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# Water Quality Assessment of Epie Creek in Yenagoa Metropolis, Bayelsa State, Nigeria

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***Authors' contributions***

*This paper was based on part of M.Sc project work of the lead author VNBE, supervised by the second author LTK. Authors SCI and BOE carried out the statistical analysis. While author VNBE wrote the initial draft. Author LTK edited the manuscript. All authors read and approved the final manuscript.*

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## ABSTRACT

This study evaluated the physicochemical and microbial quality of water samples from Epie creek, Niger Delta. Water samples were collected from five different locations (Akenfa, Agudama-Epie, Tombia, Opolo and Biogbolo) in two seasons viz: dry i.e. January and February and wet season i.e. May and June, 2016). The samples were analyzed following standard procedure. Results from the water quality ranged from 5.80- 7.01 (pH), 0.12 mg/l-2.58 mg/l (salinity), 265.00 -1096.75 µS/cm (conductivity), 31.29-105.04NTU (Turbidity), 133.00-548.50 mg/l (total dissolved solid), 3.74-10.562 mg/l(total suspended solid), 6.23-7.17 mg/l (dissolved oxygen), 65.17-94.95 mg/l (biological oxygen demand), 121.72-252.80 mg/l, (chemical oxygen demand), 6.504-14.30 mg/l (sulphate), 0.63-1.69 mg/l (nitrate), 2.18-4.28 mg/l (Bicarbonate), 15.25-61.75 mg/l (chloride), 19.20-62.00 mg/l (Alkalinity), 52.86-280.00 mg/l (Total hardness), 16.53-43.09 mg/l (calcium), 3.07-10.46 mgl (magnesium), 3.34-16.02 mg/l (sodium), 2.06-5.26 mg/l (potassium), 0.32-2.52 mg/l

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(iron), 0.016-0.188 mg/l (manganese), Analysis of variance showed that there was significance difference (P<0.05) in most of the location, months and interaction. The values showed that anthropogenic activities (mostly from marketing wastes in the creek is having an impact on the water quality).

*Keywords: Anthropogenic activities; epie creek; surface water; wastes*

## 1. INTRODUCTION

Pollution is a major threat to environmental sustainability. Environmental pollution is majorly caused due to anthropogenic activities and to lesser extent human activities in the environment. Probably due industrialization, urbanization and population growth, the activities of human in the environment have increased leading to impact on land/soil, air and aquatic ecosystem.

Aquatic ecosystem gets contaminated from direct activities in the ecosystem and indirectly through runoff after precipitation. Water could be contaminated indirectly when substances that could alter water quality parameter and affect the diversity/composition and abundance of fisheries and planktons. For instance, the use of pesticides close to aquatic ecosystem and/ or ruff of improper discharge of empty cans of pesticides could affect end up the water bodies nearby and may affect fisheries [1-9]. Direct anthropogenic activities that affects water quality includes domestic and industrial effluents [10-15], dredging [16-17], oil and gas activities [18-19], food processing effluents such as oil palm [20-22], cassava processing, market etc.

Market activities generate several wastes stream predominant solid wastes. The wastes often lead to odour via decomposition. In Bayelsa state, most markets are located close to surface water. Most of the wastes generated from the marketing activities often end up in the water bodies. This waste has the tendency to affect water quality parameters including microbial, general physicochemistry and heavy metals. Depending on the composition of the wastes, it could also cause eutrophication and acidification. Others water structures such as sediment could be affected. Typically, sediment occurs as deposited or suspended sediment [23-25].

Typically water is useful resources needed for the sustenance of life [26-33]. Water is also a habitat for several biodiversity. Water is also essential for growth and development of the human body [30]. Most of the water resources mostly utilized in developing country like Nigeria include surface, ground and rain water. The level of use of each type of water depends mainly on its availability.

Several studies have been carried out in some surface water in Bayelsa state. Some of these include Ikoli creek [27,34,35], Epie creek [36], Kolo creek [18,26,34,37,38], Igbedi creek [39], Nun river [28,29], Efi lake [40,41], Taylor creek [42], Sagbama creek [33].

But due constant urbanization and increased anthropogenic activities in these water resources, there the need to frequently assess the water quality. Hence, the study updates the physicochemical characteristics of Epie creek, Niger Delta, Nigeria.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

Epie creek is one of the major essential surface water in Bayelsa state (Fig. 1). The creek is connected to several creeks in the region such as Ikoli creek and Taylor creek. The creek serves as a receiver of poorly managed wastes and the water is also used for drinking, bathing, recreational and transportation activities [36]. Other activities carried out in the creek fishing, canoeing/boating. The creek is also receiver of several wastes stream.

### 2.2 Sample Techniques

Water samples were collected from five direct locations of the creek stretching from Akenfa to Biogbolo between January and February 2016 (dry season) – May and June 2016 (wet season). Based on locations, there are major market activities aligning the water body apart from Biogbolo. The water samples were collected with 1 litre bottle. The samples were transported to the laboratory in an ice chest for laboratory analysis.


**Fig. 1. Map of Yenagoa local government area showing water sampling points along Epie creek, Bayelsa state**

## 2.3 Analysis of Water Samples

The water quality parameters were analyzed in-situ viz: pH, conductivity, dissolved oxygen, salinity, turbidity, total dissolved solid, using multimeter. While Total suspended solid, nitrate, chloride, sulphate, bicarbonate, alkalinity, total hardness, calcium, potassium, magnesium, sodium, chemical and biological oxygen demand using the method previously described by APHA [43], Ademoroti [44]. Iron and manganese was analyzed using atomic adsorption spectrophotometer.

## 2.4 Statistical Analysis

SPSS software version 20 was used to carry out the statistical analysis of the physicochemical parameters of the water samples. Two-way analysis of variance was carried out at $P = 0.05$, and Duncan's multiple range test (DMR) was used to determine source of the observed differences were n=4 for spatial distribution and n=5 for monthly distribution. Spearman correlation matrix was used to identify the relationship between the physicochemical parameters of the water. The chart for the physicochemical parameters was plotted using Paleontological statistics software package by Hammer et al. [45]. The standard error bar was determined at 95% interval level.

## 3. RESULTS AND DISCUSSION

General physicochemical water quality parameter of Epie creek from Akenfa to Biogbolo in Yenagoa Metropolis, Bayelsa state, Nigeria is presented in Table 1. While the Spearman's correlation coefficient (r) matrices for the analyzed physicochemical parameters and p-value (significance level) of the statistics carried out are presented in Tables 2 and 3 respectively. The monthly (January and February i.e. dry season and May and June wet season) variation is presented in Figs. 2–22.

**Table 1. General physicochemical water quality parameter of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

| Parameters | Akenfa | Agudama-Epie | Tombia Junction | Opolo | Biogbolo |
|---|---|---|---|---|---|
| pH | 6.27±0.26a | 6.34±0.25ab | 6.53±0.26b | 6.46±0.17ab | 6.43± 0.31ab |
| Salinity, $mgl^{-1}$ | 0.17±0.06a | 0.12±0.01a | 0.55±0.36a | 2.58±0.22a | 0.16±0. 02a |
| Conductivity, $\mu Scm^{-1}$ | 340.50±89.93a | 265.00±27.61a | 1096.75±645.80a | 671.25±195.90a | 358.50±39.74a |
| Turbidity, NTU | 105.04±72.74a | 36.67±2.93a | 39.87±3.61a | 36.31±3.59a | 31.29±1.71a |
| TotalDissolvedSolid, $mgl^{-1}$ | 170.40±45.07a | 133.00±13.72a | 548.50±322.85a | 336.00±98.01a | 179.38±19.95a |
| TotalSuspendedSolid, $mgl^{-1}$ | 6.38±2.20a | 4.86±1.31a | 6.07±1.70a | 6.98±1.46a | 6.61± 1.31a |
| Nitrate, $mgl^{-1}$ | 0.91±0.29a | 0.90±0.28a | 1.69±0.73a | 1.44±0.43a | 1.05±0. 30a |
| Chloride, $mgl^{-1}$ | 17.00±4.0a | 15.25±4.52a | 61.75±24.03b | 32.00±6.01ab | 24 .00±5.89ab |
| Sulphate, $mgl^{-1}$ | 10.33±1.48ab | 7.30±0.68a | 13.53±3.11b | 14.30±2.93b | 7.5 8±0.67a |
| Bicarbonate, $mgl^{-1}$ | 2.18±0.23a | 2.28±0.38a | 4.28±0.50b | 3.28±0.50ab | 2.93± 0.42ab |
| Alkalinity, $mgl^{-1}$ | 38.00±11.43a | 24.25±7.26a | 59.50±15.06b | 38.00±8.74a | 3 0.25±8.66a |
| Total Hardness, $mgl^{-1}$ | 165.33±43.65ab | 121.68±38.98a | 209.00±42.80b | 147.08±57.69a | 136.75±59.49a |
| Calcium, $mgl^{-1}$ | 17.32±1.03a | 16.53±3.53a | 43.09±13.21b | 27.09±4.06ab | 1 9.53±2.89a |
| Magnesium, $mgl^{-1}$ | 3.81±0.65a | 3.07±0.65a | 10.46±3.34b | 6.88±1.07ab | 5.36 ±0.83a |
| Sodium, $mgl^{-1}$ | 4.74±1.06a | 3.80±0.72a | 16.02±9.05a | 8.78±3.66a | 5.53±1 .11a |
| Potassium, $mgl^{-1}$ | 2.44±0.43ab | 2.24±0.48a | 5.26±1.86b | 3.54±0.42a | 3.12± 0.39a |
| Iron, $mgl^{-1}$ | 1.09±0.53ab | 1.07±0.50ab | 1.39±0.71b | 0.98±0.46ab | 0.87 ±0.37a |
| Manganese, $mgl^{-1}$ | 0.15±0.08a | 0.11±0.06a | 0.10±0.06a | 0.05±0.02a | 0.05±0 .02a |
| Dissolved Oxygen, $mgl^{-1}$ | 7.17±0.15c | 6.68±0.10abc | 6.23±0.15a | 6.38±0.17ab | 7.0 8±0.52bc |
| Biological Oxygen Demand, $mgl^{-1}$ | 74.10±1.87b | 65.17±3.21a | 94.95±2.01d | 82.16±2.07c | 88 .53±4.06cd |
| Chemical Oxygen Demand, $mgl^{-1}$ | 192.95±15.21a | 168.75±10.45a | 183.23±65.45a | 219.63±2 1.89a | 242.23±31.27a |

*Data are expressed as mean ± standard error (n=4); Different letters(a,b,c) across the row indicate significance variation (P<0.05) according to Duncan multiple range test*

