Comparative Quality Assessment of Water Samples from Protected Well and Unprotected Well in Ayobo Area of Lagos State, Nigeria

Adams Oladapo Adewale [1], Helen Obiagheli Ali [1], Taiwo Bakare-Abidola [2], Sewanu Tosin Akapo [1], Oluwafemi Sunday Obayori [1], Kabir Olusegun Akinyemi [1]

[1] *Lagos State University*
Lasu Main Rd, Ojo, Lagos 102101, Nigeria

[2] *Georgia Southern University*
1332 Southern Drive, Statesboro, GA 30458, USA

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Corresponding Author:
Bakare-Abidola Taiwo

Abstract. The majority of the population in Nigeria's semi-urban and urban areas depends on wells as their primary water source, due to a recent increase in cases of waterborne disease. This study was conducted to examine the quality of well water in the Ayobo area of Lagos State. Water samples from 10 protected and 10 unprotected wells were randomly selected and analysed for their physicochemical and bacteriological qualities. The results obtained for the protected wells were compared with those of the unprotected well. The physicochemical results show that all the parameters examined were within the Nigerian Standard for Drinking Water Quality (NSDWQ), except pH, which was below the acceptable range of 6.5-8.5. The bacteriological result indicated that all the water samples had coliform counts above the World Health Organisation acceptable standard of ≤ 1, also all the water samples were contaminated with bacterial pathogens such as *Klebsiella spp* 33.3%, *Enterobacter spp* 29.6%, *Escherichia coli* 18.5%, *Proteus spp* 11.1%, and *Pseudomonas spp* 7.4%. Comparative analysis showed no significant differences in the physicochemical parameters between the protected and unprotected wells. Compared with protected wells, the unprotected wells were more contaminated with bacterial pathogens. This result highlights that most wells analysed in Ayobo metropolis are not bacteriologically safe for drinking without disinfection, which could lead to an outbreak of waterborne disease. Therefore, it is necessary to prevent waterborne disease in this community by ensuring that well water is properly disinfected before drinking.

Keywords: Bacteriological; waterborne; well water; physicochemical.

INTRODUCTION

Water is vital to both our environment and our body systems. Water quality is the most fundamental controlling factor for health and disease in all living things. Water is an essential part of human nutrition, both directly as drinking water and indirectly as a constituent of food, as well as for various other daily-life applications. Water is not only essential for life, but it also remains an important vector of illness and infant mortality in many developing countries and even in technologically more advanced countries. It is also a key parameter influencing the survival and growth of microorganisms in foods and other microbial environments [1].

The United Nations World Development Report shows that about 2 billion people worldwide lack access to safe drinking water, and approximately 3.6 billion people (46% of the world's population) lack adequate sanitation services [2]. In developing countries, including Nigeria, access to clean piped water is limited and inadequate for the teeming population. Thus, an increasing number of people in semi-urban areas in the country depend on boreholes, hand-dug wells, and water vendors for water supply [3]. Groundwater accounts for about 80% of safe drinking water in

rural or suburban areas with widely dispersed populations and limited water treatment infrastructure. Groundwater plays a crucial role in the water cycle, establishing vital connections with surface environments and significantly influencing the functioning of aquatic ecosystems [4]. Groundwater is usually of good quality, but this can deteriorate due to inadequate sources of protection and poor resource management. Intensive use of natural resources and increased human activity have created serious problems with groundwater quality [5]. Groundwater is particularly sensitive to various sources of pollution, including uncontrolled wastewater discharges, solid waste disposal, and fertiliser and pesticide applications. These natural hydrosystems are likely to be contaminated by many sources of pollution [6], including the effects of extensive agro-industrial activities and urbanisation, as well as agricultural fertilisers and pesticides, industrial and domestic wastes, and landfill dumping and pit latrines [7].

Water samples from different sources (protected concrete well, unprotected concrete well, protected non-concrete well and unprotected non-concrete well) in Masaka, Nasarawa State, Nigeria were comparatively assessed. It was discovered that, apart from pH and temperature, which have low concentrations, all other analysed parameters, such as colour, turbidity, conductivity, Alkalinity, Total hardness, Iron, Chloride, Nitrate, Calcium, magnesium, and phosphate, show high variation in the concentration of the elements in the well water. It was also discovered that the total coliform count exceeds the WHO standard, which ranges from 500 to 900 cfu/100 mL, except for the water samples from the protected non-concrete well [8].

