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# Contamination of Drinking Water and Typhoid Fever Outbreak in Biu Local Government Area, Borno State

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## Abstract

*The present study examined the relationship between contaminated drinking water sources and typhoid fever incidents in four communities in Biu, Local Government Area of Borno State. These communities are, Burantia, Gur, Gunda and Garubula. The study adopted a cross-sectional, comparative and quantitative survey design.Water samples were collected from boreholes and hand-dug wells while hospital records of typhoid incidents were collected from General Hospital Biu, Borno State. Water samples were tested for physical parameters such as pH, Turbidity, temperature, electrical conductivity, and microbial parameters such as enteric bacterial contamination using Salmonella-Shigella Agar (SSA) and Eosin Methylene Blue (EMB) media. Results showed that physical parameters of water samples were within WHO permissible limit for drinking water. However, bacterial contamination indicators revealed higher levels compared to the 0 Colony Forming Units (CFU) per 100 ml. From the analyzed samples, 13 (54.2%) showed presumptive growth on SSA and 17 (70.8%) showed presumptive growth on EMB, with an overall mean colony count of 83.7 CFU/100ml and 77.5 CFU/100ml for SSA and EMB respectively. Specifically, 50% of borehole samples and 58.3% of well samples were positive for SSA, with corresponding mean colony counts of 54.0 and 109.1 CFU/100ml, respectively. The contamination was more pronounced on EMB agar, where 58.3% of borehole samples and a staggering 83.3% of well samples were positive. On the whole, well water exhibiting a higher rate of contamination than borehole water, with a greater percentage of positive samples on both media (58.3% vs. 50.0% on SSA and 83.3% vs. 58.3% on EMB). The mean colony counts for well water were also higher on SSA (109.1 CFU/100ml) and EMB (81.2 CFU/100ml). Findings also showed that cases of typhoid cases (adults and children) were highest in September (14.9%) corresponding with rainfall peak. Based on these results we concluded that there is systemic microbial and fecal contamination of drinking water sources in the area. On-site sanitation facilities, e.g., pit latrines and unlined wastewater drains, are likely the most common sources of fecal contamination of groundwater in the area. Water abstracted from boreholes and hand-dug wells needs to be treated before use for consumption purposes. More so, efforts should be made to delineate protected areas around groundwater abstraction points to minimize contamination from point sources of pollution.*

**Keywords: Borehole, Hand-dug Well, Physical Parameters, Bacterial Contamination, *Salmonella Typhi.***

## 1. Introduction

Easy accessibility to safe water is an important component in the development of human and public health (Okafor *et al.,* 2024). However, in low-income regions waterborne diseases continue to pose significant challenges as sanitation systems and infrastructure are inadequate (Bose *et al.,* 2024; Okesanya *et al.,* 2024). Nigeria is among the countries that are affected with disease outbreak resulting from poor water treatment, improper disposal of waste, and limited access to hygiene facilities. Safe drinking water is very fundamental for human health, unfortunately many communities in Nigeria rely on untreated surface or ground water which is susceptible to contamination by microbes (Irene *et al*., 2025; Olanrewaju *et al.,* 2025). The wide spread of water contamination and poor sanitation in Nigeria has implications for the attainment of Sustainable Development Goal 6 (SDG 6) which aims to ensure the availability and sustainable management of water and sanitation for all by 2030.

Biu Local Government Area (LGA) of Borno State depends heavily on wells, boreholes, streams, and stored water for domestic and drinking purposes (Moses *et al.,* 2023). Water from these sources is vulnerable to microbiological contamination from sources such as septic systems, open defecation, runoff from agricultural farms, and indiscriminate dumping of wastes (Kingimi *et al.,* 2025). The presence of these enteric bacteria in these water sources causes risk of infections among children and households that are disadvantaged (Khabo-Mmekoa *et al.,* 2022). Despite the awareness about this issue, there are few scientific studies on the relationship that exists between contamination of drinking water and occurrence of typhoid in the study area.