**Table 2. Spearman correlation matrix of the physicochemical water quality parameters studied**

| Parameters | pH | Sal | Cond | Turb | TDS | TSS | $NO_3$ | Cl | $SO_4$ | $HCO_3$ | Alkalinity | TH | Ca | Mg | Na | K | Fe | Mn | DO | BOD | COD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1 | | | | | | | | | | | | | | | | | | | | |
| Salinity | .194 | 1 | | | | | | | | | | | | | | | | | | | |
| Cond. | .263 | .901$^{**}$ | 1 | | | | | | | | | | | | | | | | | | |
| Turbidity | -.108 | .206 | .110 | 1 | | | | | | | | | | | | | | | | | |
| TDS | .263 | .901$^{**}$ | 1.000$^{**}$ | .110 | 1 | | | | | | | | | | | | | | | | |
| TSS | -.557$^{*}$ | .220 | .119 | .467$^{*}$ | .119 | 1 | | | | | | | | | | | | | | | |
| $NO_3$ | -.332 | .467$^{*}$ | .418 | .347 | .418 | .479$^{*}$ | 1 | | | | | | | | | | | | | | |
| Cl | .233 | .527$^{*}$ | .658$^{**}$ | -.321 | .658$^{**}$ | -.251 | .293 | 1 | | | | | | | | | | | | | |
| $SO_4$ | -.156 | .615$^{**}$ | .604$^{**}$ | .581$^{**}$ | .604$^{**}$ | .485$^{*}$ | .704$^{**}$ | .172 | 1 | | | | | | | | | | | | |
| $HCO_3$ | .198 | .561$^{*}$ | .776$^{**}$ | -.158 | .776$^{**}$ | -.094 | .401 | .880$^{**}$ | .295 | 1 | | | | | | | | | | | |
| Alkalinity | -.587$^{**}$ | .327 | .297 | .410 | .297 | .759$^{**}$ | .616$^{**}$ | .229 | .597$^{**}$ | .298 | 1 | | | | | | | | | | |
| Total Hardness | -.268 | -.108 | .015 | -.384 | .015 | -.094 | -.108 | .532$^{*}$ | -.205 | .338 | .349 | 1 | | | | | | | | | |
| Ca | .110 | .608$^{**}$ | .720$^{**}$ | -.093 | .720$^{**}$ | -.044 | .445$^{*}$ | .916$^{**}$ | .483$^{*}$ | .853$^{**}$ | .443 | .449$^{*}$ | 1 | | | | | | | | |
| Mg | .353 | .547$^{*}$ | .701$^{**}$ | -.313 | .701$^{**}$ | -.247 | .206 | .961$^{**}$ | .205 | .854$^{**}$ | .187 | .431 | .896$^{**}$ | 1 | | | | | | | |
| Na | .039 | .463$^{*}$ | .424 | .371 | .424 | .273 | .546$^{*}$ | .068 | .587$^{**}$ | .264 | .332 | -.465$^{*}$ | .268 | .164 | 1 | | | | | | |
| K | .460$^{*}$ | .543$^{*}$ | .568$^{**}$ | -.368 | .568$^{**}$ | -.423 | .123 | .886$^{**}$ | .132 | .670$^{**}$ | .013 | .352 | .815$^{**}$ | .895$^{**}$ | .116 | 1 | | | | | |
| Fe | .810$^{**}$ | .270 | .328 | .096 | .328 | -.487$^{*}$ | -.198 | .136 | -.014 | .119 | -.482$^{*}$ | -.357 | .011 | .257 | .110 | .333 | 1 | | | | |
| Mn | .597$^{**}$ | .340 | .322 | .343 | .322 | -.169 | -.213 | -.010 | .111 | -.016 | -.280 | -.319 | -.075 | .082 | -.118 | .128 | .828$^{**}$ | 1 | | | |
| DO | -.607$^{**}$ | -.379 | -.470$^{*}$ | -.190 | -.470$^{*}$ | .152 | -.165 | -.438 | -.245 | -.525$^{*}$ | .068 | .087 | -.453$^{*}$ | -.470$^{*}$ | -.038 | -.391 | -.388 | -.440 | 1. | | |
| BOD | .211 | .501$^{*}$ | .605$^{**}$ | -.211 | .605$^{**}$ | .031 | .126 | .705$^{**}$ | .078 | .706$^{**}$ | .313 | .321 | .615$^{**}$ | .795$^{**}$ | .244 | .609$^{**}$ | .222 | .130 | -.321 | 1 | |
| COD | -.564$^{**}$ | .030 | .005 | -.166 | .005 | .511$^{*}$ | .294 | .014 | .072 | .038 | .450$^{*}$ | .170 | .045 | -.007 | .046 | -.174 | -.493$^{*}$ | -.479$^{*}$ | .384 | .131 | 1 |

**. Correlation is significant at the 0.05 level (2-tailed).*
***. Correlation is significant at the 0.01 level (2-tailed).*
*N=20*

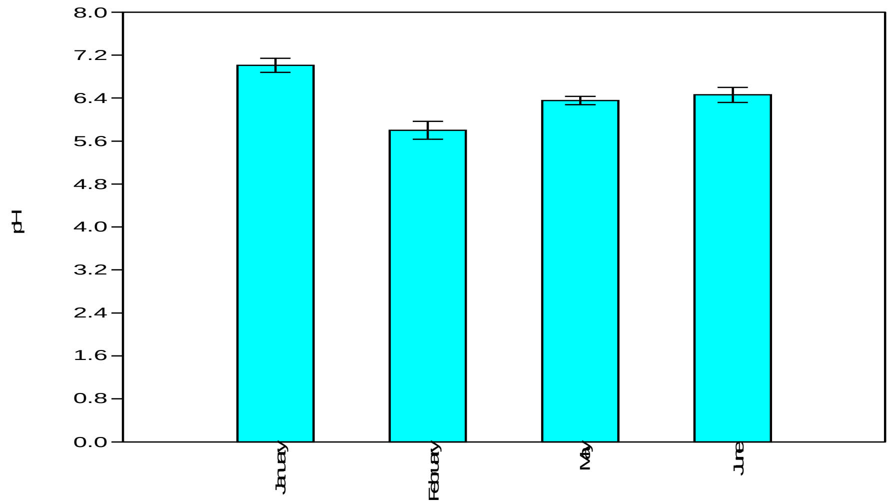


**Fig. 2. pH monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

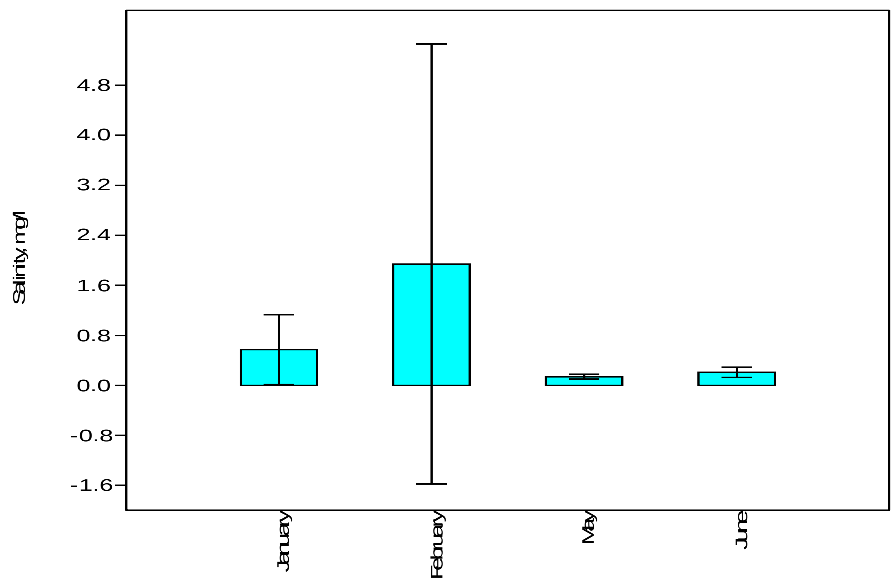


**Fig. 3. Salinity monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

### 3.1 pH

The pH of Epie creek i.e. from Akenfa to Biogbolo ranged from 6.27 – 6.53 for spatial distribution, while on monthly distribution, pH ranged from 5.80 – 7.01 (Fig. 2). Significance difference ($P<0.05$) exist at monthly distribution and interaction between spatial and monthly distribution. However no significant variation ($P>0.05$) in the spatial distribution for pH was observed (Table 3). The pH of water sample shows positive relationship with iron and manganese at $P<0.01$, potassium at $P<0.05$ and negative relationship with total suspended solid at $P<0.05$ and, total alkalinity, dissolved oxygen and chemical oxygen demand at $P<0.01$ (Table 2). The difference (i.e. monthly distribution and interaction between location and months) could be associated with the amount of acidic material leached into the water from various human activities in both seasons as well as dilution effects resulting from changes in season.

Based on location, lack of difference suggests similar pattern of activities in the various communities from which the samples were obtained. The pH values in this study are comparable to the values previously reported in some surface water in Bayelsa state. Some of the values ranged from 7.4 – 7.6 from Tombia bridge construction area [39], 7.11 – 7.32 from dredging site in Igbedi creek [17], 6.61 – 6.793 from Kolo creek [26], 6.95 - 7.50 for lower Kolo creek [37], 5.87 – 6.21 for spatial distribution and 6.02 (wet season) and 6.03 (dry season) for seasonal distribution from Kolo creek [38], 5.53 – 6.85 from Ikoli creek receiving effluents ([27]), 6.910 – 7.350 from Nun river [28], 6.525 – 7.105 from River Nun in 2007 [29], 7.4 – 7.57 (dry season) and 6.9 – 7.33 (wet season) of Epie creek [36], 7.2 from Taylor creek [42], 6.82 - 7.28 from Efi lake of Sabagreia which ranged from 6.55 - 7.20 [41], 6.7 from Efi lake [40]. The similarity of the findings of this work with previous work could be attributed to similarity in life pattern and habits. For instance, surface water is a major receiving end of wastes including sewage in the region. Again based on the work of Izonfuo and Bariweni [36], the Epie creek has not changed significantly with regard to pH.

### 3.2 Salinity

The salinity of Epie creek i.e. from Akenfa to Biogbolo ranged 0.12 – 2.58 mg/l for spatial distribution. While on monthly distribution, the salinity ranged from 0.57 – 1.94 mg/l (Fig. 3). No significance variation (P>0.05) existed at spatial and monthly distribution, and interaction between spatial and monthly distribution (Table 3). The salinity of water sample shows positive correlation with conductivity, total dissolved solid, sulphate, calcium at P<0.01, nitrate, chloride, magnesium, sodium, potassium and biological oxygen demand at P<0.05 (Table 2). No significant variation in location and interaction suggested that the water quality is uniform for all fresh water. The salinity in this study has some similarity with previous works on surface water in Bayelsa state. Some of the salinity values previously reported ranged from 0.003 – 0.007‰ from Kolo creek [26], 0.009 – 0.04‰ for lower Kolo creek [37], 0.01 – 0.03 mg/l from Ikoli creek receiving effluents [27], 0.000 – 0.017 mg/l from Nun river [28], 0.010 – 0.050‰ from River Nun [29], 0.05‰ from Efi lake [40]. The similarity suggests that the water is homogenous i.e. fresh and is not influenced by the anthropogenic activities in the area.

