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Assessment of the Water Quality Index of Otamiri and Oramiriukwa Rivers

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Abstract: Problem statement: The impact of anthropogenic activities on Otamiri and Oramiriukwa Rivers as a result of the increasing rate of urbanization in Owerri, Nigeria is of a great concern due to the fact that water from these rivers is the source of water distributed for public use. These rivers are of particular importance in the study of surface water pollution because effluents from industries, municipal waste, agricultural and urban run-off are discharged into it thereby deteriorating the quality. **Approach:** This study used the application of Water Quality Index (WQI) in evaluating the quality of Otamiri and Oramiriukwa Rivers for public usage. This was done by subjecting the 180 samples collected to comprehensive physicochemical and bacteriological analysis using APHA standard methods of analysis. **Results:** The overall WQI for the samples was 174.49. The high concentration of conductivity, color, total solids, turbidity, total coliform, iron, manganese, COD, BOD and nitrate were responsible for the high value of WQI which may be attributed to the anthropogenic interference along the river bank. The results of the analysis when compared with the Nigerian Standard for Drinking Water Quality (NSDWQ) permissible limit showed that the rivers were polluted and that the water is not safe for domestic use and would need treatment. **Conclusion:** The use of WQI in elucidating surface water quality evaluation and management has been demonstrated by this study. WQI is also valuable tool in categorizing the pollution sources of surface waters.

Key words: Otamiri and Oramiriukwa rivers, water quality index, Global Positioning System (GPS), Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Solids (TS), anthropogenic activities

INTRODUCTION

River water quality monitoring is necessary in present day society, especially for rivers affected by urban effluents. Studies on water quality in the aquatic environment are still popular in the evaluation and management of rivers ecosystems in many countries (Watts and Smith, 1994; Njenga, 2004; Campbell, 1994). This is due to the changes in water chemistry of river and drainages can be the results of domestic, industrial or agricultural discharges which may in turn lead to aquatic ecosystem degradation (Pereira *et al*., 2007) such as deterioration of water quality in the rivers and drainages. Therefore, the determination of physico-chemical and bacteriological parameters of the water samples can act as indicators of water pollution due to both natural and anthropogenic inputs (Amadi *et al*., 2010, Yisa and Jimoh, 2010). According to Tahri *et al*., (2005), the importance of the provision of potable water supply in any nation cannot be over emphasized. With increasing population, wealth and economic activities generally, there is a corresponding increase in the demand for water supply globally (Lakhan *et al*., 2003).

In the last few decades, there has a tremendous increase in the demand for water due to rapid growth of population and the accelerated pace of industrialization (Ramakrishnaiah *et al*., 2009). Human health is threatened by most of the agricultural development activities particularly in relation to excessive application of fertilizers and unsanitary conditions. In most towns in Nigeria with rivers passing through them, such rivers have been converted into dump sites or latrines, with the consequence adverse effects on the health of the downstream users. Most houses, public offices, schools does not have latrines causing individuals to excrete anyhow in the bushes, rivers and open spaces is a pointer to the fact the Nigerian environment has been deteriorated. This is in addition to the poor sanitation culture exhibited by Nigerian populace. In addition, once the surface water is contaminated, its quality cannot be restored by stopping the pollutants from the source (Ramakrishnaiah *et al*.,

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2009). It therefore becomes imperative to regularly monitor the quality of the water and to device ways and means to protect it.

The quality of both Otamiri and Oramiriukwa Rivers are been studied because they are the source of water for domestic, industrial and agricultural purposes in Owerri region. In the course of the sampling exercise, it was discovered that the banks of these rivers now serves as dump sites and also effluents from cottage industries, municipal sewage, agricultural and urban run-off are discharged into the river bringing about considerable change in their quality. These anthropogenic activities on these rivers pose a serious threat not only to organisms in the river but also the downstream water users. Otamiri and Oramiriukwa Rivers are studied together because they have a common source upstream and flows differently downstream.

Water Quality Index (WQI) is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. It thus, becomes an important parameter for the assessment and management of surface water. WQI is a scale used to estimate an overall quality of water based on the values of the water quality parameters. It is a rating reflecting the composite influence of different water quality parameters. WQI is calculated from the point view of the suitability of surface water for human consumption.

