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Original Research Article

Microbial Quality of Open Shallow Wells and Health Outcomes in Okofia Community, Anambra State, Nigeria

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ABSTRACT

Background: Access to microbiologically safe drinking water remains a major public health challenge in many low-resource communities where open shallow wells serve as primary sources of domestic water. This study assessed the prevalence of *Escherichia coli* contamination in open shallow wells in Okofia Community, Anambra State, Nigeria, and evaluated its public health implications.

Methods: A descriptive cross-sectional study was conducted involving laboratory analysis of fourteen (14) open shallow well water samples and structured questionnaires administered to 206 adult residents. Water samples were analyzed for *E. coli* using standard microbiological techniques, while questionnaire data were used to assess water-use practices, environmental risk factors, and self-reported water-related illnesses. Descriptive statistics and Pearson correlation analysis were performed using IBM SPSS version 25.

Results: *Escherichia coli* was detected in 6 of the 14 sampled wells (42.9%), with contamination levels ranging from 15 to 260 CFU/100 mL, while 8 wells (57.1%) complied with the World Health Organization guideline of zero *E. coli* per 100 mL. Most households (81.6%) relied on open shallow wells for drinking and domestic purposes. Common environmental risk factors included proximity of wells to latrines, refuse dumps, and stagnant water. Self-reported illnesses included typhoid fever (36.4%), diarrhoea (17.4%), and other gastrointestinal symptoms. A strong positive correlation was observed between *E. coli* concentrations and gastrointestinal diseases ($r = 0.851$, $p < 0.001$), indicating that increasing microbial contamination was associated with a higher occurrence of gastrointestinal illness.

Conclusion: A substantial proportion of open shallow wells in Okofia Community are microbiologically unsafe and pose significant public health risks. Strengthening routine microbial surveillance, improving well construction and sanitary protection, enforcing appropriate separation distances from contamination sources, promoting household water treatment and safe storage, and expanding access to safely managed drinking water are essential to reducing waterborne disease transmission and improving community health.

Keywords: *Escherichia coli*; open shallow wells; drinking water quality; waterborne diseases; environmental sanitation.

INTRODUCTION

Access to safe drinking water is a fundamental human right and an essential determinant of public health (WHO, 2023). Despite global efforts to improve water safety, approximately 2.2 billion people still lack safely managed drinking water services, with many relying on unimproved water sources such as open wells and springs (WHO, 2023). Consequently, consumption of contaminated water remains a major contributor to waterborne diseases and associated morbidity and mortality, particularly in low- and middle-income countries (WHO, 2023). Among the microbiological indicators used to assess drinking water quality, *Escherichia coli* (*E. coli*) is regarded as the most reliable indicator of fecal contamination (Odonkor & Ampofo, 2013). *E. coli* is a Gram-negative bacterium that naturally inhabits the gastrointestinal tract of humans and warm-blooded animals (CDC, 2024). Although most strains are harmless, the presence of *E. coli* in drinking water signifies recent fecal pollution and suggests the possible presence of other enteric pathogens capable of causing disease (Odonkor & Ampofo, 2013; WHO, 2018). Consequently, *E. coli* is widely used as an indicator organism for evaluating microbiological water safety (WHO, 2018).

Open shallow wells are particularly susceptible to contamination due to inadequate protection and exposure to environmental pollutants. Proximity to pit latrines, septic systems, refuse dumps, animal enclosures, and stagnant wastewater facilitates microbial contamination through seepage and surface runoff, especially during rainfall events (Howard et al., 2003; Graham & Polizzotto, 2013). Inadequate well construction, lack of protective covers, and poor drainage systems further increase vulnerability (Howard et al., 2003). As a result, microbial contamination of groundwater remains a significant public health challenge in many developing countries, particularly in sub-Saharan Africa where access to safely managed drinking water is limited (WHO, 2023). Numerous studies have reported elevated levels of E. coli in hand-dug wells and groundwater sources used for domestic purposes (Bain et al., 2014; Graham & Polizzotto, 2013). Consumption of such contaminated water has been linked to outbreaks of diarrheal diseases, cholera, typhoid fever, dysentery, and other gastrointestinal infections, which disproportionately affect children, older adults, and immunocompromised individuals, contributing substantially to the global burden of disease (WHO, 2023; UNICEF, 2024).

