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Water Quality Assessment and Prevalence of Waterborne Diseases within Chikun Local Government Area, Kaduna State-Nigeria

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Abstract

The health and well-being of individuals in a nation are intrinsically tied to the quality of water available for consumption. Access to high-quality water plays a vital role in supporting proper nutrition, ensuring food security, and preventing waterborne diseases. Therefore, this study was carried out to assess water quality and prevalence of waterborne diseases within Chikun Local Government Area, Kaduna State. A cross-sectional study was conducted between January and June 2024. Data were collected through the administration of questionnaires (400 respondents) and laboratory water analysis. Water samples were analyzed from various sources involving boreholes, rivers and wells through composite sampling and physicochemical and microbiological analyses. Results showed samples from Unguwan Maigero and Tricania possessed varying physicochemical properties, while water from Goningora and Nasarawa revealed high turbidity and heavy metal contamination. Chloride levels were below 500 ppm, and sulphate concentrations ranged from 10.76 to 378.3 ppm. Sodium levels ranged from 19.5 to 110 mg/l, and potassium levels exceeded the permissible limit in some samples. Total coliform counts exceeded national limits (zero coliform per 100ml of water), indicating significant microbial contamination. Parasitological analysis indicated helminths and protozoan contamination in non-borehole sources. Findings showed 41% prevalence of waterborne diseases with diarrhea and typhoid. The study indicates that community awareness, appropriate water treatment, surveillance, and monitoring are essentials for assuring the availability and utilisation of safe and high-quality drinking water in Chikun LGA, Kaduna State.

Keywords: Assessment, Prevalence, Waterborne Diseases, Water Quality

INTRODUCTION

According to Omolade and Zainab (2017), water is a crucial natural resource that plays a vital role in maintaining human existence and sustenance. Water has perpetually existed as an element of the natural world, maintaining its original state when undisturbed in its native habitat; it can become contaminated (Imam *et al.*, 2018). Water from boreholes or taps, wells, dams, rivers, streams, lakes, city water, and precipitation are all potential sources of drinking water (WHO, 2017). In most urban and rural areas of developing countries, there are insufficient facilities for disposing of human waste (UNICEF, 2015). As a result, people defecate haphazardly in nearby regions, including on the ground and rocks, by the edges of streams, at their homes, ponds, and wells, and occasionally even directly into the streams (Azuonwu *et al.*, 2017).

Industrialization has become recognized as a critical component of a country's development through the building of factories (UNIDO, 2013). However, a number of toxins are present in these operations' byproducts, which are released into the environment untreated and contaminate soil, groundwater, and surface waterways (Umeh *et al.*, 2020). Endoparasitic helminth infections are especially vulnerable to either the beneficial or harmful effects of pollution on parasites (Ogeneogaga and Solomon, 2017). Water pollution with pathogenic bacteria, viruses, protozoa, and helminths causes water shortages and restricted access to clean water sources (Sadiya *et al.*, 2018; Onuorah *et al.*, 2017). constitute a serious threat to people's health. The United States Environmental Protection Agency (US-EPA, 2020) claims that inadequate sanitation systems, wastewater reuse, improper management of water supplies, and ignorance and unsanitary conduct among human populations were the main causes of these contaminations. People all around the world are affected by the significant issue of contaminated water, which can result in excruciating agony, crippling illnesses, and even fatalities (WHO & UNICEF, 2019; Pruss-Ustun *et al.*, 2019).

People can contract a number of diseases when they drink or come into contact with water that has been contaminated by particular parasites (CDC, 2018).

In the majority of Nigeria's largest cities, the amount and quality of pipe-borne water are both substandard. As a result, cholera, typhoid, and other waterborne diseases are on the rise (UNICEF, 2019; Okoh et al., 2014). Approximately 80% of typhoid patients at University College Hospital Ibadan are between the ages of 10 and 30, according to data supplied by Karunanidhi *et al.* (2022). In addition to once-rare kidney and cardiovascular conditions like hypertension, typhoid fever is still a significant socioeconomic problem in developing countries. These ailments are all related to tainted water use (Pruss-Ustun *et al.*, 2019). Because water is essential for illness prevention, poor water quality and sanitation have a considerable negative influence on children's health and development (Jaiswal *et al.*, 2022).

