



An Evaluation of the Spatial Distributions of the Physico-Chemical and Microbial Contents of Nworie River in Owerri, Southeastern Nigeria

**S. O. Onyekuru^{1*}, C. N. Okereke¹, S. I. Ibeneme¹, A. O. Nnaji²,
C. Z. Akaolisa¹, C. A. Ahirakwem¹, M. O. Ibecheozo¹ and L. N. Ukiwe³**

¹Department of Geosciences, Federal University of Technology, Owerri, Imo State, Nigeria.

²Departmental of Environmental Technology, Federal University of Technology, Owerri, Imo State, Nigeria.

³Department of Chemistry, Federal University of Technology, Owerri, Imo State, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Authors SOO, MOI and CZA designed the study. Authors CAA and CNO performed the statistical analysis, wrote the protocol. Author SOO wrote the first draft of the manuscript and managed literature searches. Authors SII, AON and LNU managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

Original Research Article

Received 4th April 2014

Accepted 7th June 2014

Published 5th July 2014

ABSTRACT

Water quality assessment of a tropical river arises due to the importance of such rivers as main sources of water for domestic, agricultural, tourism and industrial purposes. The spatial distribution of the physical, chemical and microbial contents of Nworie River water was assessed to ascertain its suitability for the intended uses. Three sets of eight raw water samples collected at pre-designated points on the river were analyzed using the Atomic Absorption Spectrophotometer (AAS) and flame photometry to determine the concentrations of cations (Ca^{2+} , Mg^{2+} , Fe^{2+} , Na^+ and K^+) and anions (CO_3^- , SO_4^{2-} , Cl^- and NO_3^-). Digital Meters were used to determine pH, conductivity and Total Dissolved Solids, while Standard Plate Counts were employed to ascertain the extent of bacterial loads in the Nworie River water. The results of the analyses indicated that average pH, conductivity and Total Dissolved Solids (TDS) of Nworie River water were 7.00, 22.62 $\mu\text{S}/\text{cm}$ and 28.85 mg/l, respectively. Mean concentrations of analyzed cations (Ca^{2+} , Mg^{2+} , Na^+ and K^+) were 10.23, 7.51, 3.36 and 5.40 mg/l, respectively, while the mean

*Corresponding author: E-mail: samuel.onyekuru@futo.edu.ng;

concentrations of analyzed anions (CO_3^- , SO_4^{2-} , Cl^- and NO_3^-) were 16.13, 4.48, 5.72 and 5.40 mg/l, respectively. Characterization of the river water, therefore, followed the trend of $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{K}^+ > \text{Na}^+$, for the cations and $\text{CO}_3^- > \text{NO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$ for the anions. These trends indicated that Nworie River water is predominantly CaCO_3 water. Other physical attributes in terms of odour, however, is satisfactory, while colour and turbidity fell short of the recommended standards for safe drinking water. The coloured and turbid Nworie River water resulted from high concentrations of iron (Fe^{2+}), which ranged from 2.97 - 4.80 mg/l. The Sodium Adsorption Ratio (SAR) of 0.19 is indicative of excellent quality of the river water for irrigation purposes. Bacteriological analysis indicated the dominance of aerobic bacteria and *E. coli*. Some of the samples collected from other sampling stations however, showed satisfactory counts indicating that bacterial contamination arose from point sources. The generally increased Coliform Counts and high iron contents were the major environmental problems observed in the Nworie River water. These degradations are associated with increased anthropogenic activities on the Nworie River Watershed within the period in focus.

Keywords: Tropical; River; physico-chemical; characterization; degradation and anthropogenic.

1. INTRODUCTION

Water quality assessments of tropical rivers arise due to the importance of such rivers as main sources of water for domestic, agricultural, tourism and industrial purposes [1]. The Nworie River in Owerri area, no doubt, has been a favourable site for fishing and sand mining activities, while also serving as a veritable source of water for drinking and other domestic uses for the teeming population living on its watershed. Wastes are also discharged into the river from many sources, including leachate from waste disposal sites, industries and institutions. It has been observed from groundwater flow modeling that chemically-conservative material released at abandoned disposal sites would still have impact on groundwater/surface water quality unless the sites were abandoned and reactivated [2]. Thus, continued discharge of effluents and leachate into Nworie River would definitely impair the quality of the resource.

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 [1]. These parameters are expected to exhibit large uncertainties due probably to contaminant sources and/or the natural attenuation capacity of the river water system [3]. It is therefore probable that the concentration of the contaminants along the flow line of Nworie River will vary spatially.

It had been noted that contaminant mass is a poor indication of a potential environmental damage [4]. A better representation of the potential problem is given by the degree of environmental degradation revealed from groundwater and surface water quality studies [4].

1.1 Aim and Objective of the Study

Periodic water quality monitoring of Nworie River is aimed at revealing the extent of degradation of the surface water system from anthropogenic and/or natural impacts. The

main objective of this study, therefore, is to assess the pollution vulnerability of the Nworie River water through water sampling and analysis as a basis for evolving appropriate protection strategy for the resource.

The study will ensure that a tropical river like Nworie River would be able to satisfy its intended uses.

1.2 Location of Study

Nworie River is a major surface water system that drains some parts of Owerri municipality and adjoining communities in Imo State, Nigeria. It flows south-eastwards through Coca Cola Bottling Company near Irete and drains through communities like Egbeada, Akwakuma and Amakohia, institutions like the Federal Medical Centre (FMC), Alvan Ikoju Federal College of Education (AIFCE) and FUASON Iron/Aluminium Company at the Orlu/Bank Road junction. Shortly before the Nworie River empties into Otamiri River, it flows past the Holy Ghost and Emmanuel Colleges, Owerri. The entire watershed of Nworie River lies between Latitudes 5°46' and 5°67'N and Longitudes 7°01' and 7°15'E. The river course, however, covers an area of about 5km² from its source to the point where it empties into the Otamiri River to form a confluence (Fig. 1).