Typhoid fever is a systemic bacterial infection caused by *Salmonella enterica* serovar Typhi (*Salmonella* Typhi or *S*. Typhi), and is transmitted via fecally-contaminated food and water and the majority of typhoid fever incidence is known to occur in low- and middle-income countries (LMIC) (Antillón, 2017; Kim, *et al.,* 2017, Kim *et al.,* 2024). Study has shown that while typhoid fever has been largely eliminated in higher-income countries with modern sanitary facilities and safe drinking water, the disease persists as a significant public health issue in many low- and middle-income countries (LMICs) worldwide (Cutler and Miller, 2005, World Health Organization, 2018). According to John *et al*., (2016), this public health issue is compounded by increasing antimicrobial resistance (AMR) and rampant economic loss due to the impact of this disease on productive members of the population. The World Health Organization (WHO) estimates the global burden of typhoid fever at 11–20 million cases per year, resulting in ~140,000 deaths (World Health Organization, 2018). Earlier studies reported somewhat varying estimates: 21 million cases worldwide in 2000 (Crump et al., 2004); 27 million (interquartile range: 18–36 million) cases in 2010 (Buckle *et al.,* 2010); 12 million (95% confidence interval: 10–15 million) or slightly higher in 2010 (Mogasale *et al.,* 2014, Kim *et al.,* 2017); and 17.8 million cases in 2015 but with much wider uncertainty intervals (95% credible interval: 6.9–48.4 million) (Antillón *et al.,* 2017).

In Nigeria, typhoid disease is very common, where it occurs all year round and the country is rated as an endemic zone for typhoid fever (Gbodo *et al.,* 2019). The Global Burden of Disease 2019 study estimated that Nigeria experienced at least: 291,909 typhoid cases (136 cases per 100,000) 3,584 typhoid deaths 273,473 disability-adjusted life-years lost to typhoid (Institute for Health Metrics and Evaluation, 2019). Some of the risk factors associated with the transmittance of the infection is drinking of untreated contaminated water, inadequate toilet facilities, poor personal hygiene, lack of proper education about the disease etc. Typhoid fever is a disease that is preventable, however, its persistence in Biu shows is an indication of limitation in the basic water safety measures, sanitation, and public health management.

Despite increasing cases of typhoid fever reported in health centres within Biu, there is limited empirical evidence that presents the direct connection between the sources of contamination and occurrence of diseases. The lack of baseline scientific data has made

intervention very slow, and insufficient. This situation has made the population vulnerable to disease outbreaks that are recurrent, prolonged illness, economic burden, and mortality that is avoidable. The lack of well-documented information on the assessment of water quality and connection with outbreak of typhoid is a major knowledge gap that requires urgent investigation.

For designing an effective disease control and prevention strategies, it is important to understand the microbial status of water sources for drinking (Saima *et al.,* 2023). The assessment will provide evidences that are needed by policy makers, community leaders and health authorities to implement interventions. Understanding the link between water and disease is crucial for policy formation and strengthening the surveillance of diseases towards reducing morbidity. Therefore, this study investigates the microbiological quality of drinking water in Biu Local Government Area. This study is justified as it will present the extent of contamination in the major water sources consumed in Biu, show the link between water quality to incidence of typhoid to enable early response measures to disease reduction and improvement of public health. Ultimately, the research will support the development of solutions that are sustainable to ensure the access to clean drinking water, reduce the cases of typhoid fever, and enhance the well-being of residents in Biu Local Government Area.

## 2. Materials and Methods

### *2.1. Description of Study Area*

Biu Local Government Area is located in the southern part of Borno State, Nigeria (Fig. 1). Geographically, the study area is situated at latitude 10°36'46.26"N and longitude 12°11'40.49"E, with an elevation of approximately 762 meters above sea level. The terrain is characterized by hills and mountains above 600m, plains below 600m, and volcanic-like cones, particularly around the Miringa area. The Biu Plateau is located between Upper Benue and Chad Basins to the south and north respectively and has an elevation which decreases gradually towards the north and west (Dibal *et al*., 2020). The combination of the Northern Guinea Savannah and Sudan Savannah vegetation are located within the study area. Two seasons i.e. wet and dry seasons characterize the area with a mean temperature and annual rainfall measuring between 33°C and 600 to 700 mm respectively (Bukar *et al.,* 2022). The plateau annual rainfall is about 800mm with wet and dry seasons between May to October and November to April respectively, and the temperature is cooler when compared with lowlands in the area (Dibal *et al.,* 2020).

