ASSESSMENT OF THE PHYSICOCHEMICAL AND MICROBIAL CONTENT OF HAND DUG WELLS IN BORIKIRI, PORT HARCOURT, RIVERS STATE, NIGERIA



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Abstract

Groundwater from hand-dug wells remains a major source of domestic water supply in many developing regions; however, its quality is often compromised by natural and anthropogenic activities. This study assessed the physicochemical, heavy metal, and microbiological quality of water from three hand-dug wells (A, B, and C) with the aim of evaluating their suitability for drinking purposes. Water samples were analyzed for key parameters including pH, temperature, electrical conductivity, turbidity, alkalinity, nutrients, major ions, selected heavy metals, and total coliforms using standard laboratory procedures. Data were statistically evaluated using one-way Analysis of Variance (ANOVA) and Tukey's Honestly Significant Difference (HSD) post-hoc test to determine spatial variations among the wells at a 95% confidence level. In addition, the Water Quality Index (WQI) approach was

employed to integrate the measured parameters into a single comprehensive indicator of water quality. The results showed that most basic physicochemical parameters, such as pH, temperature, turbidity, electrical conductivity, and total hardness, were within World Health Organization (WHO) permissible limits. However, significant differences ($p < 0.05$) were observed among the wells for several parameters, including electrical conductivity, nutrients, major ions, and heavy metals. Phosphate, lead, arsenic, copper, zinc, and total coliform levels exceeded WHO guideline values in all the wells. Lead and arsenic concentrations were particularly high, posing serious public health concerns. The computed WQI values for Wells A, B, and C were far above 100, classifying all the wells as excessively polluted and unsuitable for drinking. Well B recorded the highest WQI value, indicating the poorest water quality among the sampled wells. The study concludes that despite acceptable levels of some physicochemical parameters, the combined effects of heavy metal contamination and microbial pollution render the hand-dug wells unsafe for direct human consumption. Appropriate water treatment, improved sanitation practices, and regular groundwater quality monitoring are strongly recommended to safeguard public health and ensure sustainable use of groundwater resources.

***Keywords**: Assessment, water quality index, concentration, physicochemical parameters, hand-dug wells, Borikiri Community.*

1.1 Introduction

Access to clean and safe water is crucial for human health (Akinfolarin et al., 2025, Kalagbor & Akinfolarin, 2023, Akinfolarin & Chukwuji, 2020), yet millions of people globally still rely on potentially contaminated water sources, especially in rural and peri-urban areas.

The consumption of water from surface and groundwater sources without any form of treatment is widely reported in the literature (Edokpayi *et al.,* 2018). Groundwater is often the first alternative of many consumers due to its perceived cleanness and safeness. However, many studies have shown that groundwater can appear clean but houses a wide variety of pathogenic organisms. The safety of groundwater (shallow and deep groundwater sources) depends on a few factors amongst which are (I) the geology of the area (II) human activities/land use

activities of the area (III) environmental and meteorological conditions of the area. Groundwater with high fluoride, arsenic, mercury and cyanide levels have been reported globally (Amaibi et al., 2022). There is an urgent need for the constant monitoring of groundwater as a major component of Water Resource Management (Ahmed et al., 2022).

Hand-dug wells remain a common water source in many parts of the world, particularly in areas with limited access to piped water systems. In Nigeria, hand-dug wells are frequently used for domestic purposes, including drinking, cooking, and bathing, especially in rural and semi-urban regions. Borikiri, a community in Port Harcourt, Rivers State, is one such area where many residents depend on these wells.

However, the quality of water from these wells may be compromised due to factors such as poor sanitation practices, pollution from nearby agricultural or industrial activities, and the infiltration of pathogenic microorganisms. The contamination of hand-dug wells, either by chemical pollutants or harmful microorganisms, poses significant public health risks. It is essential to assess both the physicochemical parameters (such as pH, turbidity, dissolved oxygen, and concentrations of heavy metals) and the microbial quality of water to evaluate the suitability of these water sources for consumption.