Microbial indicators of faecal contamination are also used as markers of water quality because faecal matter may harbour pathogenic organisms that pose health risks or adverse effects [9]. If among faecal contaminants are carriers of infectious diseases, drinking such water may result in new cases of the disease. These pathogenic organisms are almost always outnumbered by the normal intestinal excretory organisms, which are easier to detect as indicators of faecal pollution. If indicator organisms are not detected in water, it can be inferred that disease-causing microorganisms are absent [10]. Bacteria, specifically *E. coli* or faecal Streptococci, are well-known indicators of sewage pollution in drinking and bathing water. One of the most useful indicators of water pollution is the total coliform count. The coliform group includes several types of organisms from the family Enterobacteriaceae. E. coli and E. aerogenes are well-known members of the coliform group and are widely found in polluted water. As a predominant microorganism in human excreta, Escherichia coli serves as an excellent indicator of faecal pollution in water [11].

The study area is Ayobo. Ayobo is a suburb in the Alimosho Local Government Area of Lagos State, Nigeria. It's the last town in Lagos bordering Aiyetoro, Ogun State. Most of the inhabitants of Ipaja-Ayobo rely on groundwater, such as boreholes and hand-dug wells. Residents in this area believe that boreholes are a source of potable water, compared to protected or unprotected wells. To safeguard people's health and reduce to the barest minimum the dangers posed by drinking or using low-quality water, it is necessary to monitor water quality and find lasting solutions to the health problems associated with its use.

MATERIALS AND METHOD

Ayobo (also known as Igbo Ilogbo-Ayobo) is a suburb in the Alimosho Local Government Area of Lagos State, south-western Nigeria. Anchor University, Lagos, is located there. Ayobo is the last town in Lagos bordering Aiyetoro, Ogun State. Ayobo is a town with about 10 sub-towns under it. Megida, Isefun, Olorunisola, Bada, Sabo, Kande-Ijon, Orisumbare-Ijon, Jagundeyi, Alaja, etc. Megida and Isefun are the most prominent towns under Ayobo. Megida is the capital and commercial city of Ayobo, the home of the Anchor University. At the same time, Isefun/Kande-Ijon is home to one of the modern Lagos waterways (under construction). Ayobo shares Local Council Development Area with Ipaja (Ipaja/Ayobo Local Council Development Area).

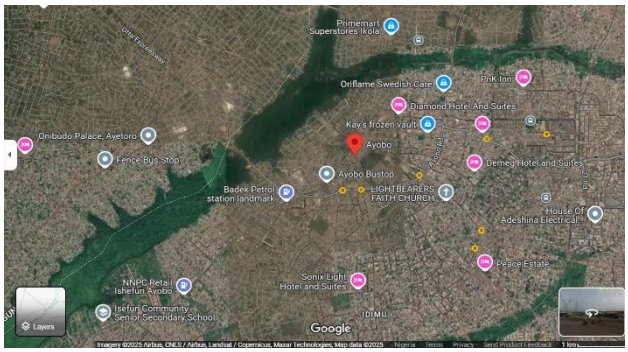

Figure 1 - Google Maps satellite view

Water Sample Collection. For the physicochemical analysis, water was sampled in clean 75 ml

plastic bottles and thoroughly rinsed with water from each source before collection. For the bacteriological analyses, samples were collected with screw-capped glass bottles that had been sterilised in an autoclave for 15 minutes at 121 °C. The protected well water samples were labeled as; 1p, 2p, 3p, 4p, 5p, 6p, 7p, 8p, 9p, 10p, while the unprotected well water samples were labeled as 1u, 2u, 3u, 4u, 5u, 6u, 7u, 8u, 9u, 10u. After collection, the samples were immediately transported to the laboratory for analysis.

Water Physicochemical Analysis. The physicochemical parameters were determined according to the APHA (1998) method. These tests include the determination of turbidity, temperature, odour, colour, total hardness, calcium hardness, magnesium hardness, total dissolved solids, pH, iron content, residual Chlorine, total acidity, salinity, nitrate, nitrite, and chloride content were analysed and then compared with the Nigerian Standard for Water Quality (NSDWQ).