The study area is inhabited by several communities, such as Balbaya, Buratai, Charenji, Chemi Moda, Dula, Dibirow, Filin Jirgi, Galdimare, Garubula, Garundana, Gunda, Gur, Kabura, Kagul, Kimba, Kirkidum, Kogu, Kunar, Kumari, Kugur, Kwaya Kusar, Maina Hari, Mandafuma, Mandagirau, Mangada, Mbulamel, and Mirnga (Moses *et al.,* 2023). The predominant human activities are subsistence farming, trading, rearing of animals, and some businesses on a small-scale. Dominant crops include maize, sorghum, millet, and groundnut. These activities, coupled with the widespread use of pit latrines and open defecation, increase the risk of surface and groundwater contamination particularly during the rainy season when runoff carries fecal matter and other pollutants into water sources.

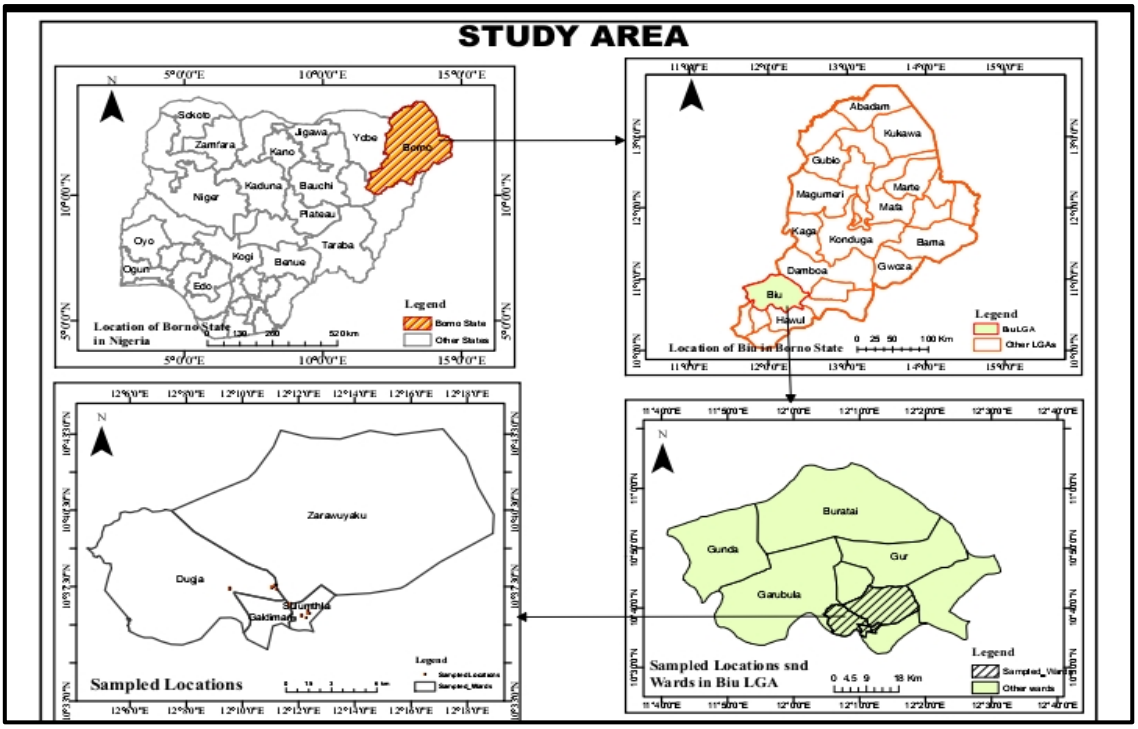



Figure 1: Map of the Study Area
Source: Department of Urban and Regional Planning, Nigerian Army University Biu.
Modified from Administrative map of Biu, Borno State, Nigeria.

### *2.2. Research Design*

The study adopted a cross-sectional, comparative and quantitative survey design. It is cross-sectional as all water samples were collected at a single point in time to assess their current status. It is comparative because it directly compares the contamination levels of two distinct groups (boreholes and hand-dug wells).

#### *2.2.1. Types and Sources of Data*

***Primary Data:*** Water samples were collected from boreholes and hand-dug wells across the selected rural communities in Biu LGA (Buratai, Gur, Gunda and Garubula communities) (Fig.1). Data was collected only for rainy season due to the effects of storm water runoff on contaminant load transportation. Data collection was carried out in the month of July between the hours of 7am-8am daily at each collection point. This time was chosen to allow for accessibility into residential areas. Daily water sample collection is justified by the need to ensure public health safety and detect contaminants in real-time, especially as these water sources are used on daily basis.

