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Microbiological and Parasitological Assessment of Quality of water used in Food Preparation by Restaurants and Local Food Vendors in Aba, Abia State, Nigeria

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Abstract

This study assessed the microbiological and parasitological quality of water used for food preparation by restaurants and local food vendors in Aba, Abia State, Nigeria. A total of 120 water samples were collected from 60 food-service facilities comprising restaurants and local food vendors. Samples were obtained from boreholes, rainwater, municipal water, and itinerant water supplies and examined for bacterial and parasitic contaminants. Statistical associations were evaluated using chi-square/Fisher's exact tests and Cramer's V. The findings revealed that, overall, 20.0% of the 120 water samples showed microbial contamination. Microbiological examination detected total coliforms in 12 (10.0%) samples, *Escherichia coli* in 5 (4.2%), *Salmonella* spp. in 3 (2.5%), and *Staphylococcus aureus* in 4 (3.3%). The distribution of microbial contamination did not differ significantly according to water source ($\chi^2 = 1.53$, $p = 0.997$) or facility/location ($\chi^2 = 4.80$, $p = 0.964$). Parasitological examination revealed contamination in 12 (10.0%) samples, with significantly higher contamination associated with itinerant water supplies (50.0%) than borehole (5.45%), municipal (6.0%), and rainwater (0.0%) sources ($\chi^2 = 23.82$, $p < 0.001$; Cramer's V = 0.446). The parasites detected were *Ascaris* spp. (2.50%), *Giardia lamblia* (3.33%), and *Cryptosporidia* spp. (4.17%). However, parasitic profiles did not differ significantly across facility/location categories ($\chi^2 = 3.20$, $p = 0.921$). The findings demonstrate that water used for food preparation in the study area may constitute a potential route for exposure to bacterial and parasitic contaminants. There is need for improved source monitoring, water treatment, hygienic storage, and routine microbiological and parasitological surveillance among food-service establishments.

Introduction

Water and food are fundamental requirements for human survival, health, and socioeconomic development. Ensuring the safety of both commodities is therefore a critical public health priority, particularly in settings where inadequate sanitation, unreliable water supplies, and weak food safety systems increase the risk of disease transmission. Restaurants and other food service establishments constitute important components of the food supply chain in many low- and middle-income countries, including Nigeria, where they provide ready-to-eat meals to large segments of the population. Food establishments and local food vendors commonly obtain water from diverse sources, including surface water, dug wells, boreholes, standpipes, and piped municipal supplies, with the quality of these sources often influenced by environmental conditions, source protection, and handling practices (Kristanti et al. 2022). Globally, foodborne and waterborne diseases remain major contributors to morbidity and mortality, disproportionately affecting populations in developing countries where inadequate sanitation, unsafe water supplies, poor environmental hygiene, and limited food safety surveillance persist (Fayemi et al. 2026). The World Health Organization (WHO) recognizes unsafe food contaminated with pathogenic bacteria, viruses, parasites, or hazardous chemicals as an important contributor to the global burden of disease, particularly gastrointestinal infections (WHO, 2024). Contaminated water can introduce bacteria, viruses, protozoa, and helminth parasites into foods during preparation and handling, particularly foods that are consumed with minimal or no subsequent heat treatment (Odo et al. 2020; WHO/UNICEF, 2023). The increasing urban population and changing lifestyles have further intensified reliance on restaurants, street food vendors, and other small-scale food establishments as sources of affordable and convenient meals (Mukherjee et al. 2019). These establishments make important contributions to food accessibility, household income, and employment; however, many operate in environments characterized by inadequate water infrastructure, insufficient sanitation facilities, limited food safety training, and inconsistent regulatory monitoring. Such conditions may facilitate the introduction and transmission of foodborne pathogens through contaminated water, food, equipment, and food handlers (FAO and WHO, 2023).

Oyeneho and Hedberg (2013) reported that 59% of restaurants included in their survey obtained water from private boreholes, whereas 41% depended on municipal water supplies. Similarly, Oseyemi (2023) documented considerable reliance on private boreholes among restaurants, with 59% obtaining water from boreholes and 41% from municipal sources. These findings demonstrate the importance of assessing not only the source of water but also its microbiological safety at the point where it is used for food preparation. Kristanti et al. (2022) further observed that water quality in food establishments may vary according to source protection, environmental contamination, storage conditions, and hygiene practices. Thus, even water obtained from sources that are considered relatively protected may become contaminated during transportation, storage, or handling.

In resource-constrained settings, particularly in sub-Saharan Africa, food preparation and vending frequently occur under conditions where access to safe water, adequate sanitation, and effective hygiene-control measures is limited (Muinde and Kutia, 2020). Microbiological contamination of water used for food preparation is therefore a significant public health concern because pathogenic organisms introduced through water may subsequently contaminate food and food-contact surfaces. Indicator organisms, particularly total coliforms, faecal coliforms, and *Escherichia coli*, are widely employed in water-quality assessment because their presence provides evidence of inadequate sanitary conditions and possible faecal contamination (Bokhari and Syed, 2026).

