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Water Quality Index classification of ground water samples collected from Opete, community, Delta State, Southern Nigeria

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Abstract
The overall quality of groundwater samples collected from different sampling points in Opete Community, Delta State was evaluated using Water Quality Index (WQI) assessment. Ten ground water samples abstracted in duplicates were obtained from 10 sampling points in various areas within Opete. Selected physico-chemical evaluation of the water samples was conducted using standard techniques. The parameters were; Electrical conductivity (EC), pH, dissolved oxygen (DO), total hardness, total alkalinity, total dissolved solids (TDS), magnesium and calcium. All the water samples were acidic as the pH values ranged from 3.20 to 6.00. The mean TDS readings varied from 9.80 mg/L to 134.50 mg/L. The water quality index values obtained ranged from 34.506 to 69.44. The WQI classification of water samples collected from sampling point (SP) 3 and 10 was bad while samples sourced from SP 2,4,5,6,7,8 and 9 were of medium quality. Although the results indicated the unsuitability of the sampled ground water for direct anthropogenic consumption, the water is suitable for conducting domestic chores such as sanitation activities.

Keywords: Groundwater, Opete, Physico-chemical parameters, Water quality index.

INTRODUCTION
Nigeria is very rich in water resources. The country is estimated to contain about 215 km^3 annually of available surface water and an estimated total groundwater resource potential of 155.8 billion km^3 annually (BGS, 2021). When compared with data from other African countries particularly those located in the northern and southern parts of the continent, this quantity is significantly higher. An example that is illustrative of this disparity is South Africa, which has only approximately 49 km^3 each year (Idu, 2015). Water is an essential compound

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for life at all levels and various environmental processes. It possesses unique properties which differentiate it from most substances in nature (Divya and Mahadeva, 2013). There are several sources of water in the environment. They include precipitation, rivers, lakes, glaciers and groundwater (Khublaryan, 2002; FAO, 2005).

It has been recommended that the minimum water consumption per person per day should be 27 litres. However, on a global scale, most people are not able to meet this recommendation (Minh *et al.,* 2011). The increase in population and rising demand for food along with environmental pollution and other problems such as drought and desertification has led to an increased dependence on groundwater (Rodak *et al.,* 2011). The likelihood of groundwater drying up in natural conditions is low and it is a water source for irrigation, livestock and domestic uses (Calow *et al.*, 2011). Groundwater is known to be vulnerable to pollution due to permeability of overlying soil layers and sources of pollution being numerous (Singh *et al.,* 2012). Contamination of ground water is occasioned by human activities which include haphazard waste disposal, poor agricultural practices, septic tank constructions and those of pit latrines and graves close to boreholes (Lu, 2004; Kelly *et al*, 2011). The rate of groundwater contamination from these sources is governed by several factors including the characteristics of leachates, hydrogeological conditions and the physicochemical properties of the soil (Al-Muhisen *et al.,* 2019; Zeng *et al.,* 2021).

Water quality has been defined as the measure of the condition of water in relation to the requirements which water must satisfy for living organisms, human needs or other uses (Tyagi *et al.,* 2013; Sutadian *et al.,* 2016). Standards which are used to assess water quality often encompass ecosystem health, safe human contact and safety of drinking water (Divya and Mahadeva, 2013). The Water Quality Index (WQI) is a type of average that is calculated by relating a set of variables to a common scale and merging them into a single value. WQI is a univariate expression that combines several sub-indices of components (quality variables) to summarize data (Adelagun *et al.,* 2021). The group should include the most important parameters from the dataset so that the index may accurately depict the overall position and reflect change (Darapu *et al.,* 2005). Several water quality indices exist which have been used to present data relating to water quality in a format which is easy to express and comprehend. Some of these indices include; the National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment (CCME) Water Quality Index, Oregon Water Quality Index (OWQI) and Weighted Arithmetic Water Quality Index (Tyagi *et al.,* 2013; Sutadian *et al.,* 2016).