**Table 3. P- value (significance level) for the water quality parameters studied**

| Parameters | Model | Months | Location |
|---|---|---|---|
| Ph | 0.000 | 0.000 | 0.102 |
| Salinity, $mgl^{-1}$ | 0.473 | 0.482 | 0.399 |
| Conductivity, $\mu scm^{-1}$ | 0.215 | 0.193 | 0.266 |
| Turbidity, NTU | 0.497 | 0.410 | 0.489 |
| Total dissolved solid, $mgl^{-1}$ | 0.215 | 0.193 | 0.366 |
| Total suspended solid, $mgl^{-1}$ | 0.000 | 0.000 | 0.263 |
| Nitrate, $mgl^{-1}$ | 0.376 | 0.202 | 0.581 |
| Chloride, $mgl^{-1}$ | 0.163 | 0.458 | 0.091 |
| Sulphate, $mgl^{-1}$ | 0.015 | 0.028 | 0.025 |
| Bicarbonate, $mgl^{-1}$ | 0.099 | 0.758 | 0.035 |
| Alkalinity, $mgl^{-1}$ | 0.002 | 0.002 | 0.021 |
| Total hardness, $mgl^{-1}$ | 0.000 | 0.000 | 0.018 |
| Calcium, $mgl^{-1}$ | 0.190 | 0.652 | 0.087 |
| Magnesium, $mgl^{-1}$ | 0.065 | 0.274 | 0.039 |
| sodium, $mgl^{-1}$ | 0.103 | 0.077 | 0.204 |
| Potassium, $mgl^{-1}$ | 0.190 | 0.259 | 0.175 |
| Iron, $mgl^{-1}$ | 0.000 | 0.000 | 0.162 |
| Manganese, $mgl^{-1}$ | 0.012 | 0.003 | 0.264 |
| Dissolved $mgl^{-1}$ Oxygen, | 0.030 | 0.059 | 0.040 |
| Biological oxygen demand, $mgl^{-1}$ | 0.000 | 0.066 | 0.000 |
| Chemical oxygen demand, $mgl^{-1}$ | 0.236 | 0.209 | 0.286 |

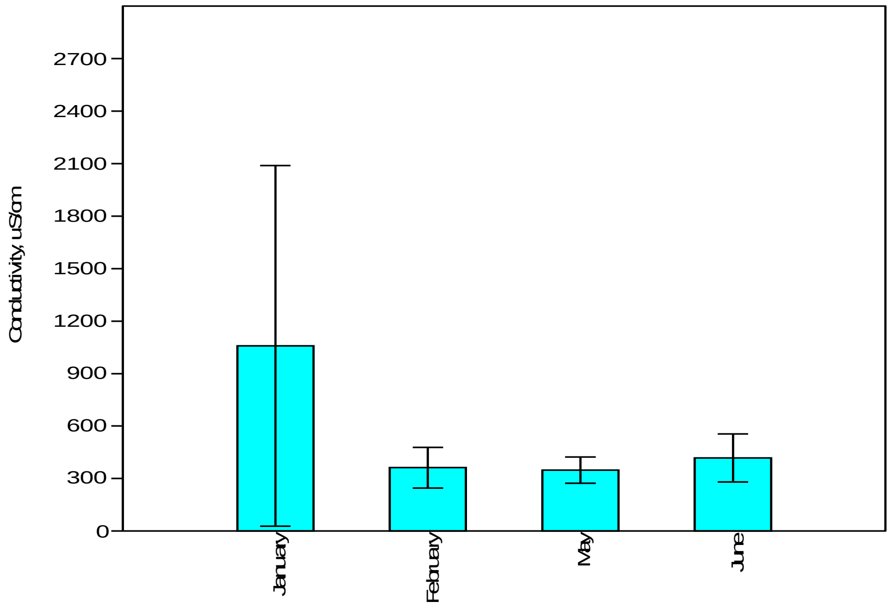


**Fig. 4. Conductivity monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

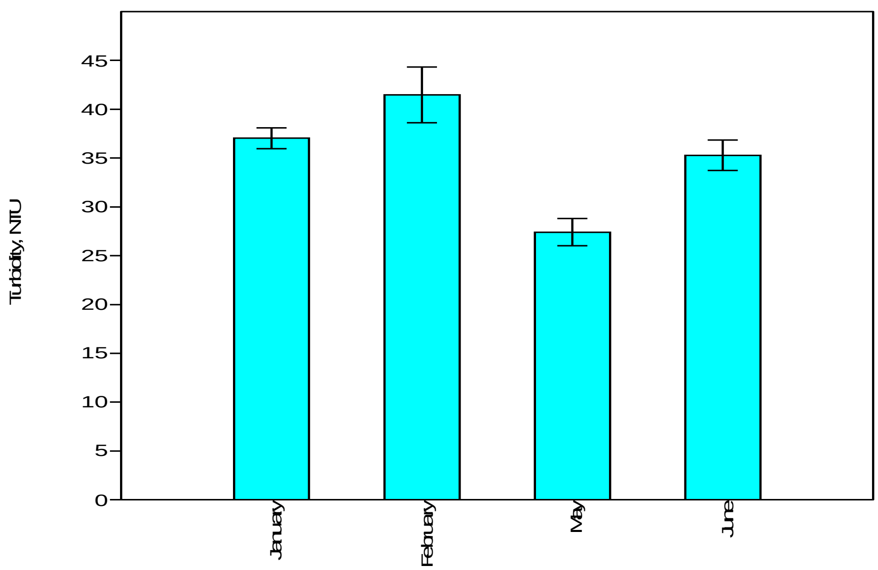


**Fig. 5. Turbidity monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

### 3.3 Conductivity

The conductivity of Epie creek i.e. from Akenfa to Biogbolo ranged from 265.00 – 1096.75 µScm$^{-1}$ for spatial distribution. While in the monthly distribution, the conductivity 347.80 - 1058.60 µS/cm (Fig. 4). No significance variation (P>0.05) exist at spatial and monthly distribution, and interaction between spatial and monthly distribution (Table 3). The conductivity of water sample shows positive correlation with total dissolved solid, sulphate, chloride, biocarbonate, calcium, magnesium, potassium and biological oxygen demand at P<0.01, and

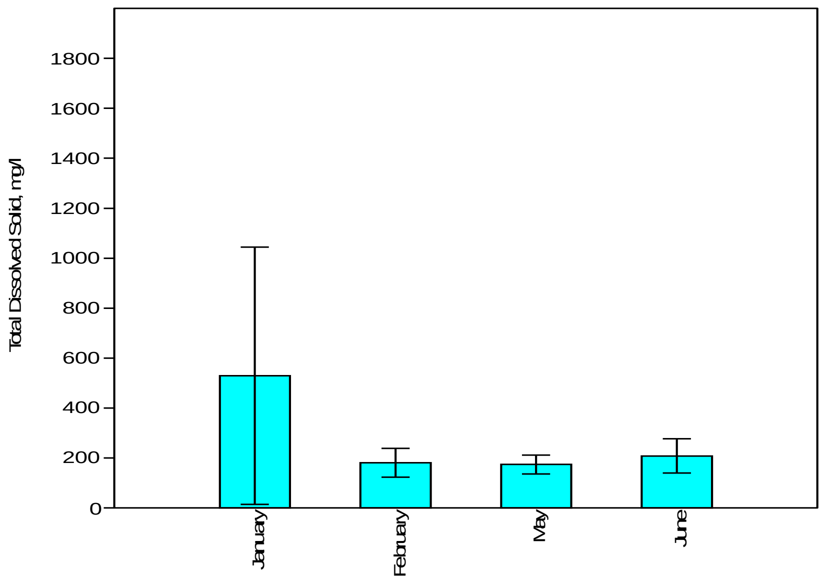


**Fig. 6. Total dissolved solid monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

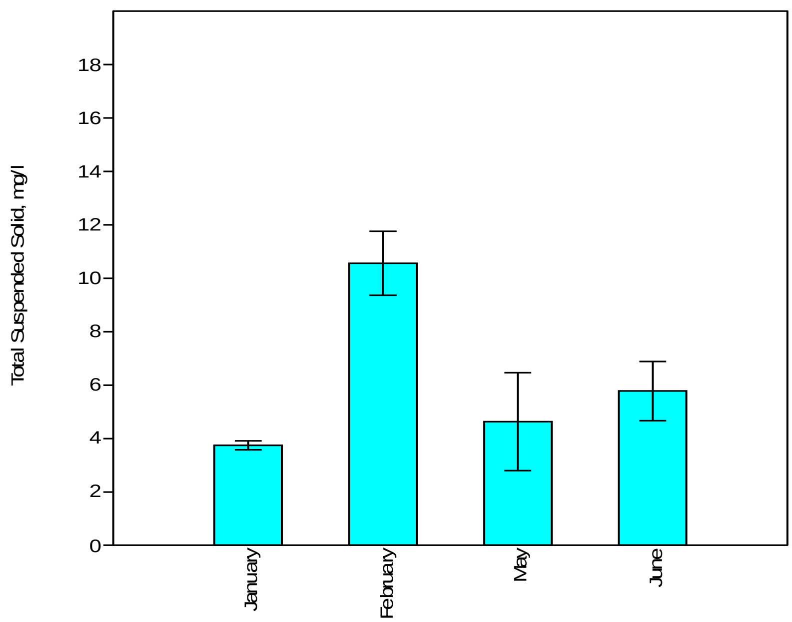


**Fig. 7. Total suspended solid monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

negatively correlate with dissolved oxygen at $P<0.05$ (Table 2). Absence of significant variation in location and interaction suggested that the water quality is uniform and has the same tendency to convey electrical current. The conductivity in this study is higher than the range previously reported by authors in surface water in Bayelsa state. Some values previously reported ranged from 87 – 95 umhos/cm from Tombia bridge construction area [39], 64.91 – 97.41 umhos/cm from dredging area in Igbedi creek [17] 57.3 – 105.0 µS/cm from Ikoli creek receiving effluents [27], 31.60 – 39.167 µS/cm from Kolo creek [26], 82.30 – 102.00 µS/cm from lower Kolo creek [37], 12.50 – 32.50 µS/cm for spatial variation and 18.00 µS/cm (wet season) and 27.10 µS/cm (dry season) for seasonal distribution of water from Kolo creek [38], 33.167 – 68.00 µS/cm from Nun river [28], 78.33 – 89.33 µS/cm (dry season) and 47.73 – 54.00 µS/cm (wet season) from Epie creek in Yenagoa metropolis [36], 48.13 - 68.93 µS/cm from Efi lake [41], 56.075 – 64.950 µS/cm from River nun in 2007 [29], 58.00 µS/cm from Taylor creek [42], 16.7 µS/cm from Efi lake [40]. Generally, the magnitude of conductivity is a useful indication of the total concentration of the ionic solutes [28]. Again the conductivity slightly exceeded the maximum permissible limit for drinking water as recommended by Nigeria Drinking water standards. This suggests that anthropogenic activities and or runoff in the area have affected the Epie creek from Akenfa to Biogbolo area with regard to conductivity.

### 3.4 Turbidity

The turbidity of Epie creek i.e. from Akenfa to Biogbolo ranged 31.29 – 105.04 NTU for spatial distribution. For monthly distribution, the turbidity ranged from 37.028 -93.428 NTU (Fig. 5). No significance variation (P>0.05) existed at spatial and monthly distribution, and interaction between spatial and monthly distribution (Table 3). Turbidity significantly correlate with sulphate at P<0.01 and total suspended solid at P<0.05 (Table 2). The absence of significant variation suggests that the water polluted frequently from wastes materials. Turbidity is a major indicator of the anthropogenic effects such as runoff from construction, agricultural practices, logging and wastes water discharge [39]. The turbidity level observed in this study is comparable to previous works on surface water in Bayelsa state. Some of the values ranged from 58.96 NTU from Taylor creek [42], 103.752 – 117.252 NTU from river Nun and Igbedi from Wilberforce Island [29], 5 – 64 NTU from Tombiabridege construction area [39], 35.95 – 82.32 NTU from dredging area in Igbedi creek [17], 35 – 40.5 from lower Kolo creek [37], 25.70 – 40.53 NTU from Nun river [28], 3.5 – 19.25 NTU based on spatial distribution and 13.40 (wet season) and 6.20 NTU (dry season) from Kolo creek [38], but higher than the range7.87-17.29 NTU from Efi lake [41], 5.00 mg/l from Efi lake [40], 27.367 – 31.800 NTU from Kolo creek [26], 11.67 – 19.67 NTU (dry season) and 16.67 – 28.00 NTU (wet season) from Epie Creek [36]. The variation could be attributed to the different anthropogenic

