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Physicochemical, Bacteriological and Biochemical Assessment of Water Samples from Unprotected Wells in Lagos State Metropolis

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Authors' contributions

This research work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study presents the results of the physicochemical parameter data and water quality index use to assess the quality of unprotected well water in Lagos southwest, Nigeria.
Methodology: 20 water samples were collected from selected locations namely; PPL, Okokomaiko, Cassidy, Iba express and Iba junction and they were analyzed for 7 physical parameters (temperature of the water, temperature of air, colour, odor, turbidity, conductivity, total dissolved solids) and 7 chemical parameters (pH, iron, Total Alkalinity, Total Hardness, Chloride, organic matter and residual chlorine).
Results: The result showed that 5 (25%) samples had pH below the NSDWQ limit for drinking water quality and 10 (50%) samples had conductivity that were above the standard limit. 15 (75%) samples had Total dissolve solid that were above the standard limit. All other physicochemical parameters were within the NSDWQ. Microbiological analyses were done to assess the total plate count and the coliform count of the water samples and the results showed that 9 samples had

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colonies that were too numerous to count exceeding the permissible limit of 100 CFU/ml set by WHO. The coliform count of the water samples showed that the MPN per 100 ml of all the water samples were above the WHO limit by having results greater than 1. The IMViC result showed that *Klebsiella* species and *Enterobacter* species were found in 6 plates (30%), *Citrobacter* species were found in 7 plates (35%) and *Escherichia* species were found in 7 plates (35%).

Conclusions: This result highlight that the well water in these areas are not safe for human consumption without additional treatment such as boiling or addition of disinfectants, therefore there is need to enlighten the consumers around these researched study areas to at least disinfect and filtrate their well water before drinking in order to avoid outbreak of waterborne diseases.

Keywords: Physicochemical; bacteriological; biochemical; Lagos State; analysis; public health and well water.

1. INTRODUCTION

Water is an essential natural resource for sustainability of life on earth. Human may survive for several days or weeks without food but barely survive few days without water because constant supply of water is needed to replenish the fluids lost through normal physiological activities such as respiration, urination etc [1]. Though the hydrosphere is estimated to contain about 1.36 billion km^3 of water, only about 0.3% of the water existing as fresh water in rivers, streams and aquifers is available for human use; the remaining 99.7% is locked up in seas and oceans.

Lagos state covers an area of about 3,577 km^2 with its headquarters at Ikeja. It is located between longitudes 2°42'e and 3°42'e and latitudes $6^0$22'n and 6°52'n. It is bounded in the south by the guinea coast, in the west by the republic of Benin and in the north and east by Ogun state. The state falls within tropical climate. Annual average rainfall is 1532mm. It experiences an annual temperature of 27°C. The vegetation cover is dominated by swamp forest, wetlands and tropical swamp forest comprising of freshwater and mangrove. Surface water and groundwater quality and salinity in the aquifers change from north to south with salt water intrusion which may be tidal, seasonal and/or diurnal [2]. The usual source of drinking water in rural areas is the streams, rivers, wells and boreholes which are mostly untreated and are associated with various health risk [3].

Well water is a major source of water supply for domestic, agricultural, recreational and industrial purpose in Lagos, a fast-emerging mega city in Africa. Water quality reflects the composition of water as affected by natural cause and man's cultural activities expressed in terms of measurable quantities and qualities [4]. Well water is generally less susceptible to contamination and pollution when compared to surface water bodies. Importantly, well water can also be contaminated by naturally occurring sources. Water of good quality is of basic importance to human physiology as well as indispensable to man's continued existence. Its role as a medium of water borne disease which constitutes a significant percentage of the disease that affect human and animals cannot be underestimated [5]. Availability of facilities and financial constrains are the major obstacles in the provision of water of good quality in developing countries and rural areas. In Nigeria, treated water borne water is limited to urban areas and such service may not even be available in certain areas within the metropolis. Due to this scenario, an increasing number of people depends on wells as source of water supply [6]. The quality of water influences the health status of any populace, hence quality assessment for physical, biological and chemical properties including trace element content in water are very important for public health studies [7].