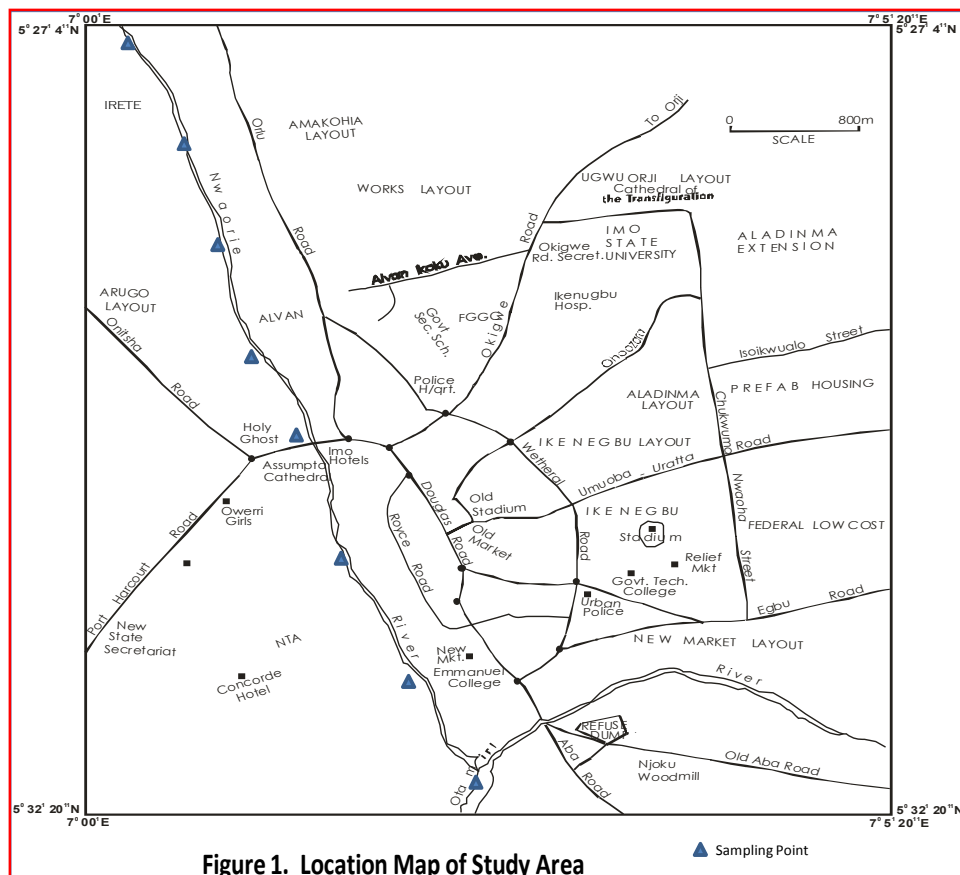


Fig. 1. Location map showing Nworie and Otamiri rivers watershed [5]

1.3 Geology

The study area is underlain by the Benin Formation which is a major lithostratigraphic unit in the Niger Delta Basin (Fig. 2). The Benin Formation which is Pliocene to Miocene in age consists of friable sands with intercalations of shale/clay lenses [6]. It also contains some isolated units of gravels, conglomerates and very coarse sands [7]. The sand grains have an average mineralogical composition of about 98% (unreactive) quartz minerals [8]. Hence, any degradation in the quality of surface and groundwater systems in the study area is a direct result of human impacts and/or natural interventions.