Most studies performed on the quality of surface and groundwater fail to present the results in the simplest form possible to policymakers and concerned citizens about the state of their water resources (Ideriah, 2024). This problem is overcome if the results are reported using the Water quality index (WQI). Thus, complex water quality parameters investigated on water resources can be combined in a simple mathematical equation to generate results which are easy to understand by policymakers who may not be water specialists (Akinfolarin et al., 2024). WQI thus transforms a large number of water quality data into a single number. It aids the understanding of water quality issues by integrating complex data and generating a score that describes water quality status (Ideriah et al., 2015).

This study aims to assess the physicochemical and microbial quality of water from three selected hand-dug wells in Borikiri, Port Harcourt, Rivers State, Nigeria. The

findings will provide insight into the safety of these water sources and contribute to ongoing discussions about water quality management in the region.

2.0 Literature Review

Ossai *et al.* (2025) investigated the concentration and health risk implications of selected heavy metals—namely copper (Cu), arsenic (As), nickel (Ni), chromium (Cr), lead (Pb), mercury (Hg), and cadmium (Cd)—in surface water along the Ethiope River in Delta State, Nigeria. Their study focused on five sampling locations across Umuaja, Ebedie, Abraka, Sapele, and Ughara during the rainy season (June–October 2023), a period typically associated with increased runoff and pollutant transport.Using standard analytical procedures, the authors assessed heavy metal concentrations, computed the Heavy Metal Pollution Index (HPI), and conducted human health risk assessments. Statistical tools, including descriptive statistics and analysis of variance, were employed to interpret spatial variations in metal concentrations. The findings indicated that heavy metal levels ranged from as low as 0.004 mg/L for Pb and Cr to a maximum of 0.020 mg/L for Cu. Elevated concentrations of Cu and Pb were particularly observed at stations associated with increased anthropogenic pressure, notably industrial effluent discharge, domestic wastewater input, and surface runoff.

Kalagbor *et al.* (2023) investigated the surface water quality of the Eweh River in Khana Local Government Area, Rivers State, Nigeria, using the Water Quality Index (WQI). Water samples were collected from upstream, midstream, and downstream locations over a three-month period, yielding 36 samples analyzed for physicochemical parameters, heavy metals, and microbial content using standard methods.The study reported pH values ranging from 4.40 to 5.00, indicating slightly acidic conditions, with temperatures between 27.6°C and 28.9°C. Alkalinity, hardness, total dissolved solids (TDS), chloride, calcium, and magnesium levels were generally low, suggesting fresh and soft water. Nutrient concentrations were minimal, with phosphate ranging from 0.024 to 0.08 mg/L, sulphate below 1.0 mg/L, and nitrate below 0.05 mg/L. Heavy metal analysis revealed manganese and lead below detectable limits and iron concentrations

ranging from 0.109 to 0.267 mg/L. Microbial analyses showed Total Coliform Bacteria (TCB) of 2.0 cfu/mL downstream, Total Heterotrophic Bacteria (THB) between 32 and 430 cfu/mL, while Fecal Coliform Bacteria (FCB) were not detected.

Akinfolarin and Chukwuji (2020) carried out assessment of borehole water in Oroworukwu Port Harcourt. The result obtained from this analysis showed a pH range of 4.8 - 5.9 which was below the permissible limit (6.8-7.8) of World Health Organization (WHO) and Nigeria Industrial Standard (NIS). All other physicochemical parameter results were within permissible limits. There were no bacteria detected in the water sample.