2. MATERIALS AND METHODS

2.1 Sampling

Study area: Ojo is a Local Government Area and town in Lagos State, Nigeria and the Lagos State University is located there. Ojo is located on the eastern section of the Trans–West African Coastal Highway, about 37km west of Lagos. It is part of the Lagos Metropolitan Area. In December, during the Dry season Water samples were collected from 20 different unprotected well in Ojo namely PPL, Cassidy, Okokomaiko, Obadore axis, Iba express and Iba junction, which are all common residential areas for Lagos State University, Ojo students.

2.2 Physicochemical Analysis

Visual inspection: The water was observed to determine its appearance.

pH: The pH was measured using a pH (ELL model 7030 pH meter), the electrode was immersed in water samples. The reading on the screen were taken and recorded. Buffer solutions of known pH were used to calibrate the pH meter.

Temperature: This was measured using mercury and flow filled thermometer (Skalenwart 1K model 1GL 11996), which was inserted into water sample directly.

Conductivity: This was measured with conductivity meter (model HACHDR 2010) by calibrating the electrode using 0.0119 standard potassium chloride solutions, which has an electrical conductivity of 127.8 msm4 at 20°C.

Turbidity: This was measured with calibrated turbid meter (Partech model DRT-100B) with standard solution of formation.

Total hardness: About 6 drops of Eriochrome black T indicator solution was added to 50 ml of water sample and mixed thoroughly. An appropriate volume of buffer solution (borax 0.5 ml, NH_4CL, buffer of 2 ml was added to the solution). The solution was mixed and titrated with standard EDTA solution. The total hardness was estimated as follows;

$$\text{Total hardness (as CaCo3 mg\l)} = \frac{1000 \text{ xVEDTA}}{\text{Vsample}}$$

Chloride ion: Exactly 100 ml water sample was titrated against silver nitrate using 1 ml of potassium chromate solution as indicator, until a slight red colour was obtained. A blank was carried out on distilled water.

$$\text{Chloride (mg\l)} = \frac{\text{V AgNO2(for nitrate)} - \text{V AgNO2 (for blank)x 100}}{\text{V sample}}$$

Total dissolved solid (TDS): These were determined by geometric analysis. An empty porcelain-evaporating dish was dried in an oven at 150°C. This was allowed to cool in a desiccator. The dish was weighed after cooling and 100ml of mixed sample was measured. The dish was kept in the oven for 24 hours at 105°C after which it was allowed to cool and weighed to constant mass.

$$\text{Total solid (TDS)} = \frac{\text{mass of solids in (mg) dish}}{\text{Volume of samples}}$$

Total Alkalinity: Exactly 100 ml of water sample was titrated against 0.1ml HCl using 2 drops of phenolphthalein as indicator until the pink colour disappeared. 2 drops of methyl orange indictor were then added and shacked until the colour changed to orange which was the end point.

$$\text{Phenolphthalein alkalinity (CaCo3 mg\l)} = \frac{50{,}000 \text{ x A x N}}{\text{V}}$$

$$\text{Total alkalinity (CaCO3 mg\l)} = \frac{50{,}000 \text{ xB x N}}{\text{V}}$$

A= titre value of sample
N= normality of $CaCO_3$
B= titre value of distilled water

Total acidity: Exactly 100 ml of water was titrated against 0.02 m NaOH solution using 3 drops of phenolphthalein indicator until pink colour was obtained. Acidity as calculated as;

$$\text{Acidity} = \frac{\text{V NaOH x 2000}}{\text{V H2O}}$$

2.3 Sampling for Bacteriological Analysis

The water samples collected from 20 different unprotected well namely PPL, Okokomaiko, Cassidy, Iba express and Iba junction were analyzed using the total plate count and multiple tube fermentation techniques. Different quantities i.e 0.1 ml and 10 ml of samples were added to the test tubes containing double strength MacConkey broth.