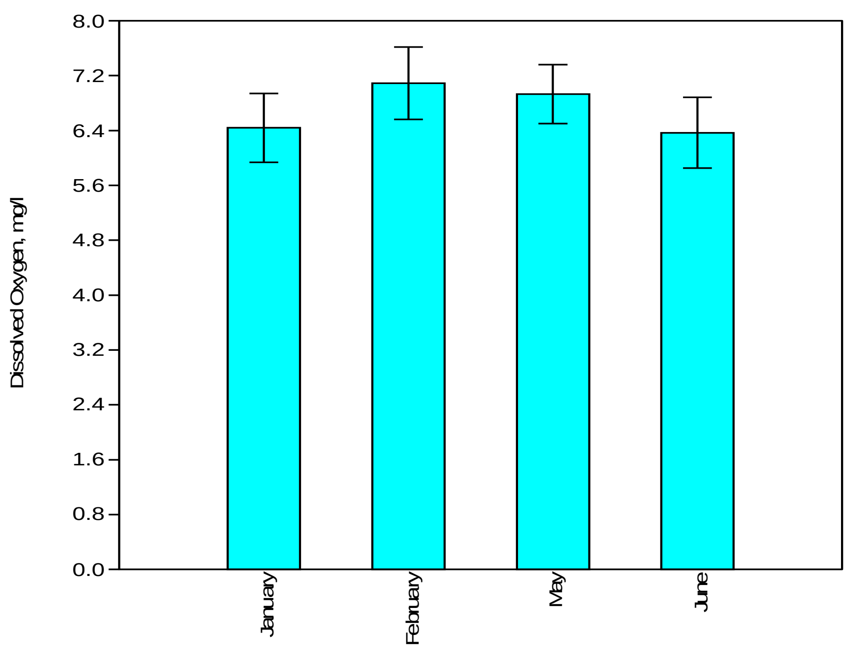


**Fig. 8. Dissolved oxygen monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

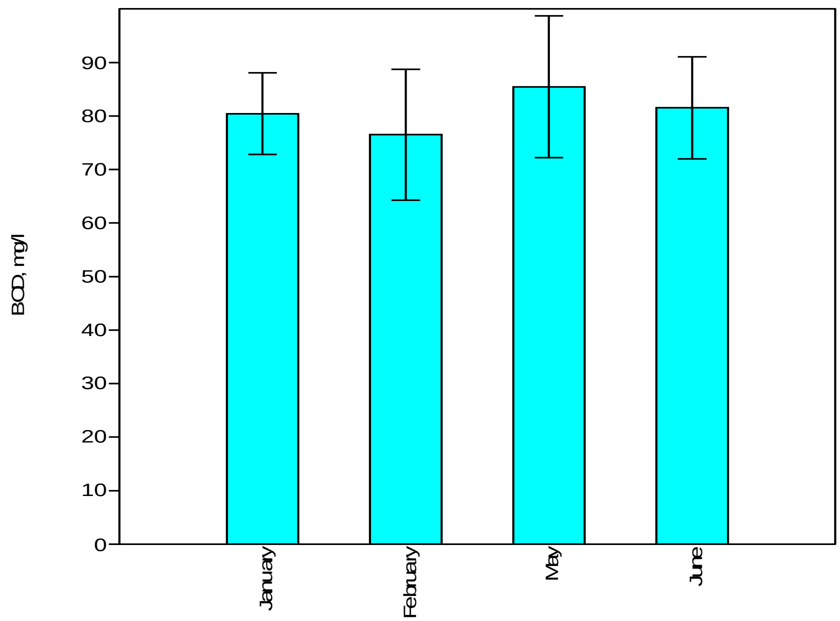


**Fig. 9. Biological oxygen demand monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

activities going on in the water during sampling [28]. The variation in turbidity values might be a reflection of anthropogenic activities of the inhabitants aligning the coastal settlement [28,29].

### 3.5 Total Dissolved Solid

The total dissolved solid of Epie creek i.e. from Akenfa to Biogbolo ranged 133.00 – 548.50 $mgl^{-1}$ for spatial distribution. For the monthly distribution, the total dissolved solid ranged from 174.20 -529.60 $mgl^{-1}$ (Fig. 6). No significance variation ($P>0.05$) exist at spatial and monthly distribution, and interaction between spatial and monthly distribution (Table 3). Total dissolved solid showed significantly correlate with chloride, sulphate, bicarbonate, calcium, magnesium, potassium, biological oxygen demand at $P<0.01$ and negatively correlate with dissolved oxygen at $P<0.05$ (Table 2). Similarity in total dissolved oxygen content suggests that the water has similar dissolved solid across the months under study and spatial distribution. The total dissolved solid in this study is higher than the concentration previously reported in surface water in Bayelsa state. Some of the values ranged from 28.90 mg/l from Taylor creek [42], 10.333 – 34.333 mg/l from River Nun [28], 28.180 – 32.550 mg/l from some rivers around Wilberforce Island [29], 41.45 – 51.0 mg/l from lower Kolo creek [37], 16.10 – 19.23 mg/l from Kolo creek [26], 28.70 – 53.0 mg/l from Ikoli creek receiving effluents [27], 31.93 – 39.48 mg/l from dredging area at Igbedi creek [17], 62.1 – 67.9 mg/l from Tombia bridge construction area [39], 55 - 62 mg/l (dry season) and 33 – 37.33 mg/l (wet season) from Epie creek [36], 54.25 – 102.92 mg/l from Efi lake [41], 8.35 mg/l from Efi lake [40]. The high total suspended solid in this study could be to the fact that high dilution in the surface water and the current intensity of the river play a significant role in the dissolution of solid in water [28]. As such high concentration of total dissolved solid may suggest low flow rate of the water body.

### 3.6 Total Suspended Solid

The total suspended solid of Epie creek i.e. from Akenfa to Biogbolo ranged 4.86 – 6.98 mg/l for spatial distribution. For the monthly distribution, the total dissolved solid ranged from 3.74-10.562 $mgl^{-1}$ (Fig. 7). Significance variation ($P<0.05$) exist at monthly distribution and interaction between spatial and monthly distribution, and no significant difference ($P>0.05$) on spatial distribution (Table 3). Total suspended solid showed significantly correlate with alkalinity at $P<0.01$ and nitrate, sulphate, iron and chemical oxygen demand at $P<0.05$ (Table 2). The variation could be due to difference in amount of material deposited into

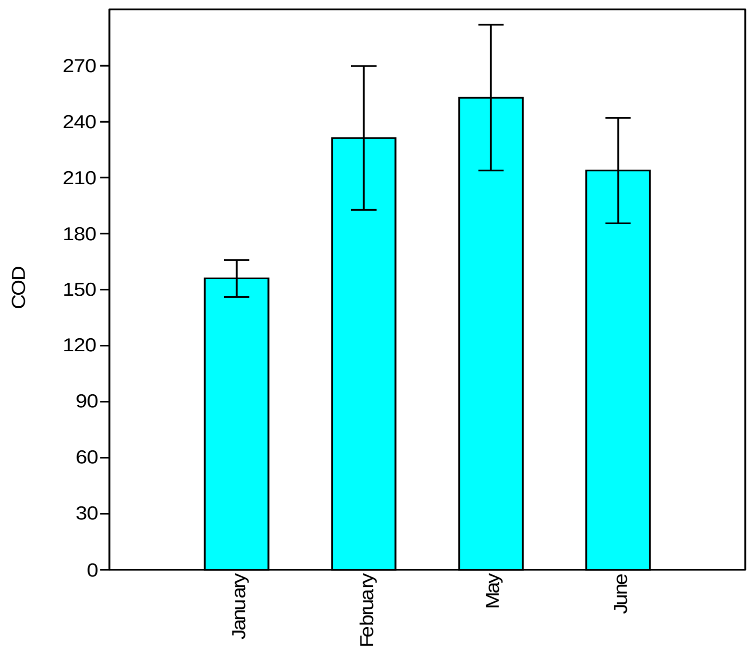


**Fig. 10. Chemical oxygen demand Monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

the water as well as flow rate in each of the months. No variation across location suggests similar flow rate in of the water in all the sampling areas. The total suspended solid in this study is higher than the concentration previously reported in surface water in Bayelsa state. Some of the values ranged from 0.30 $mgl^{-1}$ from Efilake [40], 1.75 – 3.42 mg/l from Kolo creek [26], 0.05 – 0.25 $mgl^{-1}$ from Kolo creek [37], 3.4333 – 5.466 $mgl^{-1}$ from River Nun [28], 2.7 – 4.35 $mgl^{-1}$ from Ikoli creek [27]. The higher total suspended solid in this study could be due low dilution effects.

### 3.7 Dissolved Oxygen

The dissolved oxygen of Epie creek i.e. from Akenfa to Biogbolo ranged from 6.23 – 7.17 $mgl^{-1}$ for spatial distribution. For the monthly distribution, the total dissolved solid ranged from 6.37 - 7.09 $mgl^{-1}$ (Fig. 8). Significance variation ($P<0.05$) exist at spatial distribution and interaction between spatial and monthly distribution, and no significant difference ($P>0.05$) on monthly distribution (Table 3). The changes in the monthly distribution could be associated to the flow rate of the water during the period. The dissolved oxygen in this study is comparable to the concentration previously reported in surface water in Bayelsa state. Some of the values ranged from 5 – 7.92 $mgl^{-1}$ from Kolo creek [37], but lower than the values 10.200 – 14.225 mg/l from River Nun [29], 9.07 – 19.52 $mgl^{-1}$ from Efi lake [41], and higher than the values of 2.7 – 4.1 $mgl^{-1}$ from dredging area in Igbedi creek [17], 4.8 – 5.2 mg/l from Tombia bridge construction area [39], 1.76 – 5.68 mg/l (dry season) and 1.38 – 9.06 mg/l (wet season) from Epie Creek [36], 5.69 mg/l from Taylor creek [42], 2.78 – 4.08 mg/l for spatial distribution and 3.01 mg/l (wet season) and 3.53 mg/l (dry season) for seasonal variation from Kolo creek [38]. The high dissolved oxygen observed from this study could be associated to the time of the sampling (i.e afternoon) [29].

### 3.8 Biological Oxygen Demand

The biological oxygen demand of Epie creek i.e. from Akenfa to Biogbolo ranged from 65.17 – 94.95 mg/l for spatial distribution. While on monthly distribution, the total dissolved solid ranged from 76.512 – 85.46 mg/l (Fig. 9). Significance variation ($P<0.05$) exist at spatial distribution and interaction between spatial and monthly distribution, but no significant difference ($P>0.05$) on monthly distribution (Table 3). The changes in the monthly distribution could be associated to the flow rate of the water during the period as well as the pollution index. The biological oxygen demand in this study is higher than the concentration previously reported in surface water in Bayelsa state. Some of the values ranged from 1.00 – 2.40 mg/l for spatial distribution and 1.55 mg/l (wet season) and 1.52 mg/l (dry season) for seasonal variation from Kolo creek [38], 4.24 mg/l from Taylor creek [42], 1.53 – 6.77 mg/l (dry season) and 0.31 – 4.29 6mg/l (wet season) from Epie Creek [36], 2.6 – 2.9 mg/l from Tombia bridge construction area [39], 2.4 – 4.7 mg/l from dredging area in Igbedi creek [17], 1.50 - 3.35 mg/l from Lower Kolo creek [37]. The higher Biological Oxygen Demand in this study is a function of the amount of substances that could reduce oxygen availability in the water. Again, the result also showed that the water is highly contaminated more than some neighboring surface water in Bayelsa state.

### 3.9 Chemical Oxygen Demand

The chemical oxygen demand of Epie creek i.e. from Akenfa to Biogboloranged from 168.75 – 242.23 $mgl^{-1}$ for spatial distribution. For the monthly distribution, the total dissolved solid ranged from 121.72 – 252.80 $mgl^{-1}$ (Fig. 10). There was significance difference (P<0.05) in monthly and spatial distribution, and interaction between spatial and monthly distribution (Table 3). The absence of variation suggests continuous pollution of the water all year round. The chemical oxygen demand in this study is higher than concentration previously reported in surface water in Bayelsa state. Some of the values ranged from 5.28 mg/l from Taylor creek [42]. The higher chemical oxygen demand in this study suggests that the oxygen equivalent of the organic matter of the water which is susceptible to oxidation by strong chemical oxidant is high [42].