Water Bacteriological Analysis. Water samples from both protected and unprotected wells were carefully collected in sterilised, screw-capped glass bottles to maintain their purity. After collection, the water samples were stored and transported to the laboratory in cooler boxes to preserve their true nature and prevent any degradation of water quality during transportation. The laboratory analysis was promptly conducted to ensure the results were fresh and reliable. This strict protocol helps to minimise any potential contamination and provides accurate data for the study. Analyses were performed at the laboratory. This bacteriological test includes total plate count, coliform test, presumptive test, confirmatory test, and completed test.

RESULTS AND DISCUSSION

The physicochemical analysis of water samples from the Ayobo area of Lagos State reveals that all samples have temperature values within the acceptable limits of the Nigerian Standard for Drinking Water Quality (NSDWQ). The colour, appearance, odour, taste, turbidity, total dissolved solids (TDS), and conductivity values are all within the acceptable limits. The pH of all samples falls below the NSDWQ limit (6.5-8.0), except for sample 8 p, which is 6.5 units below the limit. All water samples have total alkalinity, total hardness, calcium hardness, Chloride, organic matter, and iron values within the acceptable limits. The tested parameters all meet the limit, except for magnesium hardness, where two samples (3u and 10u) exceeded the acceptable limit. Statistical paired-sample test (Table 4) for the physicochemical analysis: all samples paired show no significant differences, except for turbidity, which is 0.026, which is less than the ≤ 0.05 (95%) confidence level. The 2-tailed sample test for the physicochemical analysis shows no significant difference (Table 3), and all the mean values are negative. From the tables, the correlation and the t-test cannot be computed because the standard error of the difference is 0 (Table 4).

Table 1 – Physicochemical analysis of protected well water sample in Ayobo

No	Parameters	1p	2p	3p	4p	5p	6p	7p	8p	9p	10p	NSDWQ
1	Temperature of water (°C)	28	28	28	28	28	28	28	28	28	28	25-30
2	Temperature of Air (°C)	30	30	30	30	30	30	30	30	30	30	25-30
3	Appearance	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
4	Colour (Hz)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
5	Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
6	Taste	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject
7	Turbidity (NTU)	0	0	0.5	0	0.7	0	0.7	0.2	0.7	0.1	5NTU
8	Total Dissolved Solid (mg/l)	98	206	114	122	134	75	75	61	124	318	1200
9	Conductivity (μs)	150	318	175	188	206	115	115	93	190	489	1000
10	pH	5.4	5.0	5.6	5.2	4.6	5.2	5.9	6.5	4.7	6.0	6.5-8.5
11	Residual Chlorine (mg/l)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
12	Total Alkalinity CaCO3 (mg/l)	4	5	4	4.3	4	6	4.1	4.7	5	4	150
13	Total Hardness CaCO3 (mg/l)	50	106	64	72	74	40	40	31	72	160	400
14	Calcium Hardness (mg/l)	30	56	34	42	44	20	20	17	42	90	200
15	Magnesium Hardness (mg/l)	20	50	30	30	30	20	20	14	30	70	50
16	Chloride (mg/l)	20	80	50	40	35	25	23	20	40	65	250
17	Organic matter (mg/l)	2	2	1	2	2	1	1	1	2	2	3
18	Iron (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.3

Table 2 – Physicochemical analysis of unprotected well water sample in Ayobo Area of Lagos State

S/N	PARAMETERS	1u	2u	3u	4u	5u	6u	7u	8u	9u	10u	NSDWQ
1	Temperature of water (°C)	28	28	28	28	28	28	28	28	28	28	25-30
2	Temperature of Air (°C)	30oC	30oC	30oC	30oC	30oC	30oC	30oC	30oC	30oC	30oC	25-30
3	Appearance	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
4	Colour (Hz)	7.5	7.5	10	10	10	7.5	7.5	10	10	10	0-15
5	Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
6	Taste	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject
7	Turbidity (NTU)	1.5	0.9	0.1	0.6	0.1	0.6	0.2	0.5	0.1	0.1	5NTU
8	Total Dissolved Solid (mg/l)	184	146	291	52	95	138	199	137	148	258	1200
9	Conductivity (µs)	129	224	447	80	146	212	306	210	227	396	1000
10	pH	5.7	6.0	4.1	6.5	5.7	4.9	4.3	5.6	5.2	5.3	6.5-8.5
11	Residual Chlorine (mg/l)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.3
12	Total Alkalinity CaCO3 (mg/l)	4.3	4	6	4.1	4.2	4.7	5	6	4	4.3	150
13	Total Hardness CaCO3 (mg/l)	54	76	190	33	45	70	110	70	65	160	400
14	Calcium Hardness (mg/l)	34	36	100	13	25	38	80	38	35	70	200
15	Magnesium Hardness (mg/l)	20	40	90	20	20	30	50	30	30	90	50
16	Chloride (mg/l)	20	50	80	15	20	60	30	60	30	100	250
17	Organic matter (mg/l)	3	1	2	0.5	1	2	2	1	1	3	3
18	Iron (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.3

