International Journal of Research
Available at https://pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 1
January 2019

# Water Quality Index and Correlation Analysis of Rumuogba, Woji, Slaughter, Elelenwo and Marine Base Rivers in Port Harcourt, Rivers State, Nigeria

Owen Godpower[1], Nngeri Peace O.[2], *D. C. Okujagu[3]
[1]Geominning Technology, School of Science Laboratory Technology, University of Port Harcourt
[2]Centre for Petroleum Geosciences, University of Port Harcourt, Nigeria
[3]Departmenmt of Geology, University of Port Harcourt, Nigeria
[3]Diepiriye.okujagu@uniport.edu.ng

## ABSTRACT

*This study was done to evaluate the surface water quality index and correlation analysis of five Rivers within Port Harcourt industrial area, which includes Rumuogba, Woji, Slaughter, Elenlewo and Marine Base. A total of nineteen parameters were analyzed, using standard procedures, for three different sample points, during the rainy and dry seasons. The results revealed the following: Mean temperature 27.20°C; mean pH 5.89; mean electrical conductivity (EC) 2345.16µs/cm; mean turbidity 56.55NTU; mean chloride 443.44 mg/L; mean sulphate 63.63 mg/L; mean nitrates 9.46; mean total hardness 224.69 mg/L; mean iron 0.57 mg/L; mean copper 0.31 mg/L; mean zinc 0.18 mg/L; mean chromium 0.04 mg/L; mean lead 0.10 mg/L; mean total dissolved solids 1519.13 mg/L; mean total coliform 934.20 MPN/ml; mean BOD 2.64 mg/L; mean dissolved oxygen 5.21 mg/L; mean chemical oxygen 85.47 mg/L. Water quality Index result was 28.68, indicating a bad water quality for all the Rivers sampled. and is supported by correlation analysis of very high positive correlation among temperature, pH, electrical conductivity, chloride, TDS, total hardness, nitrate, iron, copper, chromium, BOD supports the results of water quality index that the water from these Rivers is bad (polluted).*

**Keywords:** Water quality index, correlation analysis, rainy and dry season, Port Harcourt and Industrial Area.

## 1. INTRODUCTION

Water Quality Index (WQI) is a unit-less number ranging from 1 to 100; a higher number is indicative of better water quality (Adel *et al* 2011). Water quality index is based on some important parameters which provide a simple indicator of water quality, giving the public a general idea of the possible problems associated with the water in the area of interest. It can be assessed in terms of, 'quality for life' (e.g., the quality of water needed for human consumption), 'quality for food' (e.g., the quality of water needed to sustain agricultural activities), or 'quality for nature' (e.g., the quality of water needed to support a thriving and diverse fauna and flora in a region) (Chindah and Braide 2003).

Regular monitoring of the physical and chemical makeup of water makes it possible to detect changes in its quality and implement mitigation measures to avert detrimental consequences. The quality of water in our lakes, streams, creeks, rivers etc is a critical parameter in determining the overall quality of our lives. Water quality is determined by the solutes and gases dissolved in the water, as well as the water suspended in and floating on the water. The usefulness of water for a particular purpose is determined by the water quality. Human activities such as fertilizer application during farming (Altman and Parizek, 1995; Emongor *et. al*., 2005), oil spills from industries, release of effluent wastes from factories, sewages and domestic wastes which end up in surface water bodies, alters the natural water quality of such systems rendering it contaminated or polluted. Increase in human population increases the demand for renewable resources. Water to be used for domestic or industrial purpose, must be pure, others wise it will pose serious health challenges such as cholera, typhoid, kidney stone etc.

As surface water flows through sediments, the water naturally contains a number of different dissolved inorganic constituent which may be physical or chemical in character and biological as well. Surface water may be adversely impacted by human activity, if organic matter such as untreated human and animal waste is placed into the surface water body, dissolved oxygen diminish as an energy source consuming oxygen in the process. The total dissolved solid many increase owing to the disposal of waste water, urban runoff and increased erosion due to land use changes in the drainage basin, runoff from agricultural areas, will increase nitrate contamination and contaminants from leaking fuel tanks or toxic chemicals spills may enter the surface water and contaminate it and even destroy aquatic live. Surface water contamination is not an irreversible process. There are natural conditions that acts to remove contaminants. Alteration mechanisms include dilution, dispensation, mechanical filtration, volatilization, biological activity, ion exchange and absorption on soil particles, surfaces, chemical reaction and radioactive decay.

Water quality parameters such as pH and temperature are controlled in public water supplies partly because of the use of water in food processing and textiles. Measurement for these are conducted on the basis of the dilution needed to reduce them to a level barely detectable by human observation. Water with enough suspended particles will be visually turbid, contaminated and a potent sources for disease spread. Turbidity measurements are based on the optical properties of the suspension that cause light to be altered or absorbed rather than transmitted in a straight line through the sample. Results are then compared to those from a standard suspension. Water hardness is expressed as equivalent milligrams per liter of calcium carbonate. The bicarbonates of calcium and magnesium precipitates as insoluble carbonates when carbon dioxide is driven off by boiling. These temporary hardness called carbonate hardness should be limited where it causes scale formation in boilers and industrial equipment.

The Nigeria Vision 2020 Technical Working Group in its 2009 Report on the Environment acknowledged (among other things) that water pollution is a "major environmental threat" in the country. Water bodies in Nigeria are gravely contaminated by oil spills, dumping of untreated sewage and solid wastes, heavy metals from both legal and illegal mines, unregulated discharge of effluents, and release of sediments and dissolved ions from eroded and poorly cultivated soils (UNEP, 2008). Most of these problems can be traced to the phenomenon of rapid urbanization, application of unsustainable agricultural techniques, and a worrying dearth of appropriate supervisory frameworks for industrial activities which release their waste into surrounding water bodies.

Rapid urbanization in cities of the developing world, including Port Harcourt, has necessitated the expansion of city limits beyond hitherto defined borders, and the scope of established growth monitoring and management systems. In a city like Port Harcourt located in the Niger Delta, this translates to the establishment of more settlements around waterfronts and the reclamation of swampy terrain for land. There is a tendency then that illegal waterfront development and land reclamation operations may arise thereby releasing more sediment into the streams and resulting in the possibility of declining water quality levels across the city. In any case, the amount of waste generated by the city increases exponentially and some of it may find its way into these streams.

The Niger Delta being a site of vast oil wealth does experience frequent episodes of oil spills which regularly find their way into streams across the region. Given the transportation potential of moving water, one might expect streams within the Port Harcourt metropolis to accommodate traces of oil pollution despite the fact that there are no active oil exploration facilities within the metropolis. Also, the lack of proper sanitation facilities in many areas means that river bank dwelling communities release human waste directly into water bodies while the total absence of modern sewage treatment plants and solid waste management facilities requires that these streams become an alternative for dumping of these materials. Meanwhile poor supervisory frameworks create room for industries to illegally dump their effluent discharges and sediment into streams and rivers (WHO/UNEP, 1997).

This study is aimed at looking at the overall water quality index of five Rivers within the Port Harcourt Oil and gas hub via their physiochemical properties.

**The Study Area**

Port Harcourt is located between latitudes of $4^0\ 42^1$ north and $4^0\ 47^1$ north and between the longitudes of $6^0\ 35^1$ east and $7^0\ 08^1$ east. It is located on the eastern part of the Niger Delta in Rivers State, covering two local government areas, namely, Port Harcourt local government area (PHALGA) and Obio/Akpor local government area (OBALGA).

Port Harcourt is predominantly tropical having two seasons: wet and dry seasons. The rain last for at least for at least 7 months, March to November, giving way to a 3 months dry season from December to February. Rainfall in the region exhibits a double-maxima pattern with a little dry season in August (August Break). There might be rain during the period of December to February; however, most of the rains received are unreliable and spotty due to convective overturning of the south west wind. The highest monthly rainfall occurs in July and August at 3496mm and 3578mm respectively (Osuiwu & Ologunorisa, 2000).

Port Harcourt is peculiar in terms of surface water and the monotonously flat landscape, comprises of coastal planes crisscrossed by labyrinth of swamps, creeks, rivers and waterways which empty into the Atlantic Ocean and also serve as inlets of oceanic water into the tidal basin.

Port Harcourt metropolis consists of soils of various types of superficial deposits which are over 100m thick in places. These soils are generally poorly drained but have rich humus layers on the top soil with deficiency in minerals of nitrogen and potassium because of the intense leaching due to heavy rainfall. The region is rich in phosphorus because of the volcanic parent materials. The high forest area and mangrove swamps are rich in organic matter and they support arable agriculture (Oyegun, 2000).

International Journal of Research
Available at https://pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 1
January 2019