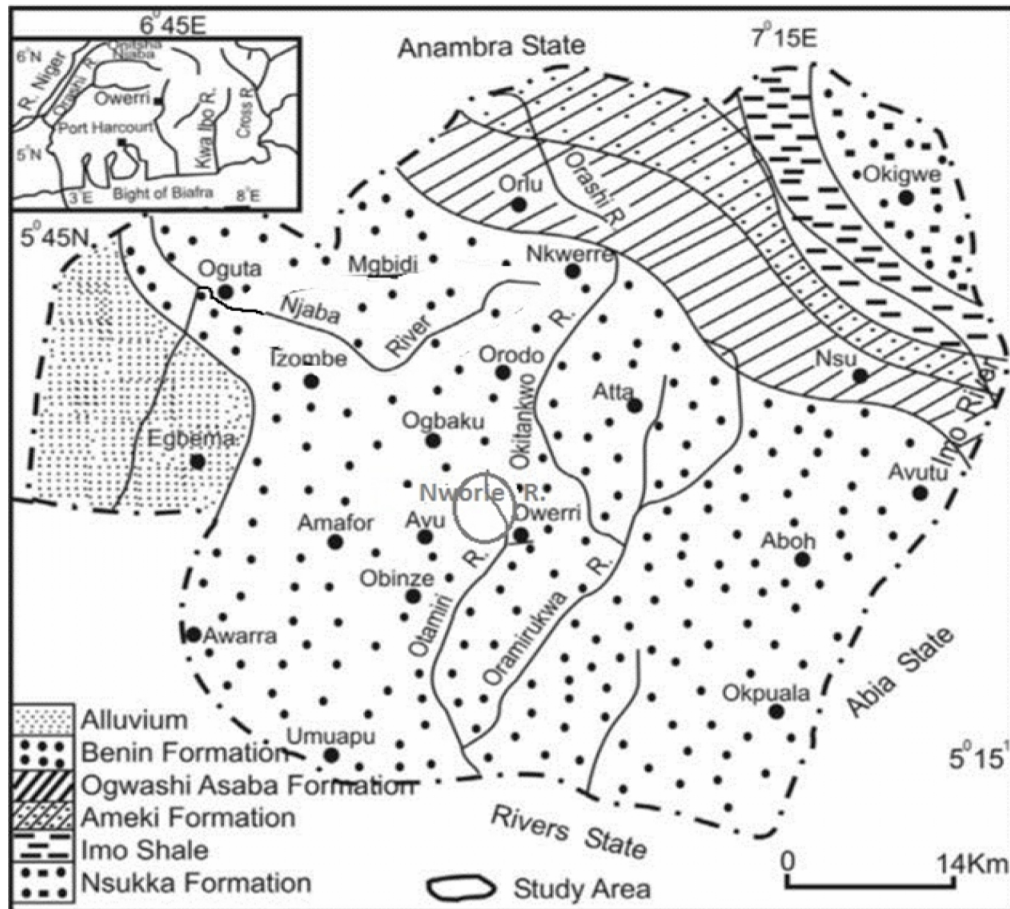


Fig. 2. Geological map of Imo State showing the study area [3]

2. MATERIALS AND METHODS

2.1 Water Sampling and Preparation

Treated water sampling bottles were used in the collection of three sets (Nwo-1_{a, b, c} - Nwo-8_{a, b, c}) of eight raw water samples at pre-designated points along the course of Nworie River. The sampling was done in the dry season, precisely between February and March, 2012. Sampling started at the confluence between the Otamiri and Nworie Rivers (Nwo-1), near

Emmanuel College Owerri and progressed in the north-western direction at an average distance of about 800 m before terminating at a location around Irete (Nwo-8) at the north-western end of the watershed.

Three sets of the samples labelled A, B and C were collected from each sampling station for cation, anion and microbial analyses, respectively. The sample sets for microbial analysis (Sample C) from each of the eight locations were acidified with drops of HNO₃ to prevent self-culturing and multiplicities in case organisms were present in the samples. The samples were subsequently kept at a temperature of about 4°C for four days before microbial analysis was conducted on them.

2.2 Laboratory Analyses

The prepared raw water samples were subjected to different kinds of analyses in the laboratory. The total dissolved and total suspended solids were analyzed by centrifugal method while total hardness was determined by titrimetry. Cations (Ca, Mg and Fe) and other heavy metals were analysed with the Atomic Absorption Spectrometry (AAS) model 210 VGP, while Na and K were determined by Flame Photometry method using photometry model Jenway PF97/L.

The anions were analyzed using different methods. For example, Chloride was analyzed by titration using the Argentometric method. Fluoride was determined with the SPANDS method colorimetrically and Nitrate was analyzed by colorimetric method using phenolsulphuric acid. Bicarbonate ions were determined by calculations from phenolphthalein and total alkalinity. Determination of the amount of sulphate was done by the turbidity method while that of phosphate was done by the colorimetric method using vanado-molybdate method.

The microbial parameters were analysed using the Standard Plate Counts to define coliform bacteria (total coliform and faecal coliform bacteria) and aerobic bacteria groups. A dilution factor of 10⁻² was used for all the samples while plate counts ranged between 8 and 40.

3. RESULTS AND DATA ANALYSIS

3.1 Physicochemical and Heavy Metal Analysis

The concentrations of the physicochemical and heavy metal parameters obtained at the different sampling points (Nwo-1 to Nwo-8) along the course of Nworie River are shown in Table 1.

The results showed that values of the Hydrogen Index (pH) obtained at 28°C ranged from 6.84 - 7.20. Concentrations of major cations like Potassium, Sodium, Calcium and Magnesium ranged from 4.40 – 6.66, 2.77 – 4.10, 8.44 – 11.48 and 6.06 – 8.66 mg/l respectively (Table 1). The concentrations of major anions in the raw water samples ranged from 5.01 - 6.48 mg/l (Cl⁻); 4.30 – 5.91 mg/l (SO₄²⁻); 8.52 -11.14 mg/l (NO₃⁻) and 17.90 – 14.03 mg/l (CO₃²⁻).

The detected heavy metal assemblages in the water samples are Iron (2.97 – 4.80 mg/l), Lead (0.01 -0.06 mg/l) and Copper (0.006 – 0.13 mg/l) (Table 1).

Table 1. Physicochemical properties of Nworie River Water

Parameters	Nwo-1	Nwo-2	Nwo-3	Nwo-4	Nwo-5	Nwo-6	Nwo-7	Nwo-8	Mean	WHO STD (2006)
Physical										
pH (28°C)	6.91	7.20	7.03	6.84	7.01	7.12	6.90	7.01	7.00	6.50-9.00
Turbidity (NTU)	45.24	39.60	39.41	43.45	33.20	30.46	42.81	32.50	38.33	50
Conductivity (ms)	28.62	22.32	22.18	25.34	20.13	18.67	24.65	19.01	22.62	1400
Chemical (mg/l)										
Potassium (K ⁺)	4.40	5.38	4.61	5.42	4.73	6.00	5.98	6.66	5.40	50
Sodium (Na ⁺)	3.38	3.26	3.43	2.94	2.77	3.16	4.10	3.81	3.36	500
Chlorides (Cl ⁻)	5.04	6.10	6.34	5.01	5.28	6.00	6.48	5.54	5.72	500
Sulphates (SO ₄ ²⁻)	4.82	4.40	5.04	4.30	3.86	3.02	5.91	4.47	4.48	400
Nitrates (NO ₃ ⁻)	8.52	10.31	10.77	9.96	11.01	8.00	11.14	9.94	9.92	40-70
Bicarbonates (CO ₃ ²⁻)	16.01	17.66	16.40	16.64	15.32	14.03	17.90	15.10	16.13	500
Calcium (Ca ²⁺)	11.34	10.19	11.15	10.01	9.61	8.44	11.48	9.58	10.23	200
Magnesium (Mg ²⁺)	8.05	8.13	7.22	8.66	7.73	6.06	7.30	6.94	7.51	150
Total Hardness	19.39	18.13	18.37	18.67	17.34	14.50	18.78	16.52	17.74	<150
Total dissolved solids	30.75	28.84	29.00	29.91	26.60	24.47	29.88	26.01	28.18	1500
Total Suspended Solids (TDS)	11.36	10.14	11.01	11.28	9.35	8.84	11.24	8.63	10.23	50
Iron (as Fe ²⁺)	4.21	4.800	3.860	3.110	2.970	4.560	3.33	4.04	3.86	0.05
Lead (pb ²⁺)	0.01	0.012	0.020	0.014	0.023	0.016	0.060	0.033	0.024	0.05
Copper (Cu ²⁺)	0.05	0.010	0.006	0.13	0.012	0.044	0.008	0.011	0.03	0.05
Mercury (Hg ²⁺)	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	
Cadmium (Cd ²⁺)	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	