#### 2.2.2. Procedure for water sample Collection

Water samples were collected using sterile plastic bottles. Prior to collection, each bottle was rinsed three times with waterom the source to ensure that the sample collected was representative. A total of 24 water samples were collected for analysis which comprised 12

water samples from borehole and 12 water sample hand-dug wells. These include twelve (12) borehole samples from Buratai, Gur, Gunda and Garubula communities, and twelve (12) hand-dug wells samples from from Buratai, Gur, Gunda and Garubula communities. To ensure fair representation, these 24 samples were taken in a proportionate manner from different communities within LGA. The sample code, location, and date of collection were well labeled with the plastic bottles. After sampling, bottles were transported to the laboratory for bacteriological analysis to investigate the bacteriological quality of the water samples using standard techniques.

### *2.2.3. Laboratory Analysis*

Eosin Methylene Blue (EMB) agar and Salmonella–Shigella Agar (SSA) were prepared in the laboratory according to the manufacturer's specifications. The quantity of agar in each medium was determined using the formula:

$$Grams\ of\ medium = volume\ of\ plate\ x\ number\ of\ plates\ x\ number\ of\ dissolving\ samples$$

For EMB agar:

= 20 ml × 24 × 37.5 / 1000 = 480 × 37.5/1000= 18g

Thus, 18 g of EMB was dissolved in 480 mL of distilled water.

For SSA agar:

= 20 ml × 24 × 63g / 1000 = 480×63g/1000= 30.24g

Therefore, 30.24 g of SSA was dissolved in 480 mL of distilled water.

Both SSA and EMB were thoroughly mixed and complete dissolution was ensured by boiling, after which it was sterilized by autoclaving for 15 minutes at 121°C. The media was allowed to cool after sterilization to about 45–50°C, after which it was aseptically poured into sterile petri dishes and left to solidify. A sterile micropipette was used to inoculate 0.1 mL of each water sample onto EMB and SSA plates and even distribution on agar was ensured using a sterile glass spreader. The inoculated EMB and SSA plates were incubated at 35°C for 18–24 and 24–48 hours respectively. Plates were then examined after the required duration for bacterial growth and metallic green sheen colonies on EMB agar were presumptively identified as *Escherichia-coli* while colorless colonies with or without black centers on SSA agar were indicative of Salmonella or Shigella species. A digital colony counter was used for colony counts and recorded in Colony Forming Units (CFU) per 100 mL of water using the formula:

$$CFU/100mL = \frac{Number\ of\ colonies\ x\ 100}{sample\ plated\ (mL)}$$

For instance, if 45 colonies were counted on an EMB plate inoculated with 0.1 mL of water sample, the CFU/100 mL was calculated as:

$$\frac{45x1x100}{0.1} = 45{,}000\ CFU/100mL$$

All culture materials were sterilized after use by autoclaving before safe disposal in accordance with laboratory biosafety guidelines.

**Secondary Data:** The background information about water borne diseases in the LGA were sourced existing records in hospitals and relevant literature such as published materials, textbooks, journal articles, government reports, and data from the National Population Commission (NPC, 2006). Institutions that were relevant within the study area were consulted for information on the study area, the use of groundwater, and standards for water quality.

### *2.2.4. Sampling Frame (Sampling Population)*

The sampling frame for this study comprised all available water sources used for domestic purposes within the selected rural communities of Biu Local Government Area (LGA), Borno State. Specifically, the population of interest included hand-dug wells and boreholes which serve as the primary sources of drinking water in the area. These sources were considered because they are the most widely accessed by households and are therefore most relevant in assessing the bacteriological quality of water consumed by the inhabitants.

### *2.2.5. Ethical Considerations*

#### *2.2.5.1. Institutional and gatekeeper Consent*

- Community Leaders: Gaining verbal assent from village heads and water point custodians in the selected communities.
- General Hospital Biu: Securing formal authorization from the Chief Medical Director (or equivalent) to access and utilize aggregate (non-identifiable) secondary data on typhoid fever cases.

#### *2.2.5.2. Confidentiality of secondary data source.*

Hospital Records: Secondary data on typhoid incidence were obtained only in aggregate, summary form (e.g., total monthly cases). No patient names, addresses, or personal medical information were accessed, ensuring the anonymity of individuals.