### 3.10 Sulphate

The sulphate concentration of Epie creek i.e. from Akenfa to Biogbolo ranged from 7.30 – 14.30 $mgl^{-1}$ for spatial distribution. For the monthly distribution, the total dissolved solid ranged from 6.504 – 13.61 $mgl^{-1}$ (Fig. 11). There was significance difference (P<0.05) in monthly and spatial distribution, and interaction between spatial and monthly distribution (Table 3). Sulphate concentration showed positive

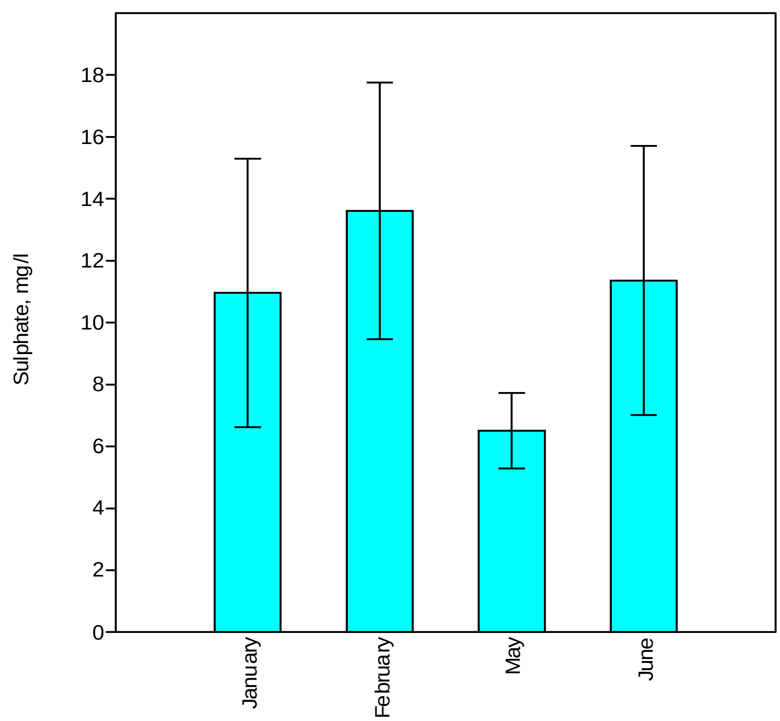


**Fig. 11. Sulphate monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

relationship with alkalinity and sodium at P<0.01 and calcium at P<0.05 (Table 2). The variations that exist suggest that the water is rich in sulphate all year round across the various locations the samples were obtained from. The sulphate concentration in this study is higher than the concentration previously reported in some surface water in Bayelsa state. Some of the values ranged from 6.09 – 8.83 mg/l from dredging area in Igbedi creek [17], 1.4 – 3.50 mg/l from Ikoli creek [27], 0.566 – 0.866 mg/l from River Nun [28], 1.98 – 2.66 mg/l and 2.22 – 6.27 mg/l for dry and wet season respectively from Epie creek [36], 0.1 – 0.5 mg/l from Lower Kolo creek [37], 0.417 – 0.567 mg/l from Kolo creek [26], but lesser than the value of 92.16 mg/l from Efi lake [40]. Sulphatein the water could be due to anthropogenic activities [28]. The higher concentration of sulphate in this study suggest that the water very rich in nutrient probably due to discharge of organic material into the water.

### 3.11 Nitrate

The nitrate concentration of Epie creek i.e. from Akenfa to Biogbolo ranged from 0.90 – 1.69 $mgl^{-1}$ for spatial distribution. While on monthly distribution, the total dissolved solid ranged from 0.63 – 1.676 $mgl^{-1}$ (Fig. 12). There was no significance difference (P>0.05) in monthly and spatial distribution, and interaction between spatial and monthly distribution (Table 3). Nitrate concentration showed positive relationship with sulphate and alkalinity at P<0.01 and sodium and total hardness at P<0.05 (Table 2). No variation in nitrate concentration suggests uniformity in nitrate content of the water probably due to anthropogenic activities in the area. The nitrate concentration in this study has some similarity with the concentration previously reported in some surface water in Bayelsa state. Some of the values previously reported ranged from 0.117 – 0.394 $mgl^{-1}$ from River Nun [28], 0.330 – 0.813 mg/l from some surface water in Wilberforce Island [29], 0.02 – 0.27 mg/l and 0.14 – 0.28 $mgl^{-1}$ for dry and wet season respectively from Epie creek [36], 0.13 – 0.146 $mgl^{-1}$ from Kolo creek [26], 0.1 – 0.24 $mgl^{-1}$ from Kolo creek [37], 0.32 – 4.15 $mgl^{-1}$ from Tombia bridge construction area [39], 1.34 - 2.82 mg/l from Efi Lake [41], 1.62 – 3.60 mg/l for spatial distribution and 2.17 $mgl^{-1}$ (wet season) and 2.54 mg/l (dry season) for seasonal variation of water from Kolo creek [38], 0.1 – 0.24 mg/l from lower Kolo creek [37], 0.31 mg/l from Taylor creek [42], 0.12 – 0.26 mg/l from Ikoli creek ([27]), 0.092 – 0.226 mg/l from dredging area in Igbedi creek [17]. The variation in nitrate concentration is the amount of organic nitrogen [28]. The occurrence of nitrate in water under study is as a result of discharge of organic materials into the water, which is a common practice to the inhabitant of the sample collection areas [28].

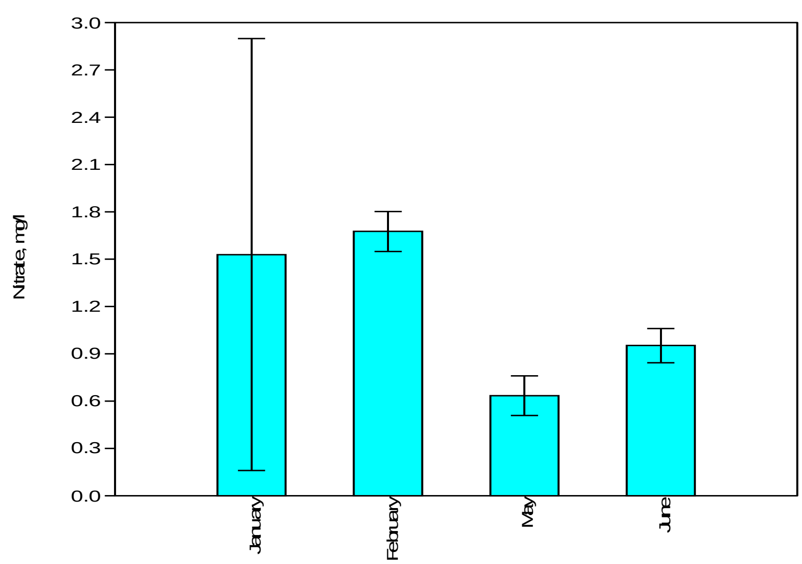


**Fig. 12. Nitrate monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

### 3.12 Bicarbonate

The bicarbonate concentration of Epie creek i.e. from Akenfa to Biogbolo ranged from 2.18 – 4.28 $mgl^{-1}$ for spatial distribution. While on monthly distribution, the total dissolved solid ranged from 2.92 – 3.20 mg/l (Fig. 13). There was no significance difference (P>0.05) in monthly and interaction between spatial and monthly distribution, and significance variation (P<0.05) exist in the spatial distribution (Table 3). Bicarbonate concentration showed positive relationship with calcium, magnesium, potassium and biological oxygen demand at P<0.01 and showed negative significant relationship with dissolved oxygen at P<0.05 (Table 2). Typically, carbonate in water is as result of dissolved ions, dissolved carbon dioxide in the water. Thus the concentration of bicarbonate in the water samples suggest that Epie creek i.e. from Akenfa to Biogbolo is rich in ion especially cations.

### 3.13 Chloride

The chloride concentration of Epie creek i.e. from Akenfa to Biogbolo ranged 15.25 – 61.75 mg/l for spatial distribution. While on monthly distribution, the total dissolved solid ranged from 16.60 – 41.206 mg/l (Fig. 14). There was no significance difference (P>0.05) in monthly and spatial distribution, and interaction between spatial and monthly distribution (Table 3). Chloride concentration showed positive relationship with bicarbonate, calcium, magnesium, potassium and biological oxygen demand at P<0.01 and total hardness at P<0.05 (Table 2). No variation in chloride concentration suggests uniformity in nutrient concentration such as chloride which could be due to anthropogenic activities in the area. The chloride concentration in this study is higher than the concentration previously reported in some surface water in Bayelsa state. Some of the values previously reported ranged from 0.36 – 0.46 mg/l from dredging area in Igbedi creek [17], 1.60 – 3.40 mg/l from Ikoli creek [27], 6.29 mg/l from Taylor creek [42], 1.65 – 4.62 mg/l and 3.62 – 4.28 mg/l for dry and wet season respectively from Epie creek [36], 1.257 – 1.467 mg/l from Kolo creek [26], 0.50 – 3.47 mg from River Nun [28], 14.00 mg/l from Efi lake [40]. The higher concentrations of chloride in the water in this study compare to previous study suggest that higher concentration of cation in the water [28].

