**Volume-2, Issue-6, June-2019: 19-32**
**International Journal of Current Innovations in Advanced Research** **ISSN: 2636-6282**

# Evaluation of Pollution Potential of Nworie River and Its Sediments Using Physico-Chemical Characteristics in Imo State, Southeastern Nigeria

**Agudozie, I.H., Ahiarakwem, C.A., Nwankwor, G.I. and Fagorite, V.I.**

Department of Geology, Federal University of Technology, Owerri, P.M.B 1526 Imo State, Nigeria
Email:fagorite@gmail.com

**Received:**June10, 2019; **Accepted:**June17, 2019; **Published:** June 21, 2019

**Abstract:**The physico-chemical characteristics of Nworie River and its Sediments were investigated using standard methods. Samples were obtained at four locations Federal Medical Centre (FMC), Warehouse (WH), Emmanuel College (EC) and Control Point (CP). Results obtained from physico-chemical analysis show that except for Colour, Turbidity, pH, Fe, Hg, Pb, Al, and Cd, other measured parameters such as (Conductivity, TDS, Calcium and Magnesium Hardness, Alkalinity, Total chloride, Nitrate, Nitrogen (NO,N), Phosphate ($PO_4^{3-}$), Sulphate ($SO_4^-$), Potassium (K), Copper and Zinc) conformed with World Health Organization (WHO) 2011, standards. The mean concentration values for major cations (Ca, Na, Mg and K) at FMC, WH and EC were (7.57, 7.32 and 5.76), (26, 24, and 22.2), (1.76, 1.79 and 1.80) and (3.87, 4.64and 5.53) mg/l respectively, while mean values for anions ($HCO_3$, $NO_3$, $SO_4$ and $Cl^-$) were (9, 8 and 9), (17, 22.33, and 18.1), (25.0, 30.0 and 32.0) and (30.0, 15.0 and 15.30) mg/l respectively. Also, the stream sediments shows that aside pH, Total Chloride, Hg, NO3, Fe, K, Pb, Cd and Al, all other parameters conform to Federal Ministry of Environment (FME)2006 standards. The environmental and health implications of the variables were examined to establish current levels of pollution. An attempt has been made to show the relationships between pollution levels, human, industrial and agricultural activities that introduce pollutants into the River. The spatial distribution of pollutants due to a poor land use system and human activities were investigated, thus emphasizing integrated planned development as a preventive measure for arresting pollution levels in the river. The mean pH values for the three segments (FMC, WH and EC) were 5.76, 5.77 and 5.40 respectively, while the mean pH values for the sediments were 5.0, 5.66 and 6.0 respectively, thus showing that the water and sediment is acidic and does not conform to the WHO 2011 drinking water standard. There is therefore the need for proper treatment of the water so as to ensure its suitability for domestic and commercial use. The pH of the river can be treated using sodium carbonate (soda ash).

**Keywords:** pH, Physico-chemical, sediments, Nworie River, Sodium carbonate.

**Citation:** Agudozie, I.H., Ahiarakwem, C.A., Nwankwor, G.I. and Fagorite, V.I. 2019. Evaluation of Pollution Potential of Nworie River and Its Sediments Using Physico-Chemical Characteristics in Imo State, Southeastern Nigeria.International Journal of Current Innovations in Advanced Research, 2(6): 19-32.

## Introduction

Surface water bodies in developing and developed countries are vulnerable to pollution. Water is generally said to be polluted when its acceptable quality has been altered by man's activities through anthropogenic inputs such that its intended usage for commercial or domestic purpose is hampered (Ibeh and Mbah, 2007). Nworie River is one of such river which has been subjected to intensive human and industrial activities, and at the same time, is used as a source of drinking water when the public water system fails. The increasing population of the inhabitant of Owerri metropolis has led to the increase in pollution due to the enormous wastes generated from their various activities.

The river which runs approximately 5.0km course through Owerri, the capital of Imo state in south-eastern Nigeria is of great importance to the inhabitants of Owerri, serving as a source of water for domestic use such as bathing, washing, drinking etc. The river also supports recreational activities and part-time fishing. The common practice of unregulated wastes disposal into watercourses can affect their normal use by municipalities.

Aquatic environment near cities are usually prone to over loading with a variety of pollutants either through direct or indirect discharges. The situation is aggravated when the waste is untreated. Reckless dumping of wastes into natural water bodies can overtax the self-purifying capacity of the receiving water. This will not only endanger the resident aquatic life but also impair other amenity purposes and non-consumption uses that the river course might be put into.

Wastes generated as a result of human activities from institution such as Federal medical centre (FMC), Alvan Ikoku Federal College of Education (AIFCE), and Holy ghost college in Owerri situated along the river banks as well as wastes from most hotels situated within the municipality do find their ways into the river which increases the microbial load on the river.

Washing, bathing and other human activities carried out at different points of the river serve as additional sources of pollution to the river. Runoffs from agricultural farmlands surrounding the river carry agrochemicals like residual pesticides, fertilizers, manures into the river and this leaves the river in a despicable state. (Ezemonye, 2009) indicated refuse dumping as dwelling places for vectors of diseases. The assessment of the environmental fate and behaviour of constituents that have the potential to leach from the numerous contaminant sources to pollute the Nworie River is of immense interest in this study. Such assessments require the knowledge of various physical, chemical and bacteriological aspects of the surface water body (Ahiarakwem and Onyekuru, 2011).

To this end, the main objective of the study was to provide information that will be useful in the management and sustainable development of the Nworie River.

## The Location and Geology of Study Area

The study area lies between latitude $5^{0}30'$ N and $5^{0}47$ N and longitudes $6^{0}37'$ E and $7^{\circ}18$E (Figure 1). The river flows in the city through Federal Medical Centre (FMC), Alvan Ikoku Federal University of Education (AIFCE) and Holy Ghost College all in Owerri, and empties into another river, the Otamiri River. The river originates from Mbiatolu LGA of Imo State and passes though Owerri Municipal LGA of Imo State and then empties into the Otamiri River at Nekede, Owerri West LGA, Imo State. The measured length of the river is approximately 9 kilometers and the area of the catchment is approximately, 30 square kilometers.

