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# Effects of Anthropogenic Activities on the Physicochemical and Microbial Properties of Otamiri River

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## Abstract

Rivers serves as a reserviour for effluents and wastes generated from industries, agriculture and domestic activities. Anthropogenic activities often endangers and depletes aquatic resources. The effects of anthropogenic activities on the physicochemical and microbial properties of Otamiri Rivers was investigated. Water and sediments samples were collected from six locations across the stretch of the river. Samples were subjected to microbiological and physicochemical analyses using standard methods. Coliforms and faecal coliforms were detected in addition heterotrophic bacteria and fungi. High counts was recorded for bacteria and fungi indicating gross contamination. Presence of *Escherichia coli* and *Enterococcus faecalis* indicates faecal contamination. Several reports on water contamination has implicated the presence of *Klebsiella*, *Salmonella*, *Staphylococcus*, *Bacillus*, *Micrococcus* species as normal flora of water bodies responsible for some water borne diseases. Spores of *Aspergillus*, *Penicillium*, *Fusarium* and *Mucor*species are dispersed by air current into the water bodies and cause several air borne diseases in immunocompromised individuals. Physical properties such as pH, temperature and colour varies from the different points. Temperature (28.60-29.80) is slightly above ambient, pH quite acidic (5.60-6.70). Water hardness is above standard. The values for core physicochemical parameters such as turbidity (0.96-7.60), electrical conductivity (11.00-20.00), total dissolve solids (4.75-10.10) and total suspended solids (13.90-42.00) were slightly above normal. There is significant difference in Dissolved oxygen (4.90-5.80), Biochemical Oxygen Demand (1.60-3.20) and Chemical Oxygen Demand (2.56-5.12) from standard values. Otamiri River contains varying levels of inorganic elements such as; calcium (1.68 - 5.05); potassium (25.00 – 40.00); magnesium (1.19 – 4.45); nitrate (10.50 – 26.20); phosphate (1.60 – 23.00) and carbonate (22.20 – 64.00). Low pH and high temperature is inimical to the survival of aquatic organisms whereas high turbidity prevents light from penetrating to benthic organisms. Conductivity is directly related to the presence of dissolved salts in the samples and changes indicates changing water quality. Values obtained from dissolved oxygen, Biological Oxygen Demand and Chemical Oxygen Demand suggest that Otamiri River cannot sustain aquatic resources. The water body is also very rich in minerals, anions and cations that cause algal bloom (eutrophication) and affect aquatic lives. Aquatic organisms are frequently exposed to harsh environmental conditions resulting from toxic and hazardous wastes from the industries, domestics, agriculture and hospital. Indiscriminate discharge of wastes into water bodies should be given serious attention. Proper and adequate wastes treatment should be enforced before disposal into water bodies.

**Keywords:** Otamiri River, Microbiological, Physicochemical, Anthropogenic

# Introduction

## Background of Study

Anthropogenic activities result in significantly decrease of surface water quality of aquatic systems in watersheds (May *et al*., 2016; Tukura*et al*., 2009; Das and Achary, 2003). Rivers in a watershed play a major role in assimilating or carrying off municipal and industrial wastewaters and runoff from agricultural land. River inflows contribute main pollutants to most lakes in a watershed, thereby tending to induce serious ecological and sanitary problems (Kunwar*et al*., 2015; Gilbert and Wendy, 2013). On the other hand, rivers constitute the main water resources for domestic, industrial, and irrigation purposes in a watershed (Yu and Shang, 2003). Thus, it is imperative to prevent and control river pollution and to have reliable information on the quality of water for effective management. Generally, water-related environmental quality is in bad condition due to a great deal of wastes, excessive reclamation, over-fishing, frequent petroleum spills and other anthropogenic activities (Lin and Han, 2011; Chen *et al*., 2003; Tukura*et al*., 2009; Das and Achary, 2003).

Good water quality resources depends on a large number of physicochemical parameters and the magnitude and source of any pollution load; and to assess that, monitoring of these parameters is essential (Reddi*et al*., 1993). Assessment of water resource quality of any region is an important aspect of developmental activities of the region, because rivers, lakes and man-made reservours are used for water supply to domestic, industrial, agricultural and fish culture (Jackher and Rawat, 2003). Chemical composition of water is a function of hydrogeochemical processes acting in a given environment, thus, monitoring of water quality parameters provide important information for water management (Matthieu*et al*., 2005; USEPA, 1983). Skillful management of water bodies is required if they are to be used for such diverse purposes as domestic and industrial supply, crops irrigation, transport, recreation and fisheries (Abel, 1996).

