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Assessment of Ground and Surface Water Quality in some Sub-urban Areas of Owerri, Imo State.

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ABSTRACT

This study was carried out to evaluate the water quality of the two major sources of water, for drinking and domestic use, in Owerri-North; a suburban area of Owerri metropolis. The two main water sources, the boreholes and Uramiriukwa River representing ground and surface water respectively, were sampled in this study. The water samples from the River were collected from three spatial points, upstream, middle and downstream, while three boreholes, point 1, point 2 and point 3, were sampled, at different spatial points of approximately 14 km apart, while FUTO borehole served as the control point. The pollution levels of the water sources were determined using their physiochemical and biological parameter including, temperature, turbidity, electrical conductivity (EC), total dissolved solid (TDS), while the chemical parameters include pH, chemical oxygen demand (COD), biological oxygen demand (BOD), dissolved oxygen (DO), (HCO3), total hardness (TH), Chloride (Cl), Nitrate (NO3), Phosphate (POS4), sulphate Acidity, Alkalinity, Total iron (Fe2+), and biological parameters of e. coli, klebsiella, total coliform count and total bacterial count for which mean and standard mean error (SEM) were determined using the IBM SPSS software. The T-test was used to determine the difference in the physiochemical and biological properties of the Uramiriukwa River and the borehole water samples. Water quality index (WQI) of the Uramiriukwa River and borehole water samples were also determined using the weighted arithmetic method. Results from this study shows that the physical properties of the River were poor considering the high turbidity, TSS, TDS, colour, and turbid appearance, while the borehole was heavily polluted with coliforms, and bacteria, including e. coli and klebsiella. Spatial variations have no significant difference (p>0.05) for the River water samples at upstream, middle stream and downstream, while there was significant difference in the three borehole water samples used in this study. Also, there was significant difference (p≤0.05) between the means physiochemical and biological parameters of the River and borehole water samples. Calculation for WQI showed that the borehole water was good for drinking, while the Uramiriukwa water samples were unfit for drinking with WQI score of 38.92 and 169.46 respectively. it was concluded that the River was polluted with solid and chemical wastes as a result of anthropogenic activities, including dredging, industrial activities, laundry, and indiscriminate municipal waste disposal, as observed during field study. The presence of high level of coliform in the borehole and River water samples is an indication of fecal contamination, which is an indication of possible health risk. Standard water treatment especially filtration and disinfection, are required for the surface and ground water in the study area, in order to improve their quality for drinking and domestic use. There is need to monitor and regulate human activities around the water sources, since they are major factor for the water qualities.

Keywords: Water Quality, Physiochemical Parameters, Biological Parameter, Owerri-North, Water Quality Index, Borehole, Uramiriukwa River

1.0. INTRODUCTION

According to Osunkiyesi (2012), water is a vital component of all living organisms; without it, life cannot survive. Water has a significant role in the global economy, since about 70 percent of the freshwater utilized by humans is used for agriculture (Baroni *et al*., 2007), while the remaining 30 percent is used for residential and industrial reasons (Osunkiyesi, 2012). Although 70 percent of the earth's surface is covered by water, just 3 percent is fresh water and less than 1 percent is available for human consumption (Suthra-Bishnoi, Singh, Mutiyar, Nema & Patil, 2009). Water has been characterized as a colorless, odorless, and transparent liquid compound of hydrogen and oxygen (Wilson *et al*., 1995), therefore any trace of color, odor, or flavor shows the existence of contaminants or pollution.

In many developing nations of the world, including Nigeria, where it is primarily the responsibility of the government to provide drinking water for the populace, the provision of public water supply has reached an all-time low (Afolabi *et al*., 2012). The majority of the time, the government does not fully carry out its water provision responsibilities, prompting residents of urban and sub-urban cities to seek alternative sources of water supply. These alternatives include groundwater sources such as boreholes and wells, as well as surface water sources such as streams, lakes, and River s.

Many of the urban and sub-urban villages in the Nigerian state of Imo do not have access to a public water supply, which poses issues for the provision of potable water. According to studies, private and public boreholes are the primary sources of residential water supply in the state's urban and rural populations (Mbuka-Nwosu *et al*., 2022).

However, even accessible drinking water would require a series of treatments before it could be safe or fit for drinking. The extent of treatment needed is therefore determined by the quality of the raw water source (Adejuwon and Mbuk, 2011). Therefore, water has to meet certain physical, chemical, and microbiological standards—that is, it must be free from disease-causing microorganisms and chemical substances—before it can be termed potable.
The World Health Organization (WHO, 2010) recommends that the minimum daily per capita water consumption to be 27 liters/person/day. However, many people manage with far less than 27 liters. This could be because approximately 70% of the renewable water resources are unavailable for human use or under developed or unevenly distributed (Minh, Pham & Rodgers, 2011).

Industrial and agricultural activities have contributed immensely in polluting several surface water and groundwater sources (Nikolaidis *et al.*, 2008). These chemicals and industrial effluents in water from industries include dissolved metals and their salts, acids, bases, organic and inorganic compounds, solvents, solutions etc (Sullivan *et al*., 2005). Within the variety of effluents from the industries are fluorine, wastewater, heavy metals, dyes and colorants, solvents etc. Agricultural activities such as deforestation, pastoral farming, ploughing and the use of fertilizers have contributed to the devaluation of drinking water quality in our environment (Spitsov *et al*., 2020). The quality of water, whether used for drinking, domestic purposes, food production or recreational purposes has an important impact on health.

Contamination of water has increasingly become an issue of serious environmental concern after years of pollution (Akpoveta *et al*., 2011). Natural water contains many dissolved substances: contaminants such as bacteria, viruses, heavy metals, nitrates and salt have polluted water supplies due to inadequate treatment and disposal of wastes from humans and livestock, industrial discharges and over use of limited water resources. Fresh water is a fundamental resource, integral to all environmental and societal processes. However, fresh water is only a small component of the total water resources. Most countries of the world now have water resources management policies aimed at achieving the goal six of the Sustainable Development Goals (SDG) for their economic and social development (Tsani *et al.,* 2020). Achieving this objective requires that the needs and wants of the community for each water resource are defined and that these resources are protected from degradation (Di Baldassarre *et al.,* 2019). These community needs generally called the environmental values (or beneficial uses) of the water body, include water for drinking, and domestic use; the basis for which the wells were conceived and constructed. However, the environmental values for which a particular water source could serve depend on the environmental quality parameters of the water. Environmental quality parameters are the natural and man-made chemical, biological and microbiological characteristics of River s, lakes and ground-waters, the ways they are measured and the ways that they change. The values or concentrations attributed to such parameters can be used to describe the pollution status of an environment, its biotic status or to predict the likelihood or otherwise of a particular organism being present. Monitoring of environmental quality parameters of a drinking water sources is a key activity in managing the environment (water body), restoring the environment if polluted and anticipating the effects of man-made changes on wells (Oluyemi, 2013).

2.0. STUDY AREA

The study areas are parts of the Owerri suburban, in the Owerri North Local Government Area of Imo State, Nigeria, that lies between 5.4567° N, 7.1144° E. Its headquarters are in the town of Orie Uratta. It has an area of 198 square km, with a population of 175,395 (NPC, 2006). It encircles Owerri Municipal like a peninsula. Six major roads that lead out of the municipal cut across Owerri-North Communities. In North, Orlu Road leads to Amakaohia and Akwakuma communities. In the East, Okigwe Road leads to Orji Community. In the West, MCC Road off Wetheral to Obibi Uratta and Ihitaoha communities. In the South, Mbaise Road leads to Egbu and Emekuku Communities, while Aba Road leads to Naze, Agbala and Ulakwo Communities.