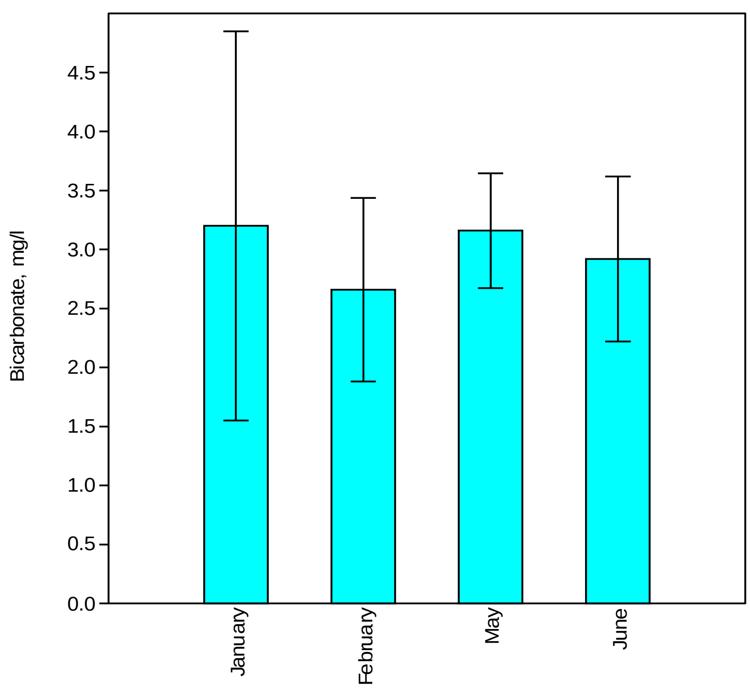


**Fig. 13. Bicarbonate monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

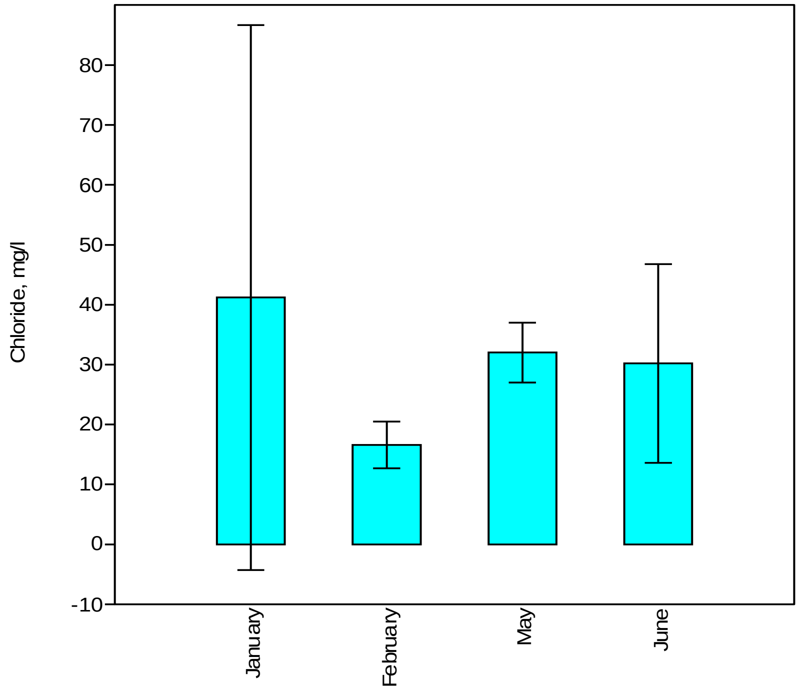


**Fig. 14. Chloride monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

### 3.14 Alkalinity

The alkalinity concentration of Epie creek i.e. from Akenfa to Biogbolo ranged 24.25 – 59.50 mg/l for spatial distribution. While on monthly distribution, the total dissolved solid ranged from 19.20 – 62.00 mg/l (Fig. 15). There was significance variation (P<0.05) in monthly and spatial distribution, and interaction between spatial and monthly distribution (Table 3). Total alkalinity concentration showed positive relationship with chemical oxygen demand at P<0.05 and negatively correlate with iron at P<0.05 (Table 2). The alkalinity concentration in this study has some similarity with the values previously reported in surface water in Bayelsa state. Some of the values ranged from 30.37.33 mg/l and 15.33 – 22.00 mg/l for dry and wet season respectively from Epie creek [36], 50.64 – 67.61 mg/l from dredging area in Igbedi creek [17]. The similarity in total alkalinity concentration in this study suggests that the acidity of the water in the region is near the same. Studies have reported geology of the Niger Delta to be similar. Again iron has been reported to be high in the region [30]. This could be the reason why acidity is high in the area.

### 3.15 Total Hardness

The total hardness concentration of Epie creek i.e. from Akenfa to Biogbolo ranged 121.68 – 209.00 mg/l for spatial distribution. For the monthly distribution, the total dissolved solid ranged from 52.86 – 280.00 mg/l (Fig. 16). There was significance variation (P<0.05) in monthly and spatial distribution, and interaction between spatial and monthly distribution (Table 3). Total hardness concentration showed positive relationship with calcium at P<0.05 and negatively correlate with sodium at P<0.05 (Table 2).The total hardness in this study is far higher than the concentration previously reported in surface water in Bayelsa state. Some of the values ranged from 0.903 - 3.333 mg/l from River Nun [28], 3.27 – 5.27 mg/l and 2.27- 3.36 mg/l for dry and wet season respectively from Epie creek [36], 1.03 – 1.37 mg/l fromKolo creek [26], 20.2 mg/l from Efi lake [40].The hardness of the water is an indication of the ability of the water to tolerate high soap concentration. The high total hardness could be due to high anthropogenic activities of the water and low flow rate of the water [28]. The high total hardness suggests that the water is hard and could wastes soap when used for domestic activities such as washing.

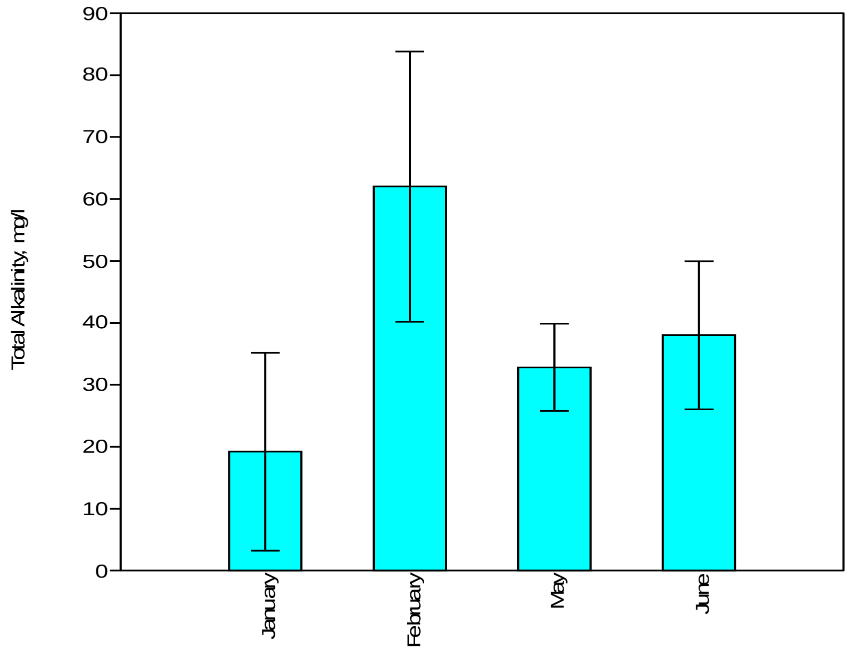


**Fig. 15. Total alkalinity monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

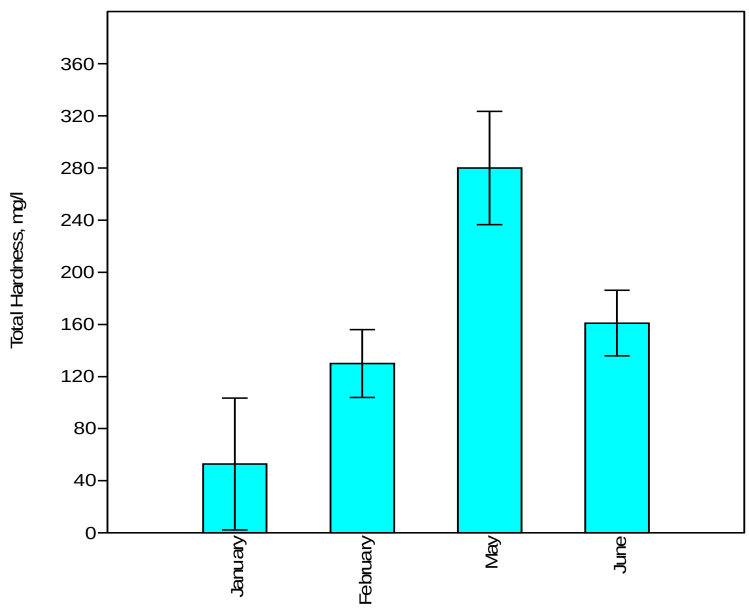


**Fig. 16. Total hardness monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

## 3.16 Calcium

Calcium concentration of Epie creek i.e. from Akenfa to Biogbolo ranged 16.53 – 43.09 mg/l for spatial distribution. While on monthly distribution, the total dissolved solid ranged from 24.36 – 31.04 mg/l (Fig. 17). There was no significance variation ($P<0.05$) in monthly and spatial distribution, and interaction between spatial and monthly distribution (Table 3). Calcium concentration showed positive relationship with magnesium, potassium and biological oxygen demand at P<0.01 and negatively correlate with dissolved oxygen at P<0.05 (Table 2). Calcium is one of the cations. No variation suggests similarity in their distribution in all year round. The calcium concentration in this study is far higher than the concentration previously reported in surface water in Bayelsa state. Some of the values ranged from 0.80 – 2.33 mg/l from River Nun [28], 1.107 – 1.183 mg/l from Kolo creek [26], 5.47 – 7.53 mg/l and 3.20 – 4.84 mg/l for dry and wet season respectively from Epie creek [36], 3.781 from Taylor creek [42], 18.00 mg/l from Efilake [40]. High concentration of calcium in this study is a reflection of higher cations in the water.

### 3.17 Magnesium

Magnesium concentration of Epie creek i.e. from Akenfa to Biogbolo ranged 3.07 – 10.46 mg/l for spatial distribution. While on monthly distribution, the total dissolved solid ranged from 3.77 -7.86 mg/l (Fig. 18). There was no significance variation (P>0.05) in monthly and interaction between spatial and monthly distribution, and significant variation (P<0.05) exist in the spatial distribution (Table 3). Magnesium concentration showed positive relationship potassium and biological oxygen demand at P<0.01 and negatively correlate with dissolved oxygen at P<0.05 (Table 2). The concentration of magnesium in this study is far higher than the concentration previously reported in surface water in Bayelsa state. Some of the values ranged from 0.37 – 0.5 mg/l from Kolo creek [26], 0.39 – 1.466 mg/l from River Nun [28], 2.00 mg/l from Efi lake [40], 2.29 – 3.60 mg/l and 1.77 – 2.98 mg/l for dry and wet season respectively from Epie creek [36]. Like calcium, higher concentration of magnesium in this study is a reflection of higher divalent cations in the water.

### 3.18 Sodium

Sodium concentration of Epie creek i.e. from Akenfa to Biogbolo ranged 3.80- 16.02 mg/l for spatial distribution. While on monthly distribution, the total dissolved solid ranged from 3.34 -15.57 mg/l (Fig. 19). There was no significance variation (P>0.05) in spatial and monthly, and interaction between spatial and monthly distribution (Table 3). The concentration of magnesium in this study is far higher than the concentration previously reported in surface