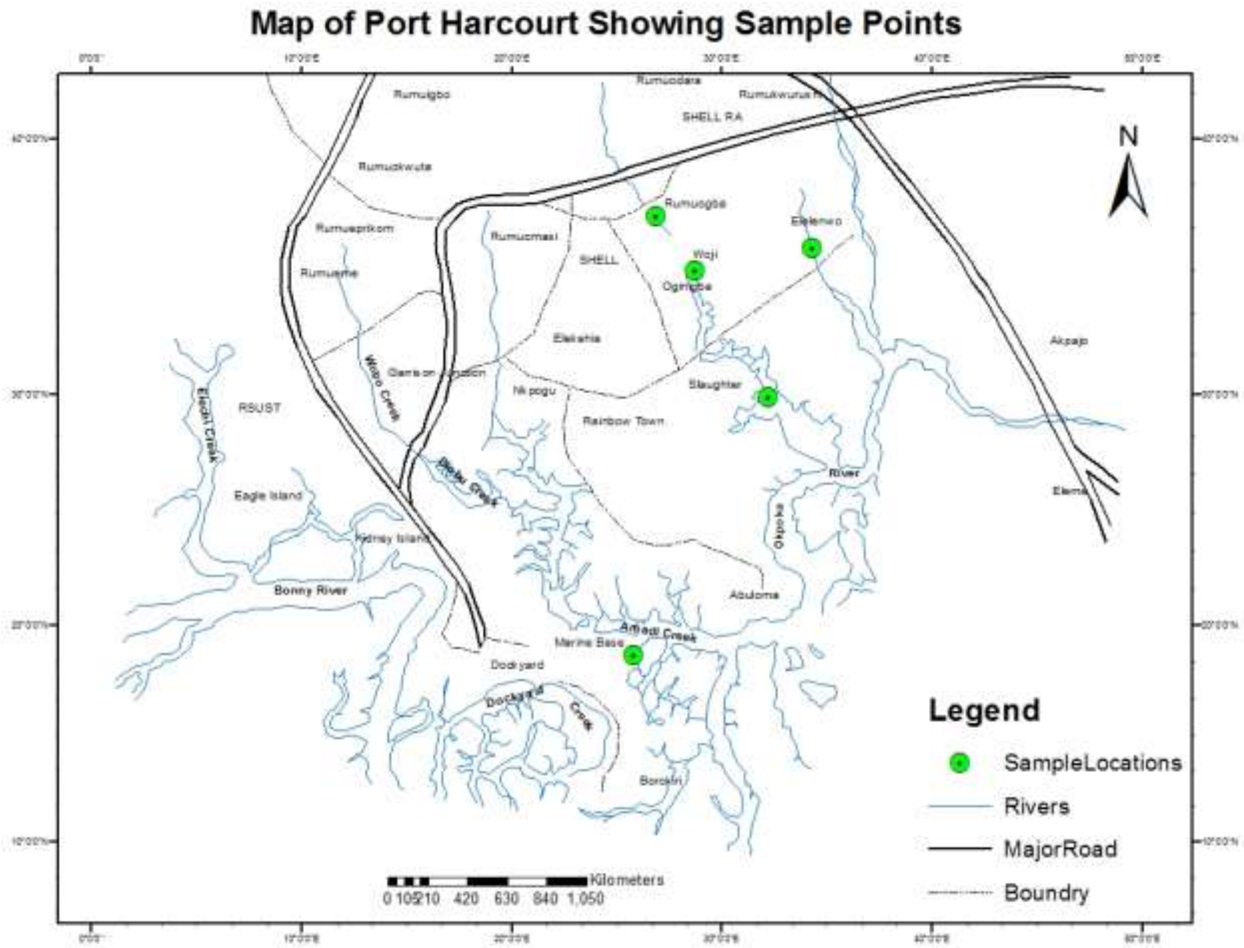


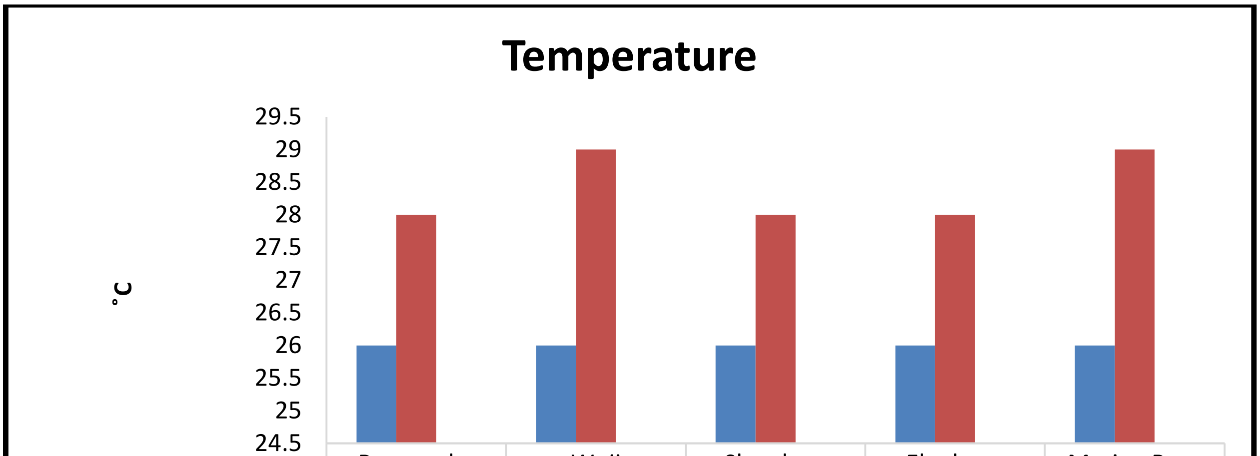

Figure 1: Location Map

## 2. METHODOLOGY

This study was carried out in two phases. Surface water sampling was carried out in Elelenwo, Woji, Rumuogba, Slaughter and Marine Base Rivers. The samples were collected at three points in each of the Rivers, onshore, midstream upstream. Samples were collected in 1 liter plastic bottles that were first rinsed with the particular sample to be collected and rightly seated and labeled. After collection to minimize oxygen contamination and escape of dissolved gases. Samples meant for cations determination were acidified with trioxonitrate (v) ($HNO_3$) to prevent the cations from adhering to the surface of the container thereby making them to remain in solution while the containers for anions determination were not acidified. Parameters like temperature and pH that have the capacity to change quickly were measured in the field, pH was measured with a pH meter while temperature was measured with a thermometer. The geographical location and elevation of each sampling point above sea level was measured using a global positional system device (Germin 330) model.

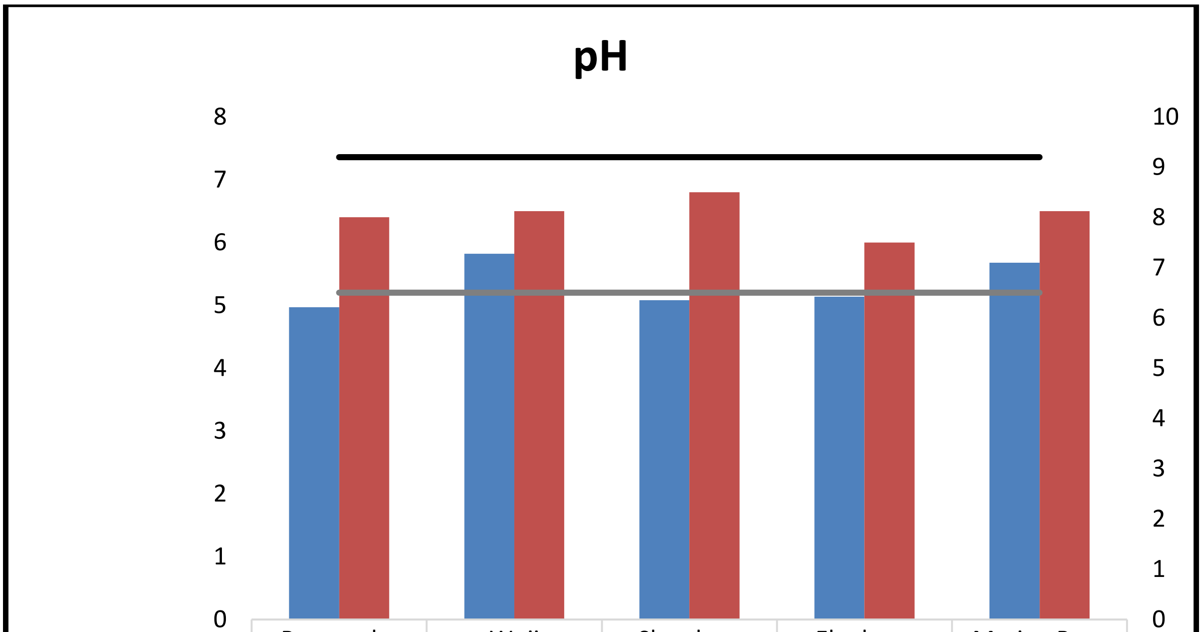
Laboratory analysis was carried out at the National Agency for food and drug administration and control (NAFDAC) Port Harcourt laboratory. Nephelometer method was used to test for turbidity, Conductivity meter was used for conductivity measurement, pH meter was used for pH measurement and Thermometer was used for temperature measurement. Mercury II nitrate method was used to test for chlorine, Turbidimetric method was used to test for sulphate, Colorimetric method was used to test for nitrate, Atomic absorption spectrophotometer was used to test for iron, Spectrophotometer technique was used to test for copper, zinc, lead and chromium, while *Ethylenediaminetetraacetic acid (EDTA),* was used to test for Total hardness. Standard multiple-tube fermentation method was used for coliform test, routine measurement biosensor measurement and spectral analysis was used to test for biological oxygen demand, automated method was used to test for carbon oxygen demand, Colorimeter method was used to test for dissolved oxygen demand and Grametric method was used to test for Total dissolve solid. The correlation was done using pearsons (r) coefficient correlation, using variable datas from both the wet and dry season for the FOUR sample areas with reference to pH, temp, EC, turbidity, chloride, sulphate, nitrate, total hardness, copper, zinc, chromium, lead, TDS, TC, BOD, COD. It was done on using the excel data analysis platform.

## 3. RESULTS AND DISCUSSION




| | Rumuogba | Woji | Slaughter | Elenlewo | Marine Base |
|---|---|---|---|---|---|
| Dry Season | 26 | 26 | 26 | 26 | 26 |
| Wet Season | 28 | 29 | 28 | 28 | 29 |
| WHO (2008) Standard | | | | | |

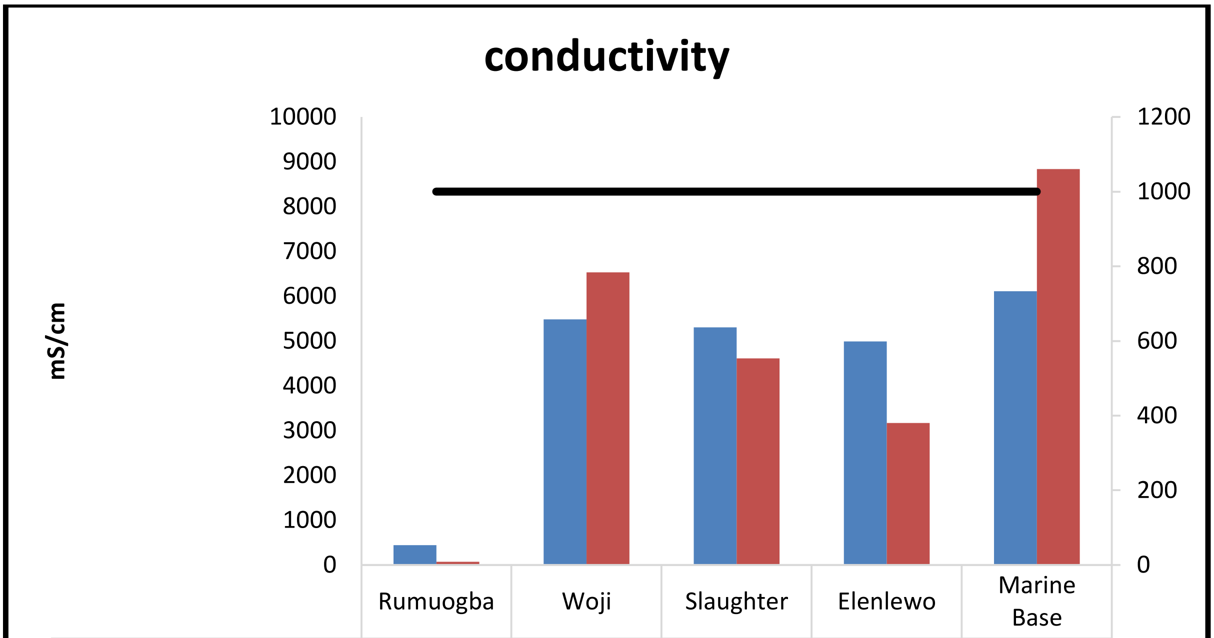
Figure 2: Temperature




| | Rumuogba | Woji | Slaughter | Elenlewo | Marine Base |
|---|---|---|---|---|---|
| Dry Season | 4.97 | 5.82 | 5.08 | 5.14 | 5.68 |
| Wet Season | 6.4 | 6.5 | 6.8 | 6 | 6.5 |
| Upper Limit | 9.2 | 9.2 | 9.2 | 9.2 | 9.2 |
| Lower Limit | 6.5 | 6.5 | 6.50 | 6.5 | 6.5 |