UNICEF and WHO reported that in 2017, only 20% of Nigerians used safe, clean water sources on-premises, while 7% relied on open water sources. Only 27% used safe sanitation, and 20% practiced open defecation (OD). Only 42% used basic hygiene facilities on premises (UNICEF & WHO, 2017). In order to identify potential hazards and create countermeasures, this study will examine the physicochemical and microbiological parameters of drinking water sources and the prevalence of waterborne diseases in Chikun LGA of Kaduna State.

MATERIALS AND METHODS

Description of Study Area

Chikun Local Government area of Kaduna State, Nigeria, Figure 1, is situated within the geographical coordinates of latitudes 70°27'15" and 100°28'06" and longitudes 70°27'44" and 100°28'35". Based on the estimates provided by the National Planning Commission (NPC, 2006), the geographical expanse of this region is approximately 4,645 square kilometers, accommodating a populace of 368,250 individuals.

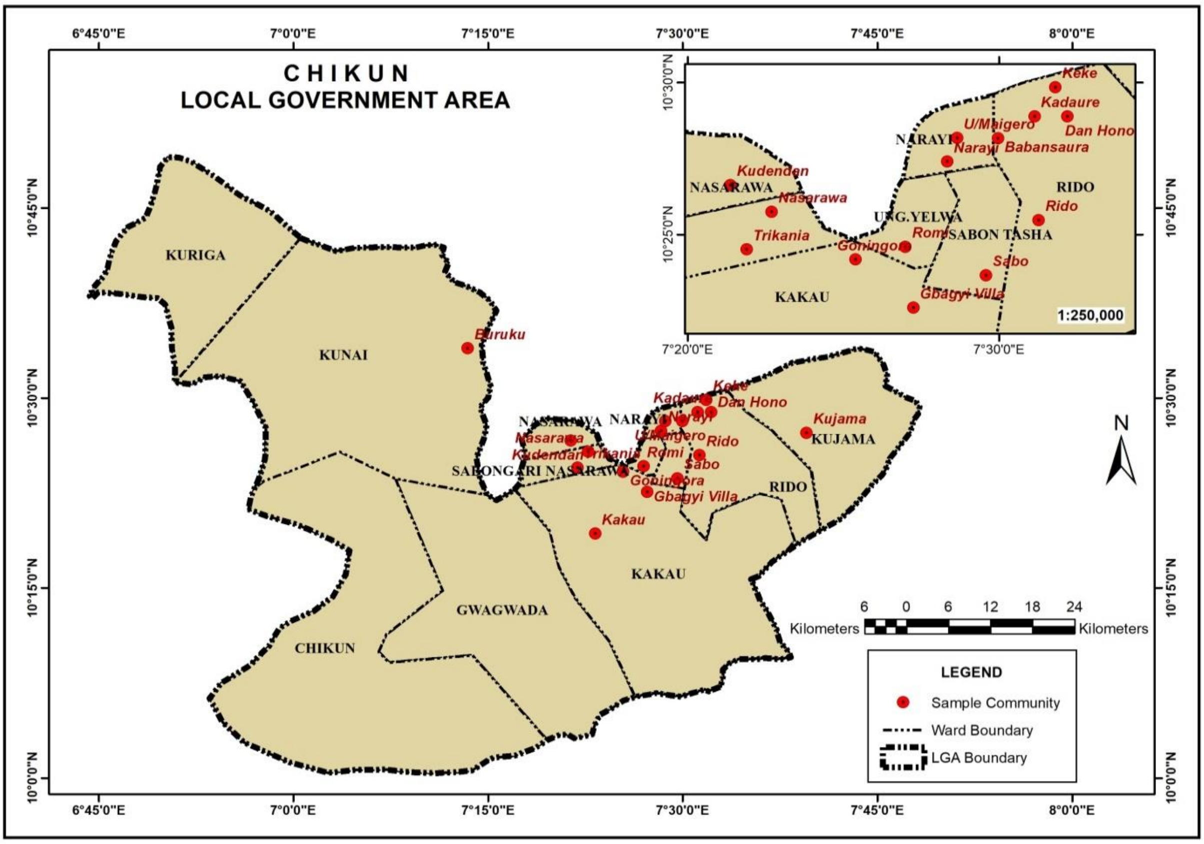

Figure 1: Display of geographical representation of Chikun Local Government Area with various sampling points

Sample and sampling technique of the Respondents: The respondents were selected through a random sampling technique. The sample size was calculated using the formula (Nnodim *et al.* 2021): $n = \frac{z^2pq}{d^2}$

Where n= sample size, z = critical value at 95% confidence level, usually set at 1.96, p= Prevalence (6.5% prevalence was used) (Adabara *et al.*, 2012), q = 1-p and d = Precision, usually 5%.