N.d = Not detected

The mean concentrations (in mg/l) of the major cations and anions and heavy metal constituents of the river water were subsequently compared with the World Health Organisation Standards for safe drinking water (WHO, 2006) (Table 1) to ascertain the potability of the river water for domestic and other uses.

3.2 Bacteriological Analysis

The result of bacteriological analysis (Table 2) showed that Nworie river water is contaminated at some sampling points by total coliform bacteria, faecal coliform bacteria and aerobic bacteria.

Table 2. Microbial constituents of Nworie River water in colonies/ml

Sample no.	Plate count	Streptococci faecal count	Clostridium Welchi count	Salmonella Count	Vibrio count	<i>E. coli</i> count	Other Coliform count
Nwo-1	25	NIL	NIL	NIL	NIL	1 colony	NIL
Nwo-2	30	NIL	NIL	NIL	NIL	10 colonies	NIL
Nwo-3	40	NIL	NIL	NIL	NIL	16 colonies	4 colonies
Nwo-4	13	NIL	NIL	NIL	NIL	NIL	NIL
Nwo-5	16	NIL	NIL	NIL	NIL	NIL	NIL
Nwo-6	26	NIL	NIL	NIL	NIL	5 colonies	NIL
Nwo-7	8	NIL	NIL	NIL	NIL	NIL	NIL
Nwo-8	16	NIL	NIL	NIL	NIL	NIL	NIL

4. DISCUSSION

The hydrogen index (pH) is a parameter that indicates the acidity or alkalinity of a water sample. The operational guideline recommends a pH range of 6.5 - 9.0 for any water to be considered safe for drinking and other domestic uses [9]. This is to ensure that water meant for drinking and other domestic uses is neither corrosive nor capable of causing incrustation in facilities. The distribution of pH along the sampled stations of Nworie River is fairly constant, ranging from 6.84 – 7.20, with a mean value of 7.00 (Table 1). This result falls within the desirable World Health Organisation [9] Standard for safe Drinking water.

Calcium Carbonate (CaCO_3) is readily soluble in water especially in environments with abundant H^+ . The concentration of this compound expressed by the cation (Ca^+) and anion CO_3^{2-} met the WHO (2006) standard. Hence, Nworie River water would readily form lather with soap. The mean concentrations of Potassium, Sodium and Magnesium also fell within the standards prescribed by the [9] for safe drinking water. The situation is indicative of low input of these cations from anthropogenic sources, like agricultural activities.

Iron as Fe^{2+} in the Nworie River water has a mean concentration of 3.86 mg/l. It is also the most abundant heavy metal component of Nworie River (Table 1 and Fig. 3). This value is anomalously high and above the limit of 0.3 mg/l prescribed by the [9] Standards for safe drinking water and other domestic uses. The sources of the iron in the river water could be the result of unregulated discharge of effluents from the numerous industries in the adjoining industrial layout in Irete and that from the defunct FUASON Aluminium Industries located at the bank of Nworie River, near Holy Ghost College, Owerri. The excessive iron is capable of polluting boreholes in areas where there exist interconnectivity between surface and groundwater systems [10]. The Nworie River water should therefore, be subjected to

treatment to remove iron before use. The distribution of other physical attributes in Nworie River water is also related to the high iron content. The turbid (brownish) Nworie River water and the observed high conductivity (Table 1) are the direct result of precipitation of Fe^{3+} when the river water is oxidized. Total Dissolved Solids (TDS) refer to the soluble inorganic substances in the Nworie River water. The principal constituents of TDS are chloride, sulphate, calcium, magnesium, Iron (Fe^+) and bicarbonates.