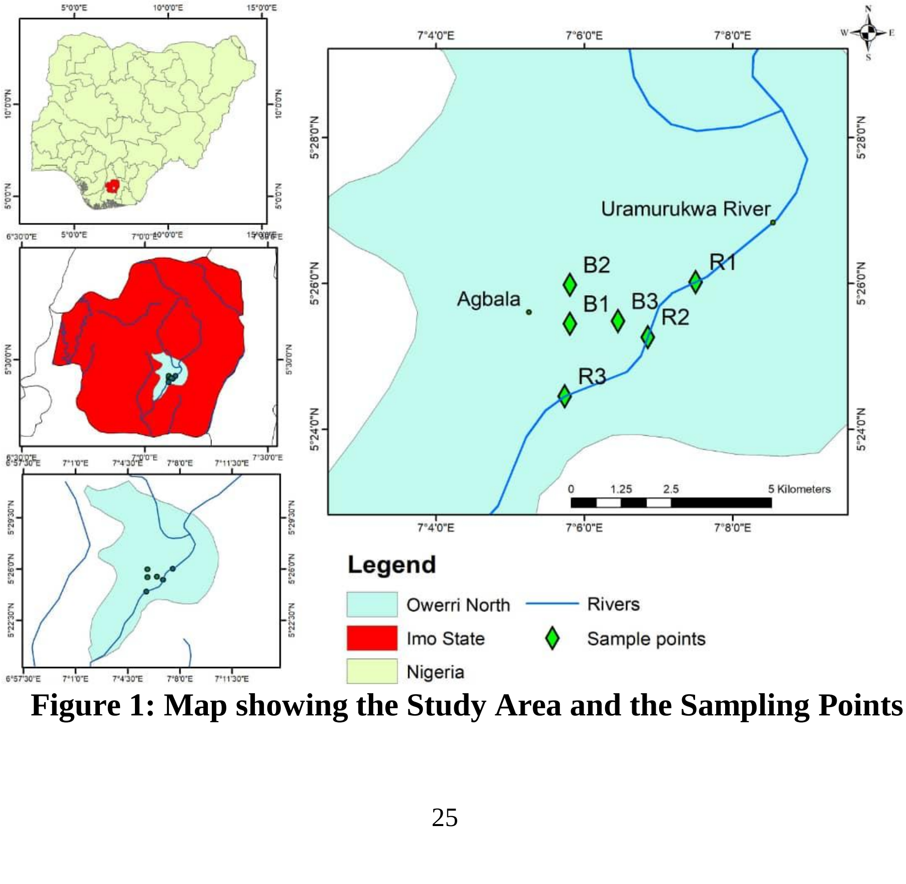

Figure 1: Map showing the Study Area and the Sampling Points

3.0. METHODOLOGY

3.1. Research Design

This study is an experimental research design with aim to determine the physiochemical and biological properties of surface and ground water in suburban area of Owerri. Samples were collected from Uramiriukwa and borehole water and analyzed in the laboratory. Results were compared to the Federal Ministry of Environment (NESREA) standard for drinking water.

3.2. Sample Collection

3.2.1. Collection of River Water samples

The samples were collected from Uramiriukwa River at three sampling points using a grab sampling method. The sampling areas were at three points including, the upstream, the middle-stream and the downstream. The points were at least 8km apart from each other. The sampling materials used were sterile screw capped bottles and the water samples were collected from about 4 - 6 cm below the water surface using sterile disposable hand glove. The process of opening of bottle caps was quickly done to avoid contamination. Samples for the biological oxygen demand were collected 250 ml bottles, while samples for other parameters were collected 500 ml bottles. The bottles containing the samples were labeled, indicating source, date, and time of collection. A GPS was used to take the coordinates of the various sampling points.

3.2.2. Borehole sample collection

The procedure for data collection started with a reconnaissance survey to the area. This enabled functional boreholes to be identified. Functional borehole was conceptualized as one that is frequently in use with level of patronage (use) greater than 50 persons per day. Through this approach, 8functional boreholes were identified, after which 4 boreholes were randomly selected without replacement, at different distance to eliminate biases. The borehole at the Federal University of Technology (FUTO) served as the control point.

Water samples were collected in 1litre plastic bottles; before the collection of water samples, the boreholes were allowed to pump for 5 minutes so that water with a constant temperature and pH, representing that from the aquifer was collected. Water samples were collected at the borehole heads.

Prior to sample collection, all plastic bottles were first washed with de-ionized water, and then several times with the sample water before collection in order to avoid any contamination. After sampling, the containers were tightly covered with tightly fitting covers wrapped in a black polyethylene plastic bag labeled 1 - 4 and put in a cooler to ensure constant temperature.

All the samples were preserved by refrigeration and analyzed within 24hours of collection. The analyses were carried out in accordance with American Public Health Association Standard (1998). The approach ensures that the samples collected were tested in accordance with agreed requirements using competent personnel as well as appropriate equipment and materials.

3.3. Selection of Sampling Points.

Considering the purpose and the study area, the surface water sampled was the Uramiriukwa stream, which runs a 14 km course through Agbala communities in Owerri.

The borehole water samples were collected from three different points, in Agbala, in Owerri-north, and then FUTO (control point). Each of the sampling point were chosen such that they were at least 8 km apart.

The sampling points with coordinates are as follows:

i. Sampling points for ground water (borehole) include:
   - B1 Borehole (Wire crossing, Agbala), Elevation: 283ft, 5.424908^{o}N, 7.112554^{o}E
   - B2 Borehole (Emeke, Agbala), Elevation: 131ft, 5.432978^{o}N, 7.096745^{o}E
   - B3 Borehole (Egbelu, Agbala), Elevation: 131ft, 5.432978^{o}N, 7.096745^{o}E
   - B4 Borehole (FUTO) (control point), Elevation: 5.05^{o}N, 7.036827^{o}E

ii. The sample points for surface water (Uramiriukwa River) include:
   - S1 Surface Uramiriukwa upstream River, 5.424225^{o}N, 7.112554^{o}E
   - S2 Surface Uramiriukwa middle River, 5.421028^{o}N, 7. 113758^{o}E
   - S3 Surface Uramiriukwa downstream River, 5.424908^{o}N, 7. 112554^{o}E

3.4. Procedure for Samples Collection

One liter polyethylene bottles were used for collection of the samples. The bottles were washed and rinsed thoroughly with distilled water to ensure the absence of contaminants. At the point of collection of the samples, the bottles were once again rinsed with the water sample before collection of the actual sample used for the experiment, and labeled immediately.

The groundwater samples were collected from four different boreholes, three from Agbala community in Owerri-north, and one point in FUTO, Owerri-west LGA. Two replicates of each of the borehole water samples, designated as B1, B2, B3 and B4, were obtained, and two replicates were also collected for the surface water samples, designated as S1, S2 and S3, for upstream, middle stream and downstream, respectively. The samples obtained were immediately sent to the laboratory for physicochemical and biological tests.

3.5. Laboratory Analysis

3.5.1 Instruments and Reagents Used

Sampled bottled borehole water, autoclave, incubator, spatula, petri dish, pH meter, thermometer, conductivity meter, beaker, evaporating dish, desiccator, hot plate, measuring cylinder weighing balance, watch glass, microscope, atomic absorption spectrophotometer, culture media (Chromocult agar and Centrimide agar), masking tape, conical flask.

3.5.2. Reagents

Phosphoric acid and sodium periodate, Ammonia buffer solution, 0.01N EDTA (Ethylenediamine tetra acetic acid), Erichrome black T indicator, Buffer solution (NaOH solution), 0.01N EDTA (Ethylenediamine tetra acetic acid), and muroxide indicator, 0.02N H_2SO_4, Methyl Orange, Potassium Chromate indicator and 0.0141N $AgNO_3$, phenoldisulphonic acid reagent and 10 % ammonia solution, Powder MacConkey agar, Barium Chloride salt and conditioning reagent.