This in actual sense was carried out using the most probable number method which also involves the presumptive, confirmatory and the complete test.

Sterilization of glassware: All equipment such as pipette, test tubes, bijou bottle, glass bottle, conical flask were all sterilized with autoclaved at 121°C for 15 minutes.

2.4 Media Preparation

2.4.1 MacConkey broth

Double strength preparation was done by measuring 80 g of the powered MacConkey broth and dissolved in 1 litre of distilled water in a

sterile conical flask was then covered with cotton with homogenous solution. The conical flask was then covered with cotton wool wrapped in foil paper. 10 ml of the solution was dispensed into five test tubes and 50 ml of the solution was dispensed into sterilize glass bottles.

The test tubes were covered with cotton wool wrapped with aluminum foil and were sterilized in the autoclave at 121°C for 15minutes.

2.4.2 Single strength

Single strength was prepared by measuring 40g of powdered MacConkey broth using weighing balance and was dissolved in 1 litre of distilled water in a sterile conical flask. The conical flask was covered with cotton wool wrapped with aluminum foil. The solution was dispensed into five test tubes and then sterilized with autoclave at 121°C for 15 minutes.

2.4.3 Nutrient agar medium

Nutrient agar medium was prepared by weighing 28 g of the powdered Nutrient agar and dissolve in 1 litre of water in a conical flask and then mixed so as to dissolve thoroughly. The conical flask was covered with cotton wool wrapped with aluminum foil and then sterilized in an autoclave at 121°C for 15minutes.

2.4.4 Brilliant green agar medium

The medium was prepared by weighing 54.1 g of powdered brilliant green agar and was dissolved in a sterilized conical flask. The conical flask was covered with cotton wool wrapped with aluminum foil and was sterilized using the autoclave at 121°C for 15minutes.

2.4.5 Simmons citrate agar

The medium was prepared by weighing 24 g of the powdered Simmons citrate agar in 1 litre of distilled water and was soaked for 10minutes. The mixture was boiled so as to mix with water. A 10ml of the medium was dispensed into different test tubes and was autoclaved for 15minutes at 121°C.

After autoclaving, the medium was set as slope in order to ensure a slant position of the medium.

2.4.6 Methyl red voges proskauer broth (Mrvp broth)

The medium was prepared by dissolving 17 g of the powdered into 1 litre of distilled water. 10 ml of the medium was dispensed into different test tubes each. The medium was then sterilized for 15minutes using the autoclave at 121°C.

2.4.7 Motility indole urea agar (MIU media)

The medium was prepared by dissolving 43 g of the MIU media into 1 litre of distilled water. 10 ml of the medium was dispensed into different test tubes each. The medium was autoclaved for 15minutes at 121°C and was allowed to cool.

2.5 Reagents Preparation

2.5.1 Crystal violet

A 2 g of crystal violet (90% of the content certified) and 20 ml of ethanol (90% concentration) was mixed in a bottle labeled A and 0.8 g of ammonium oxalate dissolves in 80ml of distilled water was dispensed in another bottle labelled B.

The contents of both bottles (A and B) were mixed to obtain crystal violet staining reagent and stored in a labelled bottle for 24 hours.

2.5.2 Kovac's reagent

The reagent was prepared by dissolving 10 g of p-dimethyl amino benzaldehyde in 150 ml of Isoamyl alcohol and 50 ml of concentrated HCl was added to the solution.

2.5.3 Iodine solution

3.33 g of iodine crystal and 6.67 g of potassium iodide was crushed using a mortal and 1 litre of distilled water was added slowly until all the iodine crystals were dissolved completely.

The reagent was then stored in an amber reagent bottle.

2.5.4 Ethanol (decolourizer)

A 50 ml of ethanol (95% concentration) was mixed with 50ml of acetone. The mixture was stored and labeled.

2.5.5 Safranin o

The solution was prepared by mixing 25 g of safranin o in 100 ml of ethanol (95% concentration), then 10 ml of the mixture was dissolved in 90 ml of distilled water. The solution was stored and labelled.