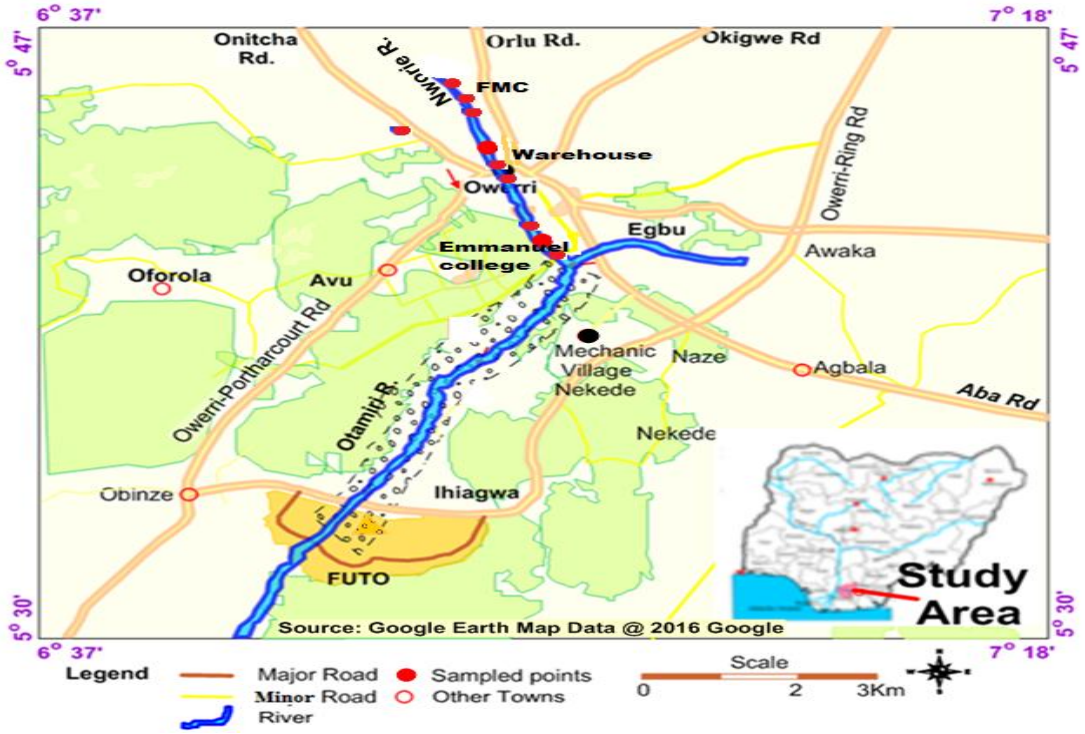


**Figure 1. Location Map of the Study Area Showing Sampling Points**

The study area is underlain by the Benin Formation of Miocene to Recent age belonging to the Benin Formation as well as the Port-Harcourt, Aba, and environs (Figure 2). The type locality of the formation is Port-Harcourt, Aba and Owerri where the formation overlies the older Ogwashi-Asaba Formation. The Formation outcrops sometimes in both surface (outcrop) and subsurface in mode of occurrence.

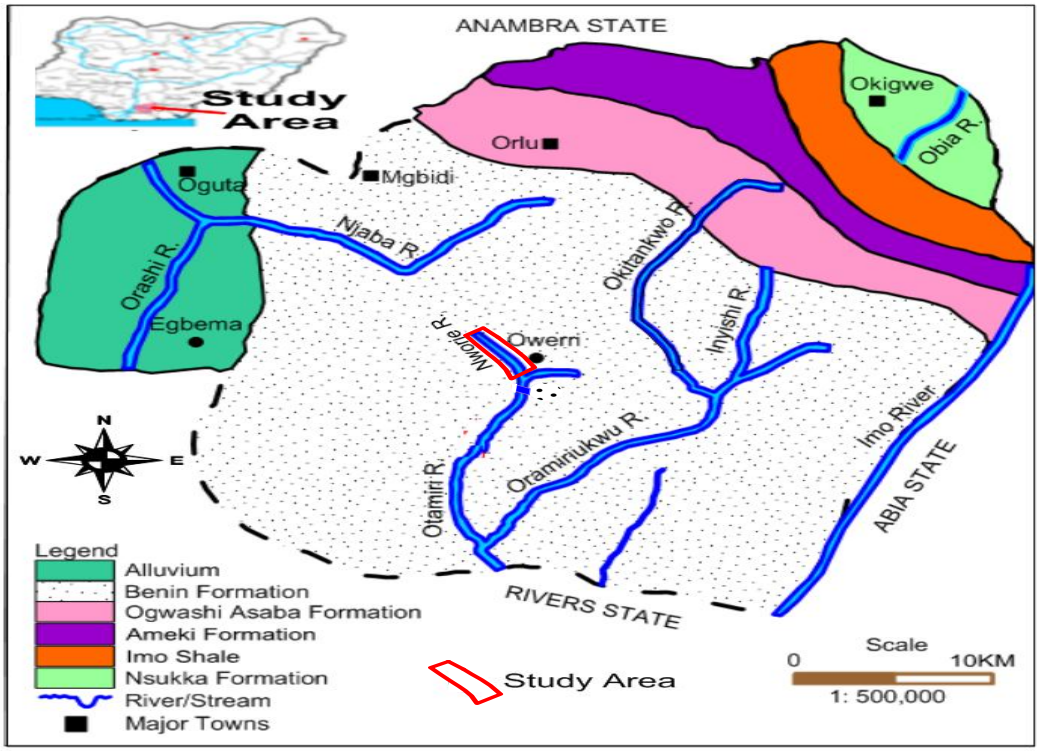


**Figure 2. Geologic Map Showing the Study Area (Adapted From Ibeh, 2017)**

## Materials and Methods

A total of nine water samples were collected from Nworie River at four gauge stations for analysis using the grab method. The stations were at Federal Medical Centre, Warehouse and Emmanuel College (FMC, WH, and EC). The sampling points were at least 500 meters apart. The sampling was done in the morning against the water current. The water samples for physico-chemical analysis were taken in sterilized plastic containers, carefully labeled and adequately documented accordingly while the sediments were collected into a black polyethene bag using a hand auger.