Akinfolarin and Ebiana (2016) carried out a study on ground water (Hand dug well water) in the Egunughan community of Emughan, Abua in Abua/Odual Local Government Area of Rivers State. The Hand dug well was assessed for potability purpose by analysing six hand dug wells (W1 to W6) for physicochemical parameters. The results obtained were compared with the permissible limits for drinking water provided by World Health Organization (WHO). The study showed that the groundwater (hand-dug well) in this community area is slightly acidic except for W3 and W5 wells which are within the acceptable limits. Their study did not cover heavy metals and microbial parameters. It was recommended that these hands dug well water (W1–W6) should be monitored regularly to avoid pollution problems that could bring about water borne diseases in the community.

3.0 Research Methodology

3.1 Study Area

Borikiri is a densely populated urban district situated in the Niger Delta region. It is in Port Harcourt, Nigeria, with Longitude 4.7833N and Latitude 7.0333E and has an altitude of approximately 20-30 meters (66-98feet) above sea level. It has a low-lying coastal plain, the area is drained by several creeks and rivers, including the Bonny River. The terrain is generally flat, with some areas having slightly elevated terrain. Its climate is characterized by high temperatures and high humidity levels throughout the year. The area experiences two main seasons: wet

season (March-October) and the dry season (November-February). Borikiri is characterized by mixed residential and commercial activities. The area is susceptible to contamination from anthropogenic activities, natural sources like flooding, nearby industrial discharges and inadequate sanitation systems.



Fig.3.1: Map of the study area

3.2 Materials and Methods

3.2.1 Sample Collection and Preservation

Water samples were collected in duplicate from three wells within the Borikiri settlement, Port Harcourt, Rivers State, during May to July 2025. Sampling was conducted using a plastic water fetcher attached to a rope, which was carefully lowered into each well and retrieved into pre-labelled plastic bottles previously washed and rinsed with distilled water. Separate aliquots for heavy metal determination were collected in glass bottles and acidified to pH 2 with nitric acid (HNO_3) to prevent precipitation and microbial activity. All samples were protected from direct sunlight and securely transported to the laboratory for subsequent analysis.

3.2.2 Physicochemical Analysis

Key physicochemical parameters including pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), and salinity—were measured using a multiparameter meter (HACH 1520). Calibration was performed according to the manufacturer's instructions prior to analysis. Other parameters, such as

alkalinity, hardness, chloride, calcium, and magnesium, were determined following standard methods (APHA, 2017).

3.2.3 Heavy Metal Analysis

Concentrations of selected heavy metals (As, Ni, Cr, Pb, and Cd) were determined using the aqua regia digestion method followed by atomic absorption spectrophotometry (AAS). All glassware used for metal analysis was thoroughly cleaned to avoid contamination, and analytical-grade reagents were employed throughout the procedure.

3.2.4 Microbiological Analysis

Microbial assessment included enumeration of Total Coliform Bacteria (TCB), Total Heterotrophic Bacteria (THB), and Fecal Coliform Bacteria (FCB). Water samples were serially diluted and cultured on appropriate selective media, with colony counts expressed in colony-forming units per milliliter (cfu/mL). Standard protocols were followed to ensure accurate microbial quantification (APHA 2017).

3.3 Water Quality Index (WQI) Calculation

The assessment of hand-dug wells using the Water Quality Index (WQI) provides an integrative view of their suitability for drinking purposes.

$WQI = \sum Wi\ Qi / \sum Wi$
Where;
WQI= Water quality index
i = Unit weightage
Wi = Unit Weightage
Qi = Sub index of ith parameter, $Qi = Vn/Sn * 100$
Where Vn = Concentration of ith parameters
$Wi = K/Sn$
$K = 1/\sum (1/Sn)$
Where;
Sn = Recommended Standard for ith parameter (Akinfolarin *et al*., 2025)

3.4 Statistical Analysis

Data analysis was performed using SPSS Version 28. The following statistical procedures were employed:

Descriptive Statistics: Mean, standard deviation, minimum, and maximum concentrations were calculated for each pollutant at all locations.

Analysis of Variance (ANOVA): One-way ANOVA was used to test for significant differences in pollutant concentrations across the five locations.
Tukey HSD post-hoc tests were applied to identify specific pairwise differences between locations.

