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Original Article

Evaluation of Groundwater Quality in Peri-urban Community of Malete, North-Central, Nigeria

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ABSTRACTS

Groundwater remains a vital source of domestic water supply in Malete, Kwara State, Nigeria. However, increasing anthropogenic activities and poor sanitation raise concerns about its quality and safety for human consumption. Five (5) wells were sampled and analysed for physicochemical and bacteriological parameters using standard procedures. Key physicochemical indicators measured included pH, temperature, electrical conductivity, total dissolved solids (TDS), hardness, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS). Microbiological analysis involved enumeration of total bacterial counts, coliforms, and *Salmonella–Shigella*, alongside biochemical characterization of isolates. Results revealed physicochemical parameters largely complied with World Health Organisation (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) standards, with pH (6.4–6.9), conductivity (30.9–88.8 µS/cm), and TDS (15.9–46.0 mg/L) within permissible ranges. However, elevated BOD values (14.4–56.0 mg/L) indicated significant organic pollution. Microbiological analysis revealed extensive contamination: total bacterial counts were too numerous to count, coliform populations ranged from 110–130 CFU/mL, and *Salmonella–Shigella* counts ranged between 50–85 CFU/mL. Pathogenic species, including *Escherichia coli*, *Salmonella*, *Shigella*, *Proteus mirabilis*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa*, were isolated across all wells. Although the groundwater sources in Malete exhibited acceptable physicochemical quality, their high microbial load renders them unsafe for drinking without treatment. The findings highlight the urgent need for improved sanitation infrastructure, routine water disinfection, and continuous monitoring to safeguard public health and reduce the risk of waterborne diseases in the community.

Keywords: Groundwater, Water quality, Physicochemical parameters, Bacteriological contamination, Anthropogenic

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INTRODUCTION

Water is an essential natural resource that sustains human health, supports ecosystems, and drives socio-economic development. Its quality directly influences drinking-water safety, agricultural productivity, industrial processes, and ecological balance. Despite its indispensability to life, water quality is increasingly threatened across the globe [1]. The main challenges include microbial contamination, chemical pollution, and emerging threats such as microplastics and per- and polyfluoroalkyl substances (PFAS), all of which pose serious risks to human and ecological health [2,3]. The United Nations [4] reports that over two billion people globally lack access to safely managed drinking water, while billions more rely on contaminated sources that heighten the risk of waterborne diseases. Deteriorating water quality has become a global concern [5-6]. Polluted water can transmit life-threatening diseases, including kidney failure, cholera, typhoid fever, gastroenteritis, and giardiasis [7,8]. Groundwater contamination alone is estimated to cause nearly two million premature deaths each year [9], underscoring the urgent need for sustainable management of this vital resource [10].

In Nigeria, groundwater is indispensable for domestic, agricultural, and industrial purposes. However, several studies have reported widespread contamination from both anthropogenic and geogenic sources [11,12]. Common issues include elevated levels of heavy metals, nitrate leaching from fertilizers, and bacterial pollution associated with poor sanitation infrastructure [13-15]. Despite increased research attention, regional disparities persist, with rural and peri-urban communities often receiving limited monitoring even though they rely heavily on untreated borehole and hand-dug well water.

Malete, a rapidly growing town that hosts Kwara State University, has experienced increasing population and business activities driven by academic and commercial opportunities. In addition to its indigenous residents, the town accommodates numerous students and traders from within and outside Kwara State. However, rapid population growth combined with inadequate waste management and sanitation systems poses a potential threat to groundwater quality. Preliminary studies indicate that borehole and well water consumed by households in Malete may not consistently meet the World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) limits [16]. Therefore, this study aims to investigate the quality of groundwater in Malete, Nigeria.

MATERIALS AND METHODS

Study Area

This study was carried out in Malete, a semi-urban community located in Moro Local Government Area of Kwara State, Nigeria. Malete lies at approximately longitude 4°28′0″E and latitude 8°42′0″N and experiences a tropical wet-and-dry climate typical of the North-Central region. The area has two distinct seasons: a rainy season (April–October), with peak rainfall between July and September, and a dry season (November–March), characterized by cool, dusty Harmattan winds originating from the Sahara Desert. Average annual rainfall ranges from 1,200 to 1,500 mm, while mean annual temperatures fluctuate between 25°C and 32°C, with the hottest period typically occurring before the onset of rainfall. This climatic regime influences local agricultural practices, water resource availability, and the socio-economic activities of residents. The major sources of water supply in the community include rivers, boreholes, and hand-dug wells, with the latter being the most used by residents