3.5.3. Physicochemical Analyses

Mercury-in-glass thermometer was used to determine the temperature at the site of collection of the water samples. The reading was taken after dipping the thermometer in the water and allowed to stabilize for about 2 minutes. Spectrophotometer was used to determine the turbidity of the samples; the absorbance reading obtained from the Spectrophotometer was the turbidity level of the water sample. Conductivity meter was used for Electrical Conductivity. The total dissolved solid was determined by evaporation method. A pH meter (Tensway method) was used to determine the pH of all water samples. Total Alkalinity, Total Hardness, Calcium, Chloride, Dissolved Oxygen, Chlorine, Chemical Oxygen Demand, and Biological Oxygen Demand were analyzed by the titration method**.** Nitrate was determined by the spectrophotometric sodium salicylate method. Barium Chloride salt and conditioning reagent by Barium Sulphate were used to determine sulphate. Spectrophotometer was used to test for iron.

3.5.4. Biological Analyses

For coliform count, 5.25 g powder of the MacConkey agar was dissolved to 1000 ml of distilled water. Mix and heat until dissolved. Sterilize by autoclaving for 15 minutes at 121 ^{o}C and poured into petri dishes. Aliquots 10ml of each sample were used to inoculate on MacConkey agar by spread plate method. The plates were incubated at 37 °C for 24hours in an incubator. After incubation, colonies were observed on the different plate, counted and recorded. Calculation: fecal coliform cfu/ml = colony observe× dilution factor (if any) × volume used.

For the determination of Total bacteria count:
Media Preparation (Nutrient agar)
28.0 gm of nutrient agar was dissolved in 100 ml distilled water, heated to make the medium completely sterile by autoclaving at 15 psi (121 ^{0}C) for 15 minutes, and then the medium was dispensed as desired in the plate

Mac-conkey Agar
52.5g powder of the mac-conkey agar was dissolved into 1000 ml of distilled water, mixed and heated until dissolved, and then sterilized by autoclaving 15minutes at 121 ^{0}C and poured into petri dishes.

For the determination of total klebsiella
Eosin Methylene Blue (EMB) Agar
36grms was suspended in 1000ml distilled water, and heated to dissolve the medium completely. It was later dispensed and sterilized by autoclaving at 15 ibs pressure (121 ^{0}C) for 15 minutes. And finally poured into petri dishes (plates).

Determination of *e.coli*.
A mixture of the culture broth, enzyme inducer and E- Coli was injected into the chambers on the top layer. A mixture of the substrate and lysis solution was injected into the chambers on the bottom layer. Then the slipchip was slide to make each chamber independent. *E. coli* was cultured in the chamber in the LB broth for 2.5h. After that the slip chip was slide again to introduce the lysis solution into the culture solution for GUS release and enzyme reaction and then incubated in the plate reader at 24°C for another 2.5hours. During incubation, the fluorescence intensity of each chamber was record.

3.6. Techniques for Data Analysis

The ANOVA statistical analysis was used to determine the means, and standard error mean of the physiochemical and biological parameters of the two water sources using the IBM SPSS software. A Duncan post-hoc test was carried out to compare the spatial variations of the physiochemical and biological parameters of the two water sources, while a T-test was carried out to compare the physiochemical and biological parameters of the two water sources.

The excel spreadsheet was also used to calculate Water Quality Index (WQI) of the two water sources.

4.0. RESULT PRESENTATION

4.1. Spatial variations of the physiochemical and biological properties of the surface water samples.

Table 1: Spatial variations of the physiochemical and biological characteristics of Uramiriukwa River water samples.

Parameters	Uramiriukwa River Water Samples		
	Point 1 (Upstream)	**Point 2 (Middle stream)**	**Point 3 (Downstream)**
Temperature (ºC)	26.25±0.05^{a}	26.25±0.15^{a}	26.25±0.05^{a}
TSS (mg/l)	152.85±2.00^{a}	157.1±17.1^{a}	121.85±9.0^{a}
TDS (mg/l)	7.15^{a}	7.8^{a}	7.15^{a}
Odour	unobjectionable	unobjectionable	unobjectionable
Colour (CP)	125^{a}	155±1^{b}	82.5±2.5^{c}
Appearance	turbid	turbid	turbid
Turbidity (NTU)	53.5±0.10^{c}	24.65±0.05^{a}	33.5±0.6^{b}
EC (μs/cm)	11^{a}	12^{a}	11^{a}
pH	7.25±0.05^{ab}	7.4±0.1^{b}	7.05±0.05^{a}
Alkalinity (mg/l)	7.00±1.00^{a}	10^{b}	5.5±0.5^{a}
DO (mg/l)	14.6^{c}	12.85±0.05^{a}	13.1^{b}
BOD (mg/l)	1.35±0.05^{a}	1.7^{b}	3.3±0.05^{c}
COD (mg/l)	208^{a}	472±8.0^{c}	280±8^{b}
Total acidity (mg/H+)	0.22±0.02^{a}	0.3±0.02^{a}	0.3±0.02^{a}
Nitrate (NO3) (mg/l)	31.70±0.16^{c}	25.535±0.16^{a}	28.08±0.08^{b}
Phosphate (PO4) mg/l	0.675±0.02^{c}	0.58^{b}	0.5±0.005^{a}
Chloride (mg/l)	29.99±2.00^{ab}	32.99±1.00^{b}	25.99^{a}
Total Hardness, mg/l	85.47^{a}	115.26±3.89^{b}	161.88±3.89^{c}
sulphate SO4 (mg/l)	1.64±0.01^{a}	1.84±0.02^{b}	15.87±0.01^{c}
Iron (Fe) mg/l	1.98^{a}	2.27±0.02^{b}	2.3±0.01^{b}
Total bacteria count Cfu/100 ml	$2.59x10^{5}±2.41x10^{5}$ ^{a}	$2.95x10^{4}$ ± $2.05x10^{4\ a}$	$3.65x10^{5\ a}$
Total coliform count Cfu/ 100 ml	$8.67\ x10^{5}±8.33x10^{5}$ ^{a}	$5.4x10^{5}$ ±$4.6x10^{4\ a}$	$2.065x10^{4\ a}$
Klebsiella count cfu/ 100 ml	NG	NG	NG
e. coli (cfu/100ml)	NG	NG	NG

Source: Field work by author. Values = mean±SEM; ANOVA result showed that water samples at the three points are not significantly different (p>0.05). Subscript a-c, indicates least to highest value, and values with same superscript along a row are not significantly different (p>0.05), NG=No Growth.

The spatial variation of the physiochemical and biological parameters of Uramiriukwa River water samples at different points, including the upstream, middle stream and downstream are shown in Table 1.

The result for the physical properties of the River shows that, the temperatures, total suspended solids, total suspended solids, and electric current, were not significantly different at the upstream, middle stream and downstream at ($p>0.05$), while colour and turbidity, were significantly different at the three points at ($p<0.05$). The appearance of the River water samples was turbid at the three points.

The result for the chemical properties of the River water sample showed significant differences ($p<0.05$) for pH, dissolved oxygen, BOD, COD, nitrate, phosphate, chloride, total hardness, sulphate at the three points, while there was no significant difference ($p>0.05$) in the total acid at the three points. Furthermore, there was no significant difference ($p>0.05$) in the total alkalinity at the upstream and downstream, while the result showed a significant difference ($p>0.05$) at the middle stream. Also, a significant difference ($p<0.05$) was observed in the iron content at the upstream, but no significant difference ($p>0.05$) in the middle stream and downstream.

Result for biological parameters of Uramiriukwa River showed no significant difference ($p>0.05$) for total bacteria count, and total coliform count at the three points, while no growth were detected for klebsiella and *e. coli*, at the three point.

