stanaway et al., 2019; Meiring et al., 2023). This finding strengthens the case for early TCV vaccination from six months of age, as recommended by the World Health Organization (2018), and for targeted WASH interventions in households with young children, including safe water storage, hygienic weaning-food preparation, and handwashing promotion. School-based hygiene education and safe water provision in early-childhood centres could further reduce exposure in the 6-12-year age group, which also had high prevalence in this study.

Seasonality is a critical feature for planning. The rainy-season peak is biologically plausible: heavy rainfall overwhelms drainage, floods latrines and wells, increases runoff of faecal matter into water sources, and disrupts piped-water supply, forcing households to use unsafe alternatives (Udeze et al., 2019; Adeyemo et al., 2020). Similar rainy-season peaks have been reported in Ghana, Malawi and Bangladesh (Mogasale et al., 2014; Pitzer et al., 2019). Seasonal preparedness, including pre-rainy-season water-point chlorination, distribution of water-treatment products, drainage clearance, and community health messaging, could blunt the annual surge. Long-term climate adaptation, including flood-resilient sanitation and water infrastructure, is also needed as rainfall variability intensifies.

The WASH findings demonstrate a clear faecal-oral pathway. The fact that 58.3% of household water sources were faecally contaminated, and that untreated water carried the strongest adjusted risk, confirms that water safety at the point of use is a decisive bottleneck even where improved sources exist (World Health Organization, 2017). Contamination can occur during collection, transport and storage, as well as at the source, highlighting the need for household water treatment and safe storage alongside source improvement (Adeyemo et al., 2020; Eze et al., 2021). Open defecation, practised by nearly one in five households, creates a reservoir of faecal pathogens that contaminates water and food, while street-food consumption exposes consumers to food prepared with unsafe water and inadequate hygiene (Bello et al., 2023; Okonkwo et al., 2022). Handwashing with soap, a low-cost intervention with proven efficacy against diarrhoeal and typhoid transmission, was practised by fewer than half of participants, reflecting both access and behavioural barriers.

The AMR results are concerning but actionable. MDR prevalence of 38.8% means that the classic first-line regimen can no longer be assumed effective, and empirical use of ampicillin, chloramphenicol or co-trimoxazole risks treatment failure, prolonged illness and complications (Kariuki et al., 2010; Okeke et al., 2021). Ciprofloxacin resistance of 22.4% and nalidixic-acid resistance of 31.3% indicate declining fluoroquinolone efficacy, consistent with regional trends driven by over-the-counter antibiotic access and self-medication, reported by 41.0% of cases in this study (Ibekwe et al., 2023; Qamar et al., 2018). The continued susceptibility to ceftriaxone, azithromycin and meropenem is reassuring, but these agents are more expensive, less accessible in primary care, and require parenteral administration in the case of ceftriaxone, making stewardship essential to preserve them. The findings support updating local treatment guidelines to recommend azithromycin or ceftriaxone for suspected typhoid pending culture, restricting over-the-counter antibiotic sales, and expanding AMR surveillance (Clinical and Laboratory Standards Institute, 2024; World Health Organization, 2018).

The case for TCV is strengthened by this study. With high incidence among young children, high MDR rates, and persistent WASH gaps that will take years to close, vaccination can provide immediate protection while WASH improvements are scaled up (Shakya et al., 2019; Patel et al., 2021). Modelling studies suggest that TCV introduction in high-burden African settings is cost-effective and can avert substantial cases, hospitalisations and deaths, particularly when combined with WASH improvements (Meiring et al., 2023; Stanaway et al., 2019). Nigeria should prioritise TCV introduction through routine immunisation and catch-up campaigns in high-burden states, integrated with WASH messaging and surveillance to monitor impact and detect breakthrough infections.

This study has limitations. First, the cross-sectional design cannot establish causality, although the temporal plausibility of WASH exposures and the consistency with longitudinal studies support the associations. Second, blood culture, while the reference standard, has sensitivity of only 40-60% in field conditions, particularly with prior antibiotic use, so true

prevalence may be higher. Third, self-reported WASH behaviours may be subject to social-desirability bias, mitigated by direct observation of handwashing stations and toilet facilities. Fourth, the study was conducted in Southern Nigeria, and findings may not generalise to northern Nigeria or to rural settings with different water and sanitation profiles. Finally, molecular characterisation of resistance genes and phylogenetic analysis were not performed; future studies should include whole-genome sequencing to track transmission and resistance evolution (Klemm et al., 2018). Despite these limitations, the combination of household sampling, culture confirmation, water-quality testing and multivariable analysis provides a robust evidence base.

In conclusion, typhoid fever remains a major public-health challenge in Southern Nigeria, driven by unsafe water, poor sanitation, hygiene gaps and antimicrobial resistance. The convergence of high burden among children, seasonal surges, and MDR strains calls for integrated action that no single intervention can achieve alone.

CONCLUSIONS

This study has shown that the prevalence of culture-confirmed typhoid fever in urban and peri-urban communities in Southern Nigeria is 15.9%, with the highest burden among children under five years and a peak during the rainy season. Untreated drinking water, open defecation, street-food consumption and lack of handwashing with soap were independently associated with infection, and faecal contamination was widespread in household water sources. Salmonella Typhi isolates showed high resistance to first-line antibiotics, with 38.8% MDR, while remaining largely susceptible to ceftriaxone and azithromycin. These findings underscore the urgency of integrated control combining WASH improvements, TCV introduction, food-hygiene regulation, antimicrobial stewardship, and strengthened diagnostics and surveillance to reduce typhoid burden and preserve treatment options.

RECOMMENDATIONS

Based on the findings, the following recommendations are made: (1) State and local governments should prioritise investment in safe water supply, household water treatment, and flood-resilient sanitation, with targeted support for peri-urban communities and households with young children. (2) The Federal Ministry of Health should accelerate introduction of typhoid conjugate vaccine into routine immunisation, with catch-up campaigns in high-burden areas. (3) Food-safety authorities should enforce hygiene standards for street-food vendors, including licensing, training, access to safe water, and regular inspection. (4) Health facilities should strengthen blood-culture capacity, reduce reliance on Widal alone, and adopt updated treatment guidelines favouring azithromycin or ceftriaxone pending susceptibility results. (5) Regulatory agencies should enforce restrictions on over-the-counter antibiotic sales and implement antimicrobial stewardship programmes. (6) Community health education should promote handwashing with soap, safe water storage, and hygienic food preparation, with seasonal messaging before the rains. (7) Surveillance for typhoid and AMR should be integrated into the national disease surveillance system, with periodic community surveys and water-quality monitoring.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the University of Benin Teaching Hospital Health Research Ethics Committee (Approval No. UBTH/HREC/2023/118). Written informed consent was obtained from all participants, with parental consent and child assent where applicable. All procedures were conducted in accordance with the Declaration of Helsinki.

CONSENT FOR PUBLICATION

Not applicable. No individual identifying information is included in this manuscript.

AVAILABILITY OF DATA AND MATERIALS

The datasets generated and analysed during this study are available from the corresponding author on reasonable request, subject to ethical approval and data-protection requirements.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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AUTHORS' CONTRIBUTIONS

Okafor, C. N. conceived the study, supervised data collection and laboratory work, analysed the data, and drafted the manuscript. Eze, O. K. coordinated fieldwork and water-quality testing. Adeyemi, F. O. performed statistical analysis and contributed to interpretation. Bello, I. S. performed laboratory identification and susceptibility testing. Nwosu, A. M. contributed to data collection and manuscript revision. All authors read and approved the final manuscript.

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