In Nigeria, a major factor which is contributing to water scarcity is environmental pollution. The dumping of waste into water bodies such as rivers and streams is a common occurrence in Nigeria (Backhaus *et al.,* 2019). In urban areas, water resources are contaminated by pollutants which are carried by storm water, and seepage of waste components from solid waste dump sites can also contaminate groundwater sources. The occurrence of certain water borne diseases in Nigeria has been linked to the consumption of untreated contaminated water; examples include; dysentery, diarrhoea and typhoid fever (Odume and Slaughter, 2017). These diseases are characterized by high mortality rates and impose varying economic costs (Etim *et al*, 2013). Within Opete in Warri, Delta State, there is physical evidence of open waste dumps and direct disposal of waste into the surrounding water bodies.

Opete is one of the major Uheredjo Sub-clans located in Udu Local Government Area of Delta State, Southern region of Nigeria approximately between 5° 45′ 0″ N and 5° 43′ 0″ E (Figure 1). Opete is located within the Urhobo speaking area of Delta State, and the town has its traditional ruler known as Ovie. The land features several rivers which flow across it and is in a tropical environment with evergreen vegetation and plantations. There are numerous, inter-connected flowing surface water sources. As a result of urbanization, Opete is now regarded as a suburb of the continually expanding municipality of Warri and is also linked by two bridges to both Enerhen and Effurun areas.

This study is aimed at assessing the quality of water from groundwater sources in Opete Community, Delta State. Some studies have examined the WQI of different ground water samples in different sections of Warri metropolis (Ezenwaji and Ezenweani, 2018; Asibor and Ofuya, 2019). However, the absence of centralised piped water system in Warri and other urbanized areas in Delta State, and the complete reliance by residents on both bottled and satchet water as drinking water source which is basically commercialized treated ground water is a trend that would justify the need for more studies on the overall quality of abstracted groundwater in Warri metropolis and other urbanized areas of Delta State, Southern Nigeria.

MATERIALS AND METHODS

Sample Collection

Duplicate groundwater samples were collected from ten (10) sampling points in Opete Community, Delta State. The sampling locations were: EarthQuest Old BH (Station 1), EarthQuest New BH (Station 2); House close to EarthQuest BH (Station 3), Small house zinc BH (Station 4), Opeans Training Centre BH (Station 5), Asjam Hotel BH (Station 6), Beside Daysprings BH (Station 7), Inside Opete BH (Station 8), House opposite Plantation City BH (Station 9) and Gas Plant opposite Plantation City BH (Station 10). The samples were collected using sterile 1 liter plastic containers and sampling was conducted in February, 2022.