In Nigeria, shallow wells constitute an important source of water supply for many rural and peri-urban communities due to inadequate access to piped water systems (National Bureau of Statistics & UNICEF, 2022). However, poor environmental sanitation, indiscriminate waste disposal, rapid urbanization, and inadequate water quality surveillance have increased the vulnerability of groundwater sources to fecal contamination (Graham & Polizzotto, 2013). Studies conducted in various regions of Nigeria have reported the presence of *E. coli* and other coliform bacteria in groundwater sources at concentrations exceeding recommended drinking water standards (Howard et al., 2003; Graham & Polizzotto, 2013). Such contamination poses considerable health risks to populations that depend on untreated well water for drinking and household purposes. The World Health Organization recommends that drinking water intended for human consumption should contain no detectable *E. coli* in any 100 mL sample (WHO, 2018). The detection of *E. coli* therefore indicates fecal contamination and non-compliance with established microbiological safety standards (WHO, 2018). Routine monitoring of drinking water sources is therefore essential for safeguarding public health and preventing outbreaks of waterborne diseases (WHO, 2023).

Okofia community, like many semi-urban communities in southeastern Nigeria, relies substantially on open shallow wells for domestic water supply. However, information regarding the microbiological quality of these wells and the associated public health implications remains limited. The paucity of local data constrains evidence-based interventions aimed at improving water safety and reducing the burden of waterborne diseases among residents. Therefore, this study assessed the prevalence of *Escherichia coli* contamination in open shallow wells in Okofia community in Nnewi, Anambra State, and examined its public health implications among residents. Specifically, the study determined the prevalence of *E. coli* contamination in selected wells, evaluated compliance with recommended microbiological safety standards, identified environmental factors associated with contamination, and assessed the occurrence of water-related illnesses among community members. The findings are expected to provide evidence for public health planning, water quality management, and community-based interventions aimed at improving access to safe drinking water and supporting the achievement of Sustainable Development Goal 6 on clean water and sanitation (United Nations, 2024).

MATERIAL AND METHODS

Study Design: This study employed a descriptive cross-sectional design to assess the prevalence of *Escherichia coli* contamination in open shallow wells and its public health implications among residents of Okofia Community, Otolo, Nnewi North Local Government Area (LGA), Anambra State, Nigeria. The design enabled the simultaneous collection of environmental and health-related data, providing a snapshot of water quality status and associated health outcomes within the study area.

Study Area: The study was conducted in Okofia Community, Otolo, Nnewi North Local Government Area (LGA), Anambra State, southeastern Nigeria. Nnewi is located at approximately latitude 6°01′N and longitude 6°55′E and serves as the administrative headquarters of Nnewi North LGA. The town lies southwest of Awka, the capital of Anambra State, and falls within the tropical rainforest ecological zone of southeastern Nigeria. The climate is characterized by high annual rainfall and temperatures that favor microbial survival and transmission. Rapid urbanization, population growth, and inadequate public water infrastructure have increased dependence on groundwater sources, particularly open shallow wells, for domestic water supply.

Study Population: The study population consisted of:

1. Open shallow wells used as sources of drinking and domestic water in Okofia Community.
2. Adult residents who relied on these wells as their primary source of water for domestic use.

A preliminary survey identified approximately 30 functional open shallow wells within the study area.

Inclusion and Exclusion Criteria

Inclusion Criteria

Water Sources

- Open shallow wells actively used for drinking or domestic purposes within Okofia Community.