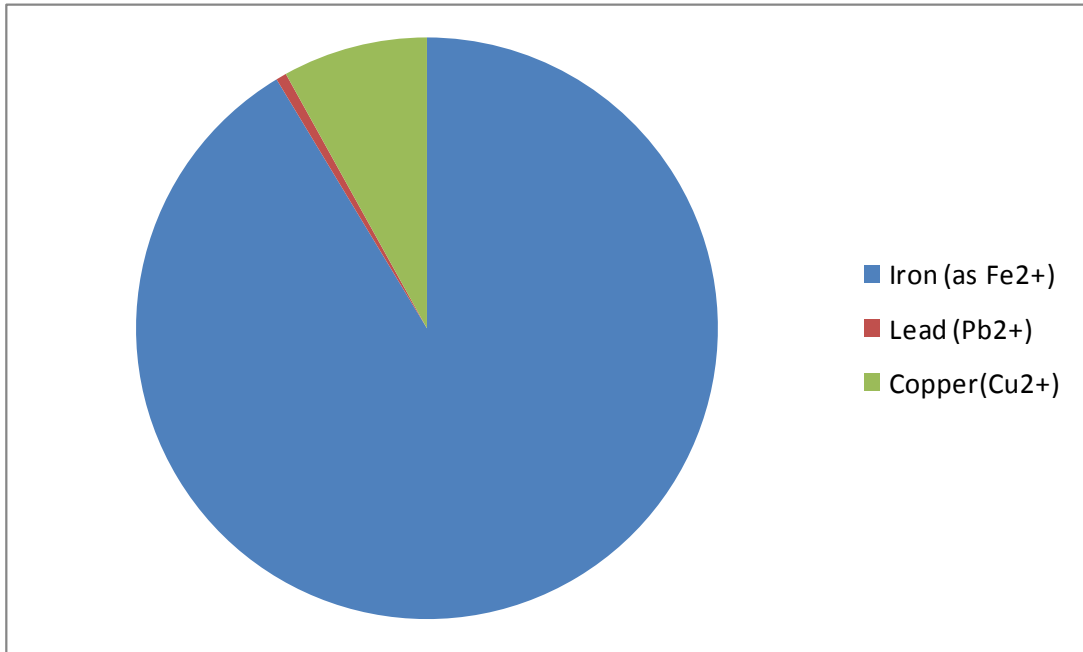


Fig. 3. Pie chart showing the relative abundance of heavy metals in nworie river water

The mean concentration of TDS in Nworie River water is 28.18 mg/l, which is substantially below the recommended value of 500 mg/l [9]. The TDS value of the river water was used to classify the Nworie River water as fresh water (Table 3; [11]).

The Sodium Absorption Ratio (SAR) employed to determine the suitability of the water for irrigation purposes indicated that the Nworie River water has a mean SAR value of 0.19. Accordingly, the water is classified as excellent for irrigation purposes [12].

Table 3. Showing the classification of water based on TDS [11]

Water Name	Concentration total dissolved solids in parts per million
Fresh	0 – 1000
Brackish	1000 – 10,000
Salty water	10,000 – 100, 000
Brine	More than 100, 000

The mean values of major cations: Ca^{2+} , Mg^{2+} , Na^+ and K^+ of the river water in the year under focus (2012) were 10.23, 7.51, 3.36 and 5.40 mg/l, respectively (Fig. 4). And the mean

values of major anions: CO_3^- , SO_4^{2-} , Cl^- and NO_3^- were 16.13, 4.48, 5.72 and 5.40 mg/l, respectively (Fig. 5).

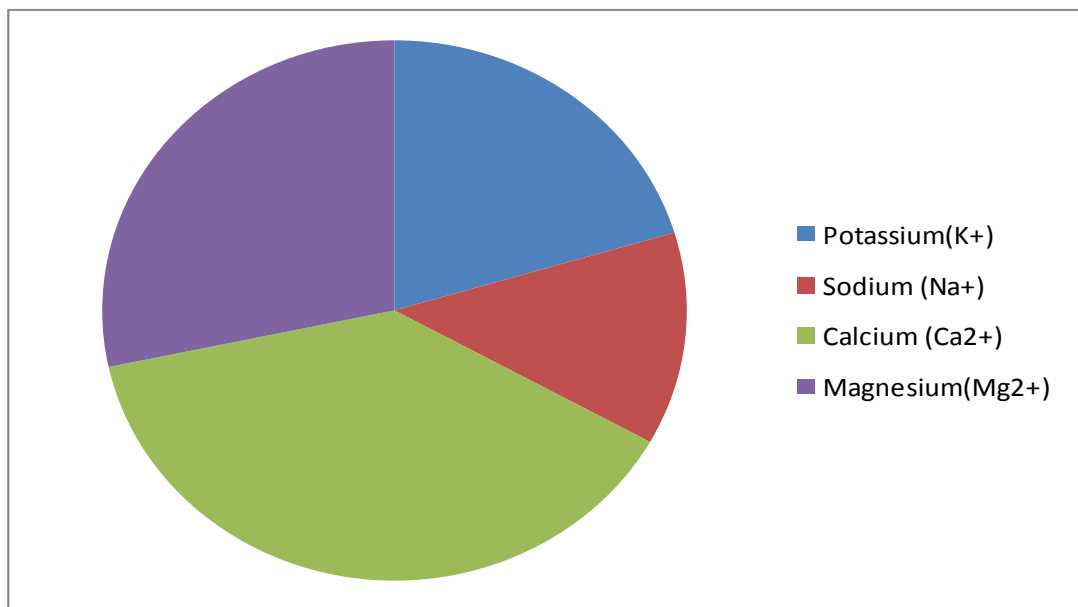


Fig. 4. Pie chart showing the relative abundance of Cations in Nworie River

Water characterisation of the river water, therefore, followed the trend: $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{K}^+ > \text{Na}^+$ (for the cations) and $\text{CO}_3^- > \text{NO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$ (for anions), indicating that Nworie River water is predominantly CaCO_3 water.

The nutrient level of the river indicated by the concentrations of nitrates and phosphates is very low; which shows that the Nworie River has very low eutrophication level.

The individual and composite samples of the Nworie River water plotted within the potable water zone of the diamond portion of the Piper Trilinear diagrams (Figs. 6 and 7). The diagrams also revealed the close relationships in the chemistry of the river water as the samples clustered in an area within the potable water zone of the diamond portion of the diagrams.

A further confirmation of this close relationship in the chemical characteristics of the river water is shown in the Stiff diagrams (Figs. 8 and 9). The diagrams have similar shapes, though with slight variations in size as a result of increased doses of some of the constituents in the samples.