4.2. Spatial variations the Physiochemical and biological parameters of the ground water sample.

Table 2: Showing spatial variations of the physiochemical and biological characteristics of borehole water samples.

Parameters	Owerri-North (Agbala) Borehole Water Samples			
	Point 1	**Point 2**	**Point 3**	**FUTO (Control point)**
Temperature (°C)	30.3 ± 0.1^{a}	30.6^{b}	31.35 ± 0.10^{c}	30.7
TSS (mg/l)	105.6 ± 4.0^{b}	62.93 ± 44.5^{a}	55.57 ± 0.70^{a}	9.53
TDS (mg/l)	8.4^{5b}	23.08 ± 16.3^{c}	**5.53**$\pm0.33^{a}$	**7.475**
Odour	unobjectionable	unobjectionable	unobjectionable	unobjectionable
Colour (CP)	2.50 ± 0.5^{b}	0^{a}	5^{c}	0
Appearance	clear	clear	clear	clear
Turbidity (NTU)	5.52 ± 0.01^{b}	0^{a}	0^{a}	4.28 ± 0.01
EC (µs/cm)	13^{b}	**35.5**$\pm0.71^{c}$	8.50 ± 0.50^{a}	11.5±0.35
pH	6.05 ± 0.1^{a}	6.4^{b}	6.15 ± 0.05^{a}	6.15
Alkalinity (mg/l)	$6a^{b}$	5.5 ± 0.71^{a}	7.50 ± 0.50^{b}	10.5
DO (mg/l)	14.1 ± 0.1^{b}	10.70 ± 0.01^{a}	14.2^{b}	10.2
BOD (mg/l)	8.45 ± 0.05^{c}	5.71 ± 0.13^{a}	6.62 ± 0.02^{b}	5.15
COD (mg/l)	640 ± 16^{c}	488 ± 11.31^{b}	160^{a}	248
Total acidity (mg/H+)	0.28^{a}	0.38 ± 0.03^{b}	0.34 ± 0.02^{ab}	0.42
Nitrate (NO3) (mg/l)	7.85^{b}	82.845 ± 0.11c	0a	ND
Phosphate (PO4) mg/l	0.45 ± 0.1^{b}	0.585 ± 0.01^{c}	0.34^{a}	0.69

Chloride (mg/l)	19.10 ± 2^{a}	24.99 ± 1.41^{a}	23.99 ± 2^{a}	18.99
Total Hardness, mg/l	90.65^{a}	124.32 ± 7.32^{c}	108.78 ± 2.59^{b}	103.6
sulphate SO4 (mg/l)	4.48 ± 0.09^{c}	0.35^{a}	1.67 ± 0.01^{b}	1.23
Iron (Fe) mg/l	0.31c	0.27b	0.135 ± 0.0^{2a}	0.3
Total bacteria count Cfu/100 ml	$1.9 \times 10^{3} \pm 100^{a}$	$5.0 \times 10^{3} \pm 3.5 \times 10^{3c}$	3.0×10^{3b}	1.8×10^{4}
Total coliform count Cfu/ 100 ml	$1.88 \times 10^{4} \pm 250^{c}$	$1.5 \times 10^{4} \pm 1.1 \times 10^{4b}$	2.0×10^{3a}	3.5×10^{3}
Klebsella count cfu/ 100 ml	1.8×10^{4b}	$2.1 \times 10^{4} \pm 1.5 \times 10^{4c}$	0^{a}	1.2×10^{4}
e. coli (cfu/100ml)	3.0×10^{3b}	0^{a}	0^{a}	$^{2.0} \times 10^{3}$

Source: Field work by author. Values = mean±SEM; ANOVA result showed that water samples at the three points are not significantly different (p>0.05). Subscript a-c, indicates least to highest value, and values with same superscript along a row are not significantly different (p>0.05). NG=No Growth.

Table 2 shows the physical, chemical, and biological properties of the borehole water samples from three different points in the Owerri-North Local Government Area of Imo State. The temperatures of the three borehole water samples were 30.3 ± 0.1 ºC, 30.6 ºC, and 31.35±0.10 ºC for points 1, point 2, and point 3, respectively, and were significantly different (p<0.05). Total suspended solids (TSS) for the three spatial points were 105.64.0 mg/L, 62.930.45 mg/L, and 55.57 mg/L respectively. TSS at point 2 and 3 showed no significantly difference (p>0.05) but showed a significant difference (p<0.05) from point 1. Total dissolved solids at all three points were significantly different (p<0.05). Colour was not detected at points 2, but was detected at points 1 and 3, with values of 2.500.5 CP and 5 CP, respectively, and significantly different (p<0.05) at all three points. The appearance at the three points was clear, while turbidity showed no detection in water samples from points 2 and 3, but was detected in points 1 with value of 5.520.01 NTU. Turbidity at point 2 and 3 were significantly similar, but different from that of point 1. The electric current of the water samples from the three spatial points were 13 µs/cm, 35.5±0.71 µs/cm, and 8.50±0.50 µs/cm, respectively, and were significantly different (p<0.05) at all points. Also, as shown in Table 4.2, the chemical parameter tests of the boreholes from the three spatial points show that the pH was 6.05±0.1, 6.4, and 6.15 ± 0.05, for points 1, 2, and 3, respectively. The pH at point 1 and 3 were not significantly different (p>0.05), but different significantly (p>0.05) from point 2. Total alkalinity was 6 mg/L, 5.5 0.71 mg/L, and 7.50±0.50mg/L, respectively, for points, 1, 2 and 3. Like the pH level, the alkalinity levels at point 1 and 3 were not significantly different (p>0.05) but significantly different (p<0.05) from point 2. The dissolved oxygen at the three points were 14.1 ± 0.1, 10.70 ± 0.01, and 14.2, for points 1, 2, and 3 respectively. Dissolved oxygen at point 1 and 3 were not significantly different (p>0.05) but significantly different (p<0.05) from point 2. The BOD of water samples at the three points were all were 8.45±0.05, 5.71±0.13, and 6.62±0.02, for points 1, 2 and 3 respectively, and were significantly different (p<0.05) at all points, while the COD of borehole water samples from all three points with values of 640 mg/L, 488 11.31 mg/L, and 160 mg/L, for points 1, 2, and 3 respectively, and also significantly different (p<0.05) at all points. Nitrate was not detected in the borehole water samples from points 3, but was detected in samples from points 1 and 2, with values of 7.85 mg/L and 82.85 mg/L respectively. Nitrate at all three points were also significantly different ($p<0.05$). The phosphate content of the borehole water samples from the three points were 0.45±0.1 mg/L, 0.59±0.01 mg/L, and 0.34 mg/L for points 1, 2, and 3, respectively, and significantly different at the three points. The chloride content of the borehole water samples from the three points had values of 19.10±2 mg/L, 24.99±1.41 mg/L, and 23.99±2 mg/L for points 1, 2, and 3, respectively, and showed no significantly difference ($p<0.05$) at all points. The total hardness of borehole water samples from the three spatial points were 9.065 mg/L, 124.32±7.3 mg/L, and 108.78±2.59 mg/L for points 1, 2, and 3, respectively, and were all significantly different ($p<0.05$). The iron contents of the borehole water samples from the three spatial points were, 0.31 mg/L, 0.27 mg/L, and 0.140.02 mg/L for points 1, 2, and 3 respectively, and were also significantly different ($p<0.05$) at the three points. Table 4.2 also shows the result of the biological properties test of the borehole water sampled from the three spatial points of the study area. The result showed that bacteria count of the three borehole water samples were, $1.9x10^3$, $5.0x10^3$, and 3.0×10^3Cfu/100 ml for points 1, 2, and 3 respectively, and significantly different at all points. The coliform counts were 1.88×10^4, 1.5×10^4, and 2.0×10^3, Cfu/100 ml for points 1, 2, and 3 respectively, and were also significantly different. Klebsiella counts were $1.8x10^4$, $2.1x10^4$, and 0 for borehole water sampled from points 1, 2, and 3, respectively, and also significantly different at all points. *E.coli* was detected in the borehole water samples from points 1 only, with values of $3.0x10^3$ cfu/100, while *e.coli* growths were not observed in borehole water sampled from points 2 and 3.