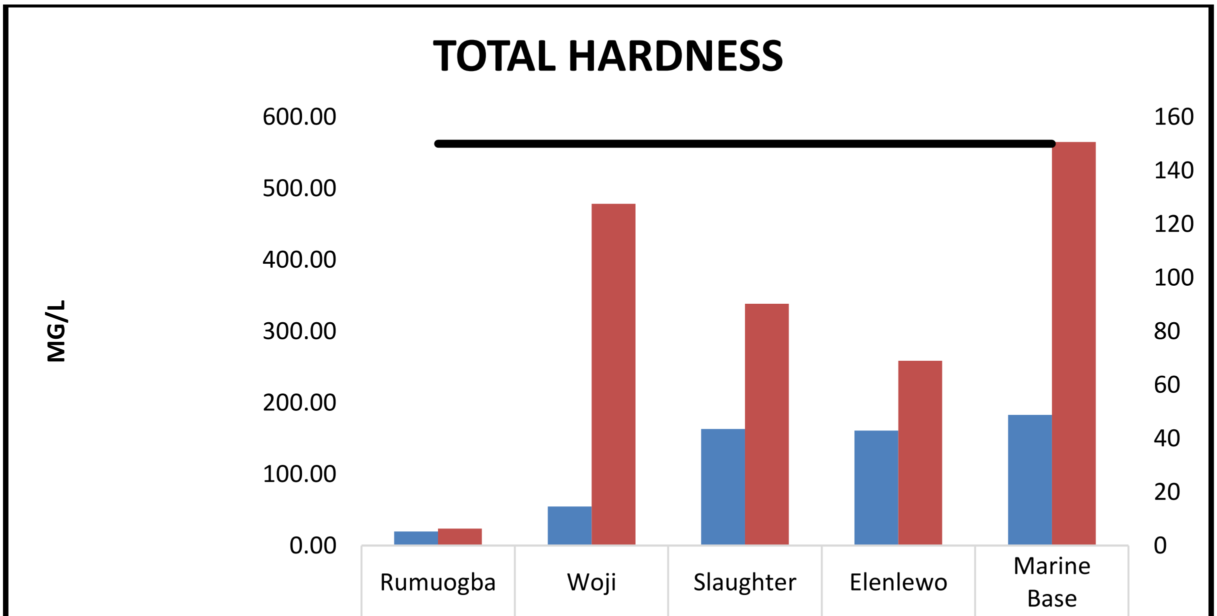
Figure 3: pH

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 1
January 2019




| | Rumuogba | Woji | Slaughter | Elenlewo | Marine Base |
|---|---|---|---|---|---|
| Dry Season | 442 | 5480 | 5301 | 4990 | 6107 |
| Wet Season | 73.8 | 6534.3 | 4614 | 3166.3 | 8840 |
| WHO (2008) Standard | 1000 | 1000 | 1000 | 1000 | 1000 |

Figure 4: Conductivity




| | Rumuogba | Woji | Slaughter | Elenlewo | Marine Base |
|---|---|---|---|---|---|
| Dry Season | 20.00 | 55.00 | 163.30 | 161.04 | 182.90 |
| Wet Season | 24 | 478.3 | 338.67 | 258.7 | 565 |
| WHO (2008) Standard | 150 | 150 | 150 | 150 | 150 |

Figure 5: Total Hardness

International Journal of Research
Available at https://pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 1
January 2019

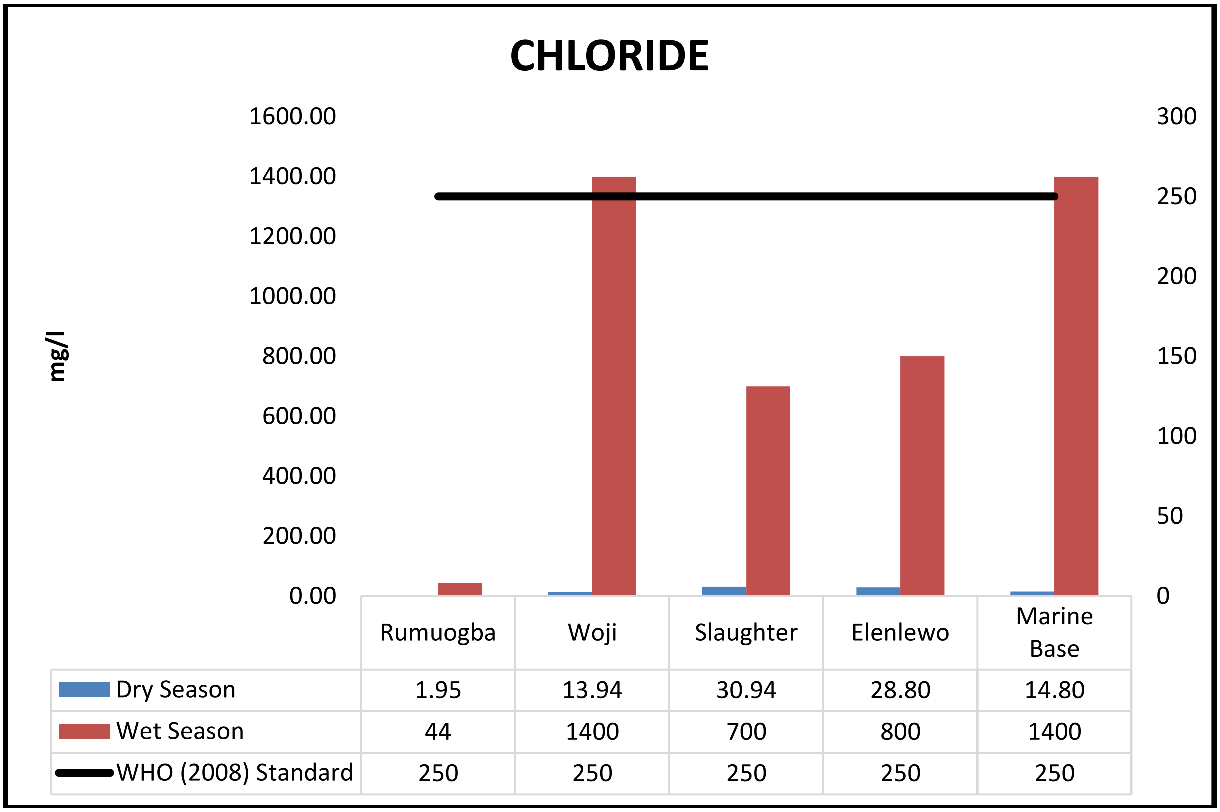



Figure 6: Chloride

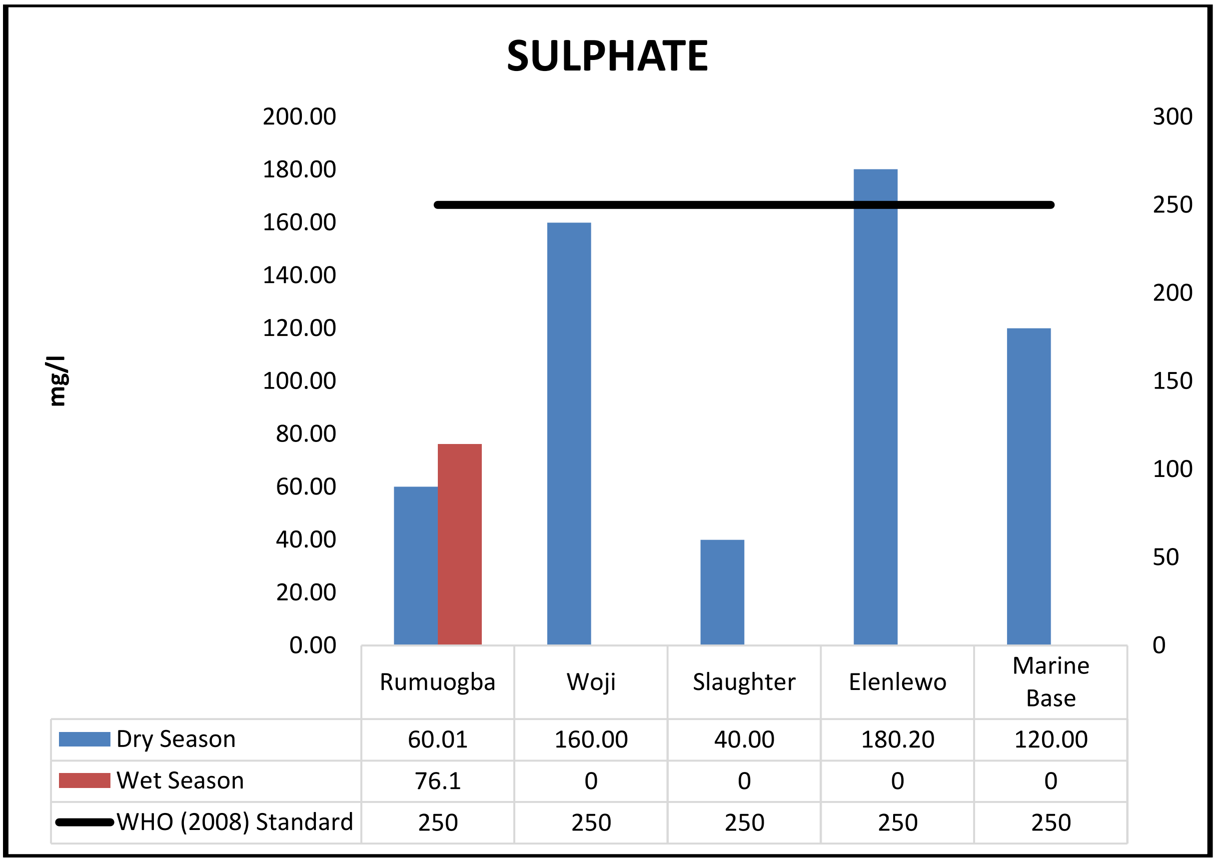
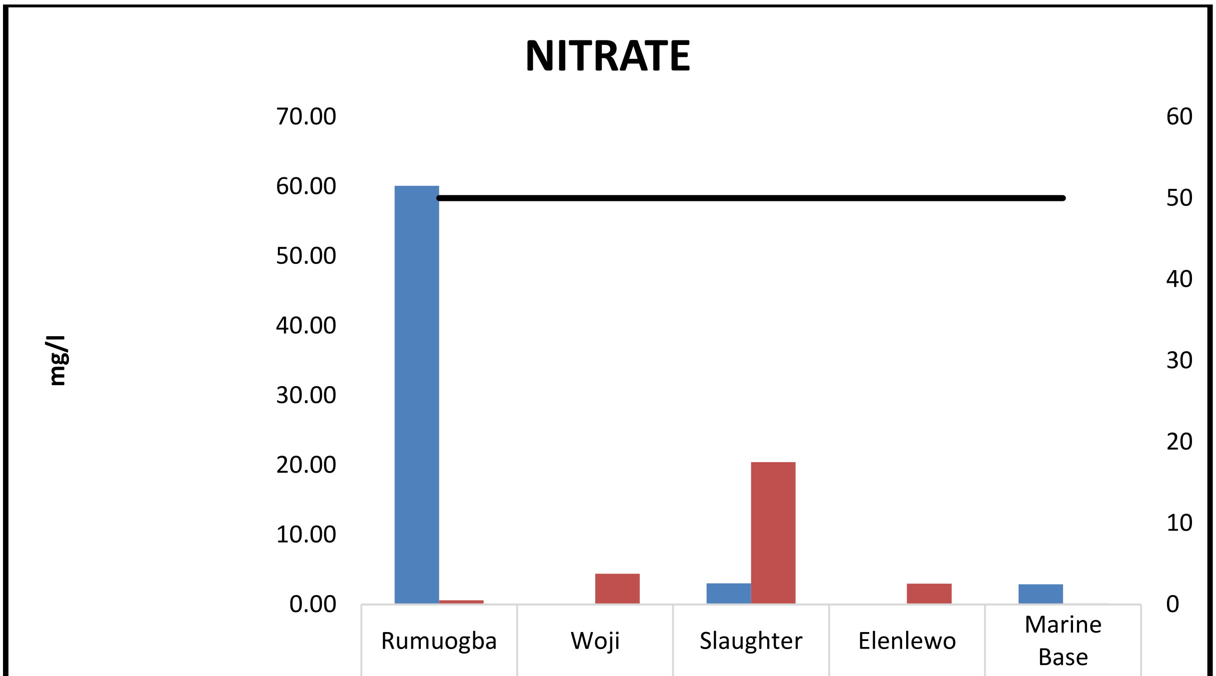