## 3. Results and Discussion

### *3.1. Results of Physicochemical parameters*

The descriptive statistics for each physicochemical parameter compared to WHO (2017) guideline values is presented in Table 1. pH values of the water samples ranged from 6.89 to 7.67, which fall within the World Health Organization's recommended range of 6.5 to 8.5 (WHO, 2017). This suggests that the water is neither too acidic nor too alkaline and is suitable for human consumption from a pH perspective. The pH recorded for borehole water (7.42) was slightly higher than that of well water (7.37), though both measured values were within acceptable limits by WHO (2017). Oladiran *et al*., (2020) and Idris *et al*., (2024) reported

similar values for borehole and well water as observed during this study. Highest mean turbidity value was measured in borehole water with 1.09 NTU and values ranged between 0.1 to 2.9 NTU. All turbidity values recorded were below the maximum permissible limit of 5 NTU (WHO, 2017) and was similarly observed by Mshelia and Mbaya (2024) in Kano Metropolis, where the turbidity values measured differed across different sources of water but were within acceptable health limits. The temperature values were consistent (24.8°C) from both water sources and indicates the aquifer is thermally stable. There are no guidelines set by World Health Organization for temperature, however the consistency in measured values from both sources indicates stability and the minimal influence of variations in surface temperatures. This was similarly reported by Mshelia (2023) who studied the temperature variations in ground water during the wet and dry seasons in Kano. EC values ranged from 0.348 to 1.95 mS/cm, with higher values recorded in well water (0.99 mS/cm). This indicates an increased concentration of ion and dissolution of minerals from surrounding geological formations or anthropogenic input into the well. Such were reported by Idris *et al*. (2024) and Hassan and Sada (2024) who observed similar patterns in EC in well water, and elevated metal ion concentrations in groundwater in Nasarawa Area, Kano respectively. Mshelia and Mbaya (2024) reported that the electrical conductivity and total dissolved solids (TDS) exceeded acceptable levels in many boreholes water samples across Kano state. This reflected that water quality of ground water can be influence by both natural and anthropogenic factors. The physicochemical quality of both borehole and well water are within the standards of WHO for drinking water, with pH and turbidity within acceptable limits. These results highlight the need for continued surveillance, a comprehensive evaluation of the bacteriological quality to determine the true potability and health risks in the study area.

**Table 1: Mean Results of Physicochemical Parameters of Water Samples.**

| Parameter | Water Source | Mean | Median | Min | Max | WHO (2017) Guideline |
|---|---|---|---|---|---|---|
| pH | Borehole | 7.42 | 7.46 | 7.15 | 7.57 | 6.5 - 8.5 |
| | Well | 7.37 | 7.44 | 6.89 | 7.67 | 6.5 - 8.5 |
| Turbidity (NTU) | Borehole | 1.09 | 0.90 | 0.1 | 2.6 | <5 |
| | Well | 0.88 | 0.65 | 0.1 | 2.9 | <5 |
| Temperature (°C) | Borehole | 24.8 | 24.8 | 24.8 | 24.8 | No guideline |
| | Well | 24.8 | 24.8 | 24.8 | 24.8 | No guideline |
| Electrical Conductivity (µS/cm) | Borehole | 0.82 | 0.78 | 0.348 | 1.21 | No guideline |
| | Well | 0.99 | 0.69 | 0.45 | 1.95 | No guideline |

pH= Hydrogen ion concentration, NTU= Nephelometric turbidity unit, $^{o}$C = degree Celsius and µS/cm = Micro siemens per centimeter