In addition to indicator organisms, pathogenic bacteria such as *Salmonella* spp., *Shigella* spp., *Vibrio cholerae*, *Staphylococcus aureus*, and pathogenic *E. coli* are associated with a range of food- and waterborne diseases, including diarrhoea, dysentery, cholera, and enteric infections (Adamu et al. 2022). Beyond bacterial contamination, parasitological contamination of water represents another important but comparatively less investigated dimension of food safety. Protozoan and helminth parasites, including *Giardia lamblia*, *Entamoeba histolytica*, *Cryptosporidium* spp., and *Ascaris lumbricoides*, can enter water systems through faecal pollution and inadequate environmental sanitation. Their infective stages, including cysts, oocysts, and ova, may persist in the environment and contribute to gastrointestinal disease following ingestion of contaminated water or foods prepared with such water (Bokhari and Syed, 2026).

Aba, a major commercial and industrial centre in Abia State, Nigeria, presents a relevant setting for investigating these concerns. Many restaurants and local food vendors in the metropolis rely on alternative water sources, including boreholes, stored water, and commercially supplied water, particularly where municipal water availability is unreliable. Although these sources support routine food preparation and cleaning activities, their safety may be compromised by environmental contamination, inadequate source protection, poor storage practices, and unhygienic handling. Because water is extensively used for cooking, washing food ingredients, cleaning utensils, hand hygiene, and preparing beverages, contamination at any stage can create multiple opportunities for microbial and parasitic transmission to consumers. Previous investigations have documented microbial contamination of water used in food service environments, including the detection of coliform bacteria and organisms indicative of faecal contamination (Chigbo, 2023). Evidence has also indicated the potential occurrence of parasitic agents, including protozoan cysts and helminth ova, in contaminated water, highlighting their possible contribution to gastrointestinal infections among exposed populations (Ajero and Chigbo, 2023).

Despite the public health importance of safe water in food preparation, there remains limited integrated evidence on the microbiological and parasitological quality of water used by restaurants and local food vendors in Aba metropolis. In particular, studies that simultaneously investigate bacterial indicators, potential pathogenic microorganisms, parasitic forms, and the hygienic practices associated with water handling are relatively scarce. This knowledge gap limits the ability of public health authorities to accurately characterize contamination pathways and develop evidence-based interventions for food establishments. The present study was designed to assess the microbiological and parasitological quality of water used for food preparation and related activities among restaurants and local food vendors in Aba, Abia State, Nigeria. The findings are expected to provide useful evidence for strengthening water-quality surveillance, food hygiene practices, environmental sanitation, and regulatory interventions aimed at reducing the risk of foodborne and waterborne diseases among consumers in Aba and comparable urban communities in Nigeria.

Materials and methods

Study Area

The study was conducted in Aba, Abia State, southeastern Nigeria, a major commercial and industrial centre and an important hub for food-related businesses in the region. Aba is situated within the southeastern geopolitical zone of Nigeria and lies approximately between 5°07'00" N and 7°22'00" E. The area experiences a tropical climate characterized by a distinct rainy season extending from approximately April to October. Seasonal rainfall and surface runoff may influence the microbiological and parasitological quality of water by facilitating the transport of faecal materials and other contaminants into surface and groundwater sources (Ogbuagu et al. 2019).

Water used by restaurants and local food vendors in Aba is obtained from multiple sources, including municipal pipe-borne water, boreholes, hand-dug wells, sachet water, and water supplied by private vendors. The reliability and quality of these sources may vary considerably because of differences in source protection, storage practices, sanitation conditions, and handling procedures. These factors are particularly important in densely populated urban settings where inadequate sanitation and improper waste disposal may increase the risk of microbial and parasitic contamination of water sources.

Aba was selected as the study location because of its high concentration of restaurants, street-food outlets, and informal food vendors, together with the diversity of water sources used for food preparation and related activities. The area also has limited documented evidence concerning the microbiological and parasitological safety of water utilized within the food-service sector. Previous studies have reported evidence of waterborne parasitic contamination in communities within the surrounding region, highlighting the potential public health relevance of water quality in the area (Ejike et al, 2021). The characteristics of Aba therefore provide an appropriate setting for investigating the microbiological and parasitological quality of water used by restaurants and local food vendors. Assessment of water sources within this urban informal food economy provides insight into potential exposure pathways and the possible contribution of contaminated water to foodborne and waterborne disease transmission. Findings from the study may also provide useful evidence for

strengthening food hygiene regulations, water safety interventions, environmental sanitation programmes, and public health policies in Aba and comparable urban communities in southeastern Nigeria.

Map 1: Map of Abia State showing the sampling locations

Source

Nkemdirim et al. 2000

Inclusion and Exclusion Criteria

Inclusion Criteria

The study included restaurants and local food vendors who:

- used water for food preparation or related food-handling activities;
- operated within the designated study locations in Aba metropolis; and
- provided informed consent to participate in the study.

Exclusion Criteria

The study excluded:

- vendors who sold only pre-packaged foods and did not prepare food on-site;
- establishments that did not use water for food preparation or related activities;
- vendors operating outside the designated study locations; and
- vendors who declined to provide informed consent.

Sample Size Determination

The sample size was determined using the guideline proposed by Nwana (1981), which recommends that when a study population comprises a few hundred individuals or establishments, approximately 20–40% may be considered an appropriate sample, depending on the population size and study objectives. The estimated population for the present study consisted of approximately 300 restaurants and food vending establishments within Aba metropolis. Based on the 20% sampling recommendation, 60 establishments were selected for the study:

Sample size = 20% of 300 = 60 establishments.

Thus, a total of 60 restaurants and local food vending establishments constituted the sampling units for the study.