The results of bacteriological analysis result showed that Nworie River water is contaminated at some sampling points by total coliform bacteria, faecal coliform bacteria and aerobic bacteria. The total coliform bacteria are a collection of relatively harmless micro-organisms that live in large numbers in the intestines of warm and cold blooded animals. The faecal coliform bacteria are a specific subgroup of the total coliform bacteria, whose commonest member is *Escherichia coli* (*E. coli*). *E. coli* are associated only with the faecal materials of warm-blooded animals such as man, cow, etc. The faecal coliform bacteria are not

pathogenic but are usually used as indicators of the probable presence of other pathogenic bacteria. The presence of *E. coli* in Nworie River, therefore, is indicative that the Nworie River water has been contaminated by faecal material from man and/or animals. Such contamination is an indication that a potential health risk exists for individuals using the untreated water for domestic purposes.

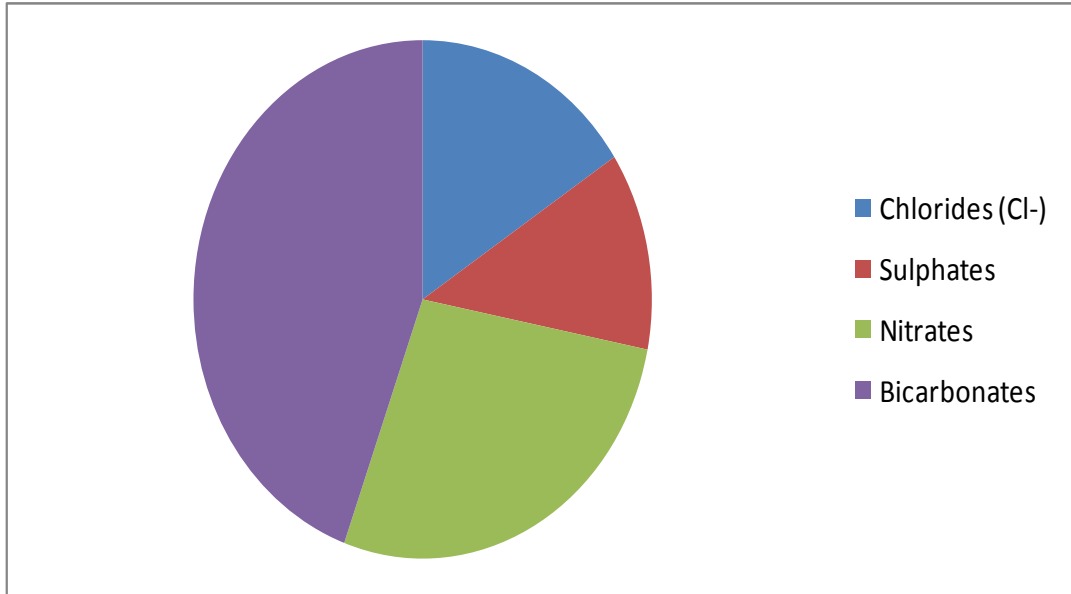