2.6 Bacteriological Analysis

2.6.1 Total plate count

The total plate count was carried out using the pour plate method. 1 ml of water sample was

dispensed into a sterile petri dish and the prepared Nutrient medium was poured into the petri dish and allow to solidify.

The petri dish was the incubated at a temperature of 35°C for 24hours for growth. The colony formed was counted directly and the result were expressed as colony forming units per ml (CFU/ml).

2.6.2 Coliform count (Presumptive test)

Using the multiple tube fermentation procedure, 1 ml of water sample was dispensed into 10 ml of single strength MacConkey broth test tubes which was carried out in 5 replicates, 10 ml of the water sample was dispensed into 10 ml of double strength MacConkey test tubes which was also carried out in 5 replicates. 50 ml of the water sample was dispensed into 50 ml of double strength broth in an incubation bottle and this was done for all the water samples.

Each test tubes contained inverted Durham tubes (use for the production of gas) and they were incubated at 37°C for 48hours.

The test tubes and incubation bottles were examined foe colour change and gas production after 48 hours of incubation. There is a change in colouration of the MacConkey broth from red to yellow which indicate a positive result. For the negative tubes, no colour change was observed and the MacConkey broth remain red in colour (no sign of gas production was observed in the Durham tubes).

The presumptive coliform test was evaluated using the Most Probable Number (MPN) technique and the results were compared to the MPN values contained in McCrady's Probability Table.

2.6.3 Confirmatory coliform test

The confirmatory coliform test is to confirm the presence of coliform in the water samples. This is done by inoculating the positive result from the presumptive test on a brilliant green agar using the streaking method and was incubated at 35°C for 24hours.

The plates were observed for growth and colour change were observed on the incubated plates. Nucleated colonies within 24 hours indicate a positive coliform test.

2.6.4 Completed test

10 ml of the Nutrient agar medium was dispensed into bijou bottles and the bijou bottles were set as slope in order to get a slant position and then allow to solidify.

Isolated colonies from the positive results of the confirmatory tests were sub cultured into Nutrient agar and streaked into agar slants. The agar slants were incubated at 37°C for 24-48 hours.

2.6.5 Gram staining

All positives result (the slants with colonies) from the Nutrient agar slants were gram stained. Using a sterile inoculating loop to pick a small portion of the colonies, a thin smear was made on a sterile glass slide and the smear was air dried and then heat.

Two drops of crystal violet were added on the smear for 1 minute and then rinsed off under slow running water. Then a drop of iodine solution was added to the smear for 1 minutes and then rinsed off under slow running water.

Drops of ethanol as a decolourizer was added on the smear for 30 seconds and then rinsed off under slow running water. Drops of safranin O was added to the smear for 1 minutes to counter stain, which was then rinsed off with water. A drop of oil immersion was added to the smear. The smear was viewed under the microscope at x100 magnification. Pink coloured short rod shaped, non-forming organisms indicates result for gram negative coliforms.

2.7 Biochemical Tests

2.7.1 Indole test

The indole test was performed on motility indole medium (MIU) medium. The result was read after the addiction of kovac's reagent.

The positive test was indicated by the appearance of red colour at the top layer of the tube after kovac's reagent has been added. Absence of colour change at the top layer of the tube indicate a negative result.

2.7.2 Methyl red test and voges-proskauer test

Both the methyl red test and the voges-proskauer test was carried out on methyl red-vogesproskauer broth.

For methyl red test, methyl red reagent was added on the broth and the appearance of red colour after the addiction of the reagent indicate a positive result. Absence of colour change indicate a negative test.

For voges-proskauer test,barritt's A and barritt's B reagent was added on the broth and the appearance of a red-brown colour indicate a positive result. Absence of colour change indicate a negative reaction.

2.7.3 Citrate test

The citrate test was performed on simmons citrate agar and the appearance of growth with a blue colour indicate a positive result. Absence of growth and blue colour indicate a negative result. The results obtained from the Indole Methyl red Voges-proskauer Citrate test (IMViC) biochemical tests were compared with the intestinal pathogen identification chart. Alfred 2009.