The sample size was calculated to be 187.9875. For convenience, the sample size of 400 respondents in all the study sites was selected.

Water Sampling

A composite sampling technique was adopted for this study. Seventeen sampling communities were selected based on accessibility and community willingness to participate (Buruku, Babansaura, Kudandan, Kakau, Keke, Narayi, Nasarawa, Romi, Sabo, Tricania, Kadaure, Dan hono, U/maigero, Kujama, Rido, Baggi villa and Goningora). Water samples were collected from the various sources of drinking viz borehole, River, and well into 750mLs wide mouth screw-capped cleaned plastic polyethylene bottles. Water samples were collected in triplicates and placed in an icebox jar to ensure water quality, after which they were thoroughly washed and rinsed.

Physicochemical Analysis

The physical variables of pH, electrical conductivity, and total dissolved solids were measured *in situ* following conventional procedures (Onuorah *et al.,* 2017). Determination of Total Hardness, Turbidity, Dissolved Oxygen Levels, Biochemical Oxygen Demand, Sulphate, Heavy Metal Content, and Chloride was conducted at the Chemistry Laboratory (Multi-user lab) located at A.B.U. Zaria, as adopted from Yusuf *et al.* (2017);

$$\textbf{Total Hardness} = \frac{\textbf{Volume of Titrant}}{\textbf{Volume of Sample}(\textbf{cm}^3)} \textbf{ X 100}$$

The measurement of the turbidity value for the water sample was acquired from the lateral aspect of the tube (Pistocchi *et al.* 2019). For the determination of biochemical oxygen demand (BOD), the level of oxygen depletion was compared to the dissolved oxygen (DO) concentration before the incubation process. According to the study conducted by Umeh *et al.* (2020), sulphate was analyzed spectrophotometrically using a Hanna 83200 Multi-parameter Bench Top Photometer. The elemental samples were introduced into a nebulizer burner assembly, and the corresponding absorbance values were recorded using the Atomic Absorption Spectrophotometer (AAS) at the specific wavelength corresponding to each element being analyzed. The quantity of chloride was determined using the following method (APHA, 2018).

$$\text{Chloride (mg/L)} = \frac{(A-B) \times N \times 35460}{V}$$

Silver Nitrate Solution Overview

- A: mL for sample titration.
- B: mL for blank titration.
- N: Normality of Silver Nitrate solution.
- V: Sample volume in mL (APHA, 2018).

Microbiological analysis

Water samples were examined macroscopically and microscopically. The culture media (Mac Conkey broth, Eosin Methylene Blue (EMB) medium) used were autoclaved at 121°C for 15 minutes. Pipettes, Petri dishes, and other glass utensils were sterilized using a hot air oven at 160°C for one hour. The presumptive Test was carried out by inoculating the water samples into lactose broth tubes, followed by incubation. The production of gas in the Durham tubes indicated the potential presence of Gram-negative coliform bacteria. A confirmatory Test was performed by transferring samples from positive presumptive tests to selective media Eosin Methylene Blue (EMB) agar, which is specific for the identification of *Escherichia coli* and other coliforms. Colonies displaying a metallic sheen on EMB agar suggested fecal contamination. The completed Test was executed by inoculating positive colonies from the confirmatory test into lactose broth again, and further incubating them. The formation of gas, along with a color change in the broth, confirmed the presence of coliform bacteria, including *E. coli* (Rompre *et al.,* 2002). The parasitological analysis was carried out following the method described by Iyagi *et al.* (2018). The procedure involved initial filtration of the water samples to concentrate any potential parasites. Following filtration, the samples were centrifuged to further isolate parasitic elements. The resulting deposit was carefully placed onto a glass slide, covered with a cover slip, and examined under a microscope. The initial examination used the 10x objective lens to focus on the general structure, while the 40x objective lens was employed for the detailed identification of specific parasitic organisms.