### *3.2. Results of Bacteriological Quality of Borehole and Well Water*

Enteric bacterial contamination in the water samples were analyzed using Salmonella-Shigella Agar (SSA) and Eosin Methylene Blue (EMB) media and presented in Table 2. It was observed from the results that there was a widespread of bacteriological contamination in both water sources when compared with 0 Colony Forming Units (CFU) per 100 ml as recommended by WHO standard (2017) for safe drinking water. From the analyzed samples, 13 (54.2%) showed presumptive growth on SSA and 17 (70.8%) showed presumptive growth on EMB, with an overall mean colony count of 83.7 CFU/100ml and 77.5 CFU/100ml for SSA and EMB respectively. Specifically, 50% of borehole samples and 58.3% of well samples were positive for SSA, with corresponding mean colony counts of 54.0 and 109.1 CFU/100ml, respectively. The contamination was more pronounced on EMB agar, where 58.3% of borehole samples and a staggering 83.3% of well samples were positive. The maximum observed contamination reached 257 CFU/100ml in well water. The widespread bacterial growth observed on EMB and SSA media is a definitive indicator of fecal and enteric contamination, constituting a severe public health risk. The EMB medium specifically screens for Total and Fecal Coliforms like *Escherichia coli*, which is synonymous to fecal pollution. The finding that 70.8% of all samples demonstrated presumptive enteric growth clearly establishes the need for proper water treatment in the community as it is not safe for consumption. Furthermore, the contamination levels between the two water sources were revealed with well water exhibiting a higher rate of contamination than borehole water, with a greater percentage of positive samples on both media (58.3% vs. 50.0% on SSA and 83.3% vs. 58.3% on EMB). The mean colony counts for well water were also higher on SSA (109.1 CFU/100ml) and EMB (81.2 CFU/100ml), which is in consonance with published reports that those shallow, unconfined wells are more vulnerable to contamination from surface runoff and proximity to poorly managed sanitation systems than deeper, protected boreholes (Adewoye *et al.,* 2021). This poor bacteriological quality directly contrasts with the physicochemical results in Table 1 as it confirms the physicochemical disconnection when the water appears safe chemically but is highly dangerous microbially (Adewoye *et al.,* 2021). The identified presence Salmonella (presumptive growth on SSA), indicates the prevalence of typhoid fever in the study area. The presence of fecal coliforms and *E. coli* aligns with WHO guidelines that emphasize microbial indicators as key determinants of water safety (WHO, 2017).

**Table 2: Bacteriological Quality of Borehole and Well Water Samples**

| Source | No. of samples | SSA positives (%) | SSA mean Colonies (CFU/100ml) | SSA Range CFU/100ml) | EMB positives (%) | EMB mean Colonies (CFU/100 ml) | EMB Range (CFU/100 ml) |
|---|---|---|---|---|---|---|---|
| Borehole | 12 | 6(50.0) | 54.0 | 14–136 | 7(58.3) | 72.3 | 14–203 |
| Well | 12 | 7(58.3) | 109.1 | 39–206 | 10(83.3) | 81.2 | 37–257 |
| Total | 24 | 13(54.2) | 83.7 | 14–206 | 17(70.8) | 77.5 | 14–257 |

SSA=Salmonella-Shigella Agar, CFU = Colony Forming Unit, EMB = Eosin Methylene Blue Agar

### *3.3. Comparison of Contamination Levels*

The bacterial colony counts (CFU/100 ml) of the two sources of water were compared using Mann-Whitney U test and presented in Table 3. The test confirmed the statistically significant differences of $p = 0.046$ with a higher median contamination of well water samples when compared with borehole water on both the SSA and EMB media. The significance indicates that the differences between both water sources are unlikely to have occurred by chance, thereby providing strong evidence of higher contamination in well water than borehole water in the study area. water sources from well also had a higher percentage of positive samples and higher colony counts. These finding corroborates previous studies who reported the increased vulnerability of shallow wells due to poor construction, inadequate protection, and exposure to surface runoff. Although boreholes were safer but not free from contamination, presented a possible risk from maintenance issues, casing failures, or contamination during collection. Overall, the results presented the urgent need for improved protection and treatment of well water, as well as continuous monitoring of borehole water quality to safeguard public health.

Table 3 Mann-Whitney U Test Results for Comparison of Contamination Levels

| **Parameter** | **Borehole Median (CFU/100 ml)** | **Well Median (CFU/100 ml)** | **U Statistic** | **p-value** | **Significant** |
|---|---|---|---|---|---|
| SSA | 7.0 | 61.0 | 32 | 0.046 | Significant |
| EMB | 19.0 | 47.0 | 30 | 0.046 | Significant |
| Sample Size (n) | 12 | 12 | | | |

### *3.4. Water Contamination and Typhoid Cases*

Due to the unavailability of disaggregated, community-specific typhoid case data from local health authorities, a direct statistical correlation between community water quality and case count could not be performed. However, the overall prevalence data is presented in Table 4. The total number of reported typhoid cases (adults and children) collected from the General Hospital in Biu Local Government Area (LGA) for the study year (2024) was 11,639 with the highest case in September (14.9%) and the least in June (2.6%). It was observed that very high incidents of typhoid cases were at the peak of rainy season. The simultaneous presence of presumptive enteric pathogens (SSA growth) in water samples and a high incidence of typhoid fever in rainy season across the study area strongly suggest a causal relationship. Typhoid fever is infections caused by Salmonella enterica subspecies serovars Typhi (Bhan *et al.,* 2005; Liu *et al.,* 2025), which are gram-negative bacteria in the Salmonella genus and are mainly transmitted through ingestion of contaminated food or water and entry into open wounds (Kirchhelle *et al.,* 2019). Hence, poor sanitation, lack of access to clean water, and poor toilet facilities are major risk factor for the disease (Mulu *et al.,* 2021).