4.0 Results and Discussion

4.1 Results

This session presents the results of the physicochemical, heavy metal, and microbiological analyses of water samples collected from three hand-dug wells (A, B, and C). The results were statistically evaluated using one-way Analysis of Variance (ANOVA) followed by Tukey's Honestly Significant Difference (HSD) post-hoc test to determine significant differences among the wells at a 95% confidence level ($p < 0.05$). Mean values were compared with World Health Organization (WHO) drinking water quality standards.

Table 4.1: Physicochemical and microbial characteristics of hand-dug wells in Borikiri

Parameteres	Well A		Well B		Well C		
	Mean	Stdev	Mean	Stdev	Mean	Stdev	WHO Standards
pH	7.00	0.40	6.50	0.70	7.10	0.30	6.5-8.5
Temperature (^{0}C)	20.47	0.04	21.47	0.97	20.75	0.15	25
Electrical Conductivity (µs/cm)	240.50	10.50	335.50	31.50	189.00	9.00	1000
Turbidity (NTU)	0.00	0.00	0.00	0.00	0.00	0.00	5
Alkalinity (mg/l)	1.40	1.40	1.25	1.25	1.55	1.55	
Nitrate (mg/l)	13.45	2.25	5.70	4.50	10.20	3.00	50
Phosphate (mg/l)	5.70	0.80	3.40	2.50	1.70	0.00	0.5
Chloride (mg/l)	16.30	2.50	26.90	4.50	12.80	2.00	250
Sulphate (mg/l)	11.40	1.50	21.70	3.50	9.60	2.00	500

Total Hardness (mg/l)	7.50	2.00	13.50	3.00	9.50	1.00	300
Copper (mg/l)	1.90	0.50	3.40	1.00	3.70	0.10	2
Lead (mg/l)	2.51	0.30	3.78	1.13	4.70	1.00	0.1
Zinc (mg/l)	7.50	1.00	7.50	1.00	7.00	0.50	5
Arsenic (mg/l)	1.10	0.30	2.60	0.30	0.40	0.00	0.1
Mercury (mg/l)	Nd	Nd	Nd	Nd	Nd	Nd	0.006
Total Coliform (cfu/ml)	4.48	2.03	7.20	5.50	8.50	3.00	2
Color (Pt-Co)	Nd	Nd	Nd	Nd	Nd	Nd	

Table 4.2: One-Way ANOVA Comparing Water Quality Parameters Among Wells A, B, and C

Parameter	**F-value**	**Sig. (p)**
pH	0.72	0.52
Temperature	2.11	0.20
Electrical Conductivity	**48.63**	**0.001***
Alkalinity	0.03	0.97
Nitrate	**6.92**	**0.03***
Phosphate	**15.44**	**0.004***
Chloride	**14.28**	**0.005***
Sulphate	**18.66**	**0.003***
Total Hardness	**7.51**	**0.02***
Copper	**9.34**	**0.01***
Lead	**8.62**	**0.01***
Zinc	0.43	0.66
Arsenic	**42.88**	**0.001***
Total Coliform	1.96	0.22

*Significant at $p < 0.05$

Table 4.3: Tukey HSD Multiple Comparisons

Parameter	Wells Compared	Mean Difference	Sig.
Electrical Conductivity	B – A	95.00	0.002
	B – C	146.50	0.001
Nitrate	A – B	7.75	0.03
Phosphate	A – C	4.00	0.004
	B – C	1.70	0.02
Chloride	B – C	14.10	0.005
Sulphate	B – A	10.30	0.004
Total Hardness	B – A	6.00	0.02
Copper	C – A	1.80	0.01
Lead	C – A	2.19	0.01
Arsenic	B – C	2.20	0.001

(Only Significant Parameters indicated)

Table 4.3 (a): Categorization of water quality for drinking water suitability**.**