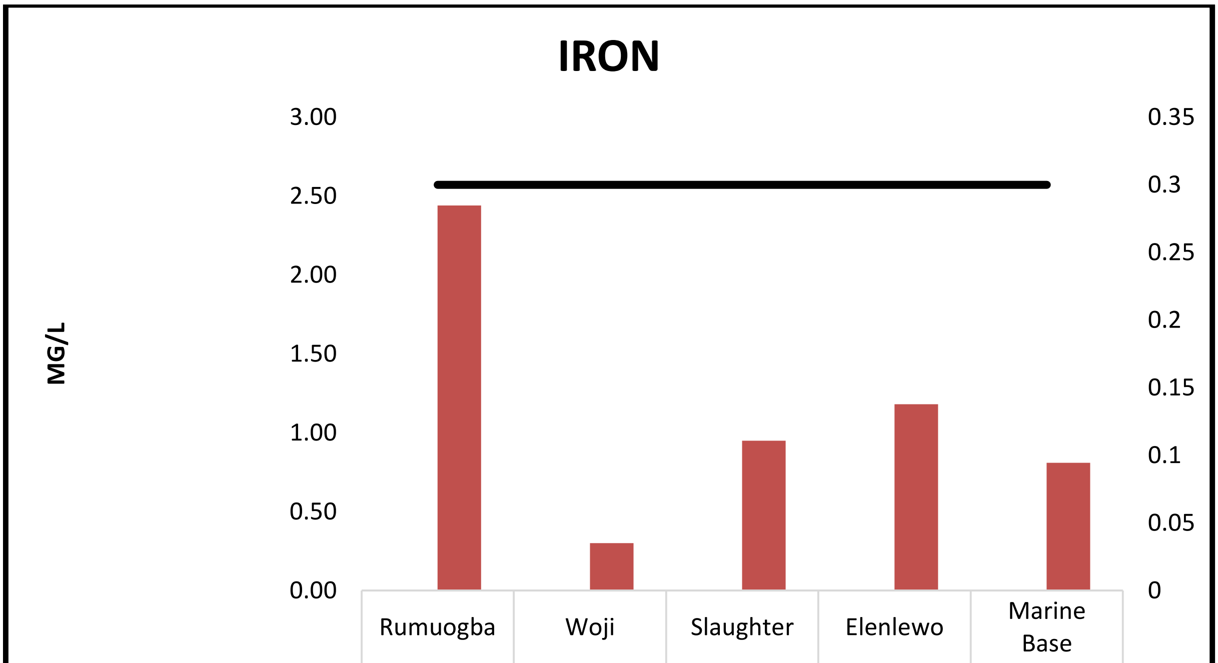

Figure 7: Sulphate

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 1
January 2019




| | Rumuogba | Woji | Slaughter | Elenlewo | Marine Base |
|---|---|---|---|---|---|
| Dry Season | 60.10 | 0.00 | 3.03 | 0.00 | 2.90 |
| Wet Season | 0.6 | 4.4 | 20.43 | 3 | 0.12 |
| WHO (2008) Standard | 50 | 50 | 50 | 50 | 50 |

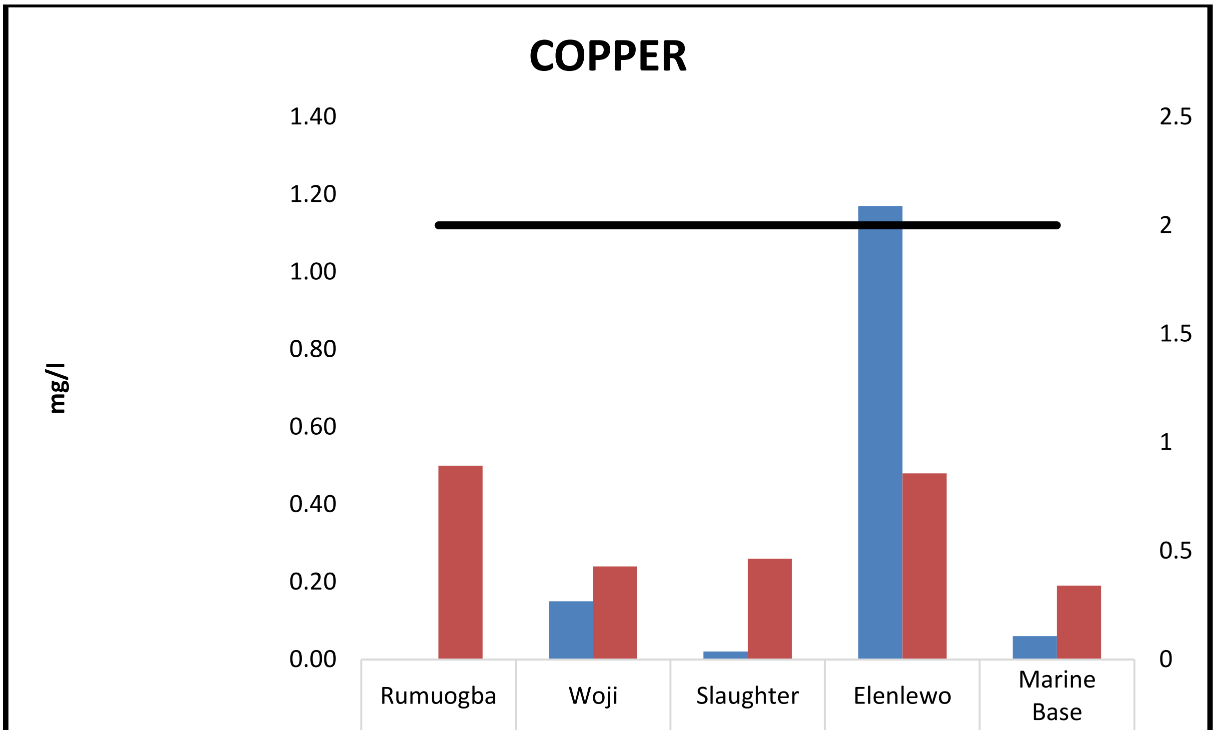
Figure 8: Nitrate




| | Rumuogba | Woji | Slaughter | Elenlewo | Marine Base |
|---|---|---|---|---|---|
| Dry Season | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Wet Season | 2.44 | 0.3 | 0.95 | 1.18 | 0.81 |
| WHO (2008) Standard | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |

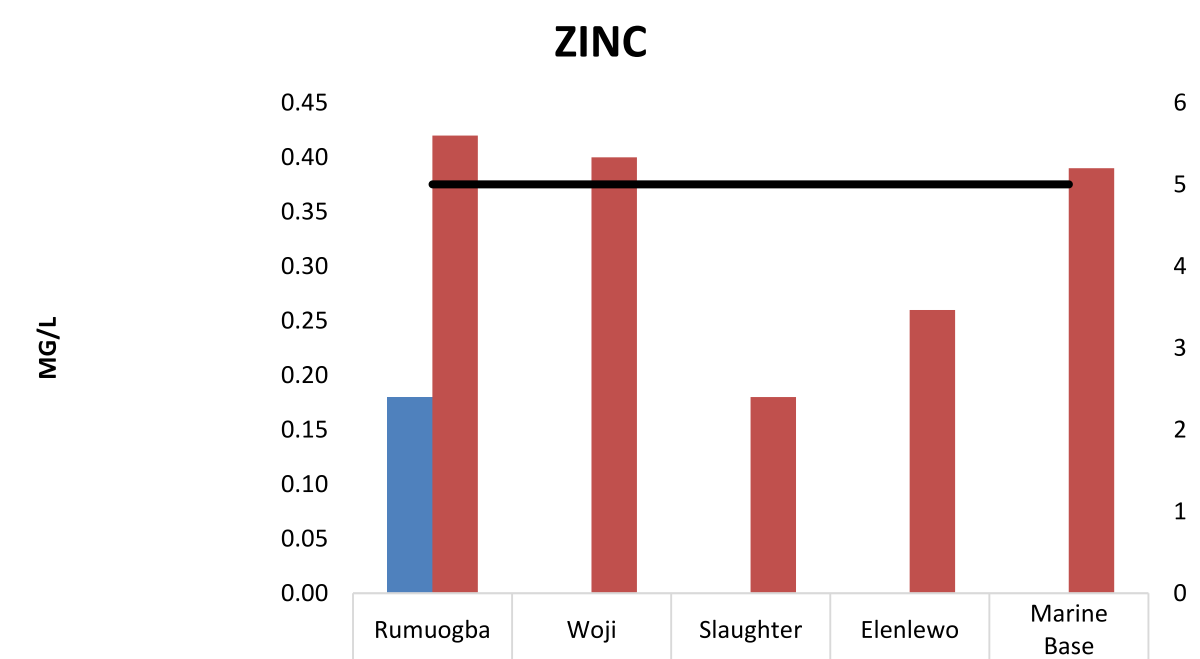
Figure 9: Iron

International Journal of Research
Available at https://pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 1
January 2019




| | Rumuogba | Woji | Slaughter | Elenlewo | Marine Base |
|---|---|---|---|---|---|
| Dry Season | 0.00 | 0.15 | 0.02 | 1.17 | 0.06 |
| Wet Season | 0.5 | 0.24 | 0.26 | 0.48 | 0.19 |
| WHO (2008) Standard | 2 | 2 | 2 | 2 | 2 |