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Table 1: Location and Description of Hand Dug Wells in Malete

Location	Coordinates	Well Identification	Well Description
Safari	8.70172 N 4.46832 E	Well 1	■ Covered with metallic slab and under lock ■ Surroundings tidy ■ 5m from pit latrine ■ Inside lined with cement ■ Used for domestic purpose ■ Multiple receptacles used
Market	8.7110434N 4.4634610E	Well 2	■ Surroundings not tidy ■ Inside lined with cement ■ Multiple receptacles used ■ Used for domestic purposes ■ Sited close to charcoal production site
Tarmac	8.7100173N, 4.4667263E	Well 3	■ Covered with rusty metallic slab that is mostly left opened ■ Surroundings tidy ■ Inside lined with concrete ■ Multiple receptacles used ■ Used for domestic and other purposes
School gate	8.715977N 4.470007E	Well 4	■ Uncovered ■ Surroundings untidy ■ Inside lined with cement ■ Multiple receptacles used ■ Used for domestic purposes ■ Close to refuse dumps
Westend	8.7036860N 4.4694534E	Well 5	■ Covered with metallic slab ■ Surroundings untidy ■ Inside lined with concrete ■ Used for domestic purposes ■ Multiple receptacles being used

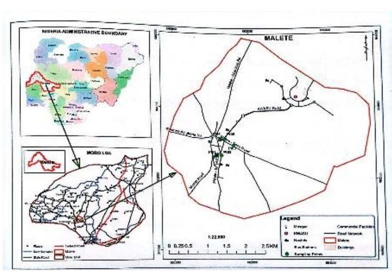
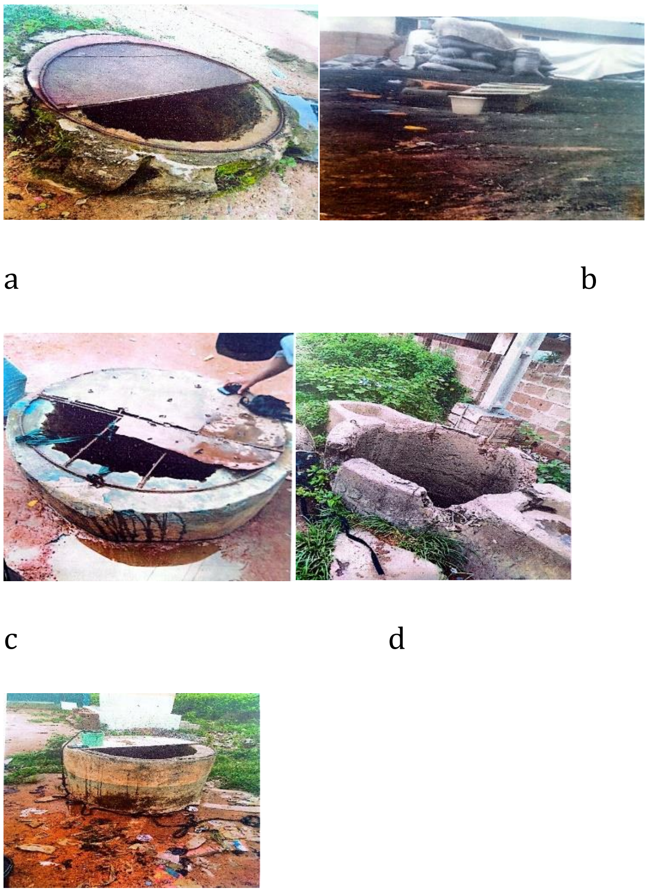


Figure 1: Map of the Study Area Showing Sampling Points

Sample collection

Water samples were collected from five (5) perennial hand-dug wells used for communal purposes across five locations in Malete: Westend, Safari, Market, School Gate, and Tarmac (Figure 2a - e). The wells were designated as Well 1 to Well 5 (Table 1) and Global Positioning System (GPS) was used to collected coordinates for production of the study area map (Figure 1). From each well, 2 L of water were collected using sterilized water samplers. Samples were properly labelled, stored in ice-cooled boxes, and transported to the laboratory for analysis within 24 hours of collection. On-site measurements of temperature, pH, and electrical conductivity were performed using standard methods described by APHA [17]. Temperature was measured with a calibrated mercury thermometer, pH was determined using a Hanna Instrument meter (Model HI9813-6) previously standardized with buffer solutions (pH 4.0, 7.0, and 9.0), and conductivity was measured with a calibrated conductivity meter using potassium chloride (KCl) as a reference standard.



a b

c d

e

Figure 2a-e: Pictures of Hand dug wells at (a) Safari, (b) Malete Market, (c) Tarmac, (d) KWASU Gate, (e) Westend

Chemical Oxygen Demand (COD), Total Suspended Solids (TSS) and Microbiological analyses were performed following APHA [17 and 18], Total and faecal coliforms were enumerated using the membrane filtration technique, and the detection of *Salmonella* and *Shigella* species was performed using an enrichment and selective plating approach.