Study Population

The study population comprised restaurants and local food vendors involved in food preparation and sales within Aba metropolis, Abia State, Nigeria. A total of 60 sampling sites were selected across three Local Government Areas (LGAs): Aba South, Aba North, and Osisioma. The target population included both registered and unregistered food establishments operating within the metropolis. These establishments varied considerably in size, structure, and mode of operation, ranging from small roadside food stalls and informal local food vendors to larger formal restaurants. Personnel considered within the study population included food handlers, water handlers, and managerial or supervisory personnel responsible for food preparation, water handling, sanitation, and hygiene practices. The inclusion of these categories provided a broader assessment of water-use practices, sanitation conditions, and hygiene management within the food-service sector. Consequently, the study population represented the diversity of food-service establishments operating within Aba metropolis and provided a basis for assessing potential public health risks associated with the quality and use of water during food preparation.

Study Design

A descriptive cross-sectional study design was adopted. The study combined field-based assessment of water-use and hygiene practices with laboratory examination of water samples for parasitological and microbiological contamination. Water samples collected from restaurants and local food vending establishments were subjected to laboratory analyses to determine the presence of parasitic organisms and bacterial contaminants.

Water Sample Collection

A total of 120 water samples were collected from the 60 selected restaurants and local food vending establishments. Samples were collected using sterile 500-mL bottles for microbiological analyses and clean 1,000-mL polyethylene bottles for parasitological analyses. Before and during collection, appropriate precautions were taken to prevent contamination of the samples. Following collection, the bottles were immediately capped securely. The bottles were not completely filled; a headspace of approximately 20–30 mm was maintained to facilitate adequate mixing of the samples before analysis, in accordance with standard water-sampling procedures (APHA, 2017). Each sample container was appropriately labelled with a unique identification code, date and time of collection, sampling site, and water source. Samples were transported to the laboratory within three hours of collection in a light-proof, insulated cold box containing ice packs. Upon arrival, samples were stored at approximately 4°C and processed promptly. Laboratory analyses were commenced immediately or as soon as practicable following collection to minimize changes in microbial populations and maintain the integrity of the samples (Gaudy, 1998). All analyses were conducted at the Department of Science Laboratory Technology, Ogbonnaya Onu Polytechnic, Aba, Nigeria.

Parasitological Processing of Water Samples

Water samples intended for parasitological examination were processed using a concentration technique based on centrifugation, following the procedure described by the World Health Organization (WHO, 2017). Before processing, each water sample was thoroughly mixed by gentle shaking. A filter paper was placed in a funnel positioned over a centrifuge tube, and approximately 10 mL of the water sample was passed through the filter into the tube. The filter was subsequently removed and discarded. The filtrates were centrifuged for 5 minutes at approximately 100 × g (300 rpm) to concentrate particulate materials and potential parasitic stages. Following centrifugation, the supernatant was carefully discarded without disturbing the sediment. The concentrated deposit was then used for microscopic examination.

Identification of Parasites

Parasites were identified based on their characteristic morphological features, including the structures of cysts, ova, and larvae, using standard parasitological identification procedures (Cheesbrough, 2000). Both direct wet-mount and iodine preparations were examined microscopically.

Direct Wet-Mount Preparation

Using a sterile Pasteur pipette, a drop of the concentrated sediment was transferred onto a clean, grease-free glass slide and covered carefully with a coverslip to avoid the formation of air bubbles. The preparation was examined microscopically using the ×10 objective for initial scanning and focusing, followed by the ×40 objective for detailed examination and identification of suspected parasitic stages.

Iodine Preparation

For iodine staining, a drop of Lugol's iodine solution was placed on a clean glass slide, and a small portion of the concentrated sediment was mixed with the iodine solution. The preparation was covered with a coverslip and examined systematically under the microscope using the ×10 objective for scanning and the ×40 objective for identification of parasitic structures. Iodine preparation enhances the visibility of internal structures of protozoan cysts and facilitates their identification (Ichimasa et al. 2014).

Microbiological Analysis

Microbiological analyses were performed using standard procedures described by Cheesbrough (2010). Culture media were prepared according to the manufacturers' instructions. All glassware, including Petri dishes, conical flasks, test tubes, beakers, and bijou bottles, was thoroughly washed and sterilized in a hot-air oven at 160°C for 1 hour. Inoculating loops were sterilized by flaming over a Bunsen burner until red hot. The laboratory work surfaces were disinfected with 70% ethanol before and during sample processing to minimize the risk of extraneous microbial contamination.

Determination of Total Viable Bacterial Count

Before analysis, each water sample was thoroughly homogenized by shaking approximately 25 times. Ten-fold serial dilutions were prepared using sterile peptone water. Briefly, 9 mL of sterile peptone water was aseptically dispensed into five sterile test tubes labelled 10^{-1} to 10^{-5}. One millilitre of the homogenized water sample was transferred aseptically into the first tube (10^{-1}) and mixed thoroughly. Serial dilution was subsequently performed by transferring 1 mL from each dilution into the next tube until the 10^{-5} dilution was obtained. The total viable bacterial count was determined using the pour-plate technique. Appropriate aliquots (1 mL) from selected dilutions, particularly 10^{-1} to 10^{-3}, were aseptically transferred into labelled sterile Petri dishes, and the analyses were performed in triplicate. Nutrient Agar was used as the culture medium. The medium was prepared according to the manufacturer's instructions and sterilized by autoclaving at 121°C for 15 minutes at 15 psi. After sterilization, the medium was allowed to cool to approximately 45°C before approximately 20 mL was dispensed into each inoculated Petri dish. The inoculated plates were allowed to solidify and were subsequently inverted to minimize condensation from falling onto the agar surface. The plates were incubated at 37°C for 24 hours. A negative control containing culture medium without a water sample was prepared alongside the test samples to monitor possible contamination during the procedure. Following incubation, plates containing approximately 30–300 colonies were selected for enumeration. Colonies were counted using a colony counter, and the bacterial load was expressed as colony-forming units per millilitre (CFU/mL). Representative bacterial colonies were subcultured on freshly prepared Nutrient Agar for further characterization and identification.