The analysis of the water was done using atomic absorption spectrophotometer. While that of the sediment was done using X-ray refraction index and later aspirated into the atomic absorption spectrophotometer. Rapid method of compass traversing and pacing with the use of G.P.S was adopted which helped to field check information collected from geological and location maps for plausibility and also in georeferencing sampling points.

The concentrations of the major constituent cations and anions in milligram/liter (mg/l) were converted to milliequivalent/liter (meq/l) using the equation 1 developed by Todd (1980)

$$\text{Concentrations (meq/l)} = \frac{\text{Concentr ations (mg/l)}}{\text{Equivalent mass}} \quad \text{.....(Eq.1)}$$

The concentrations in meq/l were used to prepare Piper trilinear, Schoeler, Durov and Stiff diagrams as well as calculation of Sodium Adsorption Ratio (SAR). The SAR was determined using the equation 2 (Wilcox, 1955).

$$\text{SAR} = \frac{Na^{+}}{\frac{\sqrt{Ca^{2+} + Mg^{2+}}}{2}} \quad \text{.....(Eq.2)}$$

The total hardness as ($CaCO_3$) of the Otamiri River water was determined using the equation 3 developed by Todd (1980).

$$\text{Total hardness as } CaCO_3 \text{ mg/l} = 2.5\,[Ca^{2+}] + 4.1\,[Mg^{2+}] \quad \text{.....(Eq. 3)}$$

The pollution index was calculated using the equation 4 developed by Horton (1965). The parameters for determining the pollution index (PI) of the water samples were pH, Total Alkalinity, Total Dissolved Solid (TDS), Sulphate and Chloride.

$$\text{PI} = \sqrt{\frac{\left(\frac{maxCij}{Lij}\right)^2 + \left(\frac{meanCij}{Lij}\right)^2}{2}} \quad \text{.....(Eq. 4)}$$

Where;
Ci = concentration of chemical parameters
Lj = World Health Organization (2011) permissible limit.

## Results and Discussion

The result of the physical and chemical characteristics of the water samples are shown in Table 1 below while concentrations of major cations and anions in mill equivalent per liter (meq/l) are shown in Table 2.

**pH Value, Odour and Colour**

The pH of the water samples ranges from 5.40 to 5.78, these shows a pH lower than 7 thus indicating the water is acidic, the mean values at FMC, Warehouse and Emmanuel College 5.76, 5.77 and 5.45 respectively. The mean pH value was 5.66. The high acidity could be from the medical waste discharge at FMC also, aluminum company at Warehouse. The odour of water samples at Nworie River is objectionable giving off some offensive smell due to rate of defecation and refuse dumping into the river. The colour of water samples collected at Nworie River was brownish white.

**Total Dissolved Solids (TDS), Electrical Conductivity and Turbidity**

TDS refers to the total amount of mobile charged ions, including minerals, salts and metals dissolved in a given volume of water. It is directly related to the purity and quality of water. This is measured by electrical conductivity of the surface water, conductance increases with increasing TDS and temperature.

The Total Dissolved Solid concentration values of Nworie River ranges from 32.5 to 72mg/l with the mean values at FMC, Warehouse and Emmanuel College 71.5, 32.5 and 33.13 mg/l respectively. This is a numerical expression of the ability of an aqueous solution to carry an electric current. The ability depends on the presence of ions, concentration, mobility and valency (APHA, 1998).

The mean electrical conductivity values of Nworie River collected at the three locations FMC, Warehouse and Emmanuel College were 106.6, 50, and 58.33 µS/cm respectively with a mean average value of 71.64µS/cm. The turbidity values ranges from 15 to 23.4 while the mean for FMC, WH and Emmanuel College were 17.69, 21.9 and 17.5 NTU respectively. The mean Turbidity value was 19.03 NTU.

**Major Cations and Anions for Water**

The calcium concentration values of Nworie River at the three locations ranges from 12 to 21.8mg/l and the values at the three locations were 21.81, 17 and 12mg/l respectively, with a mean value of 16.93mg/l. High concentration of calcium can cause permanent hardness of the water and is most common where there is high deposit of gypsum, limestone and dolomite. Magnesium has no negative health issue (Sharon, 2009). Therefore, it is not a threat to the environment. Magnesium is usually less abundant in water than calcium, because it is found in lower amount in the earth crust compare to calcium.

The magnesium concentration values of Nworie River at the three different locations were 0.07, 0.14 and 0.17mg/l. The mean concentration value was 0.13mg/l. The mean concentration of sodium in the water samples ranges from 22.2 to 26.0mg/l while the mean values at FMC, WH and EC were 26, 24 and 22.2mg/l respectively. The concentration of potassium values of Nworie River were, 3.87, 4.64 and 5.53mg/l respectively with a mean value of 4.68mg/l.