RESULTS

The physicochemical characteristics of water samples collected from the five wells in Malete are shown in Table 2. The pH of the water samples ranged from 6.4 to 6.9, while temperature values were between 24.9°C and 25.3°C. Electrical conductivity varied from 30.9 to 88.8 µS/cm, and total dissolved solids (TDS) ranged from 15.9 to 46.0 mg/L. The total hardness values were between 105.0 and 138.6 mg/L, and dissolved oxygen (DO) ranged from 73.6 to 112.0 mg/L. Chemical oxygen demand (COD) values varied from 2.0 to 9.2 mg/L, while biochemical oxygen demand (BOD) ranged between 14.4 and 56.0 mg/L. Total suspended solids (TSS) concentrations were relatively low, ranging from 1.9 to 2.9 mg/L

Table 2: Physicochemical Properties of Water Sample

Parameters	Well 1	Well 2	Well 3	Well 4	Well 5	WHO Standards (WHO, 2012)
pH	6.5	6.9	6.7	6.56	6.4	6.5-8.5
Temperature	25.00	25.30	25.20	25.00	24.90	-
Conductivity (μS/cm)	61.00	88.80	30.90	50.00	53.80	250
Total Hardness ($CaCO_3$ mg/L)	105.00	130.60	121.70	138.60	122.50	-
TDS (mg/l)	34.20	46.00	15.90	25.30	24.60	500
DO (mg/l)	90.80	102.40	73.60	112.00	96.00	5
TSS (mg/l)	2.60	2.88	2.24	2.90	1.90	20
COD (mg/l)	2.00	9.20	3.20	5.20	2.80	10
BOD (mg/l)	14.40	56.00	24.00	54.40	39.90	-

The bacteriological results presented in Table 3 show that the total bacterial counts (TNTC) in all wells investigated were too numerous to count, indicating high microbial loads. Total coliform counts ranged from 110×10^4 CFU/mL to 130×10^4 CFU/mL, while total *Salmonella–Shigella* counts ranged between 50×10^4 and 85×10^4 CFU/mL.

Table 3: Total Number of Bacteria Count

Samples	Total Bacteria count CFU/ml 10^4	Total Coliform count CFU/ml 10^4	Total *salmonella Shigella* CFU/ml 10^4
Well 1	TNTC	127	60
Well 2	TNTC	130	85
Well 3	TNTC	125	65
Well 4	TNTC	120	74
Well 5	TNTC	110	50

*TNC- Too Numerous to Count

Biochemical tests conducted on the isolates (Table 4) identified several organisms, including *Escherichia coli*, *Proteus mirabilis*, *Klebsiella pneumoniae*, *Enterobacter aerogenes*, *Staphylococcus aureus*, *Salmonella*, and *Shigella* spp. Most isolates tested positive for catalase, oxidase, citrate, and indole reactions, which aided in their identification.

Table 4: Biochemical Characterization of Isolates

Colonies	Catalase test	Oxidase test	Citrate test	Indole test	Specific Organisms
Colony A1	+	+	+	+	*Escherichia coli*
Colony A2	+	+	+	+	*Proteus mirabilis*
Colony A3	+	+	+	+	*Staphylococcus aureus*
Colony A4	+	+	+	-	*Escherichia coli*
Colony A5	+	+	+	+	*Klebsiella pneumoniae*
Colony B1	+	-	+	+	*Enterobacter aerogenes*
Colony B2	+	+	-	+	*Klebsiella pneumoniae*
Colony B3	+	+	+	-	*Enterobacter aerogenes*
Colony B4	+	+	+	+	*Enterobacter aerogenes*
Colony B5	+	+	+	+	*Salmonella*

Colony C1	+	+	+	+	*Salmonella shigella*
Colony C2	+	+	+	+	*Salmonella shigella*
Colony C3	+	+	-	+	*Salmonella shigella*
Colony C4	+	+	+	-	*Salmonella shigella*
Colony C5	+	+	+	+	*Salmonella shigella*

The distribution of bacterial isolates across the sampled wells (Table 4) revealed that *Salmonella* spp., *Shigella* spp., *Escherichia coli*, and *Pseudomonas aeruginosa* were present in all wells. Other isolates such as *Proteus mirabilis*, *Klebsiella pneumoniae*, and *Enterobacter aerogenes* were detected in most wells, while *Staphylococcus aureus* occurred in three of the five wells.