Data Analysis

Data obtained from the field survey and laboratory investigations were entered, organized, and analyzed using descriptive and inferential statistical Frequencies and percentages. Statistical associations were evaluated using chi-square/Fisher's exact tests and Cramer's V. Statistical significance was evaluated at $p < 0.05$.

Results

Sources of water used for food preparation

Table 1 presents the sources of water used for food preparation in restaurants and food vending establishments in Aba. A total of 120 water samples were collected from restaurants and local food vendors in Aba. Municipal water was the most frequently reported source of water for food preparation, accounting for 50 samples (48.17%), followed by borehole water with 55 samples (45.83%). Itinerant water supply accounted for 12 samples (10.00%), while rainwater was the least utilized source, representing 3 samples (2.50%). Across the study locations, borehole and municipal water constituted the predominant sources of water used for food preparation. Aba South obtained 12 (50.00%) samples from municipal water and 11 (45.83%) from boreholes, whereas Aba North recorded 13 (54.17%) borehole and 10 (41.67%) municipal water samples. Osisioma recorded 12 (50.00%) borehole and 9 (37.50%) municipal water samples. Local food vendors used borehole water most frequently (37.50%), followed by municipal water (33.33%), while mid-end restaurants relied mainly on municipal water (45.83%) and boreholes (41.67%). The observed differences in water sources across restaurant types/locations were not statistically significant ($\chi^2 = 10.52$, $p = 0.570$), with a weak association (Cramer's V = 0.171).

Level of microbial contamination of water sources for food preparation

Table 2 shows the microbial profile of water sources used for food preparation. Of the 120 water samples examined, 24 (20.0%) were reported as contaminated with at least one of the investigated microbial indicators/pathogens. Borehole water had 7 contaminated samples out of 55, while rainwater had 1 contaminated sample out of 3. Municipal water recorded 6 contaminated samples out of 50, whereas itinerant water supply had the highest proportion of contaminated samples, with 10 of 12 samples contaminated. Regarding specific microorganisms, total coliforms were detected in 12 samples (10.0%), *Escherichia coli* in 5 (4.2%), *Salmonella* spp. in 3 (2.5%), and *Staphylococcus aureus* in 4 (3.3%). Although itinerant water supply showed comparatively higher contamination levels than the other water sources, the differences in microbial contamination among water sources were not statistically significant ($\chi^2 = 1.53$, $p = 0.997$).

Microbiological profile of water used in food preparation

The microbiological assessment across the five categories of food-service facilities (Table 3) showed that contamination varied among locations. Aba South and Aba North restaurants each recorded 2 contaminated samples, corresponding to 4.17% total coliform contamination, with *E. coli* detected in one sample (4.17%) at each location. Osisioma restaurants recorded 4 contaminated samples, including 2 (8.33%) positive for total coliforms, 1 (4.17%) for *Salmonella* spp., and 1 (8.33%) for *S. aureus*. Local food vendors recorded the highest number of contaminated samples, with 9 (37.50%) contaminated samples; these included 4 (16.67%) total coliform-positive samples, 2 (8.33%) *E. coli*-positive samples, 1 (4.17%) *Salmonella*-positive sample, and 2 (16.67%) *S. aureus*-positive samples. Mid-end restaurants recorded 7 contaminated samples, including 4 (16.67%) with total coliforms and one each (4.17%) with *E. coli*, *Salmonella*

spp., and *S. aureus*. Overall, total coliforms were the most frequently detected microbial contaminant (12; 10.00%), followed by *E. coli* (5; 4.17%), *S. aureus* (4; 3.33%), and *Salmonella* spp. (3; 2.50%). However, microbial contamination did not differ significantly among the categories of food-service facilities ($\chi^2 = 4.80$, $p = 0.964$; Cramer's V = 0.258).

Level of parasitic contamination of water used for preparing food

Table 4 shows the level of parasitic contamination in water used for food preparation. Parasitological contamination was detected in 12 (10.0%) of the 120 water samples examined. Itinerant water supply had by far the highest level of parasitic contamination, with 6 of 12 samples (50.00%) contaminated. Borehole water recorded 3 contaminated samples (5.45%), while municipal water had 3 contaminated samples (6.00%). No parasitic contamination was detected in the three rainwater samples examined. Overall, 108 (90.0%) samples were free from detectable parasitic contamination. The association between water source and parasitic contamination was statistically significant ($\chi^2 = 23.82$, $p < 0.001$), with a moderate association (Cramer's V = 0.446), indicating that the likelihood of parasitic contamination varied substantially according to the source of water.