This study reports on the effects of anthropogenic activities on the physicochemical and microbial properties of Otamiri, River.

# Materials and Methods

## Study Area

Otamiri River is one of the main or popular rivers in Imo State that runs through Owerri Municipal City. The river has its source at Egbu from where it runs south past Owerri city and through Nekede, Ihiagwa, Eziobodo, Olokwu, Umuisi, Mgbirichi and Umuagwo to Ozuzu in Etche, Rivers State, from where it flows to the Atlantic Ocean. The Otamiri River has a length of about 105 km (Nwachukwu, 1989). The length of Otamiri River from its source to its confluence at Emeabiam with the Uramiriukwa River is 30 km. The Otamiri watershed covers about 10,000 $km^2$ with annual rainfall between 2250 mm and 2500 mm. The watershed is mostly covered by depleted rain forest vegetation, with mean temperature of 27°C throughout the year (Onweremadu, 2007). The Otamiri River is joined by the Nworie River at Nekede in Owerri. Waste management in Owerri generally is inefficient and contributes to pollution of the Nworie River. Most of the wastes from Owerri municipality are dumped at the Avu landfill in Owerri West on the Port Harcourt highway, which creates a high concentration of phosphate and nitrate that infiltrate into the Otamiri River South of Owerri. Otamiri River flows through an alternating sequence of sands, sandstones and clay-shales (Uma and Kehinde, 1992).

The study was conducted along certain stretch of the Otamiri River. The present study was conducted in location of anthropogenic activities as shown in the Figure 3.1.