4.3. The mean physiochemical and biological properties of borehole and Uramiriukwa River Water Samples, compared to the NESREA Standards.

Table 3: Comparing the mean physiochemical and biological parameters of borehole water and Uramiriukwa River in Owerri-North with the NESREA standards for drinking water.

Parameter	**Boreholes and Uramiriukwa River Water Samples**		
	Borehole (Mean ±SEM)	**Uramiriukwa River (Mean ±SEM)**	**NESREA Standards**
Physical Properties			
Temperature (°C)	30.74±0.22	26.25 ± 0.00	30.00
TSS (mg/l)	58.37±19.67	143.93 ± 11.11	10.00
TDS (mg/l)	11.13±4.03	7.37 ± 0.22	500
Odour	Unobjectionable	Unobjectionable	Unobjectionable
Colour (CP)	3.75±1.25	120.83 ± 21.03	15
Appearance	Clear	turbid	clear
Turbidity (NTU)	4.90±0.62	37.22 ± 8.53	10
EC (µs/cm)	17.13±6.20	11.33 ± 0.33	1000
Chemical Properties			
pH	6.19±0.07	7.23 ± 0.10	6.50-8.50
Alkalinity (mg/l)	7.38±1.13	7.50 ± 1.32	150
DO (mg/l)	12.31±1.07	13.52 ± 0.55	>7.50
BOD (mg/l)	6.48±0.72	2.10 ± 0.58	15
COD (mg/l)	384±109.93	320 ± 78.79	40
Total acidity (mg/H+)	0.36±0.03	0.27 ± 0.03	NS
Nitrate (NO3) (mg/l)	45.35±37.50	28.44 ± 1.79	50
Phosphate (PO4) mg/l	0.52±0.08	0.58 ± 0.06	5

Chloride (mg/l)	21.99±1.47	29.66 ± 2.03	250
Total Hardness, mg/l	106.84±6.96	120.87 ± 22.2	150
sulphate SO4 (mg/l)	1.93±0.89	6.45 ± 4.71	200-400
Iron (Fe) mg/l	0.25±0.04	2.17 ± 0.10	1.00
Biological Properties			
Total bacteria count Cfu/100 ml	6.975 x 10^3	2.18 x 10^7	0-30
Total coliform count Cfu/ 100 ml	9.813 x 10^3	3.76 x 10^7	0.10
Klebsella count cfu/ 100 ml	1.7 x 10^7	NG	0
e. coli (cfu/100ml)	2.5x 103	NG	0

Source: Author's Field work (2023). The means of the borehole and Uramiriukwa River water samples are significantly different (P<0.05).

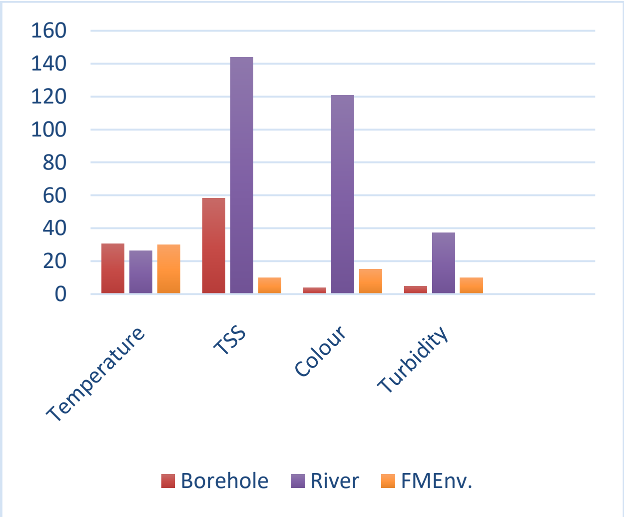

Figure 2: Graph comparing the mean temperature, TSS, colour and turbidity of the borehole and River water samples to the NESREA standards for drinking water.

Figure 2 compares some physical properties, including temperature, TSS, colour and turbidity, of the borehole and River water samples to the NESREA standards for drinking water. The result shows that the mean temperature for the borehole water was 30.74 ºC, above the NESREA standard of 30ºC for drinking water, while that of the Uramiriukwa River was 26.25ºC and below the NESREA standard. The mean total suspended solids were 58.37 mg/L and 143.93 mg/L for the borehole and River, respectively, both of which were above the NESREA permissible limit of 10 mg/L. The mean value of colour for the borehole water samples was 3.75 cp, below the NESREA permissible limit of 15 cp, while the mean colour value of the River water samples was 120.83 cp, against the NESREA limit. The mean turbidity value of the borehole water samples was 4.9 NTU, which is low compared to the NESREA standard of 10 NTU, while the turbidity of the River was 37.22 NTU, which is higher than the NESREA.

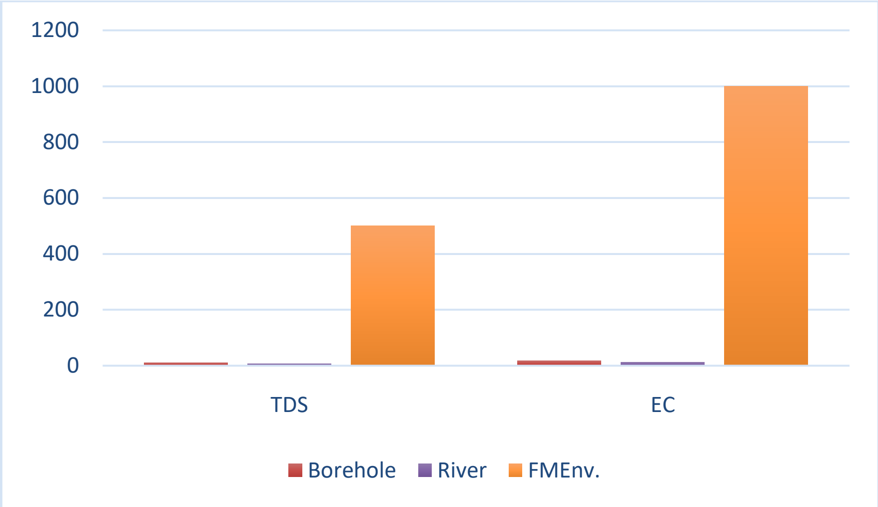

Figure 3: Graph comparing the mean TDS, and electric current of the borehole and River water samples to the NESREA standards for drinking water.

The result in Figure 3 shows that the mean total dissolved solid and electric current, for the borehole and River water samples were below the NESREA permissible levels of 500 mg/L and 1000 µs/cm for total dissolved solid and electric current respectively. The mean total dissolved solid was 11.13mg/L, and 7.37mg/L for the borehole and River water samples respectively, while the mean electric current were 17.13 µs/cm and 11.33 µs/cm respectively.