**Table 1. Physico-Chemical Properties of Water Samples from Nworie River**

| Parameter | WHO 4th Edition, (2011) | FMC | | | Mean | Warehouse | | | Mean | Emmanuel College | | | Mean | Control Point Egbaeda |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 8.2 – 8.8 | 5.78 | 5.76 | 5.74 | 5.76 | 5.97 | 5.77 | 5.57 | 5.77 | 5.45 | 5.50 | 5.40 | 5.45 | 7.0 |
| Odour | Unobjection-able | Objectionable | | | Objection-able | Objectionable | | | Objection-able | Objectionable | | | Objection-able | Objectio-nable |
| Appearance | Clear | Slightly turbid | Slightly turbid | Slightly turbid | Slightly turbid | turbid | turbid | turbid | Turbid | turbid | turbid | turbid | Turbid | Clear |
| Total Dissolved Solid, mg/l TDS | 1500.00 | 72.0 | 71.5 | 71.0 | 71.5 | 30.5 | 32.5 | 34.5 | 32.5 | 32.5 | 33.0 | 33.9 | 33.13 | 35.0 |
| Conductivity, µS/cm | 1400.00 | 105 | 110 | 105 | 106.6 | 48 | 50 | 52 | 50 | 50.0 | 60.0 | 65.0 | 58.33 | 58.33 |
| Turbidity, NTU | 1.00 | 17.44 | 18.11 | 17.53 | 17.69 | 20.2 | 23.4 | 22.1 | 21.9 | 15.0 | 18.0 | 19.5 | 17.5 | 3.0 |
| Total Chloride, mg/l $Cl^-$ | 400.00 | 30 | 32 | 28 | 30 | 17 | 15 | 13 | 15 | 16 | 14 | 16 | 15.3 | 15.0 |
| Total hardness, mg/l $CaCO_3$ | 100.00 | 29.27 | 30.0 | 29.0 | 29.42 | 20.39 | 24.39 | 28.39 | 24.39 | 15.5 | 12.6 | 14.3 | 14.13 | 12.94 |
| Calcium hardness, mg/l $CaCO_3$ | 150.00 | 21.95 | 21.50 | 22.0 | 21.81 | 14 | 17 | 20 | 17 | 12 | 10 | 14 | 12 | 9.20 |
| Magnesium hardness, mg/l $MgCO_3$ | 150.00 | 7.32 | 7.00 | 7.81 | 7.37 | 9.32 | 7.32 | 5.32 | 7.32 | 4 | 6 | 7.3 | 5.76 | 3.74 |
| Calcium, mg/l Ca | 200.00 | 7.59 | 7.57 | 7.55 | 7.57 | 5.60 | 5.40 | 5.80 | 5.60 | 4.0 | 4.2 | 4.1 | 4.1 | 3.70 |
| Magnesium, mg/l Mg | 100.00 | 1.80 | 1.78 | 1.72 | 1.76 | 1.80 | 1.78 | 1.79 | 1.79 | 1.8 | 1.9 | 1.7 | 1.8 | 0.90 |
| Mercury, mg/l Hg | 0.006 | 0.102 | 0.206 | 0.220 | 0.176 | 0.236 | 0.266 | 0.302 | 0.268 | 0.30 | 0.28 | 0.21 | 0.26 | ND |
| Bi-carbonate, mg/l $HCO_3^-$ | 50.00 | 8.8 | 9.0 | 9.2 | 9.0 | 8.0 | 8.2 | 7.8 | 8.0 | 9.5 | 8.5 | 9.0 | 9.0 | 4.4 |
| Nitrate, mg/l $NO_3^-$ | 50.00 | 17 | 19 | 15 | 17 | 20.6 | 22.4 | 24.0 | 22.33 | 16.1 | 18.2 | 20.0 | 18.1 | 8.5 |
| Phosphate, mg/l $PO^{-3}$ | 0.05 | 0.20 | 0.28 | 0.36 | 0.28 | 0.42 | 0.49 | 0.40 | 0.43 | 0.30 | 0.40 | 0.50 | 0.40 | ND |
| Sulphate, mg/l $SO_4^-$ | 200.00-400.00 | 25 | 27 | 23 | 25 | 30 | 32 | 28 | 30 | 30 | 32 | 34 | 32 | 12.5 |
| Iron, mg/l Fe | <0.10 | 1.40 | 1.60 | 1.80 | 1.6 | 0.10 | 0.20 | 0.30 | 0.20 | 0.12 | 0.20 | 0.30 | 0.20 | 0.09 |
| Sodium, mg/l Na | 200.00 | 25 | 27 | 26 | 26 | 24 | 26 | 22 | 24 | 20 | 22 | 24.6 | 22.2 | 12.5 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Potassium, mg/l K | 50-70 | 3.47 | 3.87 | 4.27 | 3.87 | 4.25 | 4.68 | 5.01 | 4.64 | 5.0 | 6.0 | 5.6 | 5.53 | 1.90 |
| Lead, mg/l Pb | 0.01 | 0.50 | 0.60 | 0.70 | 0.60 | 0.65 | 0.70 | 0.72 | 0.69 | 0.70 | 0.76 | 0.60 | 0.68 | ND |
| Copper, mg/l Cu | 2.0 | 0.03 | 0.04 | 0.05 | 0.04 | 0.02 | 0.03 | 0.04 | 0.03 | 0.02 | 0.03 | 0.04 | 0.03 | ND |
| Cadmium, mg/l Cd | 0.003 | 0.11 | 0.21 | 0.13 | 0.15 | 0.15 | 0.19 | 0.24 | 0.19 | 0.14 | 0.20 | 0.22 | 0.18 | ND |
| Aluminum, mg/l Al | <0.10 | 0.14 | 0.18 | 0.22 | 0.18 | 0.28 | 0.22 | 0.19 | 0.23 | 0.15 | 0.20 | 0.18 | 0.17 | 0.008 |
| Zinc, mg/l Zn | 5.00 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |

**Table 2. Concentrations of Major Cations and Anions of Nworie River**

| Param-eters | FMC | | | Warehouse | | Emmanuel College | | Control Point (Egbaeda) | |
|---|---|---|---|---|---|---|---|---|---|
| | Equivalent mass | Mean (mg/l) | Mean (meq/l) | Mean (mg/l) | Mean (meq/l) | Mean (mg/l) | Mean (meq/l) | Mean (mg/l) | Mean (meq/l) |
| Ca | 20 | 7.57 | 0.37 | 5.60 | 0.28 | 4.1 | 0.205 | 3.7 | 0.185 |
| Mg | 12.2 | 1.76 | 0.14 | 1.79 | 0.146 | 1.7 | 0.139 | 0.9 | 0.073 |
| Na | 23 | 26.0 | 1.13 | 24 | 1.04 | 24.6 | 1.069 | 12.5 | 0.543 |
| K | 39.1 | 3.87 | 0.09 | 4.64 | 0.11 | 5.53 | 0.141 | 1.9 | 0.004 |
| **Total** | | | **1.73** | | **1.57** | | **1.55** | | **0.805** |
| $HCO_3$ | 61 | 9.0 | 0.14 | 7.80 | 0.127 | 8.5 | 0.139 | 4.4 | 0.072 |
| $SO_4^{2-}$ | 48 | 25 | 0.520 | 30 | 0.625 | 32 | 0.660 | 12.5 | 0.260 |
| $NO_3$ | 62 | 17 | 0.274 | 22.33 | 0.360 | 18.1 | 0.291 | 8.5 | 0.137 |
| $Cl^-$ | 35.5 | 30.0 | 0.845 | 15 | 0.422 | 15.53 | 0.465 | 15.0 | 0.422 |
| **Total** | | | **1.77** | | **1.53** | | **1.55** | | **0.891** |

Bicarbonate is a weak acid produced from the chemical reaction of rain water with $CO_2$ in the atmosphere and it makes the pH of the water acidic by reducing the value.

The bi-carbonate concentration values ranges from 8 to 9.5mg/l, the three sample locations were 9, 8 and 9 respectively with a mean value of 8.66mg/l. The concentration values of nitrate ($NO_3$) at Nworie River were 17, 22.33 and 18.1mg/l respectively with a mean value of 19.14mg/l.

The concentration values of sulphate ranges from 23 to 34mg/l while the mean values at FMC, WH and EC were 25, 30and 32mg/l respectively with a mean value of 29mg/l. The concentration values of chlorine at Nworie River were 30, 15 and 15.3mg/l respectively with a mean value of 20.1mg/l.

**Heavy Metals for Water**

The Fe concentration of Nworie River from the three locations are as follows, 0.39, 0.46 and 0.12mg/l with a mean value of 0.32mg/l. The average Cu values for the three locations (FMC, WH and EC) were 0.04, 0.03 and 0.03mg/l respectively. Zinc was seen to be below detection level and thus was not detected in the water samples analysis.

The average Pb values for the three locations (FMC, WH and EC) were 0.60, 0.69 and 0.68mg/l respectively. The average Cd values for the three locations (FMC, WH and EC) were 0.15, 0.19 and 0.18mg/l respectively. While the average Al values for the three locations (FMC, WH and EC) were 0.18, 0.23 and 0.17mg/l respectively.

**Pollution Index**

The pollution index (PI) values were 0.648, 0.643 and 0.607 respectively (Table 6). According to Horton (1965), the critical value of pollution index (PI) is 1. This implies that any water sample greater than 1 requires treatment. Thus the PI of the water samples is less than 1 (I.e. not at critical).

However, predisposal treatment should still be carried out to further reduce the PI.The pollution index of the water samples is shown in Table 3 below.

**Table 3. Pollution Index of Nworie River**

| Parameters | Lij (WHO) | Cij FMC | Cij WH | Cij EC | Cij/Lij FMC | Cij/Lij WH | Cij/Lij EC |
|---|---|---|---|---|---|---|---|
| pH | 6.5 | 5.76 | 5.77 | 5.45 | 0.88 | 0.88 | 0.83 |
| TDS | 500 | 71.5 | 32.5 | 33.13 | 0.15 | 0.065 | 0.066 |
| Total Alkali | 100 | 9 | 8 | 9 | 0.09 | 0.08 | 0.09 |
| Sulphate | 400 | 25 | 30 | 32 | 0.625 | 0.75 | 0.80 |
| Chloride | 250 | 30 | 15 | 15.3 | 0.13 | 0.065 | 0.066 |
| **Mean Cij/Lij** | | | | | 0.375 | 0.368 | 0.370 |
| **PI** | | | | | 0.648 | 0.643 | 0.607 |

## Sodium Adsorption Ratio (SAR)

SAR is the indicator of the relative proportion of sodium in a water sample to those of calcium and magnesium. It is used to predict the potential for sodium to accumulate in the soil. It is a measure of the suitability of the water for irrigation purpose which is determined by the concentration of dissolved solids in water.The SAR values for the water samples were 2.24, 2.25 and 2.56 respectively (Table 4).These values shows that the water is suitable for irrigation purposes as the values fall within 0-10.

**Table 4. Water Quality for Irrigation Purposes Developed By USDA (1965)**

| SAR Range | Description | Location | SAR values |
|---|---|---|---|
| 0-10 | Excellent | FMC | 2.24 |
| 10-18 | Good | Waterhouse | 2.25 |
| 18-26 | Fair | Emmanuel College | 2.56 |
| >26 | Poor | Egbaeda | 1.55 |

## Geochemical Models

The geochemical plots show the potability of the water. The stiff shows similar shapes and size suggesting close chemical relationship which signifies dominance of Na+K – $SO_4^+$ Cl (Figures 3). The piper diagram helps determine if the water is potable without comparing to WHO standard. This was achieved by combination of cations and anions with the values plotted at the lower left and right of the big triangle (Figure 4). Schoeller shows the relative tendency of ions in mg/l which is $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ and $Cl^- > SO_4^{2-} > NO_3 > HCO_3^-$. The hydrogeochemical facies identified in the study area is mainly the water type $Na^+$+K - $SO_4$ as shown in the plotted Schoeller diagram below in Figure 4.