Human Respondents

- Residents aged 18 years and above.
- Individuals who had resided in the community for at least six months.
- Individuals who relied on open shallow wells as a major source of domestic water.
- Residents who provided informed consent.

Exclusion Criteria

Water Sources

- Boreholes, rainwater harvesting systems, protected wells, and other enclosed water sources.

Human Respondents

- Residents who did not utilize open shallow wells.
- Visitors and temporary residents.

- Individuals unwilling to provide informed consent.

Sample Size Determination

Water Samples

The total number of open shallow wells in Okofia community is currently unknown. Therefore, a preliminary reconnaissance was conducted to estimate their number. For the purpose of this proposal, an approximate total of 30 wells is assumed based on field observation. The required number of wells for sampling were determined using Yamane's (1967) formula for finite populations:

$n=N/[1+N(e)^2]$

Where:

n = sample size

N = population size (30 wells)

e = level of precision (margin of error)

n= 30/1+30(0.2) ² = 30/2.2 = 13.6

Approximately is = 14.

Number of sample of open well to be collected will be fourteen (14).

Human Respondents

The total number of residents relying on open shallow wells is unknown; thus, the sample size for the health assessment component was determined using Cochran's (1963) formula for an unknown population:

Cochran's Sample size determination formula

$n=[Z^2.p.(1-p)]/e^2$

Z-score, corresponding to the desired confidence level (e.g., 1.96 for 95% confidence)

p = Estimated proportion of the population with the attribute of interest (if unknown, use for maximum variability)

e = Margin of error (expressed as a decimal, e.g., 0.05 for ±5%)

Substituting

Z^2= 1.96

Z^2= 3.8416

p=0.84 (estimate proportion of secondary school students)

p.(1-p) =0.84× (1-0.84)

p= 0.84 x 0.16

e^2= 0.0025

n= 3.8416 × 0.84 x 0.16/0.0025

=0.5163/0.0025

=206.52

Approximately the population size, the sample size is 206.

However, due to logistical constraints and the relatively small population of households utilizing the sampled wells, 206 eligible residents were recruited for the study.

Sampling Technique

A multistage sampling approach was adopted.

Selection of Wells**:** Fourteen open shallow wells were purposively selected based on:

- Frequency of use by residents;
- Geographical distribution within the community;
- Accessibility;
- Proximity to potential contamination sources such as pit latrines, refuse dumps, stagnant wastewater, and animal enclosures.

Each selected well was assigned a unique identification code.

Selection of Respondents**:** Households utilizing the selected wells were identified, and eligible respondents were selected using systematic random sampling. Only one consenting adult respondent was recruited from each selected household.

Data Collection Instruments: Data were collected using:

- Sterile 500 mL screw-capped sampling bottles;
- Cooler boxes with ice packs;
- Personal protective equipment (gloves and face masks);
- Structured interviewer-administered questionnaires;
- Laboratory equipment including incubators, autoclaves, refrigerators, microscopes, and microbiological culture media.

Water Sample Collection: Fourteen water samples were collected from selected open shallow wells using sterile 500 mL sampling bottles. Samples were collected approximately 30 cm below the water surface to avoid floating debris and surface contaminants.

Each sample was labelled appropriately and immediately stored in a cooler box maintained at approximately 4°C. Samples were transported to the microbiology laboratory within six hours of collection and analyzed immediately upon arrival.

Questionnaire Administration: Structured questionnaires were administered to 206 consenting adult residents. Information obtained included socio-demographic characteristics, water-use practices, environmental sanitation conditions, household water treatment methods, and self-reported history of water-related illnesses such as diarrhoea, typhoid fever, cholera, and other gastrointestinal symptoms.

Microbiological Analysis: Water samples were analyzed for the presence and concentration of *Escherichia coli* using standard microbiological methods.

Culture Procedures: Samples were cultured on:

- MacConkey Agar;
- Eosin Methylene Blue (EMB) Agar.