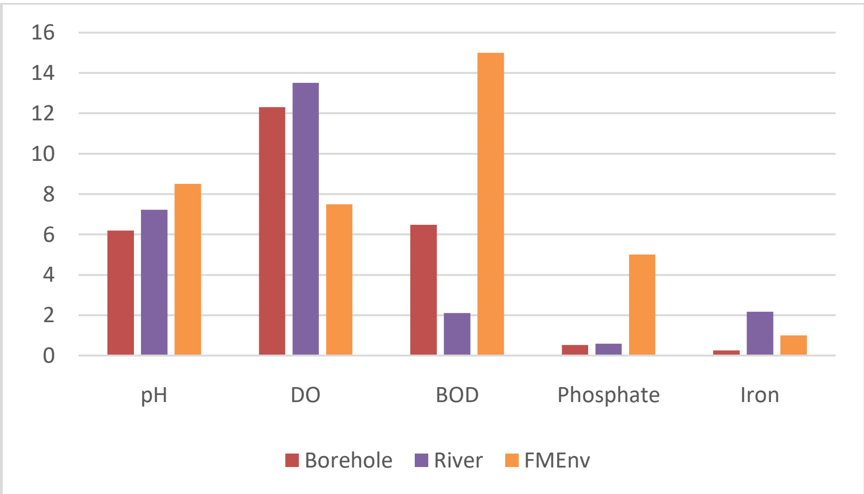

Figure 4: Graph comparing the mean temperature, pH, dissolved oxygen, biological oxygen demand, phosphate and iron content of the borehole and River water samples to the NESREA standards for drinking water.

Figure 4 compares some chemical properties, including temperature, pH, dissolved oxygen, biological oxygen demand, phosphate, and iron content, of the borehole and River water samples to the NESREA standards for drinking water. The mean pH values of the borehole and the River water were 6.19 and 7.23, respectively, and below the NESREA maximum permissible limit of 8.5. The NESREA standard for DO is set at > 7.5 mg/L, while the results show that the mean DO for the borehole and the River water samples were 12.31 mg/L and 13.52 mg/L respectively, and were greater than 7.5mg/L as set by NESREA standards. The mean BOD of the borehole and the River water samples were 6.84 mg/L, and 2.1 mg/L respectively, and were lower than the NESREA permissible limit of 15 mg/L. Mean phosphate contents were 0.52 mg/L and 0.58 mg/L, for the borehole and the River water sample respectively, and lower than the NESREA permissible limit of 5 mg/L. The mean iron content of the borehole water sample at 0.25 mg/L was lower than the NESREA permissible limit of 1.00mg/L, while that of the River water sample at 2.17 mg/L was higher than the NESREA permissible limit.

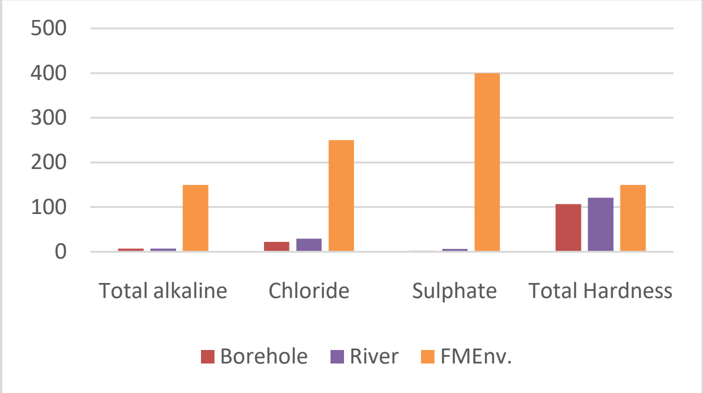

Figure 5: A plot comparing the mean total alkalinity, chloride, sulphate, and total hardness of the borehole and River water samples to the NESREA standards for drinking water.

The Figure 5 shows mean total alkaline contents of the borehole and Uramiriukwa River water samples were 7.38 mg/L and 7.5mg/L respectively, and were both below the NESREA permissible of 150mg/L. Also, the mean chloride, sulphate, and total hardness were 21.99mg/L and 29.66mg/L, 1.93mg/L and 6.45mg/L, 106.84mg/L, and 120.87mg/L for the borehole and the River water samples respectively, and were all below the NESREA permissible levels as shown in the Figure 5 above.

The biological properties of the boreholes and River water samples shows that the mean total bacteria counts were 6.975 x 10^3cfu/100ml, and 2.18 x 10^7 cfu/100ml respectively, much higher than the NESREA permissible limit of 0.30 cfu/100ml. Mean total coliform counts were 9.813 x 10^3 cfu/100ml, and 3.76 x 10^7cfu/100ml for the borehole and River water samples respectively, which were higher than the NESREA permissible limit of 0.10 cfu/100ml. Mean total klebsiella and *e. coli* were 1.7 x 10^7 cfu/100ml, and 2.5 x 10^3 respectively, for the borehole water samples, against the NESREA standard of 0 cfu/100ml for klebsiella and *e. coli*, while there was no detection of klebsiella and *e. coli* for the River water sample.

4.4. Water Quality Index of the two water sources in sub-urban area of Owerri

Table 4: Water quality index value for the borehole water sample

Parameters	NESREA STD (sn)	wn =k/sn	ideal value (vo)	mean conc. Value (vn)	vn/sn	vn/sn x 100=qn	WnQn
DO	7.5	0.078601	14.6	12.31	0.322	32.2	2.530949
pH	7.5	0.078601	7	6.19	1.62	162	12.73335
E.coli	0	0	0	25000	0	0	0
BOD	15	0.0393	0	6.48	0.432	43.2	1.69778
Temperature	30	0.01965	0	30.74	1.024667	102.4666667	2.013493
Phophate	5	0.117901	0	0.52	0.104	10.4	1.226174
Nitrate	50	0.01179	0	45.35	0.907	90.7	1.069365
TDS	500	0.001179	0	11.13	0.02226	2.226	0.002624
Turbidity	10	0.058951	0	4.9	0.49	49	2.888583
EC	1000	0.00059	0	17.13	0.01713	1.713	0.00101
Alkalinity	150	0.00393	0	7.38	0.0492	4.92	0.019336
Iron	1	0.589507	0	0.25	0.25	25	14.73767
				WQI	$= \sum qnWn / \sum wn$		**38.92**

K = 0.589507, $\sum \boldsymbol{wn} = \mathbf{1}$

The water quality index value of the mean borehole water samples parameter Table 4 was found to be 38.92, and in relative to the WQI rating in Table 4, the borehole water is rated "good" for drinking.

Table 5: Water quality index value of the Uramiriukwa River water sample

Parameters	NESREA STD (sn)	wn =k/sn	ideal value (vo)	mean conc. Value (vn)	vn/sn	vn/sn x 100=qn	WnQn
DO	7.5	0.078601	14.6	13.52	0.322	32.2	2.530949
pH	7.5	0.078601	7	7.23	1.62	162	12.73335
e.coli	0	0	0	0	0	0	0
BOD	15	0.0393	0	2.1	0.14	14	0.550206
Temperature	30	0.01965	0	26.25	0.875	87.5	1.719395
Phophate	5	0.117901	0	0.58	0.116	11.6	1.367656
Nitrate	50	0.01179	0	28.44	0.5688	56.88	0.670623
TDS	500	0.001179	0	7.37	0.01474	1.474	0.001738
Turbidity	10	0.058951	0	37.22	3.722	372.2	21.94144
EC	1000	0.00059	0	11.33	0.01133	1.133	0.000668
Alkalinity	150	0.00393	0	7.5	0.05	5	0.01965
Iron	1	0.589507	0	2.17	2.17	217	127.923
				WQI	$= \sum qnWn / \sum wn$		**169.46**

The water quality index value of the mean Uramiriukwa River water parameters was found to be 169.46, and in relative to the WQI rating in table 4.5 above, the borehole water is rated "unfit" for drinking.

5.0. DISCUSSION

The mean total suspended solids (TSS) in the water samples from the borehole and the River were 58.37±1.97 mg/L and 143.93±11.11 mg/L, respectively. Total suspended solids are particles smaller than 2 microns that do not dissolve in water and cannot be filtered out (Campbell, 2021). The water sample from the borehole has obviously less TSS than the water sample from the River, but neither water source met the NESREA threshold of 10.00 mg/L. It is general knowledge that ground water sources, such as boreholes, are devoid of pollutants, because of the fact that ground water travels through microscopic aquifers of soil particles and rocks (Famiglietti, 2014) aid in particle removal. According to Akhionbare (2015), long-distance soil filtration often eliminates practically all suspended particles, and reduces turbidity. On the other hand, surface water sources are exposed to pollution and anthropogenic activities, such as dredging, municipal waste disposal, industrial waste water, and urban runoff, to name a few, resulting in a high TSS concentration.