Table 4. Monthly Distribution of Reported Typhoid Cases in General hospital Biu LGA (2024)

| S/N | Months | No. of Typhoid fever cases | Percentage cases |
|---|---|---|---|
| 1. | January | 546 | 4.7 |
| 2. | February | 1,000 | 8.6 |
| 3. | March | 840 | 7.2 |
| 4. | April | 886 | 7.6 |
| 5. | May | 1,350 | 11.6 |
| 6. | June | 298 | 2.6 |
| 7. | July | 1,291 | 11.1 |
| 8. | August | 1,286 | 11.0 |
| 9. | September | 1,735 | 14.9 |
| 10. | October | 400 | 3.4 |
| 11. | November | 1,487 | 12.8 |
| 12. | December | 520 | 4.5 |
| | **Total** | **11,639** | **100** |

***Source: General Hospital Biu, Secondary Data, 2024.***

The study's finding of widespread bacteriological contamination specifically the growth on SSA (presumptive enteric pathogens) and EMB (fecal contamination) serves as a clear and likely fecal-oral transmission pathway for the disease across the study area. Therefore, the poor bacteriological quality of the water sources is considered a major contributing factor to the substantial reported typhoid burden. The epidemiological context provided by the 11,639 total reported typhoid cases in Biu LGA provides a stark public health justification for the contamination results observed in this study. Across the world, typhoid fever is a life-threatening disease (Enabulele and Awunor, 2026) that poses a public health concern in many parts of the world, especially low and middle-income countries for decades (WHO, 2023). In 2017 for example, a global incidence of 14.3 million was recorded (Stanaway *et al.,* 2019). In the same year, a global case fatality rate of 0.95% was estimated, with higher approximates among people living in lower-income countries such as Nigeria (Stanaway *et al.,* 2019). In another study, Kim et al., (2024) reported that typhoid fever, results in over 1.2 million cases and 29 thousand deaths annually from sub-Saharan Africa. In Nigeria, typhoid fever incidence ranges from 3.9% to 18.6% (Hall *et al.,* 2024), with the highest cases seen among young and middle-aged adults (Ozougwu 2018). Patients usually present sustained fever (39–40 °C) and other symptoms include weakness, stomach pain, headache, diarrhea or constipation, cough, and loss of appetite. Severe forms of illness include illegal perforation, which can lead to death (Kim *et al.,* 2024).

## 4. Conclusion and Recommendations

To potable water is a pre-requisite towards achieving Key sustainable development goals such as good health and Well-being (Goal 3) and clean water and sanitation (Goal 6). Unfortunately, where is this lacking, coupled with poor sanitation, typhoid fever, a disease caused by Salmonella enterica serotype Typhi bacteria, also called Salmonella typhi is imminent and this is particularly true of communities in developing countries such as Nigeria, where open defecation is a common practice and where weak institutional framework to curb the menace of municipal solid waste is weak. Women and children are most vulnerable to

typhoid fever due to life-style and activities that predispose them to contaminated water and food. From our findings the primary domestic water sources (boreholes and hand-dug wells) available to rural communities in the study area, are microbially unsafe for human consumption without adequate treatment, notwithstanding that basic physicochemical quality tests are within permissible limits for drinking water. The concentration levels of microbes in excess WHO standard (0 CFU/100 mL for enteric pathogens) means the water is not potable and hence pose an immediate public health risk. Similarly, the strong evidence of fecal-oral transmission (high EMB growth) coupled with the presence of presumptive enteric pathogens (SSA growth) establishes a scientifically supported link to the high endemic burden of typhoid fever reported in the LGA. Consequently, the failure to protect groundwater sources is a direct driver of waterborne disease in the study area. Based on the findings there is need for Local government Primary Health Care Board to launch a community-wide campaign aimed at promoting and subsidizing point-of-use water treatment methods (e.g., chlorination, boiling, or filtration) for all domestic water, particularly water drawn from wells. Community leaders and the LGA Water, Sanitation and Hygiene (WASH) Departments must enforce stricter sanitary practices, including, mandatory lining and covering of all hand-dug wells. Finally, there is also need for increased efforts to phase out open defecation practices in line with national targets.

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