Table 3 – Comparative analysis of both the protected and unprotected wells

		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 3	Colour Protected - Colour Unprotected	-.2500	1.4191	.4488	-1.2652	.7652	-.557	9	.591
Pair 4	Turbidity protected - Turbidity unprotected	-.1800	.7208	.2279	-.6956	.3356	-.790	9	.450
Pair 5	Total dissolved solid protected - Total Dissolved Solid unprotected	- 32.1000	86.7557	27.4345	-94.1613	29.9613	-1.170	9	.272
Pair 6	Conductivity Protected - Conductivity Unprotected	- 33.8000	131.9502	41.7263	-128.1915	60.5915	-.810	9	.439
Pair 7	pH protected - pH unprotected	.0800	71.065	.3395	-.6881	.8481	.236	9	.819
Pair 8	Total alkalinity Protected – Total Alkalinity unprotected	-.1500	51.4613	.3371	-.9125	.6125	-.445	9	.667
Pair 9	Total hardness protected - Total hardness unprotected	- 16.4000	22.1921	16.2735	-53.2132	20.4132	-1.008	9	.340
Pair 10	Calcium hardness protected - Calcium hardness unprotected	-7.4000	26.6669	10.6669	-31.5301	16.7301	-.694	9	.505
Pair 11	Magnesium hardness protected - Magnesium hardness unprotected	- 10.6000	1.0659	7.0178	-26.4753	5.2753	-1.510	9	.165
Pair 12	Chloride protected - Chloride unprotected	-6.7000	26.66	8.4328	-25.7763	12.3763	-.795	9	.447
Pair 13	Organic matter protected – Organic Matter unprotected	-.0500	1.067	.3371	-.8125	.7125	-.148	9	.885

Table 4 – The presumptive test analysis of the protected well in Ayobo

No	Number of tubes with positive reactions				MPN index	WHO STANDARD
	Sample	50 ml	10 ml	1 ml	Per 100ml	Per 100ml
1	1p	1	5	5	>180	<1
2	2p	1	0	0	1	<1
3	3p	1	5	5	>180	<1
4	4p	1	5	5	>180	<1
5	5p	1	2	2	10	<1

No	Number of tubes with positive reactions				MPN index	WHO STANDARD
	Sample	50 ml	10 ml	1 ml	Per 100ml	Per 100ml
6	6p	1	4	3	28	<1
7	7p	1	5	4	161	<1
8	8p	1	4	4	35	<1
9	9p	0	0	2	2	<1
10	10p	0	2	1	3	<1

Notes: MPN Most probable number obtained from McCrady's probability Table, 1918

Table 5 – The Presumptive Coliform Test of Unprotected Well in Ayobo Area of Lagos State

No	Number of tubes with positive reactions				MPN index	WHO STANDARD
	Sample	50 ml	10 ml	1 ml	Per 100 ml	Per 100 ml
1	1u	1	5	5	>180	<1
2	2u	1	5	5	>180	<1
3	3u	1	5	4	161	<1
4	4u	1	5	5	>180	<1
5	5u	1	5	5	>180	<1
6	6u	1	5	5	>180	<1
7	7u	1	5	5	>180	<1
8	8u	1	4	5	43	<1
9	9u	1	5	5	>180	<1
10	10u	1	5	5	>180	<1

Notes: MPN Most probable number obtained from McCrady's probability Table, 1918

Table 6 – Bacterial pathogens isolated from protected well water samples in Ayobo