Table 5: Distribution of Isolates in Sample

Isolates	Well 1	Well 2	Well 3	Well 4	Well 5
Salmonella sp	+	+	+	+	+
Proteus mirabilis	+	+	-	+	+
Klebsiella pneumoniae	+	+	+	-	-
Enterobacter aerogenes	-	+	+	+	+
Shigella sp	+	+	+	+	+
Staphylococcus sp	+	+	-	-	+
Escherichia coli	+	+	+	+	+
Pseudomonas Aeruginosa	+	+	+	+	+

DISCUSSION

The physicochemical parameters of all well water samples collected in Malete showed values within the WHO permissible limits of 6.5–8.5, except for Well 5, which was slightly acidic (6.4). Electrical conductivity and total dissolved solids were markedly below the WHO limits of 250 µS/cm and 500 mg/L, respectively, indicating low ionic strength and minimal mineralization. Water hardness values also remained within acceptable limits, suggesting the water's suitability for domestic use. Chemical oxygen demand, total suspended solids, and pH were all within recommended thresholds. These findings are consistent with the reports of Gbadebo [19] and Ganiyu et al. [20], who observed that groundwater in peri-urban and urban areas of southwestern Nigeria generally displayed physicochemical parameters below international limits. However, the biological oxygen demand (BOD) values exceeded WHO standards, indicating significant organic pollution. The unusually high dissolved oxygen (DO) values (73.6–112.0 mg/L) compared with the minimum requirement of 5 mg/L may be attributed to microbial activity and organic matter degradation within the aquifer [1,21].

The consistent detection of *Escherichia coli*, *Salmonella*, *Shigella*, *Proteus mirabilis*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa* clearly indicates faecal contamination. According to WHO [22] and NSDWQ [23] standards, potable water should contain no detectable coliforms or faecal bacteria per 100 mL. Hence, all wells sampled in this study are microbiologically unsafe for human consumption. Similar results have been reported in other Nigerian studies, where shallow groundwater sources exhibited faecal contamination due to poor waste disposal and the close proximity of wells to pit latrines [21,24].

In summary, although the physicochemical quality of groundwater in Malete generally meets WHO and NSDWQ standards, the microbiological results indicate severe contamination and a substantial threat to public health. This aligns with findings from other regions of Nigeria, where groundwater sources typically satisfy chemical quality standards but fail microbiological criteria [25-27]. The coexistence of acceptable physicochemical and poor bacteriological parameters underscores the vulnerability of shallow aquifers to faecal contamination, especially in areas with poor sanitation and unprotected wells. To safeguard residents' health, immediate interventions such as chlorination, boiling, proper well construction, and improved sanitation are strongly recommended.

CONCLUSION

The evaluation of groundwater sources in Malete showed that most physicochemical parameters (pH, conductivity, TDS, hardness, and COD) were within WHO and NSDWQ limits, confirming acceptable mineral quality. However, elevated BOD values and widespread microbial contamination indicate significant organic and faecal pollution. The detection of *E. coli*, *Salmonella*, and *Shigella* in all samples confirms that the groundwater is unsafe for direct consumption. These findings emphasize the need for effective groundwater protection, regular monitoring, and community-level interventions to reduce public exposure to waterborne pathogens. Although the chemical quality of Malete groundwater suggests suitability for domestic use, the microbiological evidence reveals it is unsafe for direct consumption. Immediate remedial actions routine disinfection, proper well design and protection, sanitation upgrades, and continuous monitoring are necessary to ensure safe and sustainable water access while minimizing waterborne disease risks.

Declarations

Ethics Approval: This study did not involve human or animal subjects and therefore required no ethical clearance.

Consent for Publication: All authors reviewed and approved the final manuscript.

Competing Interests: The authors declare no competing interests.

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Authors' Contributions: YAI conceived the study and wrote the manuscript. HOS coordinated sampling and conducted GIS mapping. AA performed the physicochemical analyses, while MAG prepared and supervised microbial assays. All authors read and approved the final version for submission.

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