Parasitological profile of contaminated water

Table 5 presents the parasitological profile of water used for food preparation in restaurants and local food vendors. Three major parasites were detected in the water samples: *Ascaris* spp., *Giardia lamblia*, and *Cryptosporidia*. *Ascaris* spp. was detected in 3 samples (2.50%), *G. lamblia* in 4 samples (3.33%), and *Cryptosporidia* in 5 samples (4.17%), making *Cryptosporidia* the most frequently detected parasite. Aba South restaurants recorded one contaminated sample, positive for *G. lamblia* (4.17%), while Aba North recorded one sample positive for *Cryptosporidia* (4.17%). Osisioma restaurants recorded two contaminated samples, involving *Ascaris* spp. (4.17%) and *Cryptosporidia* (4.17%). Local food vendors recorded five contaminated samples, comprising *Ascaris* spp. (4.17%), *G. lamblia* (8.33%), and *Cryptosporidia* (8.33%). Mid-end restaurants recorded three contaminated samples, with one sample each positive for *Ascaris* spp., *G. lamblia*, and *Cryptosporidia* (4.17% each). Despite these variations, the distribution of parasitic contamination among the different categories of food-service facilities was not statistically significant ($\chi^2 = 3.20$, $p = 0.921$; Cramer's V = 0.365).

Table 1
Sources of water for preparation of food in restaurants and food vendors in Aba

Type/location of restaurant	No. of samples	Type of water sources for food preparation				X2	p-value	Cramer's V
		Borehole	Rainwater	Municipal water	Itinerant water Supply			
Aba South	24	11(45.83)	0(0.00)	12(50.00)	1(4.17)			
Aba North	24	13(54.17)	0(0.00)	10(41.67)	1(4.17)			
Osisioma	24	12(50.00)	0(0.00)	9(37.50)	3(12.50)			
Local food vendor	24	9(37.50)	2(8.33)	8(33.33)	5(20.83)			
Mid-end restaurant	24	10(41.67)	1(4.17)	11(45.83)	2(8.33)			
Total (%)	**120**	**55(45.83)**	**3(2.50)**	**50(48.17)**	**12(10.00)**	**10.52**	**0.570**	**0.171**

Table 2
Level of microbial contamination of water sources for food preparation

Sources of water for food preparation	No. of water sampled / (No contaminated)	No. of microbial contamination				χ^2/Fisher	p-value
		Total coliform	*E. coli*	*Salmonella* spp	*Staphylococus aureus*		
Boreholes	55(7)	4(7.3)	2(3.6)	1(1.8)	1(1.8)		
Rainwater	3(1)	1(33.3)	0(0.0)	0(0.0)	0(0.0)		
Municipal water	50(6)	3(6.0)	1(2.0)	1(2.0)	1(2.0)		
Itinerant water supply	12(10)	4(33.3)	2(16.7)	1(8.3)	2(16.7)		
Total (%)	**120(24)**	**12(10.0)**	**5(4.2)**	**3(2.5)**	**4(3.3)**	**1.53**	**0.997**

Table 3
Microbiological profile of water used in food preparation in restaurants and local food vendors

Type / location of restaurant	No. of facilities visited	No. of water sample (No contaminated)	No. of microbial contamination of water sample				χ^2/Fisher	p-value	Cramer's V
			Total coliform	*E. coli*	*Salmonella spp*	*Staphylococcus aureus*			
Aba South restaurants	12	24 (2)	1(4.17)	1(4.17)	0(0.00)	0(0.00)			
Aba North restaurants	12	24 (2)	1(4.17)	1(4.17)	0(0.00)	0(0.00)			
Osisioma restaurants	12	24(4)	2(8.33)	0(0.00)	1(4.17)	1(8.33)			
Local food vendor	12	24 (9)	4(16.67)	2(8.33)	1(4.17)	2(16.67)			
Mid-end restaurant	12	24 (7)	4(16.67)	1(4.17)	1(4.17)	1(4.17)			
Total	**60**	**120 (24)**	**12(10.00)**	**5(4.17)**	**3(2.50)**	**4(3.33)**	4.80	0.964	0.258

Table 4
Level of parasitic contamination of water used for preparing food in restaurants and local food vendors in Aba

Source of Water	No. Sampled	Contaminated(%)	Not Contaminated (%)	χ^2/Fisher	p-value	Cramer's V
Boreholes	**55**	**3 (5.45)**	**52 (94.55)**			
Rainwater	3	0 (0.00)	3 (100.00)			
Municipal water	50	3 (6.00)	47 (94.00)			
Itinerant water supply	12	6 (50.00)	6 (50.00)			
Total	**120**	**12 (10.00)**	**108 (90.00)**	**23.82**	**< 0.001**	**0.446**

Table 5
Parasitological profile of water used for preparing food in restaurants and local food vendors

Type/Location of Restaurant	Outlets Visited	Water Samples Collected (No. Contaminated)	*Ascaris* (%)	*G. lamblia* (%)	Cryptosporidia (%)	χ^2/Fisher	p-value	Cramer's V
Aba South restaurants	12	24 (1)	0 (0.00)	1 (4.17)	0 (0.00)			
Aba North restaurants	12	24 (1)	0 (0.00)	0 (0.00)	1 (4.17)			
Osisioma restaurants	12	24 (2)	1 (4.17)	0 (0.00)	1 (4.17)			
Local food vendors	12	24 (5)	1 (4.17)	2 (8.33)	2 (8.33)			
Mid-end restaurants	12	24 (3)	1 (4.17)	1 (4.17)	1 (4.17)			
Total	**60**	**120 (12)**	**3 (2.50)**	**4 (3.33)**	**5 (4.17)**	**3.20**	**0.921**	**0.365**

Discussion

The present study assessed the microbiological and parasitological quality of water used for food preparation in restaurants and among local food vendors in Aba, Abia State, Nigeria. The findings demonstrate that although several conventional water sources were used,

contamination with bacterial and parasitic organisms occurred across the water sources and food-service settings examined. This is important from a food-safety perspective because water used for cooking, washing ingredients, utensils, and food-contact surfaces can serve as a vehicle for introducing pathogenic organisms into foods. The World Health Organization (WHO) emphasizes that potable water should be used wherever water comes into direct or indirect contact with food, and that water safety should be assessed according to its source, potential hazards, treatment and intended use (WHO, 2019).