WQI rating	Classification
0-25	Excellent
25-50	Slightly polluted (good)
50-75	Moderately polluted (poor)
75-100	Polluted (very poor)
> 100	Excessively polluted (unsuitable)

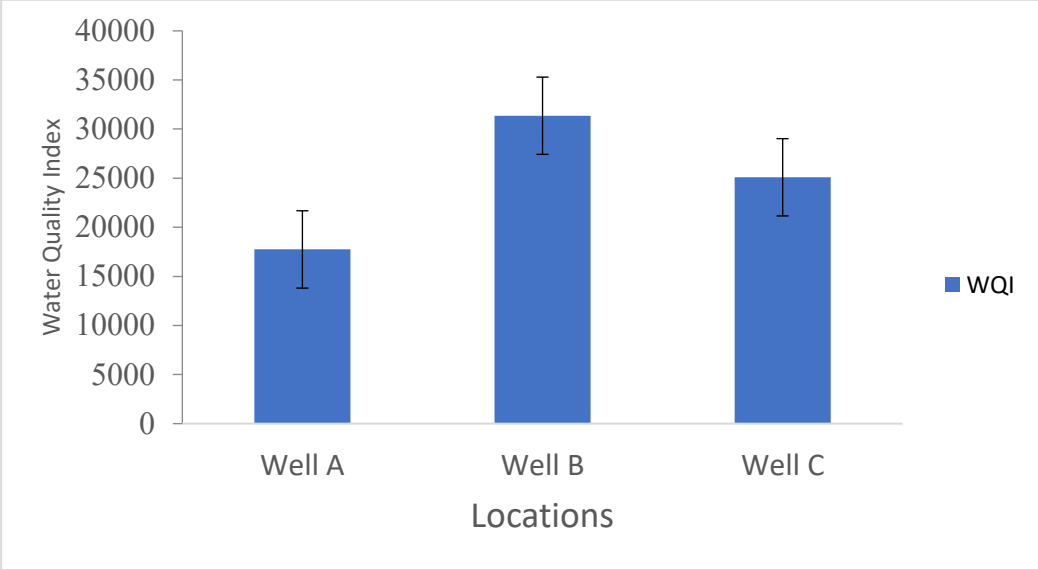

Fig.4.1: Water Quality Index of the three Hand Dug Wells

4.1.1 Physicochemical Characteristics

The pH values of the wells ranged from 6.50 to 7.10, indicating neutral to slightly acidic conditions. One-way ANOVA showed no statistically significant difference in pH among the wells ($p > 0.05$), suggesting similar geochemical buffering across the study area. All pH values complied with WHO recommended limits (6.5–8.5).

Temperature values varied slightly between 20.47 °C and 21.47 °C, with no significant difference observed among the wells ($p > 0.05$). These temperatures fall below the WHO guideline value of 25 °C and are typical of shallow groundwater systems.

Electrical conductivity (EC) showed significant variation among the wells ($p = 0.001$). Well B recorded the highest EC (335.50 µS/cm), followed by Well A (240.50 µS/cm) and Well C (189.00 µS/cm). Tukey HSD analysis revealed that Well B differed significantly from both Wells A and C. Despite these differences, all EC values were below the WHO permissible limit of 1000 µS/cm.

Turbidity was zero in all wells, indicating the absence of suspended particles and good physical clarity. Alkalinity values were low and did not differ significantly among the wells ($p > 0.05$), reflecting limited buffering capacity but no immediate aesthetic or health concern.

4.1.2 Nutrients and Major Ions

Nitrate concentrations ranged from 5.70 mg/L to 13.45 mg/L. ANOVA indicated a significant difference among the wells ($p < 0.05$), with Well A recording significantly higher nitrate levels than Well B. However, all nitrate concentrations were within the WHO guideline value of 50 mg/L.

Phosphate levels ranged from 1.70 mg/L to 5.70 mg/L and differed significantly across the wells ($p = 0.004$). Tukey HSD results showed that Well A had significantly higher phosphate concentrations than Well C. Notably, phosphate levels in all wells exceeded the WHO recommended limit of 0.5 mg/L.