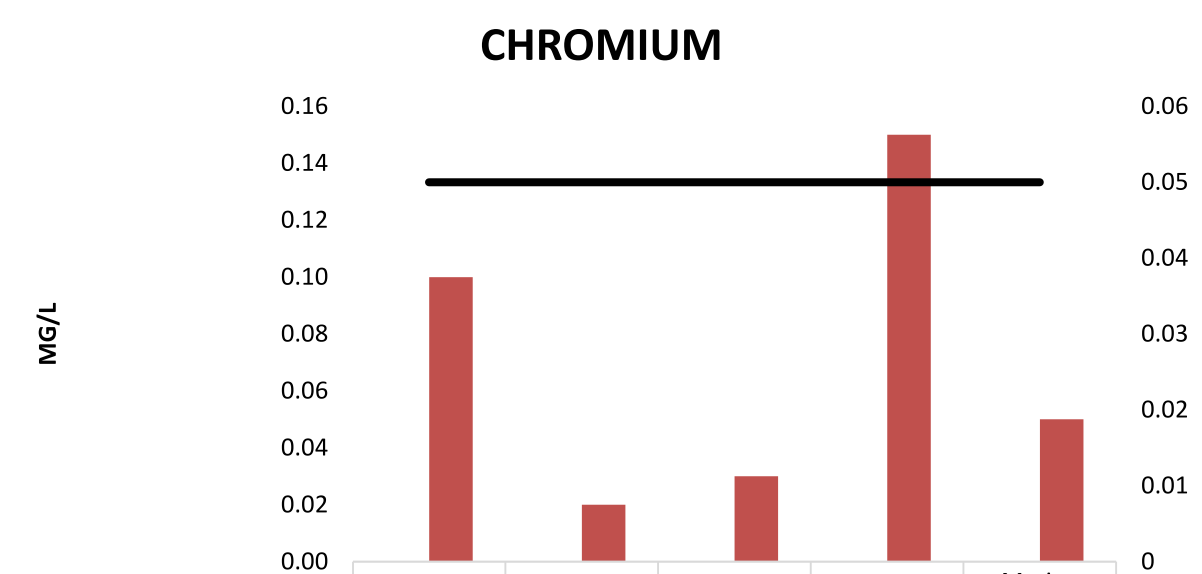
Figure 10: Copper




| | Rumuogba | Woji | Slaughter | Elenlewo | Marine Base |
|---|---|---|---|---|---|
| Dry Season | 0.18 | 0.00 | 0.00 | 0.00 | 0.00 |
| Wet Season | 0.42 | 0.4 | 0.18 | 0.26 | 0.39 |
| WHO (2008) Standard | 5 | 5 | 5 | 5 | 5 |

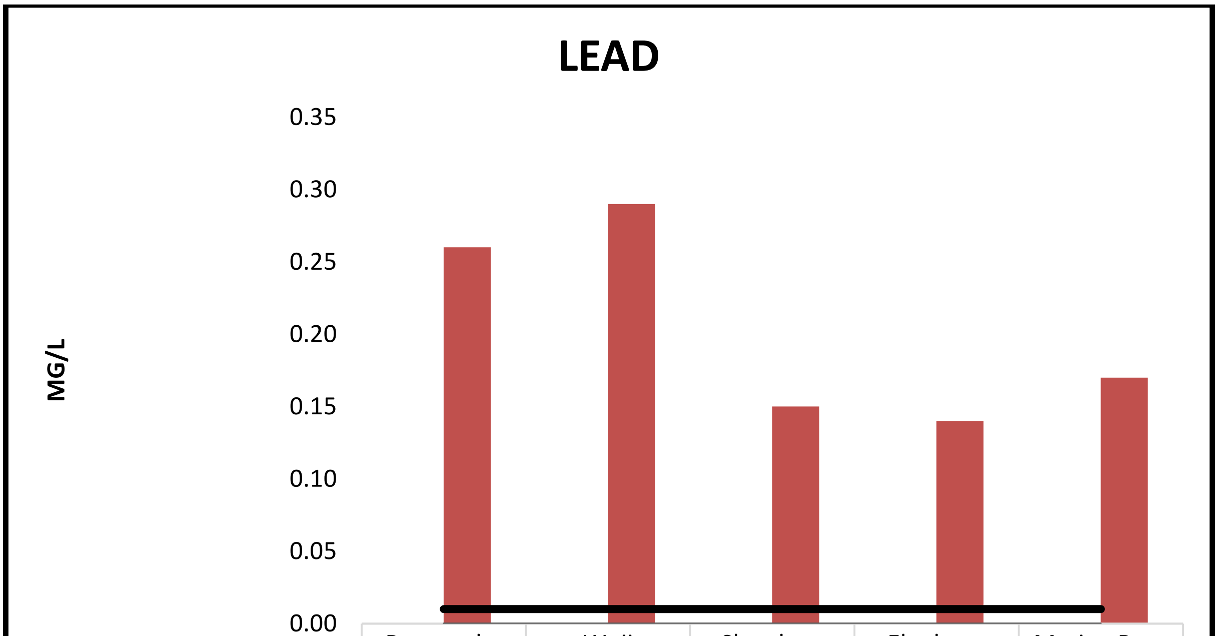
Figure 11: Zinc

International Journal of Research
Available at https://pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 1
January 2019




| | Rumuogba | Woji | Slaughter | Elenlewo | Marine Base |
|---|---|---|---|---|---|
| Dry Season | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Wet Season | 0.1 | 0.02 | 0.03 | 0.15 | 0.05 |
| WHO (2008) Standard | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |

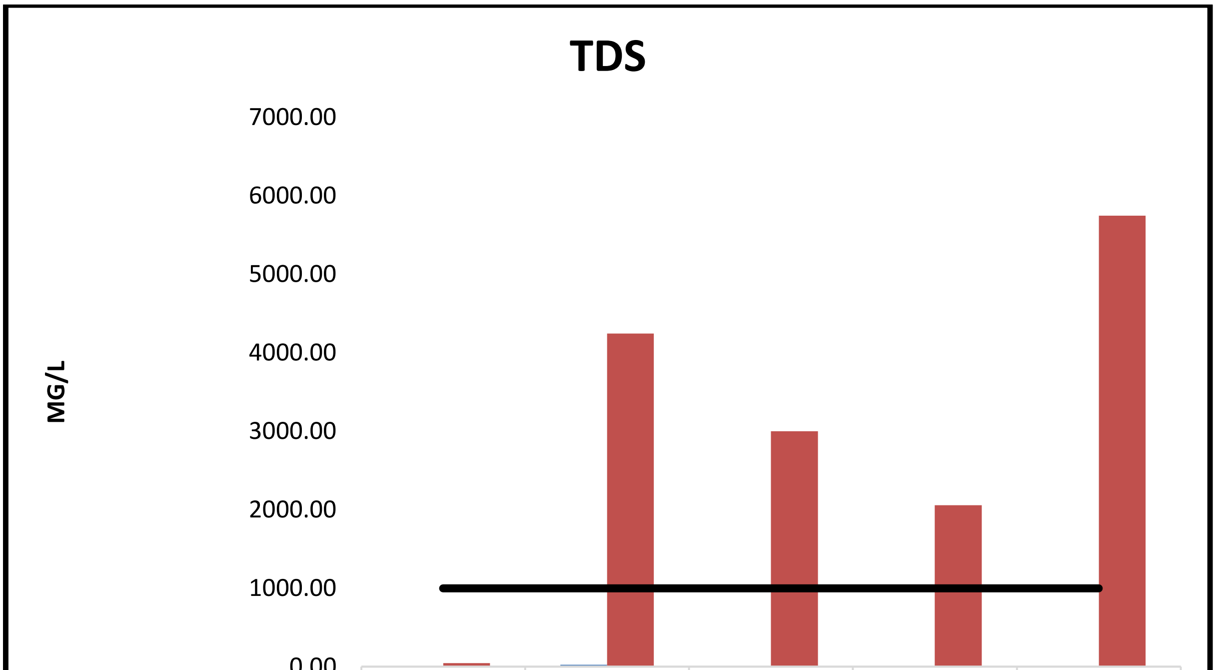
Figure 12: Chromium




| | Rumuogba | Woji | Slaughter | Elenlewo | Marine Base |
|---|---|---|---|---|---|
| Dry Season | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Wet Season | 0.26 | 0.29 | 0.15 | 0.14 | 0.17 |
| WHO (2008) Standard | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |

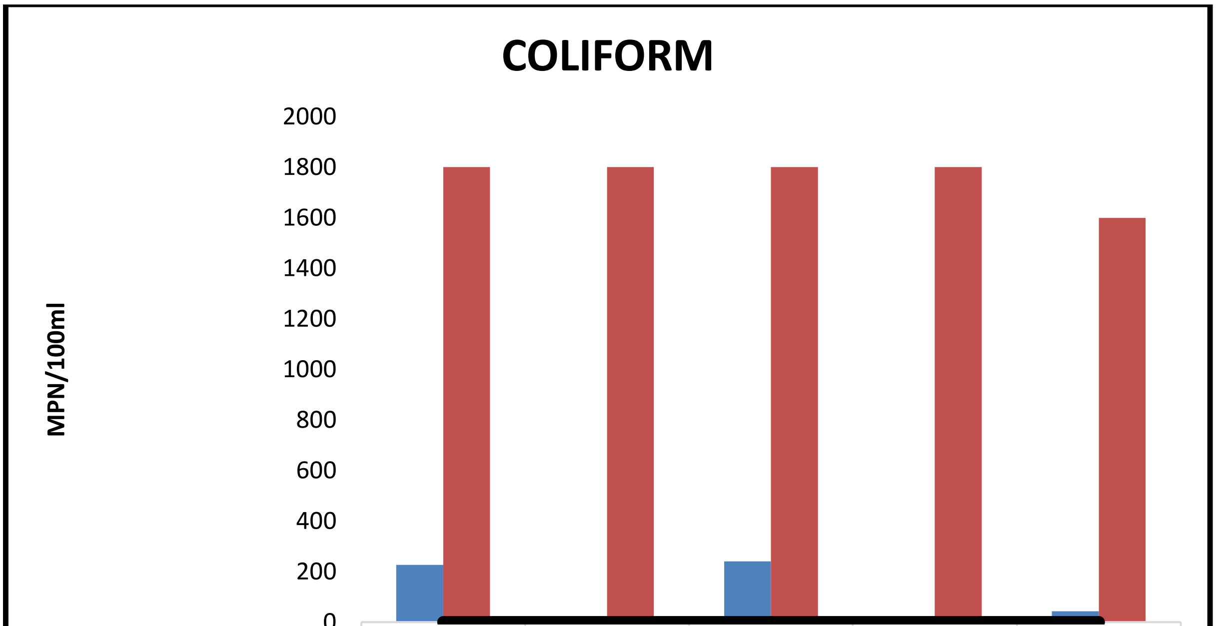
Figure 13: Lead

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 1
January 2019




| | Rumuogba | Woji | Slaughter | Elenlewo | Marine Base |
|---|---|---|---|---|---|
| Dry Season | 0.00 | 27.80 | 8.90 | | |
| Wet Season | 48 | 4247.3 | 2999 | 2058.3 | 5746.3 |
| WHO (2008) Standard | 1000 | 1000 | 1000 | 1000 | 1000 |