Sample	Methyl Red	Voges Proskauer	Urease Test	Catalase Test	Indole Test	Motility Test	Citrate test	Probable Organism
1p	+ve	+ve	+ve	+ve	+ve	+ve	+ve	Enterobacter spp.
2p	+ve	+ve	+ve	+ve	-ve	-ve	+ve	Klebsiella spp.
3p	+ve	+ve	+ve	+ve	+ve	-ve	+ve	Proteus spp.
4p	-ve	+ve	+ve	+ve	+ve	-ve	+ve	Enterobacter spp.
5pa	-ve	+ve	+ve	+ve	+ve	+ve	+ve	E.coli
5pb	-ve	+ve	+ve	+ve	+ve	+ve	+ve	Proteus spp.
6p	+ve	+ve	+ve	+ve	-ve	-ve	+ve	Klebsiella spp.
7pa	-ve	+ve	+ve	+ve	-ve	+ve	+ve	E.coli
7pb	-ve	+ve	+ve	+ve	-ve	+ve	+ve	Enterobacter spp
8p	+ve	+ve	+ve	+ve	-ve	-ve	+ve	Klebsiella spp.
9p	-ve	+ve	+ve	+ve	+ve	+ve	+ve	Enterobacter spp.
10p	-ve	+ve	+ve	+ve	+ve	-ve	+ve	Klebsiella spp

Table 7 – Bacterial pathogens isolated from unprotected well water samples in Ayobo

Sample	Methyl Red	Voges Proskauer	Urease Test	Catalase Test	Indole Test	Motility Test	Citrate test	Likely Organism
1u	-ve	+ve	+ve	+ve	+ve	+ve	+ve	Enterobacter spp.
2u	+ve	+ve	+ve	+ve	-ve	-ve	+ve	Klebsiella spp.
3ua	-ve	+ve	+ve	+ve	+ve	-ve	+ve	Psuedomonasspp
3ub	-ve	+ve	+ve	+ve	+ve	-ve	+ve	Proteus spp.
4u	+ve	+ve	+ve	+ve	+ve	-ve	+ve	Klebsiella spp
5ua	-ve	+ve	+ve	+ve	+ve	+ve	+ve	Enterobacter spp
5ub	-ve	+ve	+ve	+ve	+ve	+ve	+ve	E. coli
6ua	-ve	+ve	+ve	+ve	+ve	+ve	+ve	E. coli

Sample	Methyl Red	Voges Proskauer	Urease Test	Catalase Test	Indole Test	Motility Test	Citrate test	Likely Organism
6ub	-ve	+ve	+ve	+ve	+ve	+ve	+ve	Klebsiella spp.
7ua	+ve	+ve	+ve	+ve	+ve	-ve	+ve	E.coli
7ub	+ve	+ve	+ve	+ve	+ve	-ve	+ve	Enterobacter spp
8u	+ve	+ve	+ve	+ve	-ve	+ve	+ve	Klebsiella spp.
9u	+ve	+ve	+ve	+ve	-ve	+ve	+ve	Enterobacter spp.
10ua	+ve	+ve	+ve	+ve	-ve	-ve	+ve	Psuedomonasspp
10ub	+ve	+ve	+ve	+ve	-ve	-ve	+ve	Klebsiella spp

Table 8 – Results of spatial analysis (ANOVA) of the Total Coliform Count and the Most Probable Number

		Sum of Squares	df	Mean Square	F	Sig.
50 ml	Between Groups	.200	1	.200	2.250	.151
	Within Groups	1.600	18	.089		
	Total	1.800	19			
10 ml	Between Groups	14.450	1	14.450	6.756	.018
	Within Groups	38.500	18	2.139		
	Total	52.950	19			
1 ml	Between Groups	16.200	1	16.200	9.785	.006
	Within Groups	29.800	18	1.656		
	Total	46.000	19			
MPN	Between Groups	37324.800	1	37324.800	8.284	.010
	Within Groups	81100.400	18	4505.578		
	Total	118425.200	19			

Table 9 – Coliform forming unit at 95% confidence level

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the difference				
				Lower	Upper			
Pair 1 CFU P – CFU U	-431.300	638.947	202.053	-888.375	25.775	-2.135	9	.062

Notes: CFUP = Coliform Forming Unit for Protected Well; CFUP = Coliform Forming Unit for Unprotected Well.