The mean temperature of the borehole water samples, 30.74 ^{o}C, was slightly higher than the NESREA standard of 30^{o}C, whereas the mean temperature of the River, 26.25 ^{o}C, was lower than the NESREA standard. Temperature has a significant impact on the physiochemical and biological qualities, as it affects the growth and proliferation of microorganisms as well as chemical reactions in water. Total suspended solids concentrations are frequently correlated with water turbidity (cloudiness). If TSS is high and the water is cloudy, sunlight will not transmit properly through the water, resulting in a decrease in temperature. Therefore, it would be accurate to assume that the high TSS and turbidity of the Uramiriukwa River are responsible for its lower temperature compared to the borehole water sample.

TDS is the combined concentration of dissolved organic and inorganic minerals in water and is a function of pH and temperature (Agbaire and Oyibo, 2009). According to the USGS (2018), temperature can impact the chemistry of water, as chemical reactions can speed up as the temperature rises and vice versa. This suggests that the rate of mineral dissolution in water will increase as water temperature rises. Additionally, pH is a significant component that influences TDS. Water with a low pH value dissolves more minerals than water with a high pH value (Goel, 2009). Agbaire and Oyibo (2009) explained further that ground water with a low pH and high temperature typically dissolves minerals in rocks, resulting in elevated TDS concentrations. This explains why the River water sample has a lower TDS concentration than the borehole water sample with greater temperature and pH.

Turbidity of the borehole water sample was 4.90±0.62 mg/L, which is lower than the NESREA permissible limit of 10mg/L, and therefore met the turbidity standard for drinking water. While the mean turbidity value of the Uramiriukwa River water sample was 37.22±8.3mg/L, and they did not pass for the NESREA standard, as it was above the permissible limit. Turbidity (cloudiness) of water values is often related to total suspended solids (TSS), such that the higher the TSS, the more turbid. This explains why the River water sample has higher turbidity than the borehole sample, given than the River has a TSS value of 143.93±11.11 mg/L, which is more than two times greater than that of the borehole water sample with TSS value of 58.37±1.97mg/L. The TSS contents also accounts for the appearance of the water samples. The appearance of the borehole water was clear because of lower TSS, and passed the NESREA standard for drinking water, while the River water sample was turbid and below the standard for drinking water. It is a common knowledge that high TSS results in murky water while low TSS increases water clarity.

The electrical conductivity of water is determined by the presence of salts, acids, and bases, known as electrolytes, which are capable of creating cations and anions. As conductivity is directly proportional to the amount of dissolved salts, its magnitude can provide a reasonable estimation of the concentration of dissolved solids. Accordingly, there was a higher record of electric current in the borehole water, as a result of its higher dissolved solids, while the electric current in the River water sample was lower, giving it a lower dissolved solid. The mean electric current values for the two water sources were 17.13±6.20 µs/cm, and 11.33±0.33 µs/cm for the borehole and River water samples, respectively, which are record low compared to the NESREA standard value of 1000 µs/cm for drinking water. Several studies including Bayode, Lurunfemi & Ojo (2012), who assessed the impact of some waste dumpsites on groundwater quality in some parts of Akure metropolis, also linked pollution from dumpsite leachate to high dissolved solids and electric current in groundwater. Similarly, Odukoya *et al* (2010) have linked industrial effluent discharge to increased dissolved solids and electric current in groundwater. Hence, the low dissolved solids and electric current in the water samples in this study, may be an indication of low contamination. The mean pH values for the borehole and Uramiriukwa River were 6.19 and 7.23, respectively, the borehole water was lower than the NESREA minimum permissible level of 6.5 while the mean pH value for the River was between the NESREA permissible range of 6.50-8.50. The mean pH value of the River water sample shows that the River is higher than the borehole and also alkaline, while that of the borehole is slightly acidic. This may be due to dredging activities and excavation of earth for coarse soil and River gravels for building construction purposes, going on around the River. When water comes into contact with the soil, there is a higher tendency for its pH to shift towards alkalinity by displacing the positively charged ions in the soil, replacing them with hydrogen ions. Studies show that this displacement is increased with coarse soil types and more resisted in percolated soil types due to the presence of a higher number of colloids. On the other hand, alkaline water has a higher buffering capacity and tends to resist any change in pH (Fernandez, 2018).

A study carried out in Omoku, a suburban area in River state of Nigeria, by Dirisu *et al.*, (2016), shows that the River had mean pH of 5.54+0.035, while borehole was 4.74+0.49. Compared with the result in this study, water samples from borehole and streams in Omoku have lower pH and are acidic, which may be as a result of acid rain from gas flaring. Kolo *et al.,* (2009) reported borehole water mean pH value of 6.296 and 6.143 respectively, in Polo and Bulumkutu suburban communities in Maiduguri State, Nigeria, which are similar to the result obtained in this study. Fagorite, Ahamefule & Onyekuru (2019) reported a maximum pH value of 6.5 at the downstream (Mberichi) of Otamiri River, in the same study area as the present study. The result shows that the pH value of Uramiriukwa River is higher than that of Otamiri River and therefore more alkaline.

The mean total alkalinity of the water sources in the present study were 7.38 and 7.50 for the borehole and River, respectively. The alkalinity of the River was slightly above that of the borehole; however, both were below the NESREA permissible level of 150 mg/L. The alkalinity of water is related to pH, such that the higher the alkalinity, the higher the pH and vice versa. As mentioned earlier, alkalinity is due to the presence of these forms of the carbonate anions (HCO_3^-), (CO_3^{2-}) and (OH^-) that act as buffer systems (Chris, 2012), neutralizing acids by accepting hydrogen ions (H^+) and preventing sudden changes in the acidity levels of water. Therefore, it can be inferred that the higher alkalinity of the River can be connected to the type of soil and the interaction of the soil and the River, due to excavation and dredging activities. Dissolved oxygen is a function of temperature and microbial activity in a water sample (Premlata, 2009). Dissolved oxygen is inversely proportional to temperature and bacterial activities, such that the higher the water temperature and bacterial activities, the lower the dissolved oxygen. Furthermore, with an increase in water temperatures towards the optimum temperature that supports the stability of microbial life, dissolved oxygen is expected to increase significantly (Krishnamurthy, 1990). The mean dissolved oxygen of the borehole and Uramiriukwa River water samples was 12.31 and 13.52 mg/L, respectively, and was > 7.50 as set by NESREA. The higher dissolved oxygen in the River water sample correlated with the lower temperature and bacterial activities, while the lower dissolved oxygen in the borehole water sample also correlated with the higher temperature and bacterial activities, as shown in Table 3.

BOD is a function of dissolved oxygen required for the biochemical decomposition of organic compounds and the oxidation of certain inorganic materials and can represent organic matter contamination in water. The BOD of the borehole and River water samples in the present study were 6.48 15mg/L and 2.10 15mg/L respectively. Although it is a common believe that ground water is often free from contamination, however leakage form septic tanks, and underground tanks, coupled with land use, municipal waste leachate can lead to significant contamination of ground water. This could explain the higher detected in the borehole. However, compared to the NESREA permissible limit of 15mg/L, it can be said that the two water sources in this present study, are safe for drinking, relative to their BOD contents.