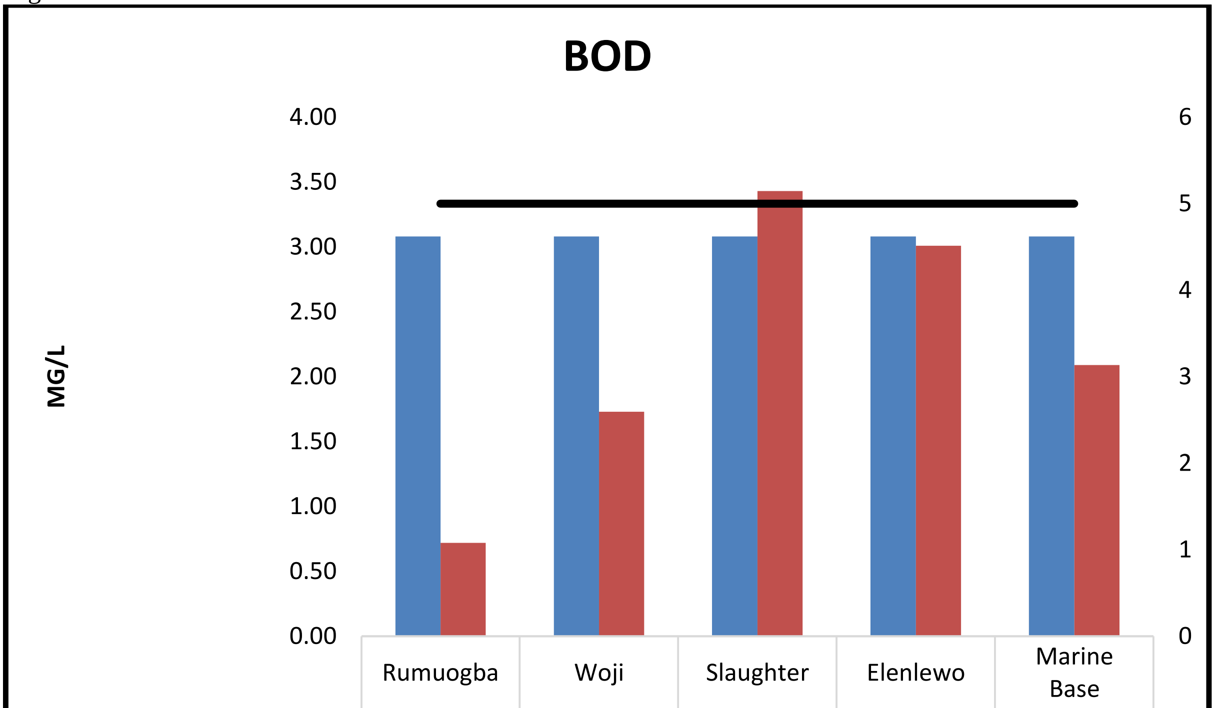
Figure 14: TDS




| | Rumuogba | Woji | Slaughter | Elenlewo | Marine Base |
|---|---|---|---|---|---|
| Dry Season | 227 | 9 | 240 | 23 | 43 |
| Wet Season | 1800 | 1800 | 1800 | 1800 | 1600 |
| WHO (2008) Standard | 0 | 0 | 0 | 0 | 0 |

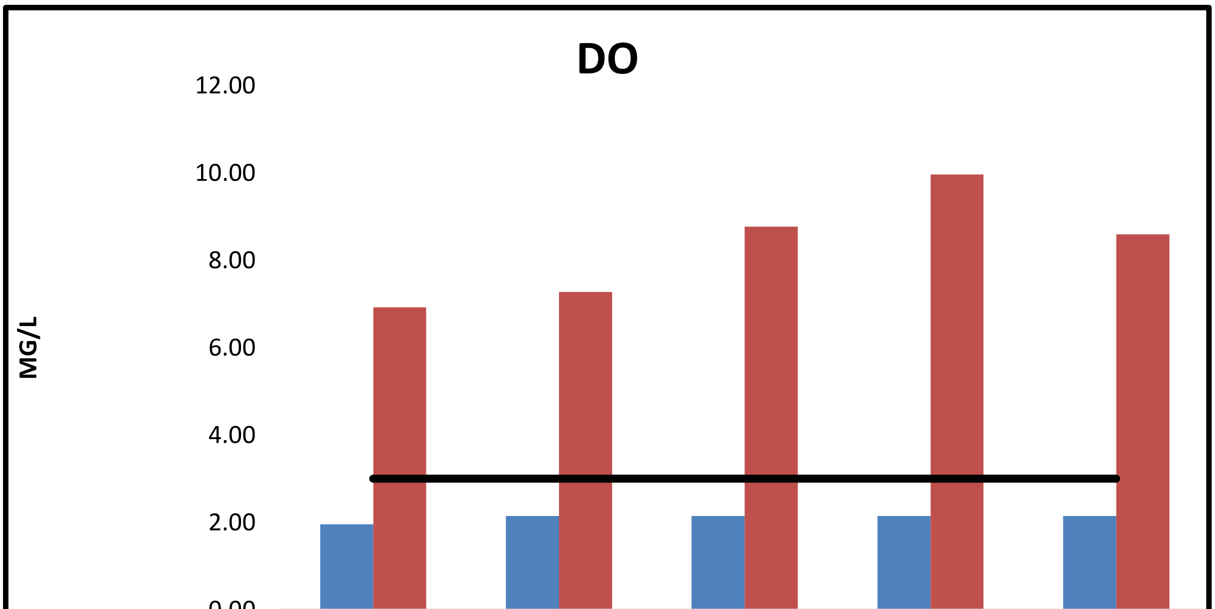
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 1
January 2019

Figure 15: Coliform




| | Rumuogba | Woji | Slaughter | Elenlewo | Marine Base |
|---|---|---|---|---|---|
| Dry Season | 3.08 | 3.08 | 3.08 | 3.08 | 3.08 |
| Wet Season | 0.72 | 1.73 | 3.43 | 3.01 | 2.09 |
| WHO (2008) Standard | 5 | 5 | 5 | 5 | 5 |

Figure 16: BOD




| | Rumuogba | Woji | Slaughter | Elenlewo | Marine Base |
|---|---|---|---|---|---|
| Dry Season | 1.96 | 2.15 | 2.15 | 2.15 | 2.15 |
| Wet Season | 6.93 | 7.28 | 8.77 | 9.97 | 8.6 |
| Lower Limit | 3 | 3 | 3 | 3 | 3 |

Figure 17: DO

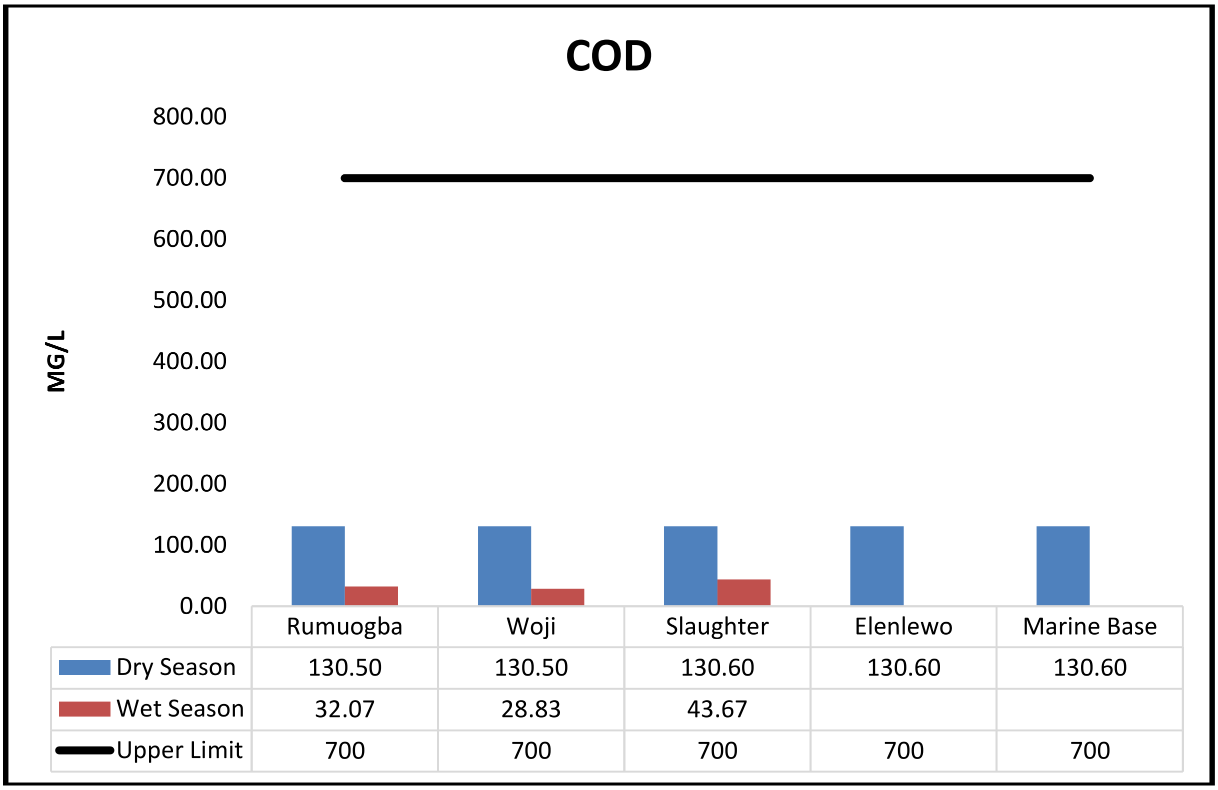



Figure 18: COD

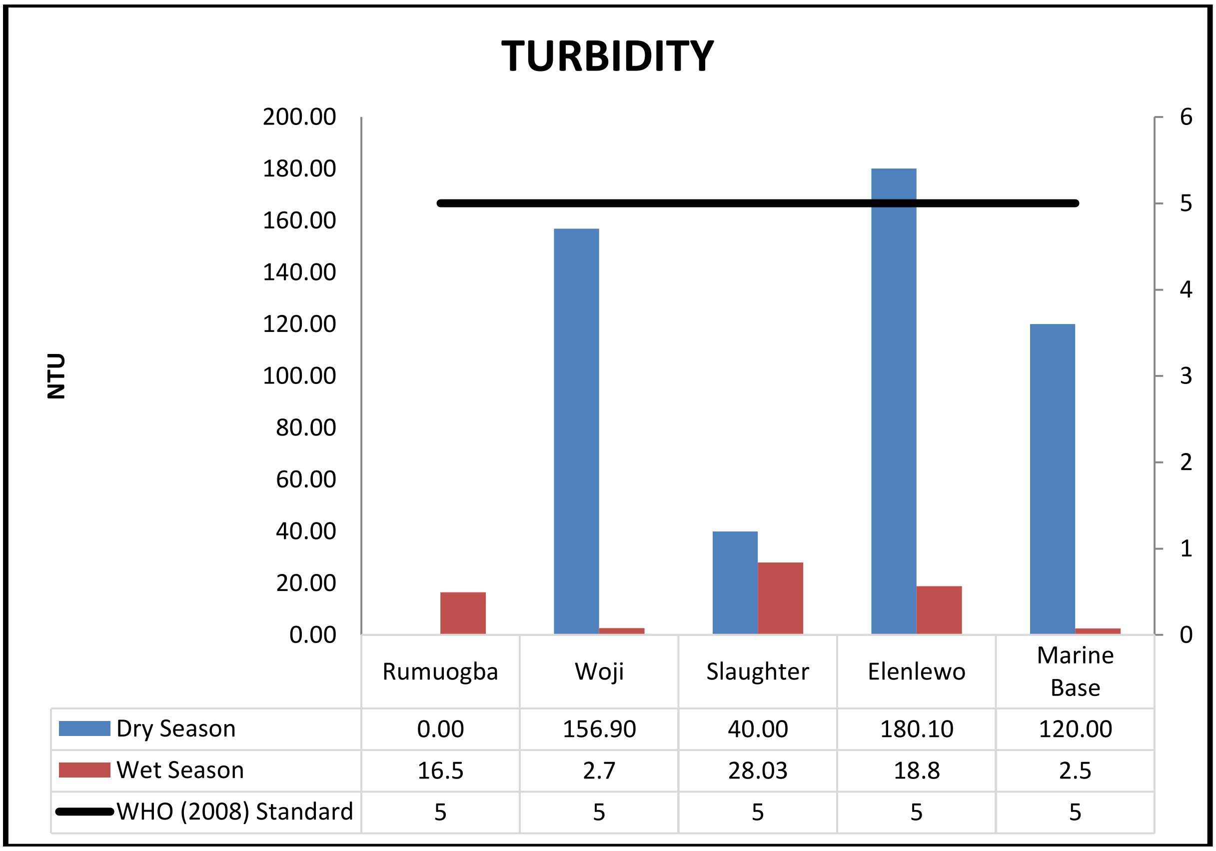


Figure 19: Turbidity

**Table1: Water Quality Index Calculation**

**Raw Data Entry**

| Dissolved Oxygen % Saturation | Fecal Coliform #/100 mL | pH | BOD-5 mg/L | Delta Temp degrees C | Phosphate mg/L | Nitrate mg/L | Turbidity NTU | TS mg/L |
|---|---|---|---|---|---|---|---|---|
| 5.21 | 934.2 | 5.89 | 2.64 | 27.2 | 0 | 9.46 | 56.55 | 1519.13 |

**Q-Value Calculation**

| Dissolved Oxygen | Fecal Coliform | pH | BOD-5 | Delta Temp | Phosphate | Nitrate | Turbidity | TS |
|---|---|---|---|---|---|---|---|---|
| 4 | 20 | 52 | 72 | 15 | 0 | 53 | 35 | 20 |

**Weighted Q-Value**

| Dissolved Oxygen | Fecal Coliform | pH | BOD-5 | Delta Temp | Phosphate | Nitrate | Turbidity | TS |
|---|---|---|---|---|---|---|---|---|
| 0.67 | 3.18 | 5.77 | 7.89 | 1.65 | 0.00 | 5.29 | 2.82 | 1.40 |

**Overall Water Quality Index (score out of 100):** **28.68**

**Water Quality Category:** **Bad**

*SOURCE:* BF Environmental Consultants, Inc.