Sources of Water Used for Food Preparation in Restaurants and by Food Vendors

The findings indicate that municipal water was the most commonly used source of water for food preparation among restaurants and local food vendors in Aba, accounting for 48.17% of the reported sources, followed closely by borehole water (45.83%). This pattern demonstrates a dual dependence on public water infrastructure and privately sourced groundwater. Such reliance is characteristic of many urban settings in developing countries, where municipal water supplies may be inadequate, intermittent, or unreliable. Similar dependence on multiple water sources has been documented in Nigerian urban communities, where households and food establishments supplement municipal supplies with alternative sources to ensure continuity of water availability (Ejike et al. 2021).

The substantial dependence on borehole water is particularly noteworthy because groundwater is often perceived as a relatively safe and dependable source. However, the microbiological quality of borehole water can be compromised by poor construction and maintenance, as well as seepage from nearby sanitation facilities and waste disposal systems (Li et al. 2026). These concerns are particularly relevant in densely populated urban environments, where inadequate sanitation infrastructure may increase the vulnerability of groundwater to contamination.

Variations were also observed according to location and type of food establishment. Restaurants in Aba South, Aba North, and Osisioma, as well as mid-end restaurants, predominantly relied on municipal and borehole water, suggesting comparatively stable access to conventional water infrastructure. In contrast, local food vendors used a wider range of water sources and demonstrated greater reliance on less formal supplies. Notably, itinerant water accounted for 20.83% of their water sources, while rainwater contributed 8.33%. This pattern may reflect differences in economic capacity, accessibility, and infrastructure between formal food establishments and informal vendors. The relatively high dependence of local food vendors on itinerant water is of public health significance because water transported through informal distribution systems may be exposed to contamination during collection, transportation, handling, and storage. The findings therefore underscore the need for improved access to reliable water infrastructure and routine monitoring of alternative water sources. Regulatory oversight of informal water vendors, together with appropriate water storage and treatment practices, could contribute substantially to reducing microbial and parasitic risks associated with food preparation.

Microbial Contamination of Water Sources Used for Food Preparation

Microbiological examination revealed that 24 of the 120 water samples analyzed were contaminated, corresponding to an overall contamination rate of 20.0%. Total coliforms were the most frequently detected microorganisms, occurring in 12 samples (10.0%), followed by *Escherichia coli* in 5 samples (4.2%), *Staphylococcus aureus* in 4 samples (3.3%), and *Salmonella* spp. in 3 samples (2.5%). The predominance of total coliforms indicates inadequate sanitary protection of some water sources, while the detection of *E. coli* provides evidence suggestive of faecal contamination. These organisms are widely recognized as important indicators of microbiological water quality and sanitary integrity (Li et al. 2021; Gaihre et al. 2024). Marked differences were observed among the various water sources. Itinerant water had the highest level of contamination, with 10 of the 12 samples examined being contaminated. Total coliforms, *E. coli*, and *S. aureus* were detected in 33.3%, 16.7%, and 16.7% of samples, respectively. The high contamination burden associated with itinerant water may be attributable to inadequate handling practices, unsuitable storage containers, repeated human contact, and limited regulatory monitoring. Similar concerns have been reported in studies examining informal water-vending systems, which have identified such systems as potential sources of microbiological contamination in urban environments (Nadeem et al. 2025; Kassa et al. 2026). Rainwater also demonstrated a relatively high contamination rate of 33.3%, although this finding should be interpreted cautiously because of the small number of samples examined. Contamination of harvested rainwater may occur through polluted atmospheric deposition, contaminated roof or collection surfaces, and inappropriate storage practices. Previous research has demonstrated that harvested rainwater can become microbiologically contaminated when collection and storage systems are inadequately maintained, particularly in urban environments (Shrestha et al. 2023; Bdelgalel et al. 2025).

Borehole and municipal water demonstrated comparatively lower contamination levels, with seven and six contaminated samples, respectively. Nevertheless, the detection of microbial contaminants in these sources demonstrates that conventional water supplies

cannot be assumed to be microbiologically safe. Borehole contamination may result from infiltration of sewage or other contaminants into groundwater, whereas municipal water may become contaminated through deficiencies in treatment, distribution infrastructure, or post-treatment handling (Awere-Duodu et al. 2025; Gautam et al. 2025).

Overall, the findings demonstrate substantial variation in microbiological quality among water sources used for food preparation in Aba. Informal and alternative water supplies, particularly itinerant water, appear to present greater microbiological risks. Strengthening surveillance of water vendors, improving source protection, maintaining distribution infrastructure, and promoting appropriate treatment and storage practices are therefore important measures for reducing exposure to waterborne pathogens in food preparation environments.