3. RESULTS AND DISCUSSION

3.1 Physicochemical Results

The physicochemical result show that out of the 20 water samples gotten from unprotected well in Lagos(A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T), five (5) water samples (A,F,K,L,O) had a pH value that is below the limit of the Nigeria standard for drinking water quality (NSDWQ).The conductivity of the water samples B,D,G,H,I,J,M,P,Q and S were above the limit of the Nigeria standard for drinking water quality(NSDWQ). The total dissolved solids of the water samples A, B, D, G, H, I, J, L, M, N, O, P, Q, S and t were above the limit of the Nigeria standard for drinking water quality(NSDWQ).All other physicochemical parameters of the water samples met the limit of the NSDWQ as shown in Table 1.

3.2 Bacteriological Analysis

3.2.1 Total plate count

The total plate count of the water samples showed that nine(9) plate (A,C,D,K,L,O,P,Q,R) had colonies that were too numerous to count (TNTC) and therefore exceeded the permissible limit of 100 CFU/ml set by the World Health Organization (WHO) as shown in Table 2.

3.3 Coliform Count

The coliform count of the water samples was evaluated using the most probable Number (MPN) technique and the results show that the MPN per 100 ml of all the water samples were above the limits set by the WHO by having results that are greater than 1(>1) as shown in Table 3.

3.4 Gram Staining Results

The gram staining results of the water samples showed that the all the isolates had a Rod shape, Pink in colour and were Gram negative as shown in Table 4.

3.5 Biochemical Analysis

3.5.1 IMVic test results

The organisms that were likely to be present in the water samples are coliform bacteria and they include; *Klebisella* specie*s* (30%), *Escherichia coli (5%)*, *Citrobacter* species (35%) and *Enterobacter* species (30%). These organisms were identified based on their reaction to the IMVic test and Alfred manual of identification of bacteria was used as a guide for the identification of the organisms as shown in Table 5.

4. DISCUSSION

Loading of contaminants to surface waters, groundwater, sediments, and drinking water occurs via two primary routes: (1) point-source pollution and (2) non-point-source pollution. Point-source pollution originates from discrete sources whose inputs into aquatic systems can often be defined in a spatially explicit manner. Examples of point source pollution include industrial effluents (pulp and paper mills, steel plants, food processing plants), municipal sewage treatment plants and combined sewage–storm-water overflows, resource extraction (mining) and land disposal sites (landfill sites, industrial impoundments). Non-point-source pollution, in contrast, originates from poorly defined, diffuse sources that typically occur over broad geographical scales. Examples of non-point-source pollution include agricultural runoff (pesticides, pathogens, and fertilizers), storm-water and urban runoff, and atmospheric deposition (wet and dry deposition of persistent organic pollutants such as polychlorinated biphenyls [PCBs] and mercury)[8].

Table 1. Showing the physicochemical result of the 20 water sample from unprotected wells in Lagos

S/N	Parameters	A	B	C	D	E	F	G	H	I	J	NSDWQ
	Physical											
1	Temperature of water (°C)	26^0C	26^0C	26^0C	26^0C	26^0C	26^0C	26^0C	26^0C	26^0C	26^0C	22-30
2	Temperature of air (°C)	30^0C	30^0C	30^0C	30^0C	30^0C	30^0C	30^0C	30^0C	30^0C	30^0C	25-30
3	colour	**10**	15	10	15	10	10	10	10	10	10	0-15
4	odor	UOB	UOB	UOB	UOB	UOB	UOB	UOB	UOB	UOB	UOB	UOB
5	Turbidity	0.00	0.00	0.14	0.29	0.00	0.00	0.00	0.00	0.00	0.00	5 NTU
6	Conductivity US. (cm)	868	1307	424	1188	737	749	1133	1024	1096	1291	1000
7	Total dissolved solids(mg/l)	563	849	275	772	479	486	736	665	712	839	500(max)
	Chemical											
8	pH	6.6	7.0	6.8	7.2	6.9	6.7	6.8	6.9	6.8	7.1	6.8-8.5
9	Iron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
10	Total alkalinity $CaCO_3$ (mg/l)	4.9	7	5	7	5	5	5	5	5	7	No guideline value
11	Total hardness $CaCO_3$ (mg/l)	170	247	97	233	152	160	230	220	204	244	400
12	Chloride(mg/l)	12.49	140	10.29	96	40	42	119	99	97	109	250
13	Organic matter KMNO4(mg/l)	0.26	0.37	0.22	0.34	0.29	0.22	0.31	0.37	0.30	0.30	0.0-3.0
14	Residual chlorine(mg/l)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.3