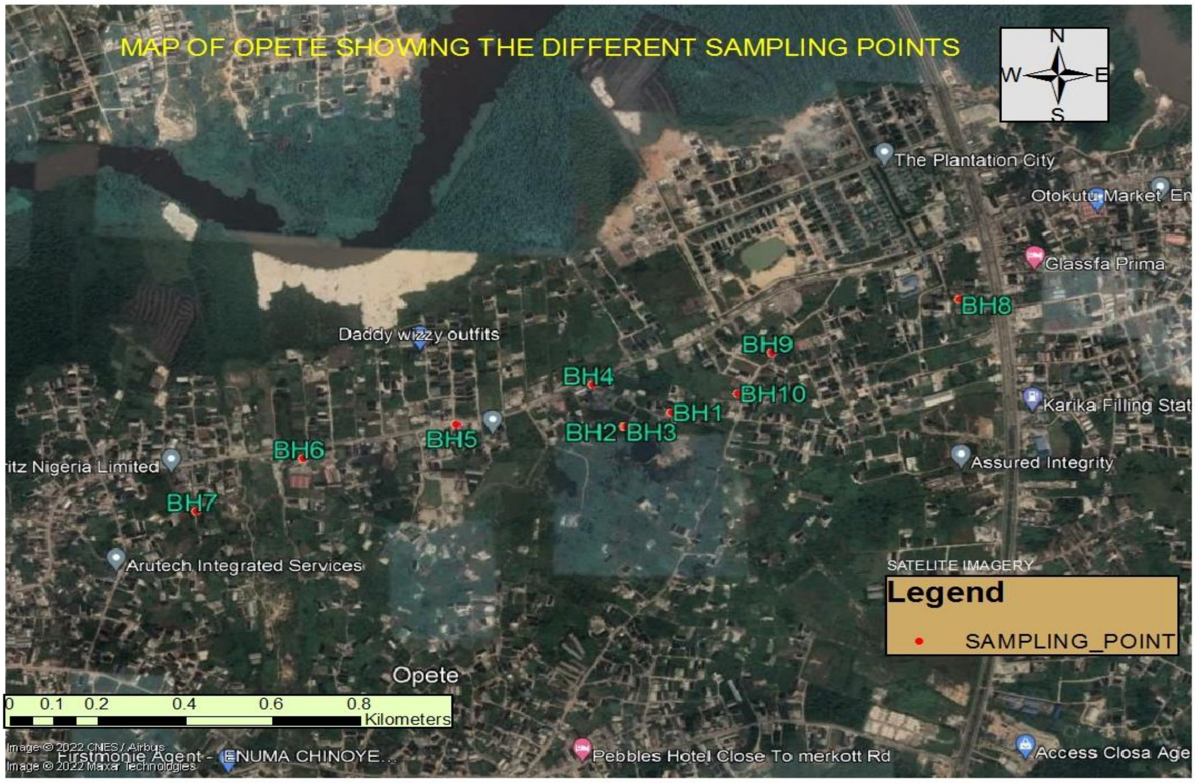

Figure 1: Map of Opete community (study area) showing the different sampling points

Physico-chemical analysis
The pH, TDS, EC and DO values of the collected water samples were derived with the aid of appropriate meters. Prior to usage, the electrode of the pH meter was calibrated using freshly prepared buffer solutions; 4.01, 7.0 and 10.2. The electrode of the EC meter was calibrated using the 1413uS/cm, conductivity standard. The hardness, calcium and magnesium parameters were determined using titrimetric methods as described by APHA (1999). The alkalinity value of the respective samples was evaluated using titrimetric procedure as described by Radojevic and Bashkin (1999).

Determination of WQI values
The water quality index of the samples was calculated using average values of the eight physicochemical parameters. The parameters were; pH, electrical conductivity (EC), total alkalinity, total dissolved solids (TDS), dissolved oxygen (DO), total hardness, calcium ions and magnesium ions (Kumar and Dua, 2009).

Weightage
Information on the weightage of each factor used in the WQI calculation is necessary. Weightage is inversely proportional to the permissible limits of the factors.
Therefore,
$W_i = \frac{k}{V_i}$………………equ. 1
Where, k = proportionality constant, W_i = unit weight of the factor and V_i = maximum permissible limit as recommended by Indian Council of Medical Research/Public Health Environmental Engineering Organization. The value of k (proportionality constant) was calculated as follows:
$k = \frac{1}{\sum_{1=1}^{8} \frac{1}{Vi}}$…………equ. 2
Where,
$\sum_{1=1}^{8} \frac{1}{Vi} = \frac{1}{Vi(pH)} + \frac{1}{Vi(TDS)} + \frac{1}{Vi(Hardness)} + \frac{1}{Vi(Ca)} + \frac{1}{Vi(Mg)} + \frac{1}{Vi(DO)} + \frac{1}{Vi(Alkalinity)} +$
$\frac{1}{Vi(EC)}$………………..equ. 3

Rating Scale
For each of the parameters, a rating scale was prepared. This rating system ranged from 0 to 100 and was divided into five intervals. When the rating was $V_r = 0$, the value of the water quality parameter exceeded the standard maximum permissible limit and indicated severe pollution levels. However, when $V_r = 100$, it indicated that the water quality parameter had the most desirable value. Other parameter ratings fell within the other categories which were; $V_r = 40$, $V_r = 60$ and $V_r = 80$. These values indicated excessively polluted, moderately polluted and slightly less polluted, respectively (Kumar and Dua, 2009).

Water Quality Index Calculation
The numeric values of each parameter were multiplied by the weighting factor which relates to the importance of the test to water quality. The values which result are then summed up to derive the overall water quality index value.
$WQI = Wi \times V_r = Wi_{(pH)} \times Vr_{(pH)} + Wi_{(TDS)} \times Vr_{(TDS)} + Wi_{(Hardness)} \times Vr_{(Hardness)} + Wi_{(Ca)} \times Vr_{(Ca)} + Wi_{(Mg)} \times Vr_{(Mg)} + Wi_{(Total\ Alkalinity)} \times Vr_{(Total\ Alkalinity)} + Wi_{(DO)} \times Vr_{(DO)} + Wi_{(EC)} + Vr_{(EC)}$
The multiplication of Wi and Vr gave the water quality index value for the respective sample (Kumar and Dua, 2009). All calculations for the determination of the water quality index values were conducted using MS Excel version 2016.