Table 10 – Comparing experimental results and Most Probable Number Index

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
50ml	Protected	10	.800	.4216	.1333	.498	1.102	.0	1.0
	Unprotected	10	1.000	.0000	.0000	1.000	1.000	1.0	1.0
	Total	20	.900	.3078	.0688	.756	1.044	.0	1.0
10 ml	Protected	10	3.200	2.0440	.6464	1.738	4.662	.0	5.0
	Unprotected	10	4.900	.3162	.1000	4.674	5.126	4.0	5.0
	Total	20	4.050	1.6694	.3733	3.269	4.831	.0	5.0
1 ml	Protected	10	3.100	1.7920	.5667	1.818	4.382	.0	5.0
	Unprotected	10	4.900	.3162	.1000	4.674	5.126	4.0	5.0
	Total	20	4.000	1.5560	.3479	3.272	4.728	.0	5.0
MPN	Protected	10	78.000	84.5931	26.7507	17.486	138.514	1.0	180.0
	Unprotected	10	164.400	43.0715	13.6204	133.588	195.212	43.0	180.0
	Total	20	121.200	78.9488	17.6535	84.251	158.149	1.0	180.0

Table 11 – Results of spatial analysis (ANOVA) of the Total Coliform Count and the Most Probable Number

		Sum of Squares	df	Mean Square	F	Sig.
50 ml	Between Groups	.200	1	.200	2.250	.151
	Within Groups	1.600	18	.089		
	Total	1.800	19			
10 ml	Between Groups	14.450	1	14.450	6.756	.018
	Within Groups	38.500	18	2.139		
	Total	52.950	19			
1 ml	Between Groups	16.200	1	16.200	9.785	.006
	Within Groups	29.800	18	1.656		
	Total	46.000	19			
MPN	Between Groups	37324.800	1	37324.800	8.284	.010
	Within Groups	81100.400	18	4505.578		
	Total	118425.200	19			

The results obtained for the Coliform forming unit (CFU) 10 paired samples (compared) indicate that, given the number of paired samples is less than for each of the grouped samples, whether the samples are protected or unprotected, the assumption that the samples are drawn from a normal distribution cannot be ascertained. Consequently, an independent paired-samples T-test at the 0.05 level of significance is appropriate for the CFU test, MPN, and the physicochemical analysis.

The comparison between the two well water samples with $\alpha = 0.05$ is not significant (Table 4).

The results for the physicochemical parameters of the well water samples at various points show that pH values in most wells are not acceptable, ranging from 4.1 to 6.5, which is below the recommended standard. pH is an important parameter that determines the suitability of water for various purposes [12]. The pH of the well water in this study is said to be slightly acidic. All biochemical reactions are sensitive to pH changes. If it is less, algae die, fish cannot reproduce, and it causes acidity, corrosion, irritation of mucous membranes, tuberculosis, and other health problems in humans [13]. Cool water is more potable for drinking because higher water temperatures promote the growth of microorganisms. Thus, taste, odour, colour, and corrosion problems may increase [14].

Electrical conductivity and total dissolved solids were also low. Electrical conductivity determines the water quality for drinking and agricultural purposes. They both indicate the salinity behaviour of groundwater—the EC values in Tables 1 and 2 range from 93 to 489. The total dissolved solids range between 52 and 258. According to [15], high TDS levels affect the palatability of cooked food and cause gastrointestinal irritation. The TDS of both the protected and unprotected well samples is higher than that of wells in the Gidan Dare and Gidan Igwai regions of Sokoto State.

For turbidity, values for both protected and unprotected wells were below the NSDWQ limit, so they were deemed adequate. The turbidity levels of the water sources suggest that they lack high levels of suspended particles, bacteria, plankton, and dissolved organic and inorganic matter.

The alkalinity of water is its capacity to neutralise a strong acid, and it is normally due to the Presence of bicarbonate, carbonate, and hydroxide compounds of Calcium, sodium, and potassium. An alkalinity value below 100 mg/l is desirable for domestic use. However, in large quantities, it imparts a bitter taste to water [9]. In the present investigation, the total alkalinity at all sampling stations is below the NSDWQ-recommended limit. The alkalinity of water refers to its ability to neutralise acids.