Data Collection

A well-structured questionnaire was designed and administered to residents of the communities from where water samples were collected.

Statistical analysis

The data was analyzed using SPSS version 24.0 software, with statistical significance determined by p values less than 0.05, and charts were created using Microsoft Excel.

RESULTS

Table 1 displays the socio-demographic characteristics of the participants. Approximately 43.75% of the participants belong to the age range of 34-45, while just 3.75% fall into the age range of 15-24. The female gender constituted the majority of the subjects, accounting for 73.25%. Out of these subjects, 75.25% were married, and a greater proportion of them had completed Primary/Secondary school. The respondents were engaged in various vocations, with 36.50% being students. Furthermore, 80% of the individuals were indigenous, while the remaining 20% were non-indigenous.

Table 1: Socio-Demographic Profile of Respondents

S/N	Variables		Frequency	Percentage (%)
1.	**Age**			
		15-24	15	3.75
		25-35	130	32.50
		34-45	175	43.75
		45 and above	80	20.00
2.	**Gender**			
		Male	107	26.75
		Female	293	73.25
3.	**Marital statute**			
		Married	301	75.25
		Single	82	20.50
		Divorce	17	4.25
4.	**Educational statutes**			
		Primary/Secondary	241	60.25
		Tertiary	132	33.00
		None	27	6.75
5.	**Occupation**			
		Student	146	36.50
		Artisan	25	6.25
		Farmer	95	23.75
		Civil Servant	134	33.50
6.	**Residential Statute**			
		Indigene	320	80.00
		Non Indigene	80	20.00

WHO and NIS permissible values were compared to the physiochemical parameters of the water sampled. The temperature of the water samples was 30.7°C, slightly exceeding the NIS standard of 30°C but within the WHO range of 25-30°C. The pH value of 7.20 was within the acceptable range of 6.5-8.5 for both standards. However, the conductivity measured at 120.87 µS/cm, while below the WHO limit of 250 µS/cm, lacks a specific NIS standard for comparison. Notably, the concentrations of dissolved solids and certain ions such as calcium (106.4 mg/L), chloride (12.77 ppm), and magnesium (45.82 mg/L) exceeded both WHO and NIS recommended limits, highlighting potential health risks (Table 2).

The results of the biological analyses of the coliform count using the Most Probable Number (Table 3). Results show varying levels of contamination across these locations. For instance, at a 10 ml sample volume, coliform counts ranged from 0 to 5, with the Most Probable Number (MPN) per 100 ml varying from less than 2 to 110. Notably, the MPN/100 ml for areas like Babansaura and Tricania exceeded the NIS limit of 10, indicating significant contamination levels in those water sources.

Table 4 below displays the total coliform risk for River, well, and borehole water samples. It showed that 75% are at high risk and 25% are at very high risk in the analysis of River water, as well as 66.67% at high risk and 33.3% at very high risk in the analysis of well water, and finally, 57.14% are at no risk while 42.86 are at low risk in the analysis of borehole water.

Table 2: Sample Test Compares with World Health Organisation (WHO) and Nigerian Industrial Standard (NIS) Standard

Parameter	WHO Standard	NIS Standard	Average results
Temperature	25-30 °C	30°C	30.7°C
pH	6.5-8.5	6.5-8.5	7.20
Conductivity	250 micros/ cm	NS	120.87 micros/cm
Dissolved oxygen	Less than 75% of saturated	20ppm	23.20ppm
Dissolved solids	concentration	2000ppm	33.70 ppm
Turbidity	NS	NS	0.52ntu
Sulphate	NS	500ppm	115.80 ppm
Chloride	500ppm	500ppm	12.77 ppm
Calcium	600ppm	75mg/l	106.4mg/l
Sodium	30mg/l	100mg/l	59.72mg/l
Magnesium	100mg/l	75mg/l	45.82mg/l
Potassium	50mg/l	10mg/l	31.37mg/l
Ammonia	10mg/l	1.5mg/l	0.040mg/l
Iron	1.5mg/l	0.3mg/l	1.364mg/l
Copper	0.3mg/l	1.5mg/l	1.533mg/l
Cadmium	1.00mg/l	0.005mg/l	0.051mg/l
Arsenic	0.005mg/l	0.05mg/l	0.172mg/l
Mercury	0.05mg/l	0.001mg/l	0.017mg/l
Manganese	0.001mg/l	0.500mg/l	1.060mg/l
Total hardness	0.100mg/l	150mg/l	143.2mg/l
Biological oxygen demand	150-500mg/l NS	NS	25.12