Following inoculation, culture plates were incubated aerobically at 37°C for 24–48 hours.

Presumptive *E. coli* colonies were identified based on characteristic colony morphology, including:

- Pink lactose-fermenting colonies on MacConkey Agar;
- Metallic green sheen colonies on EMB Agar.

Biochemical Identification: Presumptive isolates were subjected to standard biochemical tests, including:

- Indole test;
- Methyl Red test;
- Voges–Proskauer test;
- Citrate utilization test (IMViC).

Isolates exhibiting characteristic IMViC reactions consistent with *E. coli* were recorded as positive.

Enumeration of *E. coli*: Results were expressed as colony-forming units per 100 mL (CFU/100 mL) and interpreted according to WHO Guidelines for Drinking-water Quality, which require zero detectable *E. coli* in 100 mL of drinking water.

Preparation of Culture Media: MacConkey Agar, EMB Agar, and Peptone Water were prepared according to manufacturers' specifications. Prepared media were sterilized by autoclaving at 121°C for 15 minutes, cooled, dispensed aseptically into sterile Petri dishes, and stored under recommended laboratory conditions until use.

Data Analysis: Laboratory and questionnaire data were entered into Microsoft Excel and subsequently analyzed using IBM SPSS Statistics version 25. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize study findings.

Results were presented using tables and charts. The prevalence of *E. coli* contamination was calculated as the proportion of contaminated wells relative to the total number of wells sampled.

Ethical Considerations: Ethical approval was obtained from the Research Ethics Committee of the Faculty of Health Sciences and Technology, Nnamdi Azikiwe University, Nnewi Campus, prior to commencement of the study. Permission was obtained from community leaders and household heads. Written informed consent was obtained from all participants before data collection. Confidentiality and anonymity of respondents were maintained throughout the study.

RESULTS

Table 1: Socio-demographic characteristics of the participants

Variable		Number (206)	Percentage (%)
Gender	Male	68	33.0
	Female	138	66.9
	Total	206	100
Age group (years)	18-25	78	37.8
	26-35	44	21.4
	36-45	37	17.9
	46-55	28	13.6
	56+	19	9.2
	Total	206	100
Highest level of education attained	No formal education	26	12.6
	Primary education	39	18.9
	Secondary education	49	23.8
	Tertiary education	92	44.7
	Total	206	100
Household size (per person)	1-3 persons	20	9.7
	4-6 persons	39	18.9
	≥7 persons	147	71.4
	Total	206	100

Table 1 presents the socio-demographic characteristics of the 206 respondents. Females constituted the majority (66.9%), while the largest age group was 18–25 years (37.8%). Most respondents had attained tertiary education (44.7%), and the majority lived in households with seven or more persons (71.4%).

Table 2: Shows other sources of water in Okofia community

Variable		Number (206)	Percentage (%)
What other drinking sources does your House-hold use?	Borehole	56	27.2
	Sachet water	106	51.5
	Rainwater	10	4.9
	Sachet and borehole water	34	16.5
	River/stream	0	0
	None	0	0
	Total	206	100
How does your house-hold treat water?	None	40	19.4
	Boiling	75	36.4
	Filtration	53	25.7
	Chlorination	38	18.4
	Total	206	100

Table 2 shows that sachet water was the most common alternative drinking water source (51.5%), followed by borehole water (27.2%). Boiling was the most frequently used household water treatment method (36.4%), while 19.4% of respondents did not treat their water before use.

Table 3: Laboratory Analysis of E. coli Contamination

Well ID (n=14)	Colony Forming Unit/100ml (CFU/100ml)	E-coli
Well 1	0	Negative
Well 2	0	Negative
Well 3	15	Positive
Well 4	22	Positive
Well 5	48	Positive
Well 6	0	Negative
Well 7	85	Positive
Well 8	140	Positive
Well 9	0	Negative
Well 10	260	Positive
Well 11	0	Negative
Well 12	0	Negative
Well 13	0	Negative
Well 14	0	Negative

Table 3 shows that *Escherichia coli* was detected in **6 of the 14 (42.9%)** sampled wells, with counts ranging from **15 to 260 CFU/100 mL**, while the remaining **8 wells (57.1%)** had no detectable *E. coli*.