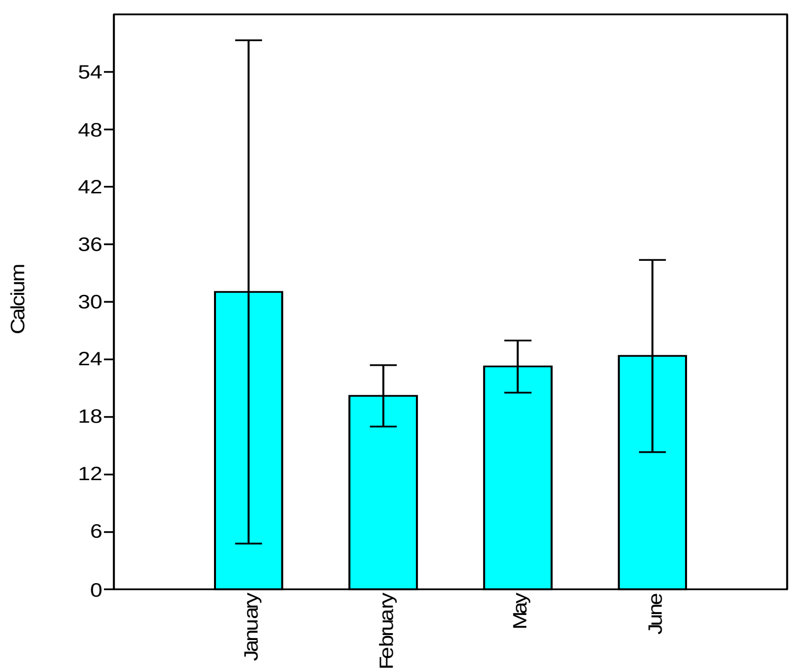


**Fig. 17. Calcium monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

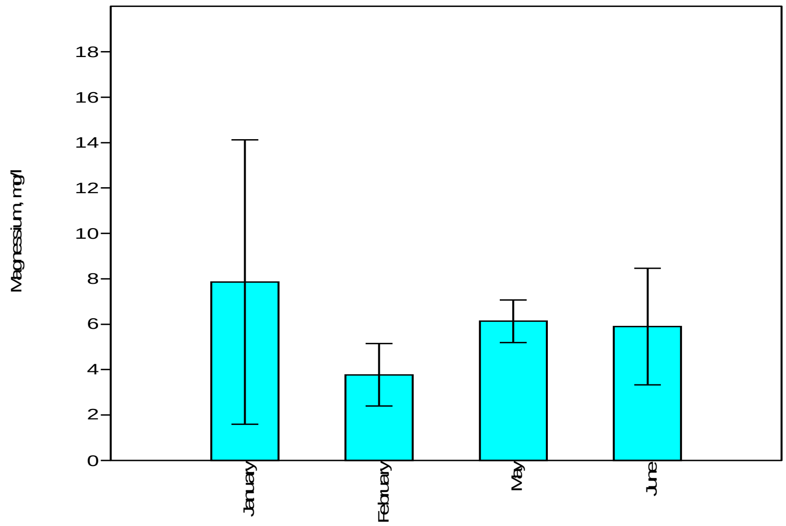


**Fig. 18. Magnesium monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

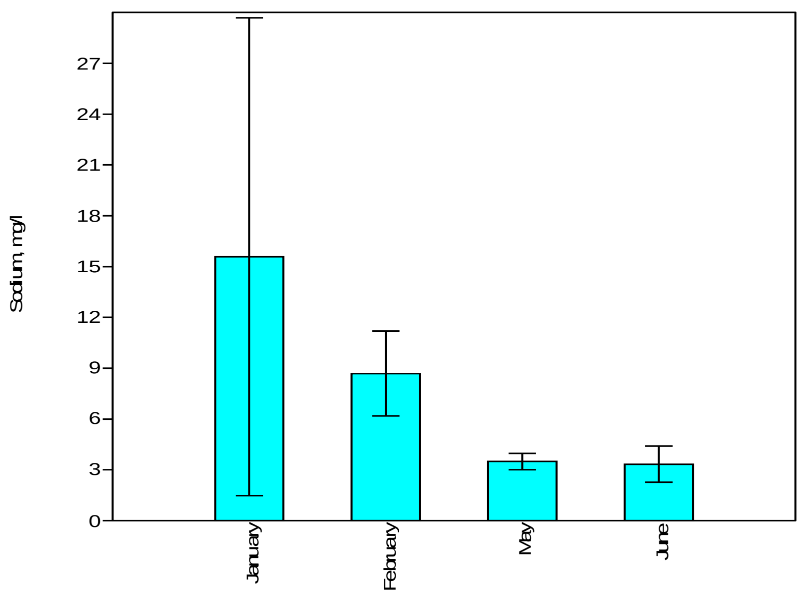


**Fig. 19. Sodium monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

water in Bayelsa state. Some of the values ranged from 0.58 – 0.68 mg/l from Kolo creek [26], 0.55 – 1.31 mg/l from River Nun [28], 7.422 mg/l from Taylor creek [42], 3.27 – 5.27b mg/l and 2.27 – 3.36 mg/l for dry and wet season respectively from Epie creek [36]. Higher concentration of sodium is a function of nutrient in the water sample under study.

### 3.19 Potassium

Potassium concentration of Epie creek i.e. from Akenfa to Biogbolo ranged 2.24 – 5.26 mg/l for spatial distribution. While on monthly distribution, the total dissolved solid ranged from 2.06 -4.39 mg/l (Fig. 20). There was no significance variation (P>0.05) in spatial and monthly, and interaction between spatial and monthly distribution (Table 3). Potassium showed positive significant relationship with biological oxygen demand at P<0.05 (Table 2). The concentration of potassium in this study is far higher than the concentration previously reported in surface water in Bayelsa state. Some of the values ranged from 0.313 – 0.363 mg/l from Kolo creek [26], 0.333 – 0.816 mg/l from River Nun [28], 2.55 – 3.33 mg/l and 2.55 – 3.35 mg/l for dry and wet season respectively from Epie creek [36]. Like sodium, high concentration of potassium is a function of high level of monovalent cation in the water under study.

The exchangeable cations including Calcium, potassium, sodium and magnesium play essential role in determining nutrient availability in water. According to Ogamba et al. [28], nutrient availability and nutrient leachability depend on the relative proportions of the monovalent and divalent cations. High concentration of exchange cations suggests that the water is classified as hard water and high in pollution some pollution indicators. This holds true because of high total hardness, biological and chemical oxygen demand concentration of the water. The trending of exchangeable cations in both spatial and monthly distribution of study were in the order; calcium> sodium> magnesium> potassium. Similar trend have been reported by Izonfuo and Bariweni [36] in dry season of Epie creek. Higher calcium in water has been variously reported in freshwater in Nigeria. High concentration of exchangeable cationscouldbe due to high organic matters leached or deposited into the water through human activities.

### 3.20 Iron

The iron concentration of Epie creek i.e. from Akenfa to Biogbolo ranged 0.87 – 1.39 mg/l for spatial distribution. While on monthly distribution, the total dissolved solid ranged from 0.32 –2.52 mg/l (Fig. 21). There was significance variation (P<0.05) in monthly distribution and interaction between spatial and monthly distribution, and no significant variation (P>0.05) among the spatial distribution (Table 3). Iron concentration showed significant negative correlation with chemical oxygen demand at P<0.05 and positively correlate with manganese at P<0.01 (Table 2). The concentration of Iron in this study is far higher than the concentration previously reported in surface water in Bayelsa state. Some of the values ranged from 0.1 – 0.16 mg/l from Kolo creek [26], 0.023 – 0.463 mg/l from River Nun [28], 0.05 – 0.10 mg/l from River

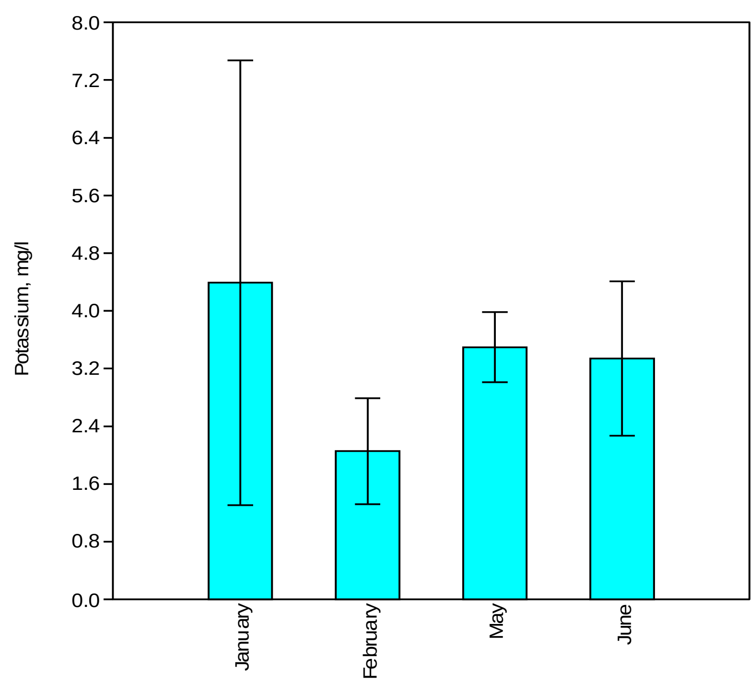


**Fig. 20. Potassium monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

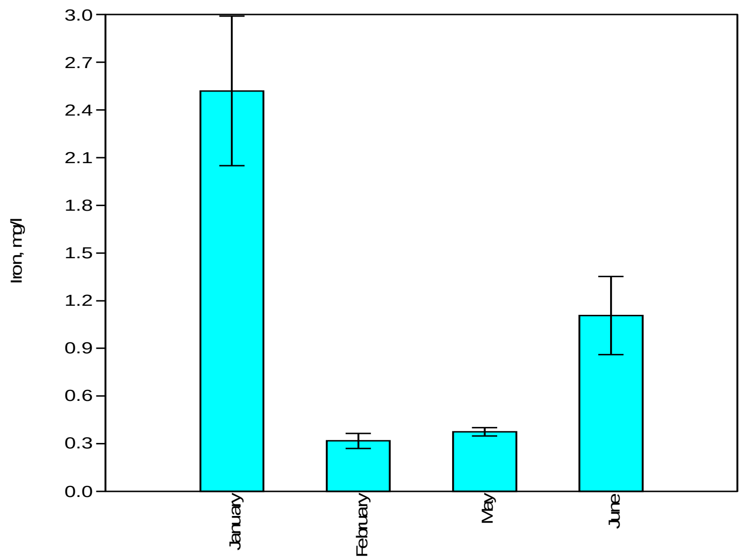


**Fig. 21. Iron monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

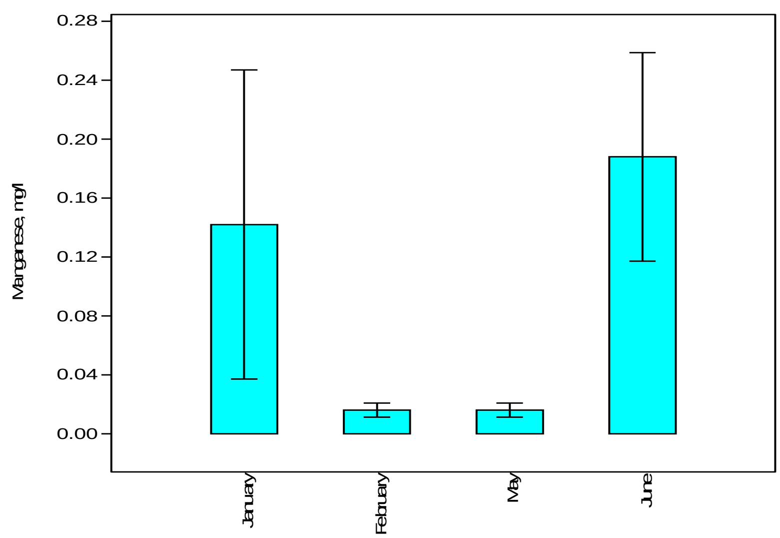


**Fig. 22. Manganese monthly distribution of Epie creek from Akenfa to Biogbolo in Yenagoa metropolis**

Nun [46]. Higher concentration in this study compare to previous study could be due no low dilution effect [28].

### 3.21 Manganese

The manganese concentration of Epie creek i.e. from Akenfa to Biogbolo ranged 0.05 – 0.15 mg/l for spatial distribution. While on monthly distribution, the total dissolved solid ranged from 0.016–0.188 mg/l (Fig. 22). There was significance variation (P<0.05) in monthly distribution and interaction between spatial and monthly distribution, and no significant variation (P>0.05) among the spatial distribution (Table 3). The concentration of manganese in this study showed significant negative correlation with chemical oxygen demand at P<0.05 (Table 2). The concentration of Iron in this study is far higher than the concentration previously reported in surface water in Bayelsa state. Some of the values ranged from 0.013 – 0.033 mg/l from Kolo creek [26], 0.003 – 0.023 mg/l from River Nun [28]. Manganese is a found in the soil and it may be brought into solution during precipitation and subsequently deposited in the aquatic ecosystem.

Based on general physico-chemical characteristics of the Epie creek, the parameters including pH, conductivity, total dissolved solid, nitrate, chloride, alkalinity, total hardness, calcium, magnesium, sodium, potassium, iron, biological oxygen demand and bicarbonate were apparently high in the Tombia junction location of the study, this suggested that the market activities is having an impact of the water quality parameters of the creek. High concentration of nutrient such as nitrate could lead to eutrophication. High biological and chemical oxygen demand in this study also suggests high pollution level.