Microbiological Profile of Water Used for Food Preparation

The microbiological assessment of the 120 water samples demonstrated a measurable burden of microbial contamination in water used by restaurants and local food vendors in Aba. Total coliforms were the most frequently detected organisms (10.0%), followed by *E. coli* (4.17%), *S. aureus* (3.33%), and *Salmonella* spp. (2.50%). The predominance of coliforms suggests inadequate sanitary quality in some of the water samples, while the detection of *E. coli* indicates possible faecal contamination and therefore potential exposure to enteric pathogens. Such contamination is generally associated with inadequate source protection, poor sanitation, and inappropriate water handling practices (Bokhari and Syed, 2026).

Local food vendors recorded the greatest microbiological burden, with nine contaminated samples and comparatively high detection rates of total coliforms (16.67%), *E. coli* (8.33%), and *S. aureus* (16.67%). The elevated contamination observed among local vendors may reflect the informal nature of their operations, including limited access to reliable treated water, inadequate storage facilities, and inconsistent implementation of hygienic food-handling practices. Comparable evidence has identified informal food-vending environments as particularly vulnerable to microbiological contamination because of inadequate water, sanitation, and hygiene infrastructure (Sharif et al. 2025).

The occurrence of *S. aureus* is also noteworthy because this organism can be associated with contamination introduced by food handlers. Its presence may therefore indicate deficiencies in personal hygiene and food-handling practices during preparation (Yohannes et al. 2025). Mid-end restaurants also exhibited appreciable levels of contamination, although their contamination burden was lower than that observed among local food vendors. This suggests that improved infrastructure and more formal operating conditions may reduce, but do not completely eliminate, microbiological risks.

Restaurants in Aba South and Aba North recorded relatively low microbial contamination, with two contaminated samples each, suggesting comparatively better water-handling and sanitation conditions. Osisioma restaurants demonstrated an intermediate level of contamination. These differences indicate that microbiological water quality varies not only according to water source but also according to the operational characteristics and hygiene conditions of individual food establishments.

The greater contamination observed among local food vendors is consistent with evidence that informal food-service environments may present increased food-safety risks because of limited regulatory oversight and inconsistent access to safe water (Holcomb and Stewart, 2020; Bokhari and Syed, 2026). The detection of potentially pathogenic bacteria in water used for food preparation is therefore of public health importance. Regular microbiological monitoring, improved access to safe water, food-handler hygiene education, and effective enforcement of food-safety regulations should be prioritized across both formal and informal food establishments in Aba.

Parasitic Contamination of Water Used for Food Preparation

Parasitological examination demonstrated an overall contamination prevalence of 10.0% among water samples used for food preparation in restaurants and by local food vendors in Aba. The finding indicates that a proportion of water used within food-service environments may constitute a potential pathway for exposure to waterborne parasitic infections, particularly where sanitation systems, source protection, and routine water-quality monitoring are inadequate. The occurrence of parasitic contaminants in water remains an important public health concern in settings where sanitation infrastructure is insufficient and environmental contamination is common (Nadeem et al. 2025; Kassa et al. 2026). Itinerant water recorded the highest level of parasitic contamination, with 6 of 12 samples contaminated, representing 50.0%. This substantially elevated prevalence suggests that informal water-distribution systems may constitute an important potential source of parasitic exposure. The high contamination level may be associated with repeated handling, inadequate storage, contaminated transportation containers, and exposure to contaminated environments during distribution. Similar concerns have been reported regarding informal water supplies, which may facilitate the introduction and persistence of parasite cysts and ova through inadequate sanitary practices (Gaihre et al. 2024). Borehole water and municipal water demonstrated considerably

lower parasitic contamination rates of 5.45% and 6.00%, respectively. Although these findings suggest comparatively lower risk, the detection of parasites in both sources indicates that conventional water supplies are not entirely protected from contamination. Groundwater may be affected by seepage from septic systems and other sources of environmental contamination, whereas municipal supplies may be compromised through deficiencies in treatment, distribution systems, or subsequent handling (Sharif et al. 2025).

No parasitic contamination was detected in the rainwater samples. However, this finding should be interpreted cautiously because the absence of detected parasites may be related to the limited sample size rather than complete microbiological safety. Rainwater remains vulnerable to contamination through collection surfaces, atmospheric deposition, and inappropriate storage conditions (Ahmed et al. 2025). Consequently, rainwater should not automatically be considered safe for food preparation without appropriate treatment and quality assessment.

Conclusion

This study demonstrates that water used for food preparation in restaurants and by local food vendors in Aba was not uniformly free from microbiological and parasitological contamination. Although most water samples were uncontaminated, 20.0% showed evidence of bacterial contamination, including total coliforms, *E. coli*, *Salmonella* spp., and *Staphylococcus aureus*, while 10.0% were contaminated with intestinal parasites. The microbiological contamination did not vary significantly according to water source or restaurant/vendor location. In contrast, parasitological contamination showed a statistically significant association with water source, with itinerant water supplies recording markedly higher contamination than borehole, municipal, and rainwater sources ($p < 0.001$). The detection of bacterial indicators and potentially pathogenic organisms, together with *Ascaris*, *Giardia lamblia*, and *Cryptosporidia* spp., indicates a potential public health concern because contaminated water can contribute to food contamination and subsequent transmission of food- and waterborne infections. Particular attention should therefore be given to itinerant water supplies. Routine quality monitoring, appropriate treatment of water before use, hygienic storage and handling practices, and strengthened regulatory surveillance of water sources used by restaurants and local food vendors are recommended to minimize potential foodborne and waterborne health risks in the study area.