Table 4: Shows the environmental and household risk factors for using open shallow wells

Variable		**Number (206)**	**Percentage (%)**
Approximate distance from households well to the nearest latrine.	Less than 10 meters 10-30 meters More than 30 meters Don't know Total	68 86 48 4 206	33.0 41.7 23.3 1.9 100
Environmental risks within 10m of household's well.	Refuse dump (solid waste) Stagnant water Animal pens/poultry Open drainage/sewage channel Latrine pit nearby None Don't know Total	70 62 10 12 25 27 0 0 206	34.0 30.1 4.9 5.8 12.1 13.1 0 0 100
Use of household open shallow well water for drinking or cooking in the last 3 months.	Yes No Total	168 38 206	81.6 18.4 100
No. of household member that experienced the following health conditions in the past 3 months	Diarrhea Cholera Typhoid fever Malaria Nil Total	30 0 75 82 19 206	17.4 0 36.4 39.8 9.2 100

Table 4 shows that most households had wells located within 10–30 m of a latrine (41.7%), with refuse dumps (34.0%) and stagnant water (30.1%) being the most common nearby environmental hazards. Most respondents (81.6%) used open shallow well water for drinking or cooking, while malaria (39.8%), typhoid fever (36.4%), and diarrhoea (17.4%) were the most commonly reported illnesses within the past three months.

Table 5: Shows the health conditions experienced by respondents in the past three months.

Well ID (n=14)	**Colony Forming Unit/100ml (CFU/100ml)**	**Gastrointestinal tract diseases (Diarrhea and Cholera)**
Well 1	0	3
Well 2	0	3
Well 3	15	8
Well 4	22	10
Well 5	48	8
Well 6	0	2
Well 7	85	14
Well 8	140	13
Well 9	0	6
Well 10	260	16
Well 11	0	6
Well 12	0	6
Well 13	0	6
Well 14	0	4
Total		105

Table 5 shows that gastrointestinal disease cases were more frequent among users of wells with higher *E. coli* counts, with the highest numbers recorded for Wells 7, 8, and 10, while wells with no detectable *E. coli* generally had fewer reported cases.

Table 6: Shows the pearson correlation of the colony forming unit(CFU/100ml) of the wells with the gastrointestinal diseases (Diarrhea and cholera)

Variable		colony forming unit(CFU/100ml)
Gastro-intestinal diseases (Diarrhea and cholera)	r-value p-value	0.851 <0.001**

p-value is significant at <0.05

DISCUSSION

This study assessed the prevalence of *Escherichia coli* contamination in open shallow wells in Okofia Community and examined its public health implications. The findings indicate that a substantial proportion of the community's shallow wells are microbiologically unsafe and that reliance on these water sources may increase residents' exposure to waterborne diseases. These findings are important because groundwater remains the principal source of drinking water for many rural and peri-urban communities in Nigeria where access to safely managed water services is limited (WHO & UNICEF, 2023).

Prevalence of *Escherichia coli* Contamination

Laboratory analysis showed that 42.9% (6/14) of the sampled open shallow wells were contaminated with *Escherichia coli*, with concentrations ranging from 15 to 260 CFU/100 mL. According to the World Health Organization (WHO) Guidelines for Drinking-water Quality, *E. coli* should not be detectable in any 100 mL sample of drinking water because its presence indicates recent faecal contamination and the possible presence of enteric pathogens capable of causing gastrointestinal infections (WHO, 2022). The detection of *E. coli* in nearly half of the sampled wells suggests that faecal contamination remains an important environmental health challenge in Okofia Community. Similar findings have been reported in many low- and middle-income countries where shallow groundwater is inadequately protected from human and animal wastes. Poor sanitary conditions, unprotected well structures, surface runoff, and infiltration from nearby sanitation facilities have consistently been identified as major pathways through which faecal microorganisms enter groundwater sources (Howard et al., 2003; Graham & Polizzotto, 2013).