## 4. CONCLUSION

This study evaluated the physicochemical characteristics of Epie creek, Niger Delta Nigeria. Results showed that there was no significant variation (P>0.05) in salinity, conductivity, turbidity, total dissolved solid, nitrate, chloride, sodium, chemical oxygen demand and potassium concentration across spatial and monthly distribution and interaction between monthly and spatial distribution. Furthermore, There is significance difference (P<0.05) in sulphate, total alkalinity, total hardness and calcium across spatial and monthly distribution and interaction between monthly and spatial distribution. There was significance difference (P<0.05) in total suspended solid and pH spatial distribution only. Significance difference (P<0.05) exist for bicarbonate, iron and manganese for monthly distribution and interaction between monthly and spatial distribution. Also no significance difference (P>0.05) in only monthly distribution for biological oxygen demand.Based on the water quality characteristics of the Epie creek, the parameters including pH, conductivity, total dissolved solid, nitrate, chloride, alkalinity, total hardness, calcium, magnesium, sodium, potassium, iron, biological oxygen demand, bicarbonate were apparently high in the Tombia junction location. This suggests the effects of market activities on Epie creek. Therefore we recommend that the discharge of wastes into the creek should be avoided.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES


1. Inyang IR, Seiyaboh EI, Job UB. Condition factor, organosomatic indices and behavioural abnormalities of *Clarias gariepinus*exposed to Lambda Cyhalothrin. Greener Journal of Life Sciences. 2017;4(1):001-005.
2. Inyang IR, Ollor AO, Izah SC. Effect of Diazinon on organosomatic indices and behavioural responses of *Clarias gariepinus* (a common Niger Delta wetland fish). Greener Journal of Biological Sciences. 2017;7(2):15–19.
3. Inyang IR, Izah SC, Johnson DT, Ejomarie OA. Effects of Lambda cyhalothrin on some electrolytes and metabolites in organs of Parpohiocephalusobscurus. Biotechnological Research. 2017;3(1):6-10.
4. Inyang IR, Obidiozo OZ, Izah SC. Effects of Lambda cyhalothrin in protein and albumin content in the kidney and liver of Parpohiocephalusobscurus*.* EC Pharmacology and Toxicology. 2016;2(3): 148-153.
5. Inyang IR, Okon NC, Izah SC. Effect of glyphosate on some enzymes and electrolytes in *Heterobranchus bidosalis* (a common African catfish). Biotechnological Research. 2016;2(4):161-165.
6. Inyang IR, Kenobi A, Izah SC. Effect of dimethoate on some selected metabolites in the brain, liver and muscle of *Clarias lazera.* Sky Journal of Biochemistry Research. 2016;5(4):63-68.
7. Inyang IR, Thomas S, Izah SC. Activities of electrolytes in kidney and liver of *Clarias gariepinus* exposed to fluazifop-p-butyl. Journal of Biotechnology Research. 2016;2(9):68–72.
8. Inyang IR, Thomas S, Izah SC. Evaluation of activities of transferases and phosphatase in plasma and organs of *Clarias gariepinus* exposed to Fluazifop-p-Butyl. Journal of Environmental Treatment Techniques. 2016;4(3):94-97.
9. Inyang IR, Akio K, Izah SC. Effect of dimethoate on lactate dehydrogenase, creatinine kinase and amylase in *Clarias lazera*. Biotechnological Research. 2016;2(4):155-160.
10. Izah SC, Angaye TCN. Heavy metal concentration in fishes from surface water in Nigeria: Potential sources of pollutants and mitigation measures. Sky Journal of Biochemistry Research. 2016;5(4):31-47.

11. Izah SC, Angaye TCN. Ecology of human schistosomiasis intermediate host and plant molluscicides used for control: A review. Sky Journal of Biochemistry Research. 2016;5(6):075-082.
12. Adesuyi AA, Njoku KL, Akinola MO. Assessment of heavy metals pollution in soils and vegetation around selected industries in Lagos State, Nigeria. Journal of Geoscience and Environment Protection. 2015;3:11-19.
13. Idris MA, Kolo BG, Garba ST, Waziri I. Pharmaceutical industrial effluent: Heavy metal contamination of surface water in Minna, Niger State, Nigeria. Bull Env Pharmacol Life Sci. 2013;2(3):40-44.
14. James OO, Nwaeze K, Mesagan E, Agbojo M, Saka KL, Olabanji DJ. Concentration of heavy metals in five pharmaceutical effluents in Ogun State, Nigeria. Bull Env Pharmacol Life Sci. 2013;2(8):84-90.
15. Anyakora C, Nwaeze K, Awodele O, Nwadike C, Arbabi M, Coker H. Concentrations of heavy metals in some pharmaceutical effluents in Lagos, Nigeria. Journal of Environmental Chemistry and Ecotoxicology. 2011;3(2):25-31.
16. Ohimain EI, Jonathan G, Abah SO. Variations in heavy metal concentrations following the dredging of an oil well access canal in the Niger Delta. Advances in Biological Research. 2008;2(5-6):97-103.
17. Seiyaboh EI, Ogamba EN, Utibe DI. Impact of dredging on the water quality of Igbedi creek, Upper Nun River, Niger Delta, Nigeria. IOSR Journal of Environmental Science, Toxicology and Food Technology. 2013;7(5):51–56.
18. Seiyaboh EI, Ayibaefie YW. Assessment of hydrocarbon level in surface water aligning Imirigi oil field facilities in the Niger Delta. Intern. J. Innov. Biosci. Res. 2017;5(2):1-9.
19. Adewuyi GO, Olowu RA. Assessment of oil and grease, total petroleum hydrocarbons and some heavy metals in surface and groundwater within the vicinity of NNPC oil depot in Apata, Ibadan metropolis, Nigeria. IJRRAS. 2012;13(1):166-174.
20. Awotoye OO, Dada AC, Arawomo GAO. Impact of palm oil processing effluent discharging on the quality of receiving soil and rivers in South Western Nigeria. Journal of Applied Sciences Research. 2011;7(2):111-118.
21. Edward JB, Idowu EO, Oyebola OE. Impact of pam oil mill effluent on physic-chemical parameters of a southwestern River, Ekiti state, Nigeria. Journal of Natural Sciences Research. 2015;4(14): 26-30.
22. Izah SC, Angaye TCN, Ohimain EI. Environmental impacts of oil palm processing in Nigeria. Biotechnological Research. 2016;2(3):132-141.
23. Seiyaboh EI, Izah SC, Oweibi S. Physico-chemical characteristics of sediment from Sagbama creek, Nigeria. Biotechnological Research. 2017;3(1):25-28.
24. Seiyaboh EI, Inyang IR, Izah SC. Seasonal variation of physico-chemical quality of sediment from Ikoli creek, Niger Delta. International Journal of Innovative Environmental Studies Research. 2016;4(4):29-34.
25. Seiyaboh EI, Inyang IR, Izah SC. Spatial variation in physico-chemical characteristics of sediment from Epie creek, Bayelsa State, Nigeria. Greener Journal of Environment Management and Public Safety. 2016;5(5):100-105.
26. Ogamba EN, Seiyaboh EI, Izah SC, Ogbugo I, Demedongha FK. Water quality, phytochemistry and proximate constituents of *Eichhornia crassipes* from Kolo creek, Niger Delta, Nigeria. International Journal of Applied Research and Technology. 2015;4(9):77–84.
27. Ogamba EN, Izah SC, Toikumo BP. Water quality and levels of lead and mercury in *Eichhornia crassipes* from a tidal creek receiving abattoir effluent, in the Niger Delta, Nigeria. Continental Journal of Environmental Science. 2015;9(1):13–25.
28. Ogamba EN, Izah SC, Oribu T. Water quality and proximate analysis of *Eichhornia crassipes* from River Nun, Amassoma Axis, Nigeria. Research Journal of Phytomedicine. 2015;1(1):43–48.
29. Agedah EC, Ineyougha ER, Izah SC, Orutugu LA. Enumeration of total heterotrophic bacteria and some physico-chemical characteristics of surface water used for drinking sources in Wilberforce Island, Nigeria. Journal of Environmental Treatment Techniques. 2015;3(1):28–34.
30. Izah SC, Chakrabarty N, Srivastav AL. A review on heavy metal concentration in potable water sources in Nigeria: Human health effects and mitigating measures. Exposure and Health. 2016;8:285–304.
31. Izah SC, Srivastav AL. Level of arsenic in potable water sources in Nigeria and their

potential health impacts: A review. Journal of Environmental Treatment Techniques. 2015;3(1):15–24.
32. Izah SC, Ineyougha ER. A review of the microbial quality of potable water sources in Nigeria. Journal of Advances in Biological and Basic Research. 2015;1(1): 12-19.
33. Seiyaboh EI, Izah SC, Oweibi S. Assessment of water quality from Sagbama creek, Niger Delta, Nigeria. Biotechnological Research. 2017;3(1):20-24.
34. Ogamba EN, Ebere N, Izah SC. Heavy metal concentration in water, sediment and tissues of *Eichhornia crassipes* from Kolo Creek, Niger Delta. Greener J. Environ. Manage. Public Safety. 2017;6(1):001-005.
35. Seiyaboh EI, Alagha WE, Gijo AH. Spatial and seasonal variation in physico-chemical quality of Ikoli creek, Niger Delta, Nigeria. Greener Journal of Environmental Management and Public Safety. 2017;5(5): 104-109.
36. Izonfuo LWA, Bariweni AP. The effect of urban runoff water and human activities on some physico-chemical parameters of the Epie creek in the Niger Delta. Journal of Applied Sciences and Environmental Management. 2001;5(1):47-55.
37. Aghoghovwia OA, Ohimain EI. Physicochemical characteristics of lower Kolo creek, Otuogidi, Bayelsa state. Nigerian Journal of Agriculture, Food and Environment. 2014;10(1):23-26.
38. Eremasi YB, Alagoa KJ, Daworiye P. Water quality evaluation and heavy metals concentration of Kolo creek, Imiringi, Bayelsa state. International Journal of Current Research, Bioscience and Plant Biotechnology. 2015;2(2):61–66.
39. Seiyaboh EI, Inyang IR, Gijo AH. Environmental impact of Tombia bridge construction across Nun River in Central Niger Delta, Nigeria. The International Journal of Engineering and Science. 2013;2(11):32–41.
40. Nwankwoala HO, Egesi N, Agi CC. Analysis of the water resources of Kiama area of Bayelsa state, Eastern Niger Delta. International Journal of Environmental Science and Technology. 2016;1(2):7–12.
41. Angaye TCN, Mieyepa CE. Assessment of elemental and microbial quality of lake EfiIn Bayelsa State, Central Niger Delta, Nigeria. Journal of Environmental Treatment Techniques. 2015;3(2):71-75.
42. Daka ER, Amakiri-Whyte B, Inyang IR. Surface and groundwater in some oil field communities in the Niger Delta: implications for domestic use and building construction. Research Journal of Environmental and Earth Sciences. 2014;6(2):78–84.
43. Ademoroti CMA. Standard method for water & effluents analysis. 1st Edition. Foludex Press Limited, Ibadan, Nigeria; 1996.
44. American Public Health Association (APHA). Standard methods for the evaluation of water and waste waters. 20th Ed. Wahington DC. American Public Health; 1975.
45. Hammer Ø, Harper DAT, Ryan PD. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica. 2001;4(1):9. Available:http://palaeo-electronica.org/2001_1/past/issue1_01.htm
46. Nwidu LL, Oveh B, Okoriye T, Vaikosen NA. Assessment of the water quality and prevalence of water borne diseases in Amassoma, Niger Delta, Nigeria. African Journal of Biotechnology. 2008;7(17): 2993-2997.



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