Fig. 5. Pie chart showing the relative abundance of anions in Nworie River

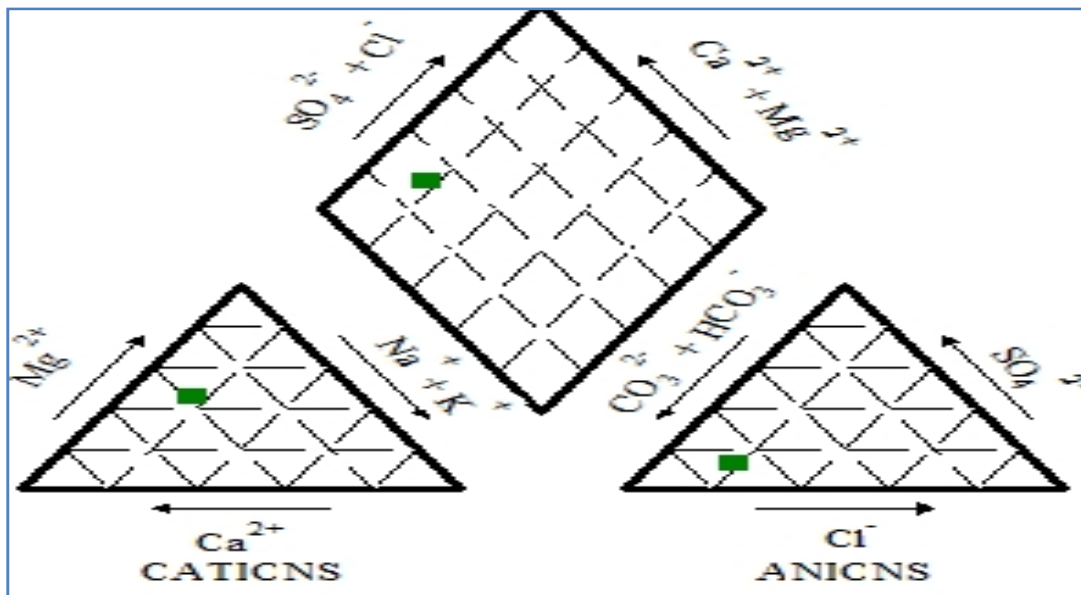


Fig. 6. Representative Trilinear diagram using Nwo-1 raw water sample

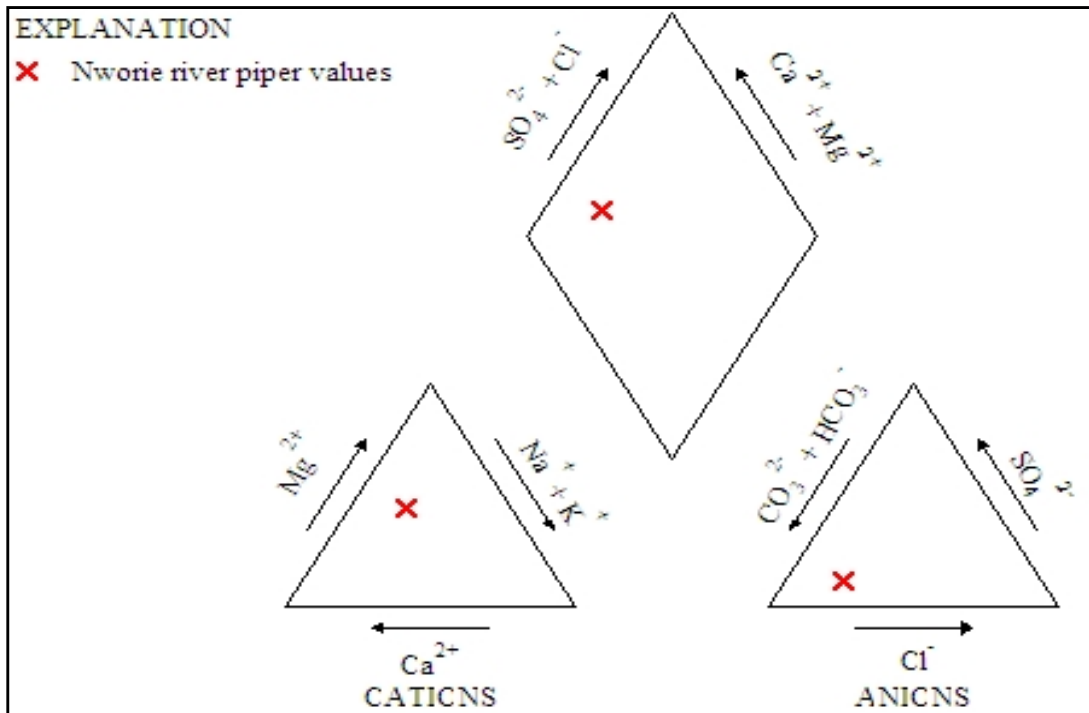


Fig. 7. Trilinear diagram of the mean concentrations of the chemical constituents of Nworie River Water

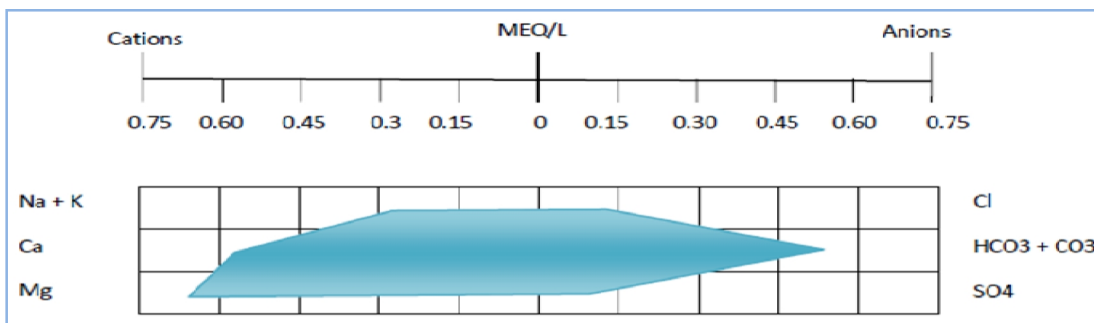


Fig. 8. Representative stiff diagram for NWO-1 (Confuence of Otamiri and Nworie Rivers)

The spatial distributions of the bacterial counts along the Nworie River water (Fig. 10) showed random variations in the number of faecal coliform bacteria counts recorded with respect to sampling points. This variability is suggestive that the bacteriological contamination of Nworie River water is from point sources. For example, the high counts recorded at Nwo-3 are expected as the sampling point is within the Alvan Ikoku Federal College of Education and the Federal Medical Centre, Owerri where the probability of discharging faecal materials into the Nworie River by students and patients is high.