The objectives of the present research is to provide information on the physico-chemical and bacteriological characteristics of Otamiri and Oramiriukwa Rivers in order to appreciate the impact of unregulated waste discharge on the quality of these rivers as well as to discuss its suitability for human consumption based on the computed water quality index values.

MATERIALS AND METHODS

Study area description: Owerri lies between latitudes 5°15-5°35'N of the equator and longitudes 6°55-7°15'E of the Greenwich Meridian. It is a low lying terrain with a good road network (Fig. 1). The prevalent climatic condition in the area is marked by two main regimes: the rainy and the dry seasons. The rainy (wet) season is from April to October while the dry season starts in November to March. The average monthly temperatures are high throughout the year. A mean annual temperature of 32°C is typical of the area (Adeleye, 1974). The area lies within the tropical rain forest belt of Nigeria. The town is drained by Oramiriukwa River (Fig. 1). Agriculture is the main employer of labor, which engages about 75% of the workforce. The major industries are that of cottage, sand quarrying and shoe making.

Geology and hydrogeology of the area: The area is within the Benin Formation belonging the Eocene age (Fig. 2). The Benin Formation is composed mainly of fresh water-bearing continental sands and gravels with clay and shale intercalations. The environment of deposition is partly lagoonal and fluvio-lacustrine/deltaic (Reyment, 1965). The formation which dips south westward starts as a thin edge layer at its contact with the Ogwashi-Asaba Formation in the northern part of the areaand thickens southwards to about 100 m in Owerri area. The sandy unit which constitutes about 95% of the rock in the area is composed of over 96% of quartz.

Water sampling: Ten sampling stations were established along each of the river course in order to give a comprehensive idea of the overall quality of the rivers and were monitored for a period of one year and six months (18 months) by taking the sample once in every month. Water samples were collected from the surface of the river. Global Positioning System (GPS) was used to geo-reference the sampling stations and the coordinates obtained were used to generate the contour map (Fig. 3) and the terrain model (Fig. 4) of the area.

Laboratory analysis: Collected water samples were subjected to filtration prior to chemical and bacteriological analysis while the physical parameters were determined in-situ. The other parameters were analyzed in the laboratory using Eaton *et al*. (1995) standard procedures for analyzing: Total Dissolved Solids (TDS), total solids, total coliform, iron, manganese, zinc, chloride, sulphate, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), nitrate, calcium, magnesium and sodium.

Statistical analysis: The statistical analysis was done for principal component analysis using SPSS 16.0. Water quality index was calculated from the point view of suitability of the water for human consumption as discussed below.

Calculation of WQI: The Water Quality Index (WQI) was calculated using the Weighted Arithmetic Index method. The quality rating scale for each parameter q_i was calculated by using this expression:

$$q_i = (C_i / S_i) \times 100$$

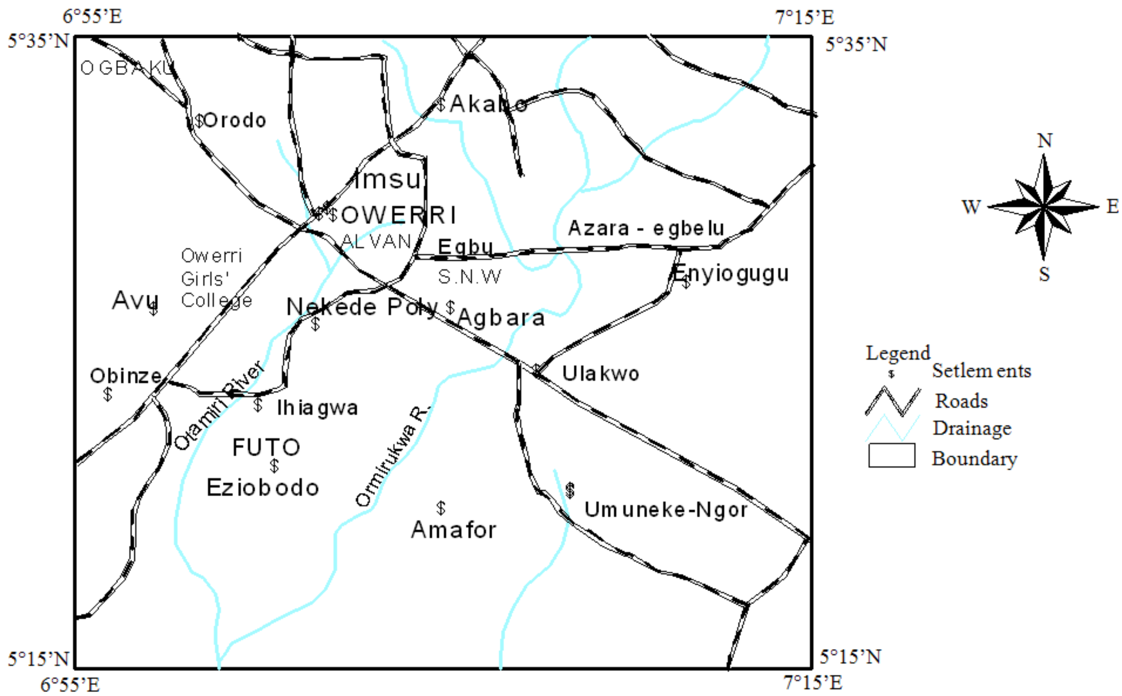

Fig. 1: Map of the study area showing the road network and major rivers

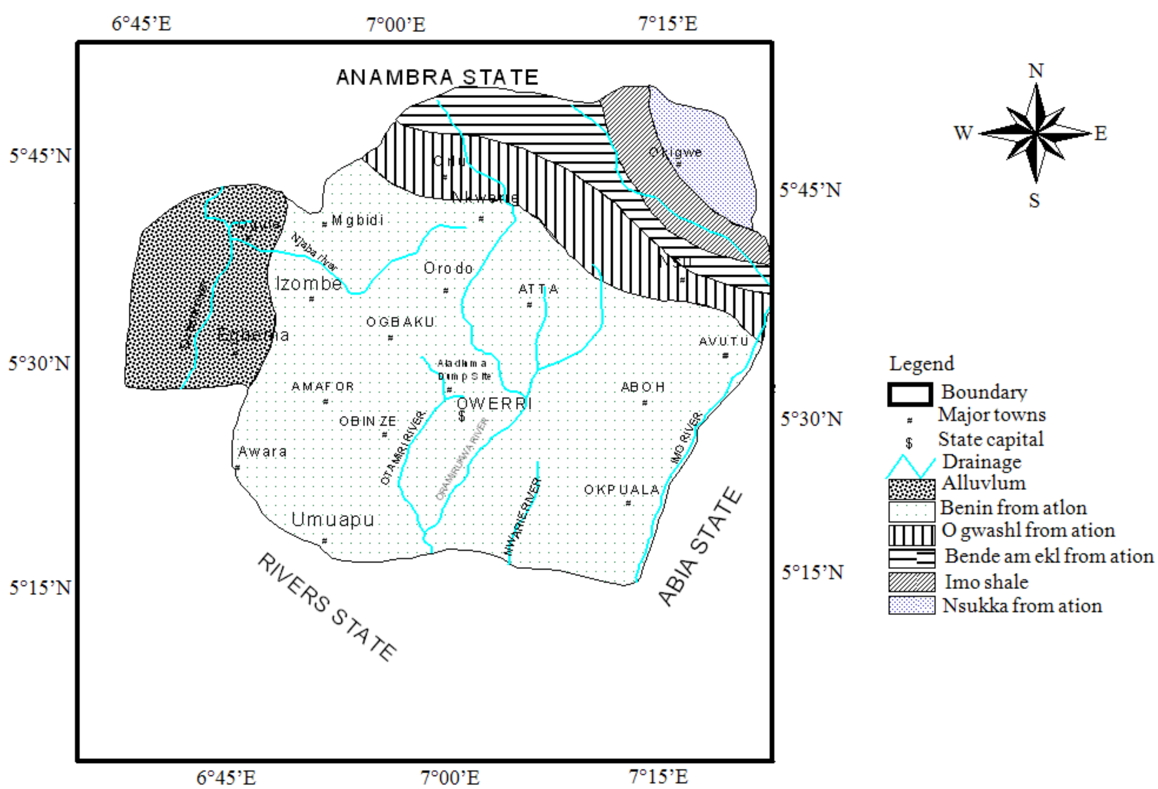

Fig. 2: Geological Map of Imo State showing the study area

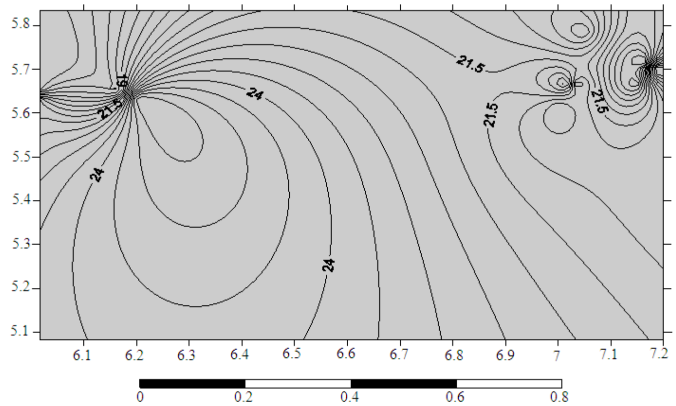

Fig. 3: Contour Map of the area

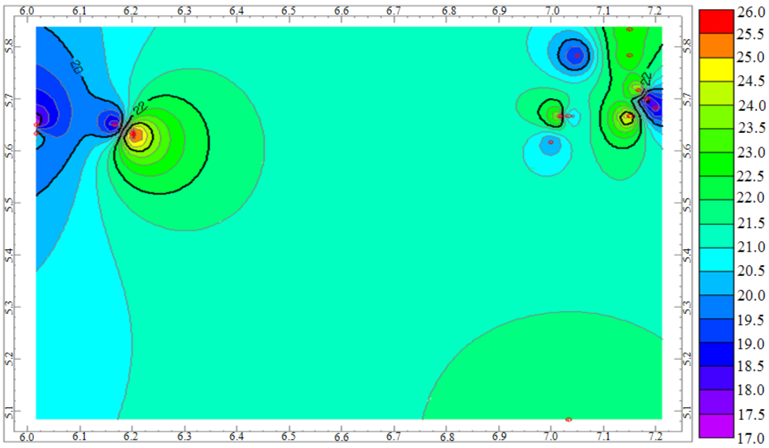

Fig. 4: Digital Terrain model for the area

A Quality rating scale (q_i) for each parameter is assigned by dividing its Concentration (C_i) in each water sample by its respective Standard (S_i) and the result multiplied by 100 Relative Weight (W_i) was calculated by a value inversely proportional to the recommended Standard (S_i) of the corresponding parameter:

$$W_i = 1/S_i$$

The overall Water Quality Index (WQI) was calculated by aggregating the Quality rating (Q_i) with unit weight (W_i) linearly:

$$WQI = \left(\sum_{n=1}^{i=n} q_i w_i\right)$$

Where:

Q_i = The quality of the i^{th} parameter

w_i = The unit weight of the i^{th} parameter

n = The number of the parameter considered

Generally, WQI were discussed for a specific and intended use of water. In this study the WQI for drinking purposes is considered and permissible WQI for the drinking water is taken as 100:

$$\text{Overall WQI} = \frac{\Sigma qiwi}{\Sigma wi}$$

RESULTS AND DISCUSSION

The statistical summary of the analyzed parameters are contained in Table 1. The pH values ranges from 4.30-7.50 with a mean value of 5.02 and water with pH values lower than 7.00 indicates acidity and it is an important indicator of the water quality and the extent of pollution in the watershed areas.