Table 3: Coliform Count for Samples of Water Analysed using Most Probable Number

Sample	10ml	1ml	0.1ml	MPN/100ml
Buruku	5	1	0	30
Babansaura	5	3	1	110
Kudandan	1	0	0	2
Kakau	3	1	1	14
Keke	2	0	0	5
Narayi	0	0	0	<2
Nasarawa	5	2	0	50
Romi	1	0	0	2
Sabo	2	1	0	7
Tricania	0	0	0	< 2
Kadaure	0	0	0	< 2
Dan hono	2	2	0	9
u/maigero	1	2	0	6
Kujama	3	2	1	17
Rido	2	3	0	12
Baggi villa	0	0	0	< 2
Goningora	1	0	0	2
WHO standard	-	-	-	-
NIS standard	-	-	-	10

Table 4. Total Coliform Risk for Rivers, Well, and Bore Hole

Total coliform (cfu/ml)	Risk grade	River (n=4) (%)	Well (n=6) (%)	Borehole (n=7) (%)
0	**A** (No Risk)	100	100	57.14
1-10	**B** (Low risk)	0	66.67	42.86
11-100	**C** (High risk)	75	33.33	0
101- >1000	**D** (Very-high risk)	25	0	0

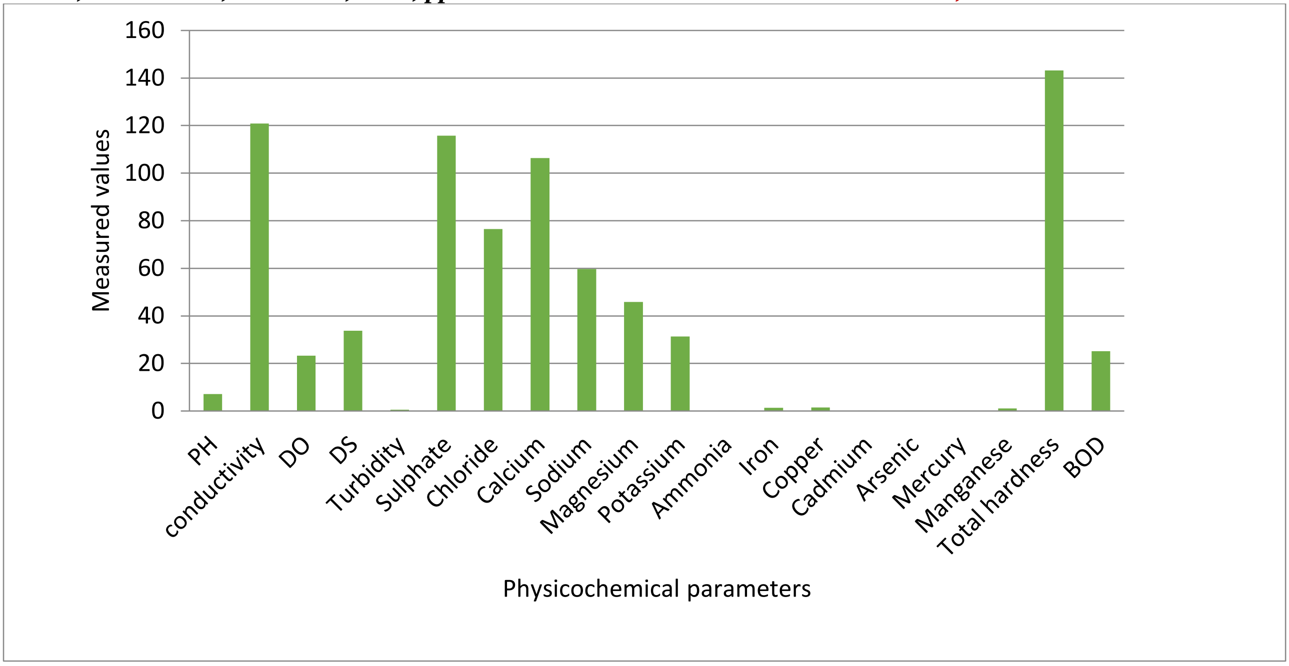

Figure 2: Physicochemical parameters of the water samples

The analysis of water samples from various communities in Chikun LGA revealed varying prevalence of parasitic contamination. *Taenia sp* was detected in 22.73% of the communities, including Buruku, Keke, and Sabo. *Cryptosporidium* was found in 22.73% of the communities, with notable occurrences in Buruku, Babansaura, Kakau, and Kujama. *Entamoeba histolytica* was detected in 18.18% of the communities, with a significant presence in Nasarawa, Kakau, and Kujama. *G. lamblia* had a prevalence of 9.09%, particularly evident in Babansaura and Keke (Figure 3).

Figure 4 displays the incidence rate of waterborne illnesses. Within the past three years, 41% of the participants reported having developed a waterborne illness. The prevalence of diarrhea and typhoid among waterborne diseases was 17.25% and 17.50% respectively. These diseases were primarily encountered in Chikun LGA, as shown in Figure 5.