RESULTS AND DISCUSSION

The mean summary of the physico-chemical data obtained for the water samples is shown in Table 1. With the exception of pH and some of the DO concentrations, all the mean physico-chemical data recorded for the water samples collected from the respective sampling points were far below the permissible limits indicated by SON. All the water samples were acidic as the pH values ranged from 3.20 in station 9 to 6.00 in station 1. These values were below the Standards Organisation of Nigeria (SON) permissible limits for water quality. The low pH values obtained in this study can be attributed to the infiltration of acidic rainwater. This observation was further buttressed by Nwaugo *et al.* (2006) who reported that acid rain attributed to gas flaring, acidified soil and groundwater. Acid rain in the area is due to crude oil and natural gas exploration and production operations taking place in the nearby town of Otor-Udu (Amaize and Onuegbu, 2018).

Another factor which may contribute to the low pH of groundwater in the Opete community and the surrounding environment is the intense level of agricultural activity conducted in the area (USEPA, 2021), as inhabitants of Opete engage in the production of rubber, palm products, cassava, maize, fruits and vegetables. The acidic nature of the investigated water samples was in agreement with results reported by Onwughara *et al.* (2013) with regards to ground water samples sourced from 12 communities in Umuahia, North Local Government Area, Abia State. However, the pH range recorded for this study contrasted with results reported by Ekundayo *et al.* (2016) which indicated higher pH values with respect to sampled stored ground water samples from residential hostels located within the Ekehaun campus of the University of Benin, Benin City, Edo State, Southern Nigeria.

The maximum and minimum EC values recorded for the respective water samples were 58.00 µS/cm for samples collected from station 4 and 268.00 µS/cm for samples collected from station 1. This EC range was similar to a range of EC values reported by Oyelami *et al.* (2013) with respect to groundwater samples collected from Aduramigba Estate, Osogbo city, Osun state, South western Nigeria. The variations observed for the mean EC readings could be attributed to the varying ion content of the respective water samples.

The mean TDS readings ranged from 9.80 mg/L for samples collected from station 2 to 134.50 mg/L for samples collected from station 1. All the TDS readings were far below the SON permissible limits for drinking water and the low mean TDS could be reflective of the low dissolved mineral content of the water samples. Alkalinity is the ability of water to neutralise acids. Its values were below detectable limits in the samples from stations, 6, 9 and 10, and had a maximum value of 28.80mg/L in station 1.

Dissolved oxygen concentrations ranged from 3.10 mg/L for water samples collected from station 3 to 7.10 mg/L for water samples collected from station 9. Aside from mean DO values recorded for samples collected from stations 1, 2, 4,5,6 and 9, the other samples had mean DO values which fell below the permissible limit stipulated by SON (2007) for this parameter. As groundwater is naturally sequestered underneath the soil, the presence of oxygen in the samples can be directly attributed to pumping and movement of the water from the aquifer and the air inflow into the storage tanks and the connecting pipes.

Mean total hardness values ranged from 5.00mg/L for water samples collected from station 3 to 72.30mg/L for samples collected from station 1. The concentration of calcium in the samples ranged from 2.369 mg/L for samples collected at station 6 to 14.82 mg/L for samples collected at station 8. The mean magnesium values varied from 4.47 mg/L for samples obtained from station 2 to 23.33 mg/L for samples sourced from station 8. The mean magnesium, calcium and hardness content for the examined water samples were far below the SON permissible limits and the variations in these parameters could be attributed to the chemical composition of both underlain rock layers associated with the aquifer and the soil layer. It has been had observed that there was a direct relationship between the concentration of mineral salts such as; $MgSO_4$ and $CaCO_3$, present in surrounding rocks, soils and the hardness profile of groundwater (Bwadi *et al.*, 2021). The range of mean hardness values recorded for the examined water samples collected from the sampling points in Opete contrasted with previous data reported by Bwadi *et al.* (2021) with respect to ground water samples obtained from several residential homes in Jalingo municipality, Taraba state, North central Nigeria.