Table 1: Statistical summary of the Physico-chemical and Bacteriological analysis of water samples from Otamiri and Oramiriukwa rivers

Parameters	Minimum	Maximum	Mean
pH	4.30	7.50	5.020
Colour (Pt-co)	12.00	23.00	18.000
Conductivity (µS cm^{-1})	10.00	715.00	250.000
TDS	230.00	980.00	468.040
Total Solid	650.00	2850.00	920.000
Turbidity (NTU)	4.00	15.00	9.000
Totalcoliform(10cfu/ml)	38.00	420.00	80.000
Iron	0.04	0.850	0.510
Manganese	0.03	0.920	0.350
Zinc	0.02	0.680	0.270
Chloride	21.90	32.800	25.120
Sulphate	17.04	24.220	21.160
COD	10.55	42.980	31.820
BOD	10.20	24.760	15.140
Nitrate	12.10	85.300	56.200
Calcium	11.28	190.100	84.220
Magnesium	10.16	120.460	60.200
Sodium	6.86	84.600	54.300

Gas flaring at the neighboring Egbema community may have resulted to acid rain formation coupled with the rusting of metals made from zinc and iron which are dumped along the river banks. The mean turbidity value obtained from the research is 9 NTU as against the maximum permissible limit of 5 NTU by the Nigerian Standard for Drinking Water Quality (NSDWQ, 2007). This could be attributed to the presence of organic matter pollution, other effluents, run-off with high suspended particles and heavy rainfall (Chapman, 1996). The color has an average value of 18.00 Pt-co as against the maximum permissible value of 15.00 Pt-co. Color in water may be due to the presence of organic matter such as humic substances, metals such as iron and manganese or highly colored industrial wastes (World Health Organization, 1997). The conductivity value ranged from 10.00 µS cm^{-1} to 715.00 µS cm^{-1} with a mean value of 250.00 µS cm^{-1} and the values are below the permissible limit of 1000.00 µS cm^{-1} by NSDWQ (2007). The dissolution of ions in water makes it conductive and such ions may be beneficial or harmful to the body (Amadi, *et al*., 2010).

Total Dissolved Solid (TDS) had concentration range between 230.00 and 980.00 mg L^{-1} with a mean value of 468.04 mg L^{-1}. The observed high TDS is a good indication of intensive anthropogenic activities along the course the river and run-off containing suspended materials (Chapman, 1996). High concentration of TDS to population density and intensive irrigation in an area. The mean concentration of total solid is 920.00 mg L^{-1} as against the maximum permissible limit of 500.00 mg L^{-1} (NSDWQ, 2007). Water containing high solids may cause laxative or constipation effects.

The concentration of Chemical Oxygen Demand (COD) ranged from 20.55-42.98 mg L^{-1} with an average value of 31.82 mg L^{-1} and these values are higher than the acceptable permissible limit of 10.00 mg L^{-1} (NSDWQ, 2007). The COD determination provides a measure of the oxygen equivalent of the portion of organic matter in water that is susceptible to oxidation by a strong chemical oxidant. It determines the quantity of oxygen required for oxidation of organic and inorganic matter in water. The high concentration of COD in the surface water is an indication that the solid waste is highly polluted with oxidizable organic and inorganic pollutants (Otukune and Biukwu, 2005). The Biochemical Oxygen Demand (BOD) accounts for the oxygen required in the decomposition of organic matter. The concentration of BOD from the water analysis varies from 10.20-24.76 mg L^{-1} with a mean value of 15.14 mg L^{-1} and this above the permissible limit of 6.00 mg L^{-1} recommended by NSDWQ (2007). The huge waste rich in organic matter and nutrient along the course of the river and probably as a result of the increased microbial activity (respiration) occurring during the degradation of the organic matter may be responsible for the high BOD value in the water.

The mean value obtained for iron and manganese from the analysis are 0.51 and 0.35 mg L^{-1} respectively. These values are above the maximum permissible limit of 0.30 and 0.20 mg L^{-1} for iron and manganese respectively (NSDWQ, 2007).

The enrichment of these elements may be due to the various human activities taking place along the river bank. These elements can affect the organoleptic quality of the water as well as coloration of the water thus initiating sedimentation in the system, which can result to corrosion. High concentration of manganese in the body causes neurological disorder. The concentration of zinc ranged between 0.02 and 0.68 mg L^{-1} with an average value of 0.27 mg L^{-1} which is below the permissible limit of 3.0 mg L^{-1} (NSDWQ, 2007).