Comparable studies conducted in Nigeria have also reported frequent microbial contamination of shallow wells and other domestic groundwater sources. For example**,** Adesakin et al. (2020) reported that well water in Samaru Community, Zaria, contained *Escherichia*, *Salmonella*, *Shigella*, *Proteus*, and *Enterobacter*, with bacterial loads exceeding WHO permissible limits, demonstrating significant faecal contamination of domestic water sources. Likewise, Olalemi et al. (2021) detected *E. coli* and other enteric bacteria in groundwater sources used for domestic purposes, highlighting the public health risks associated with consumption of untreated groundwater. Similar observations have been made elsewhere in sub-Saharan Africa, where inadequate environmental sanitation and rapid urbanization continue to compromise groundwater quality (WHO & UNICEF, 2023).

The considerable variation in bacterial counts observed among wells (15–260 CFU/100 mL) further suggests that local environmental conditions, differences in well construction, surrounding land use, and maintenance practices substantially influence groundwater quality. Such spatial variation has been widely reported in groundwater quality studies and reflects differences in hydrogeological conditions, contamination sources, and sanitary protection of individual wells (Lapworth et al., 2020).

Compliance with WHO Drinking-water Standards

Although 57.1% of the sampled wells complied with WHO microbiological standards, 42.9% failed to meet the recommended requirement of zero detectable E. coli per 100 mL of drinking water. From a public health perspective, this level of non-compliance is concerning because contamination of even a relatively small proportion of community water sources can substantially increase the risk of disease transmission among populations relying on untreated groundwater (WHO, 2022). The environmental assessment identified several contributing factors: approximately one-third of respondents reported that their household wells were located less than 10 metres from pit latrines, and refuse dumps, stagnant water, and nearby animal activities were commonly observed around wells. These conditions facilitate microbial transport into groundwater through seepage, infiltration, and stormwater runoff, particularly during periods of heavy rainfall.

These findings are consistent with previous investigations demonstrating that inadequate separation distances between wells and sanitation facilities significantly increase groundwater contamination. Lapworth et al. (2020) emphasized that groundwater quality in developing countries is strongly influenced by on-site sanitation systems, while Bain et al. (2021) similarly concluded that poor sanitation infrastructure remains one of the leading determinants of faecal contamination of drinking water sources in low-resource settings. The WHO further recommends maintaining adequate sanitary setbacks and protecting wells from surface contamination to minimize microbial pollution (WHO, 2022).

Public Health Implications

The study found that 81.6% of respondents relied on open shallow wells for drinking and domestic purposes, demonstrating the community's heavy dependence on groundwater. Such dependence increases population vulnerability because contamination of community wells exposes a large number of residents to waterborne pathogens. According to the WHO and UNICEF Joint Monitoring Programme, populations lacking safely managed drinking water services continue to experience disproportionately higher burdens of diarrhoeal diseases and other enteric infections (WHO & UNICEF, 2023). Self-reported illnesses among respondents showed notable occurrences of typhoid fever (36.4%), diarrhoea (17.4%), and other gastrointestinal symptoms, including fever, abdominal pain, vomiting, nausea, and loss of appetite. These illnesses were more frequently reported among households using Wells (Households - 7, 8, and 10), which recorded the highest *E. coli* concentrations. Conversely, respondents using wells without detectable *E. coli* generally reported fewer gastrointestinal illnesses.