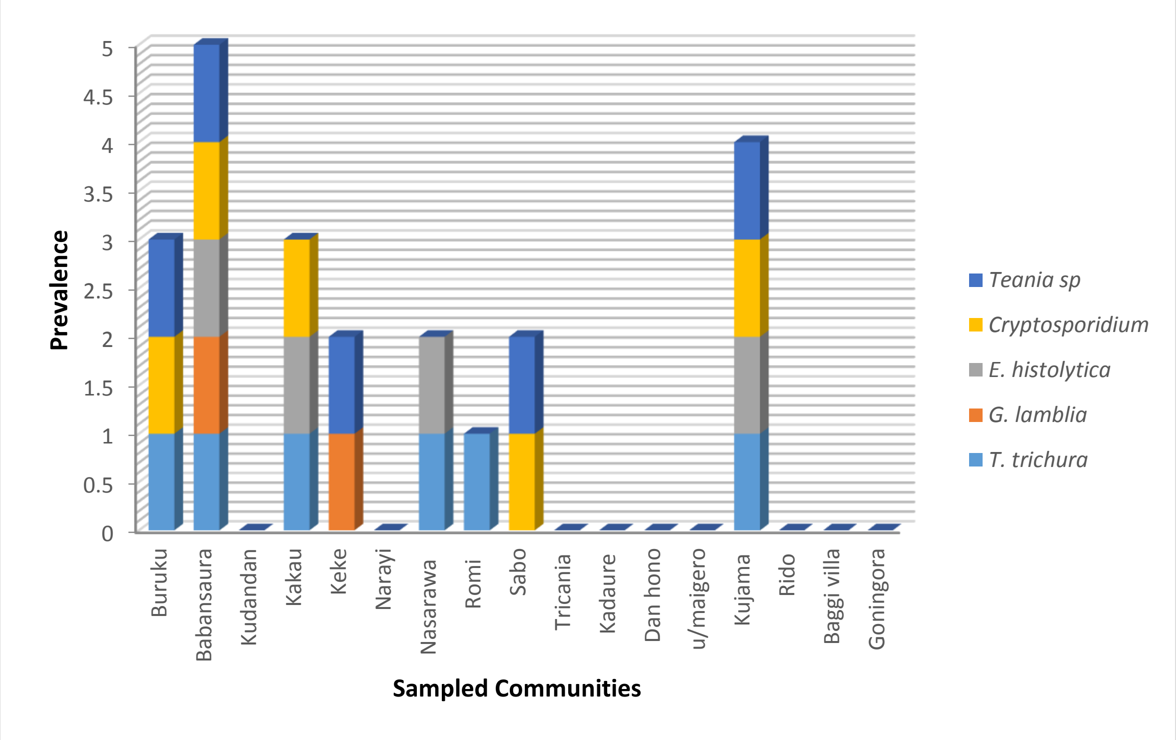

Figure 3: Prevalence of parasite species identified in the water samples

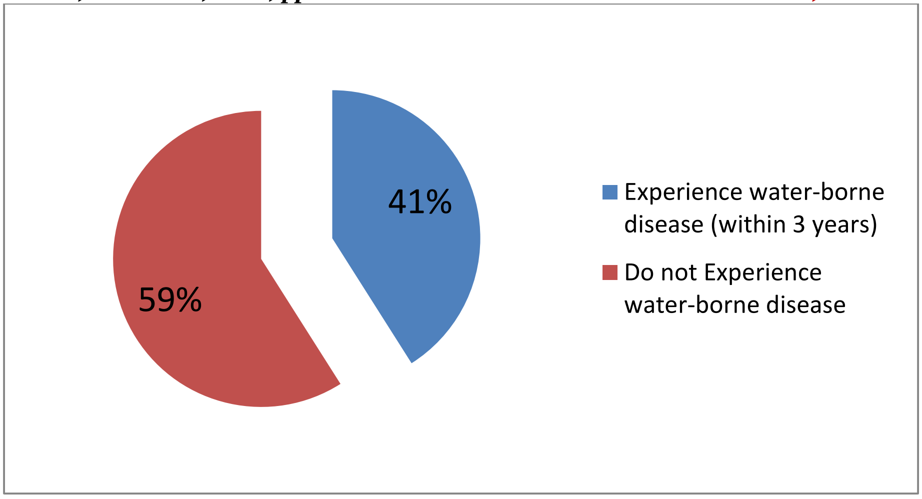

Figure 4: Prevalence of Waterborne Diseases Chikun LGA

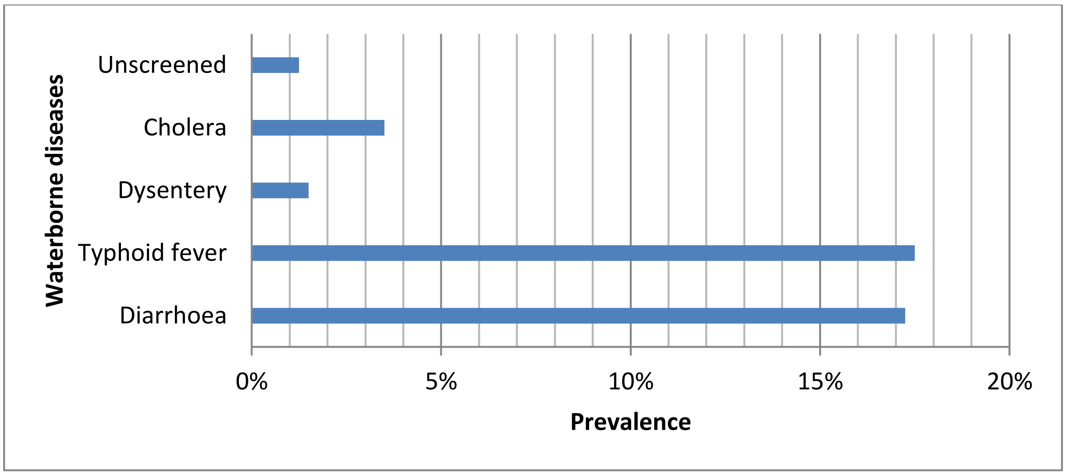

Figure 5: Prevalence of different types of waterborne diseases

DISCUSSION

The research recorded physicochemical analysis, parasitological analysis, and prevalence of waterborne diseases in Chikun Local Government Area, Kaduna State, Nigeria. The recorded water temperatures sampled in all the communities were between 29-33^{0}C, which is slightly above the WHO and NIS standards (25-30^{0}C) (WHO, 2017; SON, 2015), potentially affecting aquatic ecosystems and public health. The pH values ranged from 6.1 to 8.72, with the highest at Unguwan Maigero and the lowest at Tricania, possibly due to the carbonate or bicarbonate buffer in the soil (Sataa *et al.*, 2017). This pH variation is significant as it can influence the solubility and toxicity of chemicals and heavy metals, with implications for both aquatic life and human health. Electrical conductivity values (119.55-159.40 dsm) complied with WHO standards (should not exceed 250 dsm), indicating acceptable levels of dissolved salts (Bekele *et al.*, 2018) and minimizing the risk of corrosion in the water distribution system (WHO, 2017). Turbidity, used to measure water clarity, showed varying levels across locations, with high turbidity indicating potential contamination from human activities such as mining and agriculture (Amsalu Mekonnen Wolde, 2022). Chloride concentrations recorded in the sampled water from all communities were between 0.80-23.54 PPM. According to the World Health Organization (WHO), the guideline value for chloride in drinking water is <250 PPM. This value is based primarily on test considerations, as higher concentration can impact a salty taste to water, which may make it palatable (WHO, 2017).