Chloride concentrations varied significantly ($p = 0.005$), with Well B recording the highest mean value (26.90 mg/L). Sulphate concentrations also showed significant variation among the wells ($p = 0.003$), with Well B again recording the highest concentration. All chloride and sulphate values remained within WHO permissible limits.

Total hardness ranged from 7.50 mg/L to 13.50 mg/L and showed statistically significant differences ($p < 0.05$). Nevertheless, all wells were classified as soft water and complied with WHO standards.

4.1.3 Heavy Metals

Copper concentrations varied significantly among the wells ($p = 0.01$). Wells B and C recorded mean values (3.40 mg/L and 3.70 mg/L, respectively) that exceeded the WHO guideline value of 2 mg/L.

Lead concentrations were alarmingly high in all wells, ranging from 2.51 mg/L to 4.70 mg/L, far exceeding the WHO limit of 0.1 mg/L. ANOVA revealed significant

differences among the wells ($p = 0.01$), with Well C having the highest lead concentration.

Zinc concentrations did not differ significantly among the wells ($p > 0.05$) but exceeded the WHO guideline value of 5 mg/L in all cases.

Arsenic concentrations showed highly significant differences among the wells ($p = 0.001$). Well B recorded the highest mean arsenic concentration (2.60 mg/L), followed by Well A (1.10 mg/L) and Well C (0.40 mg/L). All values exceeded the WHO permissible limit of 0.1 mg/L.

Mercury was not detected in any of the water samples, and colour was also not detected, indicating no visible aesthetic impairment.

4.1.4 Microbiological Quality

Total coliform counts ranged from 4.48 to 8.50 cfu/ml. Although ANOVA showed no statistically significant differences among the wells ($p > 0.05$), all wells exceeded the WHO recommended limit of 2 cfu/ml, indicating microbial contamination.

4.2 Discussion

The physicochemical characteristics of the groundwater indicate generally acceptable water quality in terms of pH, temperature, turbidity, electrical conductivity, and hardness. This agrees with the study of Akinfolarin and Chukwuji (2020). The lack of significant variation in pH and temperature suggests similar hydrogeological conditions across the wells. The elevated electrical conductivity observed in Well B may be attributed to increased mineral dissolution or anthropogenic activities such as domestic waste discharge (Akinfolarin et al.,2020).

Despite nitrate concentrations being within WHO limits, the significant variation observed—particularly the higher values in Well A—may indicate localized contamination from agricultural runoff or seepage from organic waste. The consistently elevated phosphate levels across all wells are of concern and suggest

contamination from detergents, fertilizers, or sewage infiltration, which is common in areas with poor sanitation infrastructure (Akinfolarin *et al*., 2017; Akinfolarin *et al*., 2025).

Although chloride and sulphate concentrations were within permissible limits, their significant spatial variation further supports the influence of localized hydro-chemical processes and human activities. The soft nature of the water across all wells is consistent with low total hardness values and poses no health risk. This is in line with the work of Edem *et al.* (2011) and Erah *et al.* (2002).

The most critical findings of this study relate to heavy metal contamination. The exceedingly high concentrations of lead and arsenic in all wells present a serious public health concern. Lead exposure is associated with neurological impairment, especially in children, while chronic arsenic ingestion has been linked to carcinogenic and systemic health effects. The significantly higher arsenic concentration in Well B may reflect geogenic sources or leaching from subsurface materials (Chapman 1996; Smedley & Kinniburgh, 2002).

The detection of copper and zinc above WHO guideline values further indicates possible contamination from plumbing materials, waste disposal, or natural mineral sources. Although mercury was not detected, the presence of multiple heavy metals above permissible limits renders the water unsuitable for drinking without treatment (Asonye *et al*.,2007).