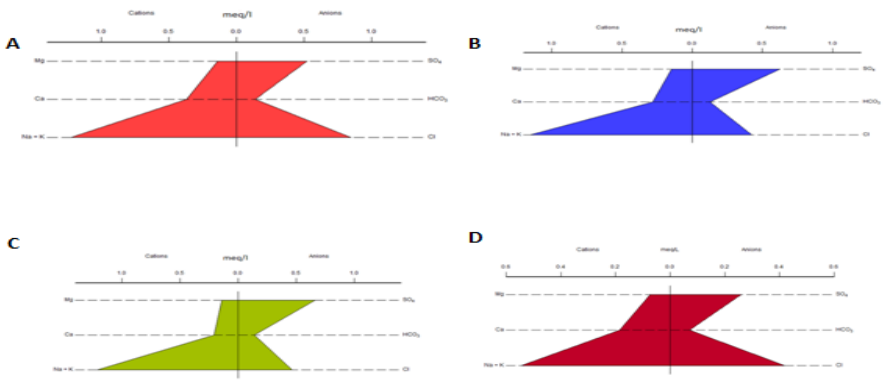


**Figure 3: A-Stiff Diagram of Water Sample at FMC.**
**B-Stiff Diagram of Water Sample at Warehouse**
**C-Stiff Diagram of Water Sample at Emmanuel College**
**D-Stiff Diagram of Water Sample at Egbaeda (Control Point)**

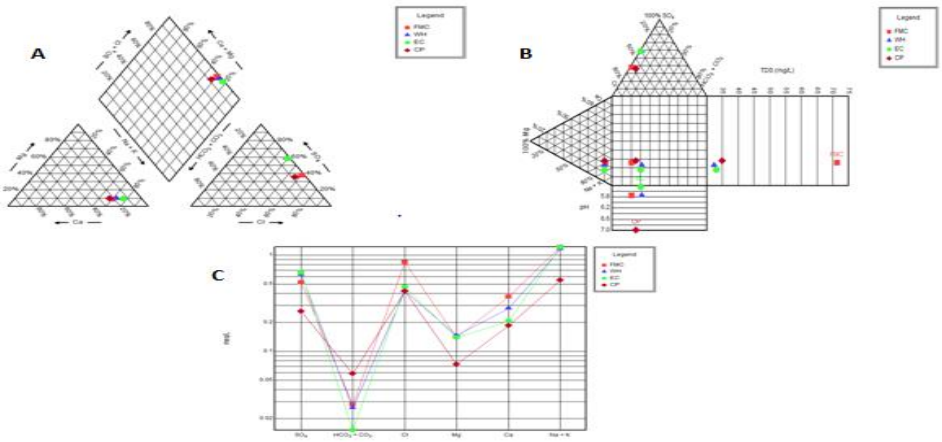


Figure 4: A- Piper Trilinear Diagram Showing the Water Type of the Study Area.
B- Durov Diagram of the Water Samples.
C- Schoeller Diagram of the Water Samples.

The physico-chemical characteristics of a water body are important in the determination of its productive capacity and effect on the biota. Consumption of low pH water could lead to acidosis, which results in peptic ulcer. The low pH observed at FMC, WH and EC sampling points could be as result of anthropogenic activities. These activities may have caused the death of some aquatic life forms. These aquatic life forms release proteins including ammonia upon death and decay. The released ammonia dissolved in water hence causing a drastic change which manifest as low pH, Calcium Hardness range (12–21.81 mg/I) and magnesium hardness range (5.76–7.37 mg/I) of the studied river indicates the soft nature of the river water. Solids found in a water body exist as total suspended or dissolved, as observed in the study and most dissolved to form dissolved solids (32.5–71.5 mg/l) as the case with Nworie River. Consumption of water with high solid could lead to gastrointestinal upset, which may pave way for other diseases. Nitrate and chlorine in water are indicators of agrochemical usage on lands surrounding the river. These may have entered the river as runoff during rain fall. Aside alkalinity that results in unpleasant taste, consumption of Nitrate and chlorine polluted water could result in gastrointestinal irritation, infantile methaemoglobinaemia, etc, in the system. The observed values for alkalinity in this study were lower than WHO standards.Revealed presence of calcium (4.1–7.57 mg/I), magnesium (1.79–1.80 mg/l), and iron (0.2– 1.6 mg/1). Calcium and magnesium in water impairs its taste, and can result in gastrointestinal irritation, which may be severe in the presence of sulphate. Iron is known for water discolouration, astringent taste and possible gastrointestinal diseases on consumption.

**Physico-Chemical Characteristics for Stream Sediments**

The soil chemical composition was analyzed as this form a part of trap of the chemicals dissolved in the water.

**Table 5. Showing Results of parameters analysed from Stream sediments**

| Parameter | FME Standard 2006 | FMC | Warehouse | Emmanuel College | Control Point |
|---|---|---|---|---|---|
| pH | 6.5 | 5.0 | 5.66 | 6 | 5 |
| Conductivity, µS/cm | 100 | 10 | 10 | 11 | 23 |
| Total chloride, mg/kg $Cl^-$ | 250 | 524.68 | 428.62 | 402.12 | 160 |

| | | | | | |
|---|---|---|---|---|---|
| Iron, Mg/kg Fe | 1 | 2.52 | 0.5 | 0.7 | 0.1 |
| Sodium, mg/kg Na | NS | 23.90 | 23.16 | 23.25 | 19.2 |
| Potassium, mg/kg K | >100 | 6.78 | 6.17 | 6.09 | 156 |
| Lead, mg/kg Pb | 0.05 | 0.65 | 0.97 | 0.77 | ND |
| Copper, mg/kg Cu | 2 | ND | 0.08 | 0.05 | |
| Cadmium, mg/kg Cd | 0.1 | 0.22 | 0.22 | 0.21 | |
| Aluminum, mg/kg Al | <0.01 | 4.87 | 6.28 | 6.31 | |
| Zinc, mg/kg Zn | 5 | 0.33 | 0.41 | 0.55 | |

## pH, Electrical Conductivity and Total Chloride

The concentrations values for sediments at FMC, Warehouse and Emmanuel College stations were 5.0, 5.66 and 6 with a control point value of 5 respectively. These values indicates slightly acidic and do not conform to the Federal Ministry of Environment (FME, 2006) standard for soil. The values for the conductivity were 10, 10 and 11 us/cm at FMC, Warehouse and Emmanuel College stations respectively with control point value of 23 us/cm. These values conform to the FME (2006) standard for soil. The mean concentration values for Total Chloride at FMC, Warehouse and Emmanuel College stations were 524.68, 428.62 and 402.12 mg/kg $Cl^-$ respectively with control point value of 160 mg/kg $Cl^-$ and the values do not conform to the FME (2006) standard for soil (Figure 5).