Table 1: Mean physicochemical characteristics of the groundwater samples

Station	Parameters							
	pH	EC (μS/cm)	TDS (mg/l)	Hardness (mg/l)	Alkalinity (mg/l)	DO (mg/l)	Calcium (mg/l)	Magnesium (mg/l)
1	6.00	268.00	134.50	72.30	28.80	5.60	9.369	13.63
2	5.50	20.00	9.80	18.80	9.90	6.20	2.517	4.47
3	4.70	96.00	48.70	5.00	5.00	3.10	11.361	10.46
4	4.60	58.00	29.30	8.50	4.00	6.10	5.506	8.63
5	4.30	84.00	43.80	6.90	4.90	6.10	2.438	5.73
6	3.20	82.00	41.20	26.90	0.01	6.30	2.369	4.52
7	5.20	70.00	34.60	14.20	10.80	6.40	9.249	6.35
8	4.50	154.00	78.20	51.50	3.80	6.60	14.820	23.33
9	3.20	62.00	30.50	16.90	0.02	7.10	5.003	8.87
10	3.60	58.00	29.60	13.80	0.03	4.80	3.072	5.99
SON limits*	6.5 - 8.5	1000	500	150	150	5	75	50

KEY: [a] SON (2007)

The Standards Organisation of Nigeria (SON) water quality standards and unit weights used in the determination of water quality index of the samples are shown in Table 2. For the WQI determination, parameters which are needed in little quantities carried more unit weights. This is due to the inverse relationship which is known to exist between the water quality standard and the unit weights. Excessive and severe categories of pollution are indicated when DO concentrations are low.

Table 2: Water quality standards and index in the study area

Parameter	SON Standards	Unit Weight
pH	7.0 - 8.5	0.322
DO	> 5	0.548
EC	< 1000	0.0027
TDS	< 500	0.003
Alkalinity	< 150	0.02
TH	< 150	0.0287
Ca	< 75	0.037
Mg	< 50	0.055

The results obtained for water quality rating for each of the parameters used in the determination of water quality index revealed that, the WQI value was highly dependent on the dissolved oxygen content of water. High values for dissolved oxygen depicts clean waters. This inference is in agreement with a study conducted by Kumar and Dua (2009).
The calculated water quality index values for each of the sampling locations is presented in Table 3.

Table 3: Water Quality Index (WQI) for each sample

Station	Water Quality Index (WQI)
1	57.218
2	54.41
3	34.506
4	67.44
5	67.386
6	69.386
7	67.64
8	66.232
9	69.44
10	47.52

The water quality index value obtained from the study was interpreted using the rating scale shown in table 4. This showed that water samples collected from stations 3 and 10 were of bad quality while those collected from the other eight (8) sampling stations were of medium quality.

Table 4: WQI rating scale

WQI Value	Quality of Water
90 – 100	Excellent
70 – 90	Good
50 – 70	Medium
25 – 50	Bad
0 – 25	Very Bad

The bad and medium quality ratings of the water samples might be indicative of the magnitude of contamination; the ground water was exposed to either underground or during pumping with the pumping machine. The sanitary conditions of the piping network used to evacuate the water from the underground aquifer might also have an influence on the overall water quality ratings of the samples. The primary cause of the low WQI value was the acidic pH values of the samples.

The results indicated the unsuitability of the pumped ground water for direct anthropogenic consumption. This trend would infer the need for usage of treatment approaches such as boiling or addition of flocculants such as alum which would improve the overall quality of the water if it is intended for drinking. However, the water is suitable for conducting domestic chores such as sanitation and cooking activities.

CONCLUSION

Application of the water quality index method is a viable method for easy and understandable presentation of water quality data. WQI assessment serves its function as a tool for communicating information on water quality to the general public and policy makers. The assessed water quality indices of groundwater samples revealed that water from these sources need to be treated prior to domestic usage particularly drinking. It is recommended that biological assessment of the water samples (coliform and heterotrophic bacterial counts) and trace metal analysis should be conducted.

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