Microbiological analysis revealed total coliform contamination in all wells, confirming that the water sources are bacteriologically unsafe. This contamination is likely due to poor well construction, proximity to latrines, and surface runoff infiltration, which are common challenges associated with hand-dug wells in developing regions.

Overall, the results demonstrate that while some physicochemical parameters meet international standards, the combined presence of heavy metals and microbial contamination makes the water from all three hand-dug wells unfit for direct human consumption. These findings align with previous studies that highlight the

vulnerability of shallow groundwater sources to contamination in densely populated and poorly serviced environments.

5. Conclusion and Recommendation

5.1 Conclusion

This study assessed the physicochemical, heavy metal, and microbiological quality of water from three hand-dug wells (A, B, and C) using one-way Analysis of Variance (ANOVA) and Tukey HSD post-hoc tests. The findings revealed that while several basic physicochemical parameters such as pH, temperature, turbidity, electrical conductivity, and total hardness were within the permissible limits prescribed by the World Health Organization (WHO), significant contamination was evident in other critical parameters.

Notably, phosphate concentrations in all wells exceeded WHO guideline values, indicating nutrient enrichment likely arising from anthropogenic activities such as improper waste disposal and agricultural practices. More critically, heavy metals including lead, arsenic, copper, and zinc were present at concentrations far above recommended limits. Lead and arsenic contamination were particularly severe across all wells, posing serious public health risks due to their cumulative toxicity and long-term health effects.

Microbiological analysis further showed that total coliform counts in all wells exceeded WHO standards, confirming bacteriological contamination and rendering the water unsafe for direct human consumption. The observed spatial variations in several parameters highlight the influence of localized environmental conditions, well construction quality, and land-use practices on groundwater quality.

Overall, the study concludes that despite acceptable values for some physicochemical indicators, the combined presence of excessive heavy metals and microbial contamination makes the water from the studied hand-dug wells unsuitable for drinking without appropriate treatment. Continuous reliance on such untreated groundwater sources may expose users to significant health hazards.

5.2 Recommendations

Based on the findings of this study, the following recommendations are made:

1. Water Treatment: Water from the studied hand-dug wells should undergo appropriate treatment methods such as filtration, disinfection, and heavy metal removal techniques (e.g., adsorption or ion exchange) before being used for drinking purposes.
2. Regular Monitoring: Periodic monitoring of groundwater quality should be implemented by relevant environmental and public health authorities to detect changes in water quality and prevent prolonged exposure to contaminants.
3. Improved Sanitation Practices: Proper waste management systems and improved sanitation facilities should be established to reduce the infiltration of contaminants, particularly nutrients and pathogenic microorganisms, into groundwater sources.
4. Well Protection and Construction: Hand-dug wells should be properly lined, covered, and located at safe distances from latrines, refuse dumps, and other potential sources of contamination.
5. Public Awareness: Community education programs should be introduced to inform residents about the health risks associated with consuming untreated groundwater and the importance of water treatment and hygiene practices.
6. Policy and Regulatory Enforcement: Regulatory agencies should enforce compliance with drinking water quality standards and support rural water supply improvement initiatives.

5.3 Contribution to Knowledge

This study contributes to existing knowledge in the following ways:

1. It provides empirical evidence on the extent of heavy metal and microbial contamination in hand-dug wells, highlighting the persistent vulnerability of shallow groundwater sources in developing regions.

2. The study demonstrates the application of one-way ANOVA and Tukey HSD post-hoc analysis in identifying statistically significant spatial variations in groundwater quality parameters among closely located wells.
3. It enriches the local groundwater quality database by generating baseline information that can support future hydrogeochemical and public health studies.
4. The findings reinforce the need to integrate statistical analysis with standard guideline comparisons in groundwater quality assessments, thereby improving the robustness of environmental monitoring studies.
5. The study offers context-specific insights that can inform water resource management policies, groundwater protection strategies, and community-level interventions aimed at ensuring safe drinking water supply.

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