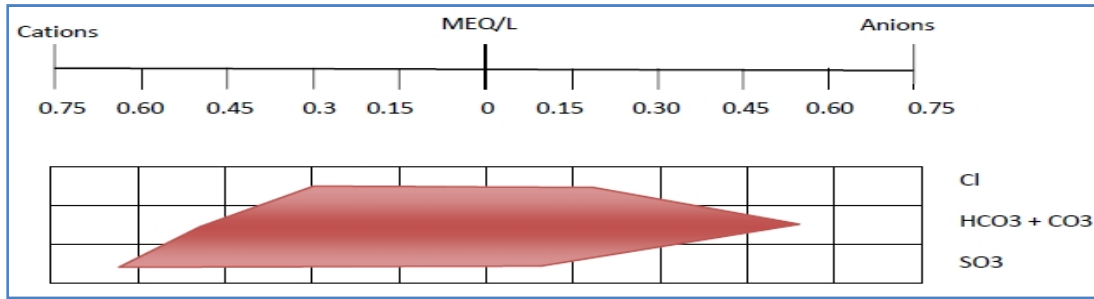


Fig. 9. Stiff diagram representing the mean concentrations of the sampled points

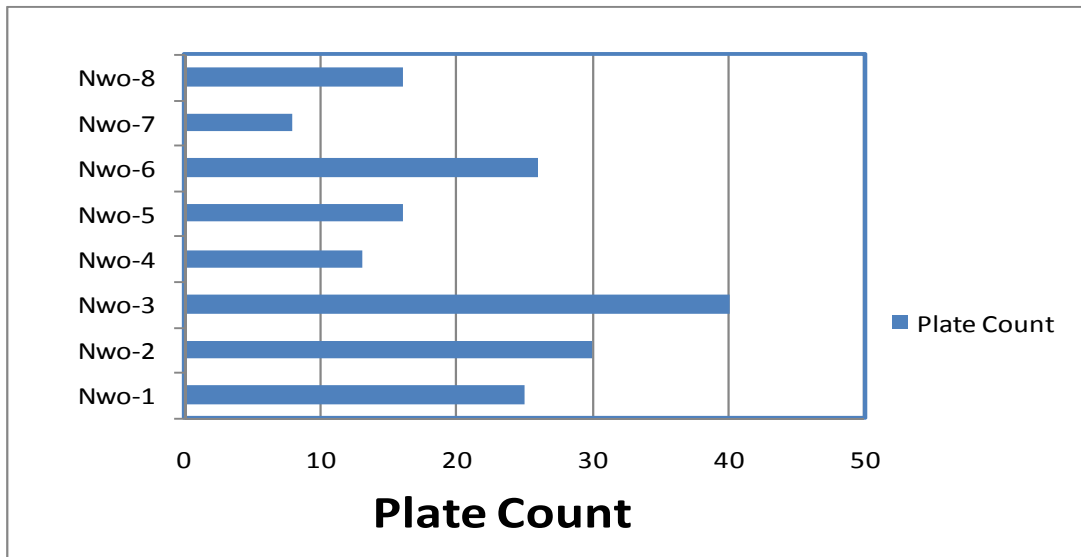


Fig. 10. Chart showing the spatial distribution of bacterial contents of Nworie River

Stations Nwo-4, 5, 7 and Nwo-8 have satisfactory results because of the absence of faecal coliform (Table 2). The low number of faecal bacteria colonies observed at points 1 and 6 further supports the spatial variability observed along the course of Nworie River water. These stations are within areas with minimal human activities.

5. CONCLUSION

Nworie River is a major surface water system in Owerri and its environs. It provides water for domestic, agricultural and industrial activities.

The appraisal of the physicochemical, heavy metal and bacteriological contents of Nworie River water was thus undertaken to ascertain the suitability of the river water for these uses. The result of the analyses showed that the values of Hydrogen Index (pH) and the concentrations of most of the analysed physical and chemical constituents of the river water satisfied the [9] standards for safe drinking water. The potability of the river water was also validated by the Piper trilinear diagrams.

Water characterisation showed that Nworie River is predominantly CaCO_3 water while nutrient levels in the river water showed very low eutrophication.

Sodium Absorption Ratio (SAR) indicated that Nworie River water is excellent for irrigation purposes.

Iron as Fe^{2+} in the Nworie River water, however, has anomalously high values that are above the limits for safe drinking water and other domestic uses. Similarly, results of bacteriological analysis showed that the river water is contaminated by total coliform bacteria, faecal coliform bacteria and aerobic bacteria.

These impairments are an indicative that a potential health risk exists for individuals using the untreated Nworie River water for domestic purposes.

6. RECOMMENDATION

In order to ensure the sustainable development of the surface water resource in Owerri area, it is recommended that:

1. River pollution abatement programmes including the prohibition of discharge of untreated effluents and solid wastes into the Nworie River.
2. Conventional water treatment methods should be used to treat Nworie River water before being used for domestic purposes.
3. Periodic measurement and monitoring of the concentration of the aspects of Nworie River is required to forestall pollution impacts.
4. Irrigation projects are recommended in the Nworie River watershed based on the values of Sodium Absorption Ratio (SAR).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ahirakwem CA, Onyekuru SO. A comparative assessment of the physico-chemical and microbial trends in Njaba River, Niger delta basin, Southeastern Nigeria. *Journal of Water Resource and Protection*. 2011;3:686-693.
2. Howard KWF, Livingstone S. Impact of Urban development on surface water as a result of shallow groundwater flow- a case study from the great lakes basin of North America, in congress of the international association of hydrogeologists, 25th adelaide, proceedings. *International Association of Hydrogeologists*. 1994;1:133–139.
3. Ibe KM, Nwankwor GI, Onyekuru SO. Groundwater pollution vulnerability and groundwater protection strategy for the Owerri Area, Southeastern Nigeria, In: *Water resources systems-water availability and global change. Proceedings of Symposium I IS02a Sapporo, IAHS*. 2003;280:184-194.
4. Villumsen A, Sonderskov C. Vulnerability maps. A Promising Tool in Groundwater Protection', *Aqua*. 1982;5:406–468.
5. Imo State Government of Nigeria (IMSGN). *Atlas of Imo State of Nigeria*, ministry of works and transport. Department of Lands, Survey and Urban Development, Owerri, Imo State, Nigeria. 1984;116.

6. Asseez IO. Review of the stratigraphy, Sedimentation and structure of the Niger Delta In: Kogbe CA (Ed). Geology of Nigeria Elizabethan pub Co. Lagos. 1976;259-273.
7. Ananaba SE, Onu NN, Iwuagwu CJ. Geophysical study of the gravel deposits in Ihiagwa, Owerri, Nigeria. Journal of Mining and Geology. 1993;29:95-100.
8. Uma KO, Egboka BCE. Water Resources of Owerri and its Environs, Imo State, Nigeria. Journ Min Geol. 1986;22(1-2):57-64.
9. World Health Organization Standard. Drinking water guidelines. Geneva. 2006;6.
10. Freeze RA, Cherry JA. Groundwater, prentice-hall, Englewood cliffs. New Jersey; 1976.
11. Gorrell HA. Classification of formation waters based on sodium chloride content. AAPG Bull. 1958;42:251.
12. United States Department of Agriculture. Classification of water for Irrigation Purposes based on Sodium Ad-sorption Ratio (SAR). 1965;20.

© 2014 Onyekuru et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:

<http://www.sciencedomain.org/review-history.php?iid=588&id=5&aid=5194>