Table 1. Cond.

S/N	Parameters	K	L	M	N	O	P	Q	R	S	T	NSDWQ
	Physical											
1	Temperature of water (°C)	26^0C	26^0C	26^0C	26^0C	26^0C	26^0C	26^0C	26^0C	26^0C	26^0C	22-30
2	Temperature of air (°C)	30^0C	30^0C	30^0C	30^0C	30^0C	30^0C	30^0C	30^0C	30^0C	30^0C	25-30 ^{o}C
3	colorr	10	10	10	10	10	10	10	15	10	15	0-15
4	odor	UOB	UOB	UOB	UOB	UOB	UOB	UOB	UOB	UOB	UOB	UOB
5	Turbidity	0.88	0.94	0.00	0.00	0.00	0.11	0.22	0.00	0.00	0.00	5 NTU
6	Conductivity US. (cm)	340	821	1448	778	8500	1201	1045	682	1358	850	1000
7	Total dissolved solids(mg/l)	221	533	941	505	552	780	679	443	882	552	500(max)
	Chemical											
8	pH	6.5	6.3	7.0	6.9	6.7	7.0	6.9	7.2	6.8	7.0	6.8-8.5
9	Iron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
10	Total alkalinity $CaCO_3$ (mg/l)	5	5	5	7	5	5	5	5	5	7	No guideline value
11	Total hardness $CaCO_3$ (mg/l)	72	165	198	119	97	187	175	88	209	80	400
12	Chloride(mg/l)	11.89	48	93	24	30	102	96	14.89	130	77	250
13	Organic matter KMNO4(mg/l)	0.14	0.33	0.32	0.29	0.22	0.18	0.33	0.31	0.34	0.28	0.0-3.0
14	Residual chlorine(mg/l)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.3

Keys: A- Water sample from unprotected well 1 from Community close, PPL; B- Water sample from unprotected well 2 from Community close, PPL; C-Water sample from unprotected well 3 from Community close, PPL; D- Water sample from unprotected well 1 from Osuagu close, Obadore; E- Water sample from unprotected well 2 from Osuagu close, Obadore; F- Water sample from unprotected well 3 from Osuagu close, Obadore; G- Water sample from unprotected well 4 from Osuagu close, Obadore; H- Water sample from unprotected well 1 from Iba junction; I- Water sample from unprotected well 2 from Iba junction; J- Water sample from unprotected well 1 from Iba express; K- Water sample from unprotected well 2 from Iba express; L- Water sample from unprotected well 3 from Iba express; M- Water sample from unprotected well 4 from Iba express; N- Water sample from unprotected well 1 from Benson street, Okokomaiko; O- Water sample from unprotected well 2 from Benson street, Okokomaiko; P- Water sample from unprotected well 3 from Benson street Okokomaiko; Q- Water sample from unprotected well 4 from Benson street, Okokomaiko; R- Water sample from unprotected well 1 from Ashiawu street, Cassidy; S- Water sample from unprotected well 2 from Ashiawu street, Cassidy. T- Water sample from unprotected well 3 from Ashiawu street, Cassidy; UOB – Unobjectable