**Table 2: Correlation coefficient matrix**

| Parameters | Temp. | pH | EC | Turbidity | Chloride | Sulphate | Nitrate | T. Hardness | Iron | Copper | Zinc | Chromium | Lead | TDS | Total Coliform | BOD | DO | COD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature | 1.00 | | | | | | | | | | | | | | | | | |
| pH | 0.84 | 1.00 | | | | | | | | | | | | | | | | |
| EC | 0.83 | 0.81 | 1.00 | | | | | | | | | | | | | | | |
| Turbidity | 0.35 | 0.06 | 0.46 | 1.00 | | | | | | | | | | | | | | |
| Chloride | 0.85 | 0.74 | 0.95 | 0.69 | 1.00 | | | | | | | | | | | | | |
| Sulphate | 0.22 | -0.29 | -0.12 | 0.58 | 0.13 | 1.00 | | | | | | | | | | | | |
| Nitrate | -0.56 | -0.41 | -0.79 | -0.89 | -0.90 | -0.23 | 1.00 | | | | | | | | | | | |
| Total Hardness | 0.68 | 0.68 | 0.97 | 0.55 | 0.92 | -0.17 | -0.87 | 1.00 | | | | | | | | | | |
| Iron | -0.67 | -0.71 | -0.85 | -0.67 | -0.93 | 0.03 | 0.88 | -0.86 | 1.00 | | | | | | | | | |
| Copper | -0.46 | -0.77 | -0.38 | 0.59 | -0.17 | 0.62 | -0.23 | -0.21 | 0.14 | 1.00 | | | | | | | | |
| Zinc | 0.17 | -0.06 | -0.35 | -0.46 | -0.36 | 0.40 | 0.61 | -0.56 | 0.59 | -0.24 | 1.00 | | | | | | | |
| Chromium | -0.59 | -0.93 | -0.60 | 0.21 | -0.49 | 0.56 | 0.16 | -0.48 | 0.57 | 0.87 | 0.11 | 1.00 | | | | | | |
| Lead | 0.37 | 0.32 | -0.16 | -0.24 | -0.05 | 0.33 | 0.35 | -0.38 | 0.09 | -0.38 | 0.73 | -0.33 | 1.00 | | | | | |
| TDS | 0.84 | 0.81 | 1.00 | 0.46 | 0.95 | -0.11 | -0.79 | 0.97 | -0.85 | -0.37 | -0.35 | -0.60 | -0.15 | 1.00 | | | | |
| Total Coliform | -0.78 | -0.42 | -0.78 | -0.66 | -0.81 | -0.45 | 0.76 | -0.74 | 0.56 | -0.07 | 0.02 | 0.05 | 0.11 | -0.78 | 1.00 | | | |
| BOD | -0.24 | -0.04 | 0.30 | 0.43 | 0.29 | -0.40 | -0.57 | 0.52 | -0.50 | 0.29 | -0.99 | -0.01 | -0.81 | 0.29 | -0.01 | 1.00 | | |
| DO | -0.24 | -0.31 | 0.24 | 0.61 | 0.26 | -0.01 | -0.62 | 0.46 | -0.32 | 0.62 | -0.80 | 0.41 | -0.91 | 0.23 | -0.29 | 0.85 | 1.00 | |
| COD | -0.43 | -0.53 | 0.01 | 0.47 | 0.02 | 0.02 | -0.41 | 0.24 | -0.05 | 0.70 | -0.67 | 0.60 | -0.93 | 0.01 | -0.16 | 0.75 | 0.96 | 1.00 |

**Chloride** concentration in the dry season is lower than the wet season with mean values of 18.09 mg/L and 868.80 mg/L respectively. Values of the dry season alongside values for Rumuogba for the wet season are all below the WHO limit while the other Rivers exceeded the WHO limit for the wet season. This is due to washoff of poly aromatic compounds on the land surface and carried into the water body especially after rain fall.

**Sulphate** has high value of 112.04mg/L during the dry season and a low value of 15.22mg/L during the wet season. Both values are below the 2008 WHO limits. This result agrees with works of Erondu and Chindah, 1991; Chindah *et. al.*, 1998; Chindah and Braide, 2003). The increase in temperature in the dry season reduces the number of microorganism that uses the nutrients in the rivers.

**Nitrate (mg/L):** the mean values for nitrates are 13.21mg/L during the dry season and 5.71mg/L during the wet season, with only Rumuogba River exceeding WHO limits in the dry season. This result does not agree with Adesuyi et al., 2015 as the

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 1
January 2019

sampled river were free from human excretal especialy during the dry season

**Iron (mg/L):** the mean values for iron is 0.0 (mg/L) and 1.14 Mg/L in the dry and wet season respectively. Both values are below the 2008 WHO limit. This result does not agree with Saeed et al., 2014 since the Sample Rivers during dry season had no inflow of heavy metal from the surrounding, but grew 0.0 Mg/L to 1.14 Mg/L as runoff water brought heavy metal impurities into the water bodies in the wet season.

**Chromium (mg/L):** The values of chromium are not detected during the dry season while in the rainy season chromium has mean values of 0.07 mg/L which is higher than the 2008 WHO limit with Elenlewo River being the only River exceeding the chromium WHO limit. This result does not agree with Saeed et al., 2014 since the Sample Rivers during dry season had no inflow of heavy metal from the surrounding, but grew from not detected to 0.07 Mg/L as runoff water brought heavy metal impurities into the water bodies in the wet season.

**Lead (mg/L):** Mean value of lead in the dry season is 0.00mg/L while that of the wet season is 0.20Mg/l, which is above the 2008 WHO limit. This result does not agree with Saeed et al., 2014 since the Sample Rivers during dry season had no inflow of heavy metal from the surrounding, but grew 0.0 Mg/L to 0.20 Mg/L as runoff water brought heavy metal impurities into the water bodies in the wet season.

**Total Hardness:** Mean total hardness for the wet season is 332.93 mg/L while for the dry season is 116.45 mg/L and is below 2008 WHO limits. Total hardness values show that Elenlewo, Woji, Slaughter and Marine base are classified as very hard Water while that of Rumuogba is slightly hard. This result agrees with Etim et al, 2013.

**Chemical Oxygen Demand (COD):** The mean value for COD during the dry season is 130.58 while that of the wet season is 40.38 mg/L, all below the WHO limit. This result agrees with Siyanbola, et at., 2011 due to numerous non-biodegradable substance in the rivers.

**Copper (mg/L):** Copper has values of 0.68mg/L during the dry season and 0.3mg/L during the wet season, with both seasons below the 2008 WHO limit except for Elenlewo which was above the WHO limit during the dry season by a very small margin as a result of reduced water level in the River. This result is in agreement with Edori and Kpee 2016.

**Zinc (mg/L):** the mean values for zinc are 0.0 4mg/L during the dry season and 0.3mg/L in the rainy season. Both seasons are below the WHO limits of 5mg/L. This result is in agreement with Edori and Kpee 2016.

**pH:** The pH mean values for dry season is 5.34 while that of rainy season is 6.44. This implies that the water is slightly acidic and they are all below the 6.5 WHO's limit. Which makes this waters unsafe for drinking and is in agreement with Etim et al 2013.

**Temperature:** the temperature of the water ranges from 26°C in the dry season to 29°C during the rainy season, while temperature is not detected in the 2008 WHO standard. The temperature was high in the wet season than that of the dry season. This findings agree with earlier reported works in the Niger Delta such as Chindah et al. (1998) who reported temperature ranges of between 26°C and 30.5°C, Zabbey (2002) between 26.3°C and 30.4°C, Braide et al. (2004) (26.64 ± 1.18°C and 30.83 ± 1.47°C), Ansa (2005) (25.9°C and 32.4°C); Hart and Zabbey (2005) (25.8°C and 30.4°C), Sikoki and Zabbey (2006) (26°C and 27.8°C), Dibia (2006) (25°C to 27°C) and Jamabo (2008) the rapid decrease in temperature especially during the wet season is due to the heavy rain fall.

**Electrical Conductivity:** the mean electrical conductivity values for dry season is 44.64µs/cm while that of wet season is 4645.68µs/cm. The values are below WHO's limit except for Marine Base during the wet season which exceeded the WHO's limit. This could be attributed to heavy flow of water current Onojake, et al., 2017. The water is classified as sea water based on the conductivity values ranging from 73.8 to 8,840 µs/cm. as

**Turbidity (NTU):** Mean values of turbidity for dry season is 99.4 NTU while that of wet season is 13.7NTU. The values for dry season is above the WHO limit while that of the wet season is below it. This may be due to turbulence as a result of movement of boats.

**Total Dissolves Solids (TDS)(mg/L):** The mean value of TDS in the dry season is 18.49mg/L while in the wet season it is 3019.78mg/L. The dry season value is below the WHO limit while that of the wet season is higher than the WHO limit. The high values during the wet season indicates increased presence of sediments like silt and clay in the River. This research has shown that waters from Elelewo, Woji, Slaughter and Marine base are classified as Brackish Water while that of Rumuogba is Fresh water according to (CARROLL, 1962) classification.

**The Biological Oxygen Demand (BOD) mg/L:** the mean value for dry season is 3.08mg/L while that of the wet season is 2.2Mg/L all below the WHO standards for all sampling points with exception of Slaughter River which concentration was slightly above the acceptable WHO limit. This result agrees with Siyanbola, et at., 2011 due to numerous non-biodegradable substance in the rivers.

**Total Coliform:** Total coliform has mean values of 108.4 MPN /ml during the dry season and 1760 MPN/ml during the wet season. Both values are above the WHO limit indicating the presence of microorganism's contamination of the Rivers.