Chemical oxygen demand (COD) is a function of the oxygen required for the oxidation of organic chemical materials, e.g. petroleum. It is a measure of wastewater and aqueous hazardous waste pollution in water. The values of COD in the two water samples were 384 mg/L and 320 mg/L for the borehole and Uramiriukwa River water samples, respectively. These values were very close to the NESREA permissible limit of 40 mg/L. The high level of COD in the water samples in the present study is an indication of significant contamination by organic chemical waste, which may be due to indiscriminate municipal or wastewater waste discharge in the River or waste dumping on land, in the case of the borehole. Ikem, Osibanjo, Sridhar & Sobande (2002) evaluated groundwater quality characteristics near two waste sites in Ibadan and Lagos and reported similar results for chemical oxygen demand. Results in the present study showed that nitrate values were 45 mg/L and 28.44 mg/L, respectively, and were below the NESREA standards of 50 mg/L. Although natural water free from significant contamination has a low nitrate content of about 5 mg/L, contamination from fertilizer leachate, septic tank leachate, unsewered sanitation, pit latrines, animal waste, or human waste can lead to increased nitrate levels in the water. Similar to the concentration of nitrate obtained in the present study, Akakuru *et al.* (2015) also reported nitrate concentration levels below the WHO (2006) recommended highest permissible limit in groundwater in Owerri, thus indicating good drinking water quality relative to nitrate content.

The chloride concentration of the borehole and River water samples were below the NESREA permissible levels. This also is an indication of good drinking water. However, the values were higher than the results obtained by Akakuru *et al.* (2015), provided an insight on some groundwater results in Owerri as Chloride concentration ranges from 0.04mg/l – 5.2 mg/l, and also, by the study of Fagorite *et al.* (2019) who reported 5.27mg/L as the highest concentration of chloride for Otamiri River , in suburban area of Owerri-west LGA, Imo state.

Hardness of water is an indication of mineral content. It is formed when water percolates through deposits of limestone, chalk or gypsum, which are largely made up of calcium and magnesium carbonates, bicarbonates and sulfates. According to WHO, hard water may have moderate health benefits, since it contains some dietary mineral like calcium and magnesium. In the present study, the hardness concentrations were, 106.84±6.96mg/L and 120.87±22.2, for borehole and the River water samples respectively, and were lower than the NESREA permissible limits, but much higher than that reported by Fagorite *et al*. (2019), for Otamiri River which is 13.20mg/L. Studies have shown that water hardness can be affected by seasonal variations, such that hardness increases in the dry seasons and decreases in the rainy seasons as a result of dilution and runoff. Nwafor *et al*. (2013) analyzed the seasonal influence on the physico-chemical concentrations in hand dug wells in Akure town, and reported higher concentrations of hardness in dry season. The total hardness difference reported in the present study and Fagorite *et al*. (2019), may be due to seasonal variation in the time of study. The sulfate concentrations of the water sources were 1.920.89 mg/L and 6.45 mg/L for the borehole and River, respectively, and were much lower than the NESREA permissible limits of 200–400 mg/L. Fagorite *et al*. (2019) reported a sulphate concentration of 4.83 mg/L for the Otamiri River, which is below the result reported in the present study. The hardness of water is an indication of mineral content. It is formed when water percolates through deposits of limestone, chalk, or gypsum, which are largely made up of calcium and magnesium carbonates, bicarbonates, and sulfates. According to the WHO, hard water may have moderate health benefits since it contains some dietary minerals like calcium and magnesium. In the present study, the hardness concentrations were, 106.84 ± 6.96 mg/L and 120.87±22.2, for borehole and River water samples, and were lower than the NESREA permissible limits, but much higher than that reported by Fagorite *et al*. 2019, for the Otamiri River which is 13.20mg/L. Studies have shown that water hardness can be affected by seasonal variations, such that hardness increases in the dry seasons and decreases in the rainy seasons as a result of dilution and runoff. Nwafor *et al*. (2013) analyzed the seasonal influence on the physico-chemical concentrations in hand dug wells in Akure town, and reported higher concentrations of hardness in dry season. The total hardness difference reported in the present study and Fagorite *et al*. (2019), may be due to seasonal variation in the time of study. The sulfate concentrations of the water sources were 1.920.89 mg/L and 6.45 mg/L for the borehole and River, respectively, and were much lower than the NESREA permissible limits of 200–400 mg/L. Fagorite *et al*. (2019) reported a sulphate concentration of 4.83 mg/L for the Otamiri River , which is below the result reported in the present study.

The iron content of the borehole water sample was 0.25±0.04mg/L and was found to be below the NESREA permissible limit of 1mg/L. While that of the River was higher, with concentration of 2.17±0.10mg/L. The highest value report by Fagorite *et al*. 2019, for Otamiri was 0.23mg/L, which is similar to the iron content levels of borehole in the present study.

Studies show that optimum temperature for klebsiella and *e. coli* is 37 ºC, and this implies that on one hand, temperature much higher or lower than 37 ºC, may negatively affect their activities, and on the other hand, temperature near 37ºC improve their activities. This correlates with the facts that klebsiella and *e. coli* were detected in the borehole water sample which has a temperature near 30.74ºC while the organisms were not detected in the River water sample with much lower temperature of 26.25ºC. The levels of klebsiella and *e. coli* present in the borehole water were 1.7 x 10^7cfu and 2.5 x 10^3 cfu respectively, which is an indication of serious contamination compared to the NESREA standard of 0. klebsiella and *e. coli* are serious pathogenic bacteria and are subgroup of faecal coliforms. Although most *e. col*i is harmless, some cause diseases. The presence of *these bacteria* in a drinking water sample almost always indicates recent fecal contamination, meaning there is a greater risk that pathogens are present (WSDH, 2021).

The two water sources had a high coliform and bacteria counts compared to the NESREA standards. However, the borehole water had higher total coliform and total bacteria counts compared to the River water sample, which could be due to the fact that the borehole water has temperature value suitable for proliferation of bacteria, also considering the possible of fecal contamination through leachate from underground septic tanks located around the two of the borehole points. Notwithstanding the difference in the coliform and bacteria population in the borehole, and River the two water sources had high coliform and bacteria counts compared to the NESREA standards.

However, the borehole water had higher total coliform and total bacteria counts compared to the River water sample, which could be due to the fact that the borehole water has a temperature value suitable for the proliferation of bacteria, as well as the possibility of fecal contamination through leachate from underground septic tanks located around the two borehole points.

Although coliform bacteria are not normally causes of serious illness, they are easy to culture, and their presence is used to infer that other pathogenic organisms of fecal origin may be present in a sample, or that said sample is not safe to consume (Liu *et al*., 2019). Notwithstanding the difference in the coliform and bacteria populations in the borehole and River water samples, both water sources could be considered heavily polluted by microbes of fecal origin and thus, may pose danger to human health.

Furthermore, the T-test result showed that there is a significant difference in the mean physiochemical and biological properties of the borehole water sample and the Uramiriukwa water sample. The result of the water quality index test (Table 4 and Table 5) showed WQI vales of 38.92 and 169.46 for the borehole and River water samples respectively, which indicates that while the borehole water samples are good for drinking, the Uramiriukwa River water samples are unfit. The WQI result of the Uramiriukwa River water samples maybe due to its physical properties, in respects its high contents of suspended solids, which resulted in turbidity and high colour value, which are very important factors to consider for drinking water.

6.0. CONCLUSION

Findings from the physiochemical properties of Uramiriukwa River and boreholes in the suburban area of Owerri, including Owerri. Agbala precisely, shows that the river is polluted with solid and chemical wastes as a result of anthropogenic activities, including dredging, industrial activities, laundry, and indiscriminate municipal waste disposal, as observed during field study. The presence of high level of coliform in the borehole and river water samples is an indication of fecal contamination, which is an indication of possible health risk.

In conclusion, given the result of the physiochemical and biological properties of the two major sources of water for drinking and domestic use, are below the NESREA standards. However, result showed that the borehole water was good for drinking, while the Urumiriukwa River is unfit for drinking.

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