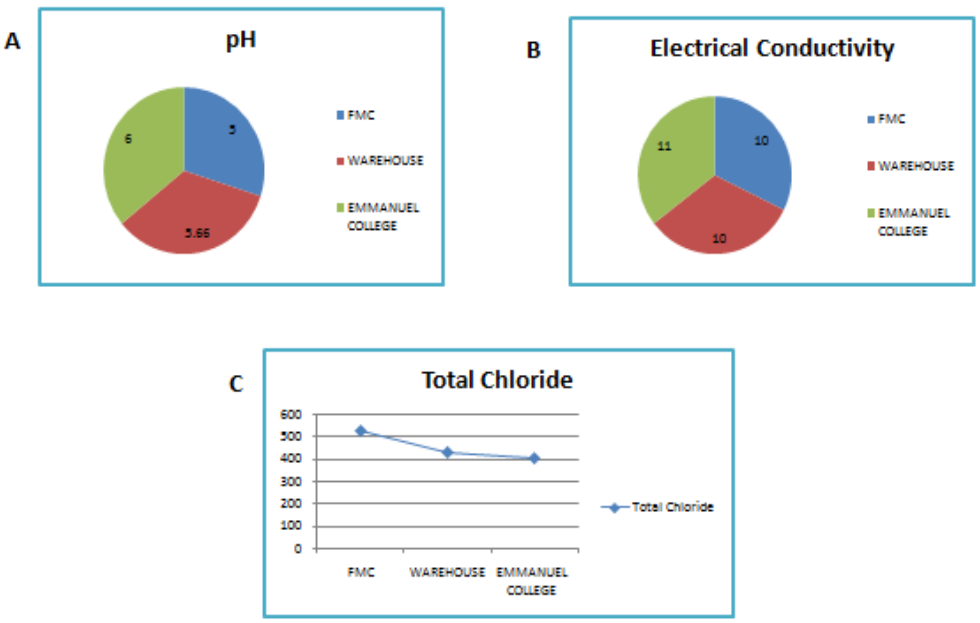


**Figure 5: A-Pie chart showing the mean concentration values for pH**
**B-Pie chart showing the mean concentration values for Electrical Conductivity**
**C- Chart showing the mean concentration variations for Total Chloride**

**Heavy Metals**

Iron (Fe) is present in significant amounts in soils and rocks, principally in insoluble forms. However, many complex reactions which occur naturally in ground formations can give rise to more soluble forms of iron which will therefore be present in water passing through such formations. The concentration values of Fe at FMC, Warehouse and Emmanuel College stations were 2.52, 0.5 and 0.7 mg/kg respectively with a control point value of 0.1 mg/kg. These values conform to the FME (2006) standard for soil except for the FMC station that exceeded the standard. The values for Pb were 0.65, 0.97 and 0.77 mg/kg respectively (Figure 6) with no detection of the metal at the control point and the values did not conform to the FME (2006) for soil which is slightly higher and indicates the presences of anthropogenic activities such as disposal of batteries in to the river. Some of the known effects on higher plants include dark green leaves, stunted foliage mid increased amounts of shoots (Ferguson, 1990). It is not known to be of any known function in the human body (Essa, 1999). The inorganic forms of lead in soil have the same toxic endpoints (National Environmental Policy Institute, 2000). While the values for Cu at Warehouse and Emmanuel College stations, 0.08 and 0.05 mg/kg respectively and they conform to the FME (2006) standard for soil with no detection at the control point and FMC station. Fish kill has been attributed to the improper use of copper as an algal toxicant. The values for Hg were 0.11, 0.17 and 0.16 mg/kg with no detection at control point and the values do not conform to the FME (2006) standard for soil. This is a very toxic element, the hazards of which are magnified by the accumulation of organo-mercury compounds in fish. When humans take this fish it can cause cancer. The concentration values for Cd at FMC, Warehouse and Emmanuel College stations were 0.22, 0.22 and 0.21 mg/kg respectively with no detection at control point. These values do not conform to the FME (2006) standard for soil and it indicates heavy disposal of e-wastes in the sediments of Nworie River. The principal physiological effects of cadmium are bone damage, chronic kidney disease, cancer and hypertension. The metal is also highly toxic to aquatic life. While the values for Zn were 0.33, 0.41 and 0.55 mg/kg with control point not detected. These values show conformity to the FME (2006) standard for soil. Zinc has been shown to exert adverse reproductive biochemical, physiological and behavioural effect on a variety of aquatic organisms as concentrations exceed 20µg/l. Toxicity in human may occur if zinc concentration in ***water*** approaches 400ig/J. This is characterized by symptoms of irritability, muscular stiffness and pain, loss of appetite and nausea. The values for Al at the three stations were 4.87, 6.28 and 6.31 mg/kg respectively with control point showing no detection. These values do not conform to the FME (2006) standard for soil. Aluminum has more recently been shown to pose a danger to persons suffering from kidney disorders.