A major finding of this study was the strong positive correlation between E. coli concentration and gastrointestinal diseases ($r = 0.851$, $p < 0.001$). This statistically significant relationship indicates that increasing levels of faecal contamination were associated with higher occurrences of diarrhoeal diseases among users of the sampled wells. Although the cross-sectional design precludes causal inference, the observed association is biologically plausible and consistent with extensive epidemiological evidence linking faecally contaminated drinking water to increased risks of diarrhoea, cholera, typhoid fever, and other enteric infections (Wolf et al., 2023; WHO, 2022). Interpretation of these findings should also consider household water-use practices. While many respondents reported treating their drinking water by boiling, filtration, or chlorination, approximately one-fifth consumed water without any treatment. Household water treatment has consistently been shown to reduce microbial contamination and decrease the incidence of diarrhoeal diseases, particularly in settings where centralized water treatment is unavailable (Wolf et al., 2023). Thus, untreated consumption of contaminated well water likely contributed to the occurrence of gastrointestinal illnesses observed in this study.

Furthermore, many households supplemented well water with sachet water or borehole water. While this practice may reduce exposure, it does not eliminate risk because open shallow wells remained the principal domestic water source for most households. Similar coping strategies have been documented in Nigerian communities experiencing unreliable access to improved drinking water sources (National Bureau of Statistics & UNICEF, 2022). Overall, the findings reinforce existing evidence that microbial contamination of shallow groundwater remains a significant environmental health problem in many developing countries. Addressing this challenge requires integrated interventions involving improved sanitation, protection of groundwater sources, routine microbiological surveillance, community education on household water treatment, and expansion of access to safely managed drinking water services. Such interventions are central to achieving Sustainable Development Goal 6, which seeks universal access to safe and affordable drinking water (United Nations, 2024).

CONCLUSION

This study provides important evidence that open shallow wells remain the primary source of domestic water for many households in Okofia Community but continue to pose significant public health concerns because of microbial contamination. Nearly half (42.9%) of the sampled wells contained *Escherichia coli*, indicating recent faecal contamination and non-compliance with the World Health Organization's microbiological standards for safe drinking water. The occurrence of contamination was closely associated with poor environmental sanitation, including the proximity of wells to pit latrines, refuse dumps, stagnant water, and other potential sources of faecal pollution, underscoring the influence of environmental conditions on groundwater quality.

The study further found that the widespread reliance on untreated shallow well water, coupled with the high prevalence of diarrhoea, typhoid fever, and other gastrointestinal illnesses, may represent a substantial environmental health challenge within the community. The strong positive correlation observed between *E. coli* contamination and gastrointestinal diseases suggest that exposure to contaminated well water may be an important contributor to the burden of waterborne diseases among residents. Although the cross-sectional design precludes causal inference, the findings reinforce the critical role of microbiologically safe drinking water in preventing enteric infections and improving community health.

Collectively, these findings highlight the urgent need for integrated, multisectoral interventions that address both water quality and environmental sanitation. Strengthening routine microbiological surveillance of community water sources, improving well design and sanitary protection, enforcing appropriate setback distances between wells and sources of faecal contamination, and promoting household water treatment and safe storage practices should form essential components of local water safety strategies. Equally important is the expansion of access to safely managed drinking water through protected boreholes and reliable piped-water systems, alongside sustained community health education and strengthened environmental sanitation programmes. Incorporating regular sanitary inspections and risk-based water safety planning into community environmental health programmes would further enhance the protection of groundwater resources and reduce preventable exposure to microbial contaminants.

Beyond its local significance, this study contributes valuable evidence to the growing body of literature on groundwater safety in low-resource settings and underscores the need to strengthen water, sanitation, and hygiene (WASH) interventions as part of broader public health strategies for achieving Sustainable Development Goal 6 on universal access to safe and affordable drinking water. Future research should build on these findings through larger longitudinal and seasonal investigations incorporating physicochemical water quality assessment, quantitative microbial risk assessment, antimicrobial resistance profiling, and molecular characterization of waterborne pathogens to provide a more comprehensive understanding of groundwater contamination dynamics and their implications for public health.

Declaration by Authors

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