Dissolved oxygen (DO) concentrations (0.00-234 ppm) were within permissible limits, essential for the health of aquatic organisms, and indicative of the water's overall quality (Yang *et al.*, 2022). Sulphate levels (10.76-378.3 ppm) were within acceptable limits, supporting findings by Singh (2020) and Zeyneb (2021). However, biological oxygen demand (BOD) values (0.00-47.2 ntu) indicated microbial contamination in several samples, consistent with previous studies (Abiola et *al.*, 2019; Fawale, 2020; Adeleye *et al.*, 2022).

Sodium (19.5-110 mg/l) and potassium levels mostly fell within acceptable ranges, though a few samples exceeded the limits, potentially due to agricultural runoff and sewage infiltration (Hassan *et al.,* 2017). Elevated manganese levels in most samples were attributed to effluents and geological factors (Singh, 2020). Mercury concentrations exceeded acceptable limits in several samples, linked to improper waste disposal and industrial activities, posing significant health risks (Umeh *et al.,* 2020). Cadmium levels were within acceptable limits in only five samples, likely due to industrial and household waste contamination (Azuonwu *et al.,* 2017; Imam *et al.,* 2018). Arsenic concentrations in some samples exceeded permissible limits, potentially from industrial activities, posing severe health risks (Yusuf *et al.,* 2017). Copper levels, though generally within acceptable limits, could pose health risks at higher concentrations (Brack *et al.,* 2017).

The results showing the presence of coliforms in all river samples align with the broader understanding that total coliform counts are key indicators of water quality. As observed in other studies, such as those conducted on the Nakdong River in South Korea, the presence of coliforms often correlates with high levels of organic pollutants that serve as nutrients for these bacteria (Seo *et al.,* 2019). Although coliforms are generally not harmful themselves, their presence suggests the potential for other dangerous microorganisms, emphasizing the need for regular monitoring and effective water quality management to ensure public health and safety (Ashbolt *et al.,* 2001; Hrudey & Hrudey, 2004). The detection of coliforms in all river samples underlines the importance of preventive measures to protect water sources from contamination.

The parasitological evaluation of the water samples from various locations indicated varying parasite burdens. The majority of the parasite species found in the study were helminths, which were represented by *Taenia sp.* and *Trichuris trichuria.* The only protozoan parasites identified were *Cryptosporidium*, *Entamoeba histolytica*, and *Giardia lamblia*. It was discovered that borehole water samples were parasite-free. This is largely due to the way they are dressed. Boreholes run a closed water system, in contrast to other sources (such as rivers and wells), which are susceptible to external pollution. This finding confirms that parasite infestation of water sources is inherently contaminative. It has been previously established that human parasites do not directly use water sources for the development of their life cycles. Instead, because their vectors live near water, they are linked to both water and specific aquatic foods (Sufyan *et al.,* 2022).

The study showed an overall 41% prevalence of waterborne diseases with diarrhoea, and typhoid was mostly experienced among the subjects in Chikun LGA. This is in line with the study of Nwabor *et al.* (2016), that also shows diarrhoea and typhoid as common waterborne diseases in sub-Saharan Africa, particularly Nigeria. Ahmed and Kafayos (2020) showed the outbreak of cholera and typhoid in Bade, Nguru, and Machina Local Government Areas of Yobe State-Nigeria and linked it to high consumption of tainted or non-potable water by the people. Another study conducted by Enabulele *et al.* (2016) reported that 45.76% of 271 test persons in Benin, Edo State, Nigeria are typhoid positive.

CONCLUSION

Findings revealed physicochemical contamination, such as elevated pH levels ranging from 6.1 to 8.72 and electrical conductivity between 119.55 to 159.40 dS/m. Additionally, high coliform counts and parasites were detected in non-borehole sources, contributing to a 41% prevalence of waterborne diseases such as diarrhea and typhoid, as it mostly occurred. Addressing these challenges requires improved water treatment, infrastructure development, public education, and economic support for safe drinking water access.

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Competing Interests

The authors have declared no competing interests exist.

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