The total hardness of water is characterised by its calcium and magnesium content [13]. Hardness is a property of water that prevents the formation of soap scum and increases its boiling point. The total hardness in the study area ranged from 31 to 190 mg/l, with the unprotected well having higher values than the protected wells. The World Health Organisation classifies water with calcium carbonate levels (0–60 mg/l) as soft water; therefore, based on the observed Total Hardness values, it can be concluded that the water in the study area is soft and is assessed as good for domestic uses such as washing, cooking, and so on. The quantities of Calcium in natural water depend upon the type of rocks. In the present study, calcium hardness and magnesium hardness range

from 17 to 100 mg/l and 14 to 90 mg/l, respectively. The 10 p sample has a high concentration of magnesium ions, while the three u and 10 u samples are both above the recommended limit.

Chloride occurs in all types of natural waters and is one of the most important parameters for assessing water quality. The high chloride concentration indicates pollution from high levels of organic waste of animal origin [18]. Chloride values obtained in the study range from 74.2 to 134.0 mg/l, which is within the NSDWQ recommended limit.

Iron in water does not usually present a health risk. Most Iron comes from food since the body cannot easily absorb Iron from water. High levels of Iron above 0.3 mg/l may give water a metallic taste and affect the taste of food and beverages. In the present study, no Iron was detected in any of the well water samples (Table 1). Water with an iron level above 0.3 milligrams per litre (mg/l) is usually considered objectionable. Iron levels are usually below 10 mg/l in natural water.

The total plate count for both protected and unprotected well water samples indicated that the number of coliforms exceeded the WHO drinking water standard of <1 colony-forming unit per 100 ml. The coliform counts of the water samples were evaluated using the most probable number (MPN) method. The results show that the MPN per 100 ml of all the water samples for the Protected and Unprotected wells were above the limits stated by the WHO, with results that are greater than 1 (>1). Thus, all samples contain Coliform. This suggests that potentially dangerous microorganisms have contaminated the well water samples, rendering them unfit for drinking. This was confirmed by characterising the isolates from well water samples collected at the study sites, which were highly contaminated with one or more bacterial pathogens, namely Escherichia coli and *Klebsiella* spp. The most predominant is the enteric coliform *Klebsiella* spp at 33.3%, followed by Enterobacter spp at 29.6%, Escherichia coli at 18.5%, Proteus spp at 11.1%, and Pseudomonas spp at 7.4%. These are pathogenic organisms mainly of faecal origin. Any water source used for drinking or cleaning purposes should not contain any organism of faecal origin [3]. The Presence of enteric coliforms, especially Escherichia coli, makes the water samples unsuitable for human consumption according to the WHO guidelines for the evaluation of the bacteriological quality of drinking water.

The organisms that were present in the protected well water sample are Coliform Bacteria, including Escherichia coli, Klebsiella spp., Proteus spp., and Enterobacter species (40 %), while the organisms present in the Unprotected well water sample are coliform bacteria, including Klebsiella spp., Escherichia coli, Proteus spp., and *Enterobacter* spp. *Pseudomonas spp. These organisms were identified based on their reactions* to biochemical tests. The standard for the identification of isolated organisms was obtained from [5] as a guide for the identification of the organisms for the result.

From the spatial ANOVA of the coliform count to know if there is a significant difference at a 95% confidence level with the $\alpha = 0.05$, the P-value for the total Coliform shows that the F-ratio is greater than the F-critical, therefore it indicates that there is a significant difference in the level of contamination between the protected and unprotected wells.

CONCLUSIONS

In the physicochemical analysis of the well water samples collected from both the protected and unprotected wells, 90% are within the NSDWQ specification, except for pH and magnesium hardness, which are below and above the recommended limits, respectively.

The bacterial concentrations in the 20 well samples above exceed the acceptable threshold limit; this can be attributed to the proximity of the wells to nearby sewers or gutters, as in the case of *E. coli* and Total Coliform Count. In this study, the unprotected well samples are the most contaminated and require serious treatment before consumption, while the protected well is also contaminated but less severely. The water sources from this area are not safe for drinking without treatment. These communities are therefore prone to health risks because of their dependence on these sources; thus, there is a need to improve and, in some cases, reconstruct the wells and treat their well water.

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