Table 2. Showing the total plate counts of the water samples

Samples	Cfu/ml	Who standard
A	TNTC	100
B	40	100
C	TNTC	100
D	TNTC	100
E	32	100
F	40	100
G	16	100
H	24	100
I	32	100
J	60	100
K	TNTC	100
L	TNTC	100
M	60	100
N	54	100
O	TNTC	100
P	TNTC	100
Q	TNTC	100
R	TNTC	100
S	48	100
T	30	100

Table 3. Showing the presumptive coliform count

Samples	Double strength 50 ml (1 tube)	Double strength 10 ml (5 tubes)	Single strength 10 ml (5 tubes)	MPN per 100ml	WHO standard
A	1	2	3	12	<1
B	0	3	1	5	<1
C	1	3	0	8	<1
D	0	2	1	3	<1
E	0	2	2	4	<1
F	1	0	0	1	<1
G	1	4	1	17	<1
H	0	2	1	3	<1
I	0	4	0	5	<1
J	0	0	2	2	<1
K	1	4	2	22	<1
L	1	0	2	4	<1
M	0	0	1	1	<1
N	0	4	0	5	<1
O	1	3	3	18	<1
P	0	1	1	2	<1
Q	0	0	1	1	<1
R	1	2	3	12	<1
S	1	1	0	3	<1
T	1	1	1	5	<1

Key: Most Probable Number obtained from McCrady's Probability Table

From the results of the test carried out, the pH test showed that 5(25%) of the water samples had pH that were below the acceptable limit (6.8 – 8.5) of the Nigeria standard for drinking water quality (NSDWQ).The result obtained from this research was different from the work done by Shalom et al [9]. where the pH of all the water samples were within the NSDWQ limit. The result of this research is similar to the work done by Adeola et al. [10] in 2016 where 70% of the water sample had pH that was within the NSDWQ limit.

Table 4. Showing the gram staining results of the isolates present in the water samples

Samples	Shape	Colour	Gram staining reaction
A	Rod shaped	Pink	Gram Negative
B	Rod shaped	Pink	Gram Negative
C	Rod shaped	Pink	Gram Negative
D	Rod shaped	Pink	Gram Negative
E	Rod shaped	Pink	Gram Negative
F	Rod shaped	Pink	Gram Negative
G	Rod shaped	Pink	Gram Negative
H	Rod shaped	Pink	Gram Negative
I	Rod shaped	Pink	Gram Negative
J	Rod shaped	Pink	Gram Negative
K	Rod shaped	Pink	Gram Negative
L	Rod shaped	Pink	Gram Negative
M	Rod shaped	Pink	Gram Negative
N	Rod shaped	Pink	Gram Negative
O	Rod shaped	Pink	Gram Negative
P	Rod shaped	Pink	Gram Negative
Q	Rod shaped	Pink	Gram Negative
R	Rod shaped	Pink	Gram Negative
S	Rod shaped	Pink	Gram Negative
T	Rod shaped	Pink	Gram Negative

The conductivity values of about 50% of the water sample were above the NSDWQ limit. The conductivity measures the ability of the water samples to transmit current. This result is slightly similar to the work done by Olushola et al. [11], where 30% of the water samples had pH that were above the NSDWQ limit.

The turbidity (turbidity measures the cloudiness of the water) of all the water samples were within the acceptable range of NSDWQ (5NTU) and this means that all the water samples were relatively clear. The result of this research is similar to the work done by Shalom et al. [9] In 2011.

The chloride value of the entire water sample met the NSDWQ limit. Chloride is obtained from the solutions of salt of hydrochloric acids and it has important metabolism activity in the human body and other main physiological process. The result of this study is different to the result obtained by Abdulrafiu et al. [12]., in 2017 where 20% of the water samples had pH that were above the NSDWQ limit.

About 65% of the water samples had total dissolved solids that were above the NSDWQ limit. The total dissolved solid measured the total amount of minerals in water. The solids can be magnesium, iron, chlorides, calcium and other minerals found on the earth surface. The dissolved minerals can produce an unpleasant taste and can contribute to scale deposits on pipe line.

All other physicochemical parameters were within the NSDWQ acceptable limits.