**Dissolved Oxygen (DO) mg/L:** The mean value of DO for the dry season is 2.11 mg/Land the value for the rainy season is 8.31 mg/L. DO is below acceptable limit for aquatic organisms survival while that of the wet season supports aquatic organisms growth /activities at all sampling stations respectively.

**Water Quality Index:**
The Water Quality Index runs on the scale from zero to hundred to rate the quality of the water, with hundred being the best rating. The WQI report is compared against the WQI Quality Scale to figure out exactly how balanced the water is.

| Table 3: - WQI Quality Scale | |
|---|---|
| 91-100: | Excellent water quality |
| 71-90: | Good water quality |
| 51-70: | Medium or average water quality |
| 26-50: | Bad water quality |
| 0-25: | Very bad water quality |

**Correlation Analysis**

**Very Strong Negative Correlation**
It was observed that very strong negative correlation exist between electrical conductivity and iron; pH and chromium; turbidity and nitrate; chloride and nitrate, iron, coliform; nitrate and total hardness; total hardness and iron; iron and TDS; zinc and BOD, DO; lead and BOD, COD, DO; TDS and coliform.

**Strong Negative Correlation**
Strong correlation existed between temperature and iron; turbidity and iron, coliform, COD; nitrate and DO; zinc and COD; pH and iron, copper; electrical conductivity and nitrate, coliform; total hardness and coliform; TDS and coliform.

**Moderate Negative Correlation**
Moderate negative correlation exists between pH and nitrate, coliform, COD; turbidity and zinc; chloride and chromium, zinc; sulphate and coliform; nitrate and COD, BOD; total hardness and chromium; iron and BOD; TDS and chromium; electrical conductivity and chromium; temperature and nitrate, copper, chromium, COD

**Weak Negative Correlation**
Weak negative correlation was observed between temperature and BOD, DO; pH and sulphate, zinc; turbidity and lead; electrical conductivity and copper, zinc; sulphate and nitrate, BOD; nitrate and copper; total hardness and copper, lead; Copper and zinc, lead, TDS; coliform and DO; chloride and zinc; iron and DO; zinc and TDS; chromium and lead.

**Very Strong Positive Correlation**
Very strong positive correlation was observed between temperature and pH, electrical conductivity, chloride, TDS; pH and electrical conductivity, TDS; electrical conductivity and chloride, total hardness, TDS; chloride and total hardness, TDS; nitrate and iron; total hardness and TDS; copper and chromium; BOD and DO; DO and COD.

**Strong Positive Correlation**
Strong positive correlation was observed between temperature and total hardness, chloride; turbidity and chloride, DO; sulphate and copper; nitrate and zinc, coliform; copper and DO, COD; zinc and lead; BOD and COD.

**Moderate Positive Correlation**
Moderate positive correlation was observed between electrical conductivity and turbidity; turbidity and TDS, BOD, COD, sulphate, copper, nitrate, total hardness; total hardness and DO, BOD; chromium and DO, COD; sulphate and chromium; iron and zinc, chromium, coliform.

**Weak Positive Correlation**
Weak positive correlation was observed between temperature and sulphate, turbidity, lead; pH and lead' electrical conductivity and BOD, DO; turbidity and chromium; chloride and BOD, DO; total hardness and COD; copper and BOD; TDS and BOD, Do; sulphate and zinc, lead; nitrate and lead.

The above correlation analysis on water quality parameters for Rumuogba, Woji, Slaughter, Elelenwo and Marine Base Rivers in Port Harcourt, have revealed that almost all variables are less or more correlated with one another Individuals Correlation matrix. It's found that several of the parameters don't have considerable correlation between them indicating various origin of pollution. From correlation analysis, pH, turbidity, conductivity, total hardness, temperature and dissolved oxygen shows significant impact on aquatic life and reproduction and contributes to the overall pollution status of the rivers. Hence it could be said that Rumuogba, Woji, Slaughter, Elelenwo and Marine Base Rivers signifies severe risk to the environment as a result of anthropogenic pollution. Because these rivers serve as lifeline for individuals of the respective communities who use the water for domestic and economic purposes.

## 4. CONCLUSION

The physico-chemical and biological characteristics of the Rivers in Rumuogba, Elelenwo, Woji, Slaughter and Marine Base analyzed during the rainy and dry seasons were determined in this study. From the results, most of the parameters did not attain the 2008 World Health Organization (WHO) recommendation limit. They are as follows chloride, nitrate, iron, copper, zinc, pH, several factors are responsible for the decrease of these parameters while compared to the WHO limits. While other parameters like chromium, lead, temperature, electrical conductivity, turbidity and total dissolved solids have values that are above the WHO limits in some of their seasons. Factors such as domestic and industrial activities in the area could be responsible for the increase in the values when compared with WHO limits and the deteriorated quality of the water.

The water quality index result ranged from 32.28 to 74.17 for the dry season and 29.86 to 41.83 for the wet season, with a mean Water quality Index 39 for the dry season and 38 for the wet, indicating a bad water quality. The water has to be properly treated if it must be used for any domestic or industrial purpose to prevent health hazard and epidemic. Correlation analysis revealed 16 very strong positive correlation, 12 strong positive correlation, 15 moderate positive correlation, 16 weak positive correlation, 14 very strong negative correlation, 13 strong negative correlation, 17 moderate correlation and 20 weak correlation among the parameters respectively. The high percentage of positive correlation among temperature, pH, electrical conductivity, chloride, TDS, total hardness, nitrate, iron, copper, chromium, BOD supports the results of water quality index that the water from theses Rivers is bad (polluted).

## REFERENCES

[1]. Adel Mashaan Rabee, Bahaa Malik Abdul-Kareem, Ahmed Saad Al-Dhamin, (2011). Seasonal Variations of Some Ecological Parameters in Tigris River Water at Baghdad Region, Iraq. *Journal of Water Resource and Protection*, 3, 262-267

[2]. Chindah AC, Braide SA, (2003). Cadmium and Lead concentrations in fish species of a brackish wetland / upper Bonny Estuary, Niger Delta. J. Nig. Environ. Soc. (JNES). 1 (3): 399-405

*[3]*. Altman SJ, and Parizek RR, (1995) Dilution of non-point source nitrate in ground water. J Environ Qual 24:707–718. United Nations Environment Program (UNEP) (2008), *Annual Report.*

[4]. Emongor V., Kealotswe E., Koorapetse I., Sankwasa S. and Keikanetswe S., (2005). Pollution indicators in Gaberone effluent. J. Appl. Sci., **5**, 147-150

[5]. WHO/UNEP (1997) Water Pollution Control - A Guide to the Use of Water Quality Management Principles Edited by Richard Helmer and Ivanildo Hespanhol Published on behalf of the United Nations Environment Programme, the Water Supply & Sanitation Collaborative Council and the World Health Organization by E. & F. Spon

[6]. Osuiwu, B. O. & T. E. Ologunorisa, 2000. “Weather and Climate” in Port Harcourt Region. Oyegun, C. U. & A. M. Adeyemo (Eds). Dept. of Geography, University of Port Harcourt, pp 57 – 68.

[7]. Oyegun, C. U., 2000. “Geology and Sedimentary Environment” in Port Harcourt Region. Oyegun, C. U. & A. M. Adeyemo (Eds). Dept. of Geography, University of Port Harcourt, pp 13 – 32.

[8]. World Health Organization (WHO), 2008. Guidelines for Drinking Water Quality: Incorporating 1st and 2nd Addenda, Vol. 1, Recommendations. – 3rd ed.

[9]. Erondu, E. S. and Chindah, A. C. (1991). Variation in the physico-chemical features and phytoplankton of the New Calabar River at Aluu, Rivers State, Nigeria NIOMR n. 75: 1 – 18.

[10]. Chindah, A.C., S.A. Braide and C. Obunwo, (1998). The effect of municipal waste discharge on the physicochemical and phytoplankton in a brackish wetland in Bonny Estuary. Acta Hydrobiol., 40: 9-15.

[11]. Adesuyi, A.A., Nnodu, V.C., Njoku, K.L. and Jolaoso, A. (2015) Nitrate and Phosphate Pollution in Surface Water of Nwaja Creek, Port Harcourt, Niger Delta, Nigeria. International Journal of Geology, Agriculture and Environmental Sciences, 3, 14-20.

[12]. Saeed Shanbehzadeh, Marzieh Vahid Dastjerdi, Akbar Hassanzadeh, and Toba Kiyanizadeh, (2014). "Heavy Metals in Water and Sediment: A Case Study of Tembi River," Journal of Environmental and Public Health, vol. 2014, Article ID 858720, 5 pages, 2014. https://doi.org/10.1155/2014/858720.

[13]. Etim, E.E., Odoh, R., Itodo, A.u and Lawal, U (2013). Water quality Index for the Assessment of water quality from different sources in the Niger Delta region of Nigeria. Frontiers in science 3(3): 89-95.

[14]. Siyanbola T.O., K.O. Ajanaku, O.O. James, J.A.O. Olugbuyiro, J.O. Adekoya, (2011). Physico-Chemical Characteristics of Industrial Effluents In Lagos State, Nigeria. G. J. P&A Sc and Tech., 2011v01 (49-54).

[15]. Edori OS, Kpee F (2016) Physicochemical and heavy metal assessment of water samples from boreholes near some abattoirs in Port Harcourt, Rivers State, Nigeria. American Chemical Science Journal 14: 1-8

[16]. Zabbey, N., 2002. An ecological survey of benthic macroinvertebrates of Woji Creek, off the Bonny River System Rivers State. M.Sc. Thesis, University of Port Harcourt, pp: 102.

[17]. Braide SA, Izonfuo WAL, Adiukwu PU, ChindahAC,Obunwo CC (2004) Water Quality of Miniweja stream, A Swamp forest stream receiving non-point source waste discharges in Eastern Niger Delta, Nigeria.ScientiaAfr 3: 1-8.

[18]. Ansa, E.J., (2005). Studies of the benthic macrofauna of the Andoni flats in the Niger Delta Area of Nigeria. Ph.D Thesis University of Port Harcourt, Port Harcourt, Nigeria, pp: 242.

[19]. Hart, A.I. and N. Zabbey, 2005. Physico-chemical and benthic fauna of Woji Creek in the Lower Niger Delta, Nigeria Environ. Ecol., 23(2): 361-368.

[20]. Sikoki, F.D. and N. Zabbey, 2006. Environmental gradients and Benthic community of the middle reaches of Imo River, South-Eastern Nigeria. Environ. Ecol., 24(1): 32-36.

[21]. Jamabo, N.A., 2008. Ecology of Tympanotonus fuscatus (Linnaeus, 1758) in the mangrove swamps of the Upper Bonny River, Niger Delta, Nigeria. PhD. Thesis, Rivers State University. pp: 340.

[22]. Dibia, A.E.N., 2006. Effect of biotope difference on aquatic Macrophytes along Mini-Chindah Stream in Port Harcourt, Rivers State M.Sc. Thesis, Rivers State University of Science and Technology, Port Harcourt, Nigeria, pp: 120.

[23]. Onojake, M.C., Sikoki, F.D., Omokheyeke, O. et al. Appl Water Sci (2017) Volume 7, Issue 2, pp 951–959. https://doi.org/10.1007/s13201-015-0306-y

[24]. Carroll D. (1962). Rainwater as a chemical agent of geologic processes: a review, USGS Water Supply Paper 1962; 1535p.