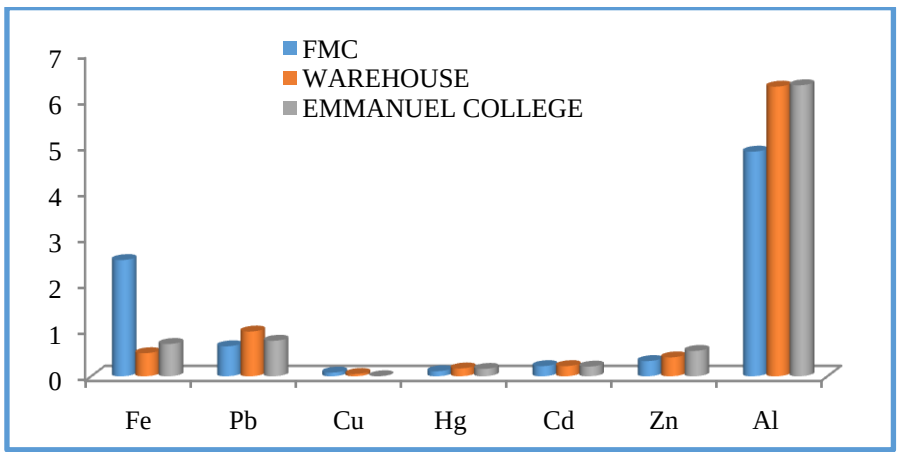


**Figure 6. Chart showing the mean concentration variations for Heavy Metals**

Bioaccumulation of heavy metals in food chain and their toxicity in biological systems due to increased concentration over time have led tremendous pressure for their separation and purification. Heavy metals can enter into water bodies through agricultural runoff, industrial effluents, household uses and from commercial applications. Adverse health implications may result from accumulation of heavy metals overload in human body. The most commonly encountered toxic metals are Arsenic, Lead, Aluminum, Mercury, Cadmium, Copper, Zinc and Iron.

**Table 6. Anthropogenic Activities at Nworie River**

| S/N | Activity | Frequency |
|---|---|---|
| 1. | Cassava fermentation | II |
| 2. | Swimming | II |
| 3. | Drinking water harvesting | II |
| 4. | Fishing | ll |
| 5. | Defecation | IIII |
| 6. | Farming | II |
| 7. | Cloth washing | III |
| 8. | Bathing | IIII |
| 9. | Solid waste disposal | IIII |
| 10. | Palm-wine tapping | III |
| 11. | Lumbering | II |
| 12. | Animal washing | IIII |
| 13. | Sand and gravel mining | IIII |
| 14. | Automobile washing | III |
| 15. | Sewage/ waste water disposal | IIII |
| 16. | Food washing | IIII |
| 17. | Transportation | II |
| KEY: I = Occasional, II = Regular, III = Frequent, IIII = Very frequent, - = Nil | | |

## Conclusions

Nworie River is under the influence of anthropogenic activities like: cassava fermentation, swimming, drinking water, harvesting, fishing, defecation, farming, cloth washing, bathing, solid waste disposal, palmwine tapping, lumbering, animal washing, sand and gravel mining, automobile washing, sewage and waste disposal, food washing and transportation. Properties such as colour, pH, turbidity, conductivity, Nitrate, phosphate, sulphate, Total Hardness, iron and copper where not in conformity with the WHO permissible limits in the river. Although some of the investigated physicochemical parameters were in conformity with WHO limits yet those depending on the river should always purify and sterilize the water from the studied river before usage in order to free it from both physicochemical and microorganism contaminants.

Study carried out on Nworie River using the mean values of physicochemical parameters shows that the percentage safety for consumption of the water is 44%, which is below 50%. This goes to tell us that the water is not safe for consumption. Considering the values of pH result from the three water samples which were below the WHO drinking water standard of 2011, with mean value of 5.66, goes to tell us that the water is Nworie River is acidic and should be properly treated before consumption or usage. Since the water is not portable for drinking, the pH of the water can be raised using soda ash.

Generally, it is observed that the concentration of sodium, chloride, sulphate and nitrates is on the increase as urbanization increases. This increase is attributed to surface water flowing from the farmlands, recreation areas, industrial effluent and the indiscriminate disposal of solid wastes into the rivers. The contamination of the river would end by an immediate stoppage of disposal of wastes into the river, planned waste disposal and properly managed landfill programs.

**Acknowledgement**
My personal effort alone would not have led in completing this project work. My sincere gratitude goes to my supervisor, Prof. C.A. Ahiarakwem,my head of Department, and other lecturers in whose advice and supervision enabled me to complete this work. My profound gratitude goes to my parent, Engr. and Mrs. A.C. Agudozie, course mates and Popoola, John. I appreciate all your efforts and encouragements. Finally, to God who made it all possible.

## References

1. Ahiarakwem, C.A. and Onyekuru, S.O. 2011. A comparative assessment of the physico-chemical and microbial trends in Njaba River, Niger Delta Basin, Southeastern Nigeria. Journal of Water Resource and Protection, 3(09): 686-693**.**
2. Akaninwor, A.M. and Egwim, B.O. 2006. Ground water studies Elizabethan press Benin Nigeria pp 50.
3. American Public Health Association (APHA). 2012. Standard methods for the examination of water and waste water (20th edition) Port city Press Baltimore USA.
4. Carrol, D. 1962. Rain water as a chemical agent of geological process. A review, US Geological Survey water supply papers. Nos. 15 & 16, 336-338pp.
5. Durov, S.A. 1948. Natural waters and graphical representation of their composition. Dokl. Akad. Nauk. USSR 59: 87-90.
6. Essa, K.A. 1999. Lead, the ugly trace element, effects, screening and treatment. Eastern Mediterranean Health Journal, 5(4): 798-802.
7. Ezemonye, M. N., 2009. Surface and GW quality of Enugu urban area. Unpublished Ph.D Thesis, Department of University of Nigeria Nsukka.
8. Ferguson, J.E. 1990. The heavy Elements: Chemistry, Environmental Impact and Health Effects. Pergamon Press, London, 614 p.
9. Ibe, I.C. 1992. Environmental contamination and other anthropogenic impacts on Otamiri and Nworie River, Owerri Nigeria. Nigeria Journal of Mining and Geology. 28: 87-91.
10. Ibeh, J. 2017. Hydrogeotechnical Characterization of Parts of Otamiri River Bank and its Environmental Implications in Owerri Area, Southeastern Nigeria. An Unpublished Master's Thesis of Department of Geosciences, Federal University of Technology, Owerri, Imo State.
11. Ibeh, L.M. and Mbah, C.N., 2007. surface water characteristics of urban river Enugu, southeastern Nigeria. World Journal of Biotechnology 8(2): 1412–1417.
12. Reyment, R.A. 1965. Aspect of geology of Nigeria. Elizebetan. Press Benin, Nigeria, 30p.