Chloride is a widely distributed element in all types of rocks in one form or the other and is an indication that the water is of a marine source (Amadi *et al*., 2010). Its affinity towards sodium is high and hence its concentration is high in groundwater due to geothermal gradient. Soil porosity and permeability plays a key role in building up the chloride concentration. High concentration of chloride makes water unpalatable and unfit for drinking and livestock watering. The concentration of chloride in the rivers is below the NSDWQ permissible limit of 250 mg L^{-1} .The concentration of nitrate ranges from 12.10, 85.30 and a mean value of 56.20 mg L^{-1} while a permissible limit 50.00 mg L^{-1} is recommended by the (NSDWQ, 2007). Nitrate is a problem as a contaminant in drinking water due to its harmful biological effects. High concentration of nitrate causes methemoglobinemia or blue baby syndrome and have been cited as a risk factor in developing gastric an intestinal cancer (Chapman, 1996).

Farming and dumping of animal waste along the river course might be responsible for the high nitrate concentration in the water. Leachates from fertilizer and waste disposal can lead to high nitrate concentration which causes eutrophication (World Health Organization, 1997). The mean sodium and sulphate concentration are 54.30 and 21.16 mg L^{-1} respectively and values are below the permissible limit of 200.00 and 100.00 mg L^{-1} for sodium and sulphate respectively (NSDWQ, 2007). The hardness of water depends on the presence of dissolved calcium and magnesium ions (Amadi *et al*., 2010). The mean concentration of calcium and magnesium are 84.22 and 60.20 mg L^{-1} which are below the recommended permissible limit of 200.00 mg L^{-1} for both calcium and magnesium (NSDWQ, 2007).

The bacteriological analysis result shows a high bacteria count (Table 1) in the water which can be attributed to leachate from dumped human faeces in the river banks. The presence of total coliform in water is an indication of faecal contamination and is responsible for most water borne diseases such as meningitis, cholera and diarrhea as well as morbidity and mortality among children (World Health Organization, 1997). It also causes acute renal failure and haemolytic anaemia in adults (World Health Organization, 1997):

$$\text{Overall WQI} = \frac{\Sigma \text{qiwi}}{\Sigma \text{wi}} = \frac{1655.89}{9.49} = 174.49$$

The WQI of all the samples taken were calculated according to the procedure explained above and presented in Table 2. The results obtained from this study indicates that the mean concentration of the following parameters: conductivity, color, total solids. Turbidity, total coliform, iron, manganese, COD, BOD and nitrate were above the permissible limit of (NSDWQ, 2007) thereby signifying contamination.

Table 2: Computed WQI values for Otamiri and Oramiriukwa Rivers, Owerri

Parameters	C_i	S_i	q_i	w_i	w_iq_i
pH	5.02	6.50-8.50	66.93	0.13	8.70
Colour (Pt-co)	18.00	15.000000	120.00	0.07	8.42
Conductivity (μS cm^{-1})	250.12	1000.000000	25.00	0.00	0.03
TDS	468.04	500.000000	93.61	0.00	0.19
Total solids	920.00	500.000000	184.00	0.00	0.37
Turbidity (NTU)	9.00	5.000000	180.00	0.20	36.00
Totalcoliform (10cfu mL^{-1})	80.00	10.000000	800.00	0.10	80.00
Iron	0.51	0.300000	170.00	3.33	566.10
Manganese	0.35	0.200000	175.00	5.00	875.00
Zinc	0.27	3.000000	9.00	0.33	2.97
Chloride	25.12	250.000000	10.05	0.00	0.04
Sulphate	21.16	100.000000	21.16	0.01	0.21
COD	31.82	10.000000	318.20	0.10	31.82
BOD	15.14	6.000000	252.33	0.17	42.90
Nitrate	56.20	50.000000	112.40	0.02	2.25
Calcium	84.22	200.000000	42.11	0.01	0.42
Magnesium	60.20	200.000000	30.10	0.01	0.30
Sodium	54.30	200.000000	27.15	0.01	0.27

Table 3: Water quality classification based on WQI value

WQI value	Water quality	Water samples (%)
<50	Excellent	12
50-100	Good water	26
100-200	Poor water	35
200-300	Very poor water	17
>300	Unsuitable for drinking	10

Table 3 shows the classification of water quality based on WQI value and distribution of the 180 water samples according to their respective quality group. Based on the WQI value, water is categorized into 5 groups ranging from excellent water to water unsuitable for drinking (Table 3). The computed overall WQI was 174.49, which implies that the water is of poor quality. The high value of WQI obtained is as a result of the high concentration of conductivity, color, total solids, turbidity, total coliform, iron, manganese, COD, BOD and nitrate in the water and can be attributed to the various human activities taking place at the river bank.