About 45% (9 plates) of the water samples had a plate count that were too numerous to count and they exceeded the limit set by the WHO (CFU/ml). the rest of the plates had count that were within the WHO limit. The result of this research is different from the work done by Idowu et al. [13] where the viable count exceeded the WHO limit.

The Most probable number (MPN) per 100ml of all the water samples ranges from 1 – 22 which exceeded the standard limit set by WHO. This result is similar to the work done by Idowu et al. in 2011 [13].

The result obtained from the IMVic test showed that coliform bacteria that are likely to be present in the water samples are; *Enterobacter* species, *Citrobacter* species, *Klebsiella* species and *Esherichia coli*.

Klebsiella species had a percentage of 30%, Enterobacter had 30%, Citrobacter had 35% and Esherichia coli had 5% in the water samples. The result obtained from this research is different to the work done by Idowu et al. [13] in which *Klebsiellas* species had 95%, *Escherichia coli*

Table 5. Showing the imvic test result of the isolates

Samples	Indole test	Methyl red test	Voges-proskauer test	Simmon's citrate test	Likely organisms
A	-	-	+	+	*Klebsiella* species, *Enterobacter* species
B	-	-	+	+	*Klebsiella* species, *Enterobacter* species
C	+	+	-	+	*Citrobacter* species
D	+	+	-	-	*Escherichia* species
E	-	-	+	+	*Klebsiella* species, *Enterobacter* species
F	+	+	-	+	*Citrobacter* species
G	+	+	-	-	*Escherichia* species
H	+	+	-	+	*Citrobacter* species
I	+	+	-	-	*Escherichia* species
J	-	-	+	+	*Klebsiella* species, *Enterobacter* species
K	+	+	-	-	*Escherichia* species
L	+	+	-	+	*Citrobacter* species
M	-	-	+	+	*Klebsiella* species, *Enterobacter* species
N	+	-	+	+	*Citrobacter* species
O	-	-	+	+	*Klebsiella* species, *Enterobacter* species
P	+	+	-	-	*Escherichia* species
Q	+	+	-	-	*Escherichia* species
R	+	+	-	-	*Escherichia* species
S	+	-	+	+	*Citrobacter* species
T	+	+	-	+	*Citrobacter* species

had 72% and another isolate was found present which is *Salmonella typhi.*

The presence of these bacteria (*Citrobacter* species, *Enterobacter* species, *Klebsiella* species and *Escherichia coli*) shows that the water consumed in these areas are highly contaminated and the pathogen are in over large numbers.

The World Health Organization identifies the greatest human health risk of microbial contamination as being through the consumption of water contaminated by human or animal faeces. While not a health threat in and of itself, the presence of coliform bacteria indicates the presence of other potentially harmful bacteria.

5. CONCLUSION

This study shows that the quality of most of the water samples were poor. Most of the physicochemical parameters of the water sample met the limit set by the Nigeria Standard for Drinking Water Quality except for the H, the conductivity and the Total Dissolved Solids. It also showed that 9 plates out of the 20 plates used for the Total Plate Count has colonies that were too numerous to count therefore exceeding the limit set by the World Health Organization (WHO) for human consumption.

The MPN per 100 ml of the water sample exceeded the acceptable limit set by the WHO for human consumption. This indicate the presence of coliform bacteria such as *Enterobacter* species, *Citrobacter* species, *Klebsiella* species and *Escherichia* species in the water samples.

The presence of these coliform bacteria indicate that the water is highly contaminated and is not suitable for drinking purpose, as consumption leads to various water borne diseases like nausea, vomiting, diarrhea, gastroenteritis etc. Hence, we recommend that good and proper personal and environmental sanitary practices must be maintained in and around the wells, periodically disinfecting well water using chemicals such as ozone, chlorine and chlorine dioxide and most importantly, installing filtration systems such as the Gravity filters, Berkey water filters to ascertain water's potability before usage. All these measures would also go a long way to prevent incidence of waterborne diseases.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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