Declarations

Ethical Considerations

This study was approved by the Imo State University Ethical Committee on Parasitic and Infectious Diseases Research in accordance with the relevant guidelines and regulations. The protocol number for this approval is (IMSU/AEB/ETH/PIDR/1.2021). Prior to participation, the purpose and procedures of the study were explained to the restaurant owners and local food vendors. Written informed consent was obtained from all participants before the collection of water samples and administration of any relevant field information. Participation was voluntary, and participants were assured that the information obtained would be treated confidentially and used exclusively for research purposes.

Consent for publication

Not applicable

Competing Interest

The authors declare no competing interest

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Author Contribution

Conceptualization: OGH and JII. Funding acquisition and project administration: OGH and JII. Sample Collection: OGH and JII. Sample processing and data generation: OGH and JII. Data curation: OGH and JII. Formal analysis and data validation: JII. Data visualization: JII. Resources: OGH and JII. Supervision: OGH and JII Writing original draft and editing: OGH and JII. Writing review, and editing: OGH and JII. All authors reviewed and approved the final manuscript.

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Data Availability

All data supporting the findings of this study are available within the paper and its Supplementary Information.

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Figures

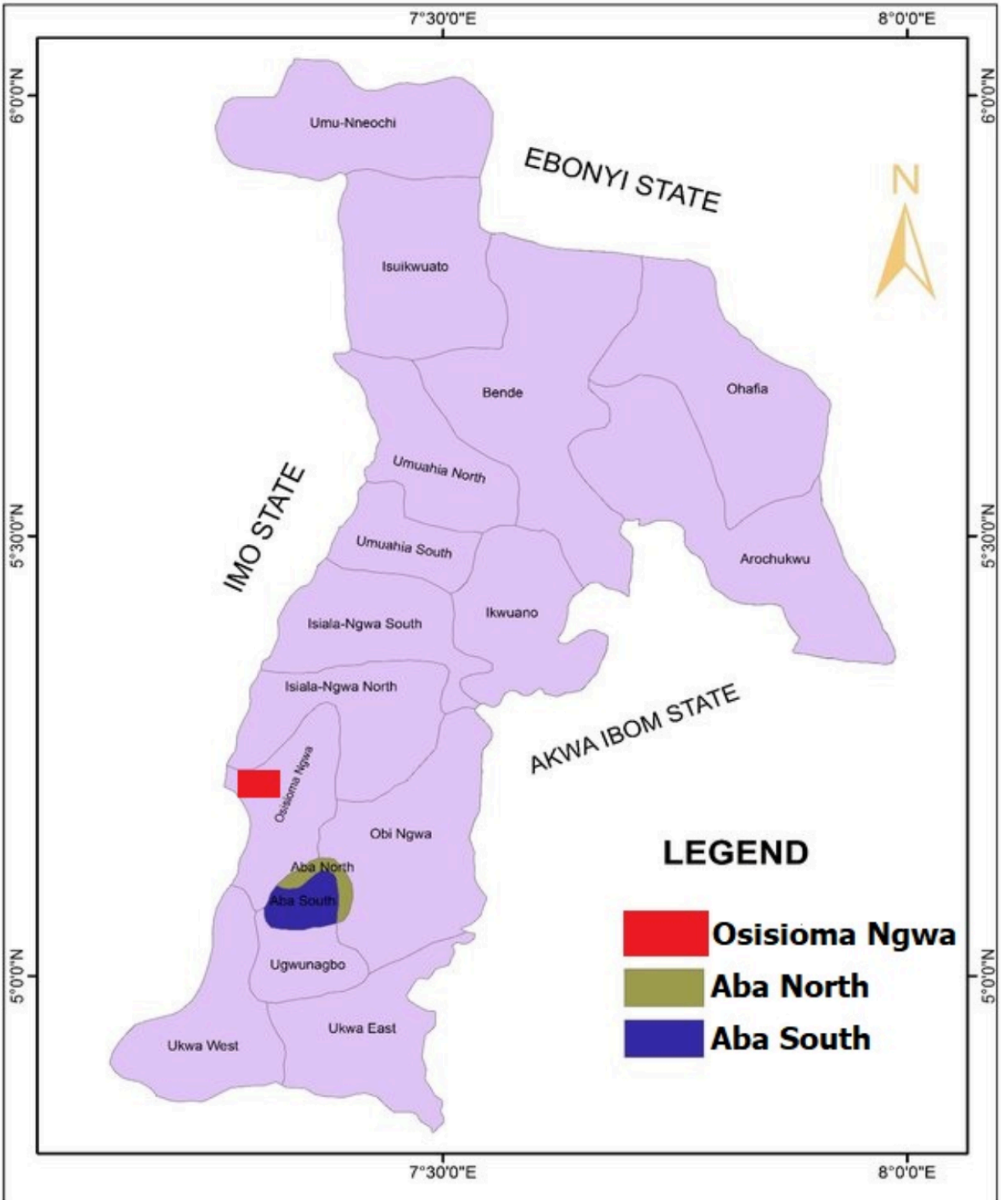


Figure 1

Map 1: Map of Abia State showing the sampling locations

Source: Nkemdirim et al. 2000