The degree of linear association between any two of the water quality parameters, as measured by the simple correlation coefficient (r), is represented in Table 4. Iron, Manganese and zinc are perfectly interrelated. This interrelationship could be due to environmental conditions, especially oxidation and reduction nature of these elements (De Miquel *et al*., 1997; Che *et al*., 2003). Nitrate and total coliform are interrelated and this is due to pollution from fertilizer run-off and human faeces or animal waste (Chapman, 1996). The linear relation between Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) might be attributed to increase in salinity, temperature and biological activity (Otukune and Biuukwu, 2005).

Table 4: Correalation coefficient matrix of water quality parameters

	pH	Color	Cond.	TDS	TS	Turb.	TC	Fe	Mn	Zn	Cl^-	SO_4^{2-}	COD	BOD	NO_3^-	Ca^{2+}	Mg^{2+}	Na^+
pH	1.000																	
Color	0.015	1.000																
Cond.	0.109	0.158	1.000															
TDS	0.149	0.184	0.994*	1.000														
TS	0.166	0.214	0.973*	0.973*	1.000													
Turb.	0.101	0.022	0.957*	0.933*	0.925*	1.000												
TC	0.022	0.011	0.871	0.867	0.962*	0.857	1.000											
Fe	0.142	0.033	0.885	0.907*	0.964*	0.077	0.073	1.000										
Mn	0.038	0.199	0.787	0.754	0.845	0.781	0.692	0.648	1.000									
Zn	188	0.316	0.747	0.074	0.908*	0.664	0.721	0.642	0.086	1.000								
Cl^-	0.515	0.003	0.041	0.096	0.328	0.044	0.025	0.134	0.469	0.527	1.000							
SO_4^{2-}	0.391	0.314	0.175	0.234	0.507	0.159	0.212	0.265	0.379	0.036	0.966*	1.000						
COD	0.344	0.033	0.035	0.037	0.184	0.321	0.108	0.362	0.029	0.109	0.551	0.544	1.000					
BOD	0.274	0.348	0.076	0.079	0.301	0.076	0.098	0.022	0.274	0.022	0.334	0.259	0.044	1.000				
NO_3^-	0.261	0.339	0.084	0.063	0.101	0.133	0.438	0.034	0.045	0.091	0.021	0.103	0.344	0.203	1.000			
Ca^{2+}	0.099	0.323	0.022	0.009	0.902*	0.024	0.363	0.038	0.134	0.055	0.202	0.316	0.243	0.224	0.911*	1.000		
Mg^{2+}	0.138	0.025	0.051	0.044	0.995*	0.038	0.353	0.001	0.182	0.078	0.173	0.277	0.306	0.101	0.936*	0.943*	1.000	
Na^+	0.155	0.469	0.544	0.576	0.858	0.437	0.386	0.583	0.047	0.295	0.291	0.041	0.415	0.56	0.027	0.014	0.049	1

Total Solids (TS) and conductivity are also interrelated and it can be attributed to the dissolution of soluble ions in the water (Tam and Wong, 2000). Calcium and magnesium are interrelated and their presence in signifies water hardness.

CONCLUSION

Prior to this study, water from Otamiri and Oramiriukwu Rivers were used for drinking without any treatment, however, the results obtained from the study reveals that these rivers are polluted and the pollution attributed to anthropogenic activities taking place along the river course as well as effluents from industries and urban run-off. The WQI of the samples was 174.49 and this value exceeded 100.00 for a good water, hence the water needs treatment before use. Application of WQI in this study has been found very useful in the assessment of the overall water quality and management. The present investigation has also shown beyond doubt that most of the pollution impacts of human activities along the river course are significant but neglected.

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