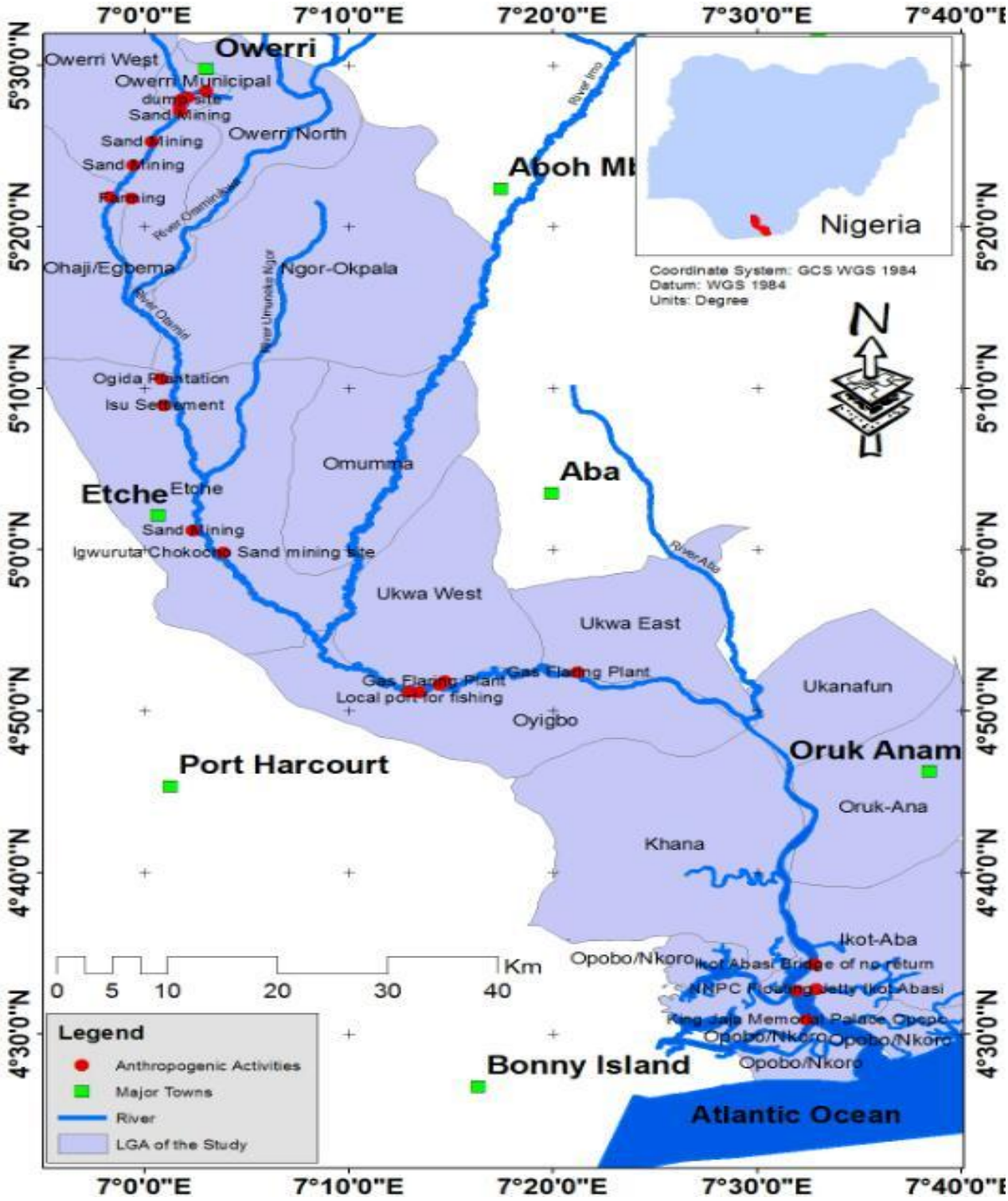


Fig. 3.1 Map of Study Area indicating sampling locations

## Sediments Collection

Sampling was conducted in the month of August, 2017 to represent rainy season. A total of 3 jabs was made at each sampling point, with a single jab consisting of a forceful thrust of the sampler into the sediment for a linear distance of 0.5 m. The sediment samples collected was transferred into plastic buckets, sieved using series of Tyler sieves with mesh sizes of between 1.00 mm and 250 mm (Cheesbrough, 2000). The collected samples was analysis immediately.

## Water Sample Collection

Samples for physicochemical parameters was collected between 1000 hr and 1600 hr at all stations.Sterile wide mouthed bottles was used for this purpose. About 500 ml of water was collected for each site and labeled. The bottles were kept in a container packed with ice and transported to the laboratory within 4 hours for immediately analysis.

## Surface Water and Sediment Analysis

### Physicochemical Analysis

Water temperature, pH, TDS and EC was determined *in-situ* using field meter probes. The surface-float method was used to measure current velocity. Water turbidity, phosphate, sulphate were determined using spectronic 2ID spectrophotometer (APHA, 1998). COD was determined using titrimetric method, chloride was determined by Mohr's method (APHA, 1998) and nitrate was determined by colorimetric method. Technicon auto analyzer flame photometer (IV) was used in determination of Sodium and potassium while calcium and magnesium was determined by EDTA titrimetric method (APHA, 1998). Heavy or trace metals was determined after digestion of the solution of the samples using PyeUnican SP Atomic Absorption Spectrometry. The essence of the digestion before analysis was to reduce organic matter interference and convert metal to a form that can be analyzed by Atomic Absorption Spectrometry (Chinedu*et al.*, 2011).

## Microbiological Analysis

### Enumeration of Bacteria

For this purpose, dilutions were made up to $10^{-7}$ for water and sediment samples. One ml of each dilution ($10^{1}$ -$10^{7}$) was inoculated on Nutrient agar (to obtain the total Heterotrophic Bacterial Counts-THBC), Salmonella-Shigella Agar (to obtain the total Salmonella-Shigella Counts-TSSC), Eosin Methylene Blue Agar (to obtain the total Enterobacteriaceae Counts-TEC), Potato dextrose agar (to obtain the total Heterotrophic Fungal Counts-THFC), and Bushneii Haas Agar (to obtain the total Hydrocarbon Utilizing Bacterial and Fungal Counts-HUB and HUF) using pour plate method. Sterilized glass spreader was used to spread the suspension on the agar surface in other to obtain discrete and countable colonies. The plates were incubated aerobically at $37^{o}$C while vapour phase method (incubation at ambient temperature, $28\pm02^{0}$C) was adopted for the determination of the total Hydrocarbon Utilizing Bacterial and Fungal Counts for 7 days. The total bacterial count (TBC) was expressed in Cfu/ml for water samples and Cfu/g for sediment samples. The percentage HUB and HUF was also calculated as a ratio of the THBC and THFC.

### Characterization and Identification of Bacterial Isolates

Microorganisms isolated from the samples were characterized based on the colonial, morphological, microscopic and biochemical characteristics and pure cultures obtained were used for further characterization. The identities of the isolates were cross matched with features obtained in standard microbiological manuals (Cheesbrough, 2000; Barnett and Hunter, 1998; Buchannan and Gibbon, 1974).

# Results

## Water Analysis

Figure 4.1 shows the physical characteristics of water collected from different locations. pH ranges between 5.60 - 6.70, temperature between

28.60$^0$C - 29.90$^0$C while colour ranges from 16.00 PCU - 35.00 PCU. The locations are shown at the foot note of the table. Result obtained from the physicochemical analysis of the water samples is shown in Figure 4.2. The lower and upper range of the different parameter is as follows; Conductivity (11.00 – 20.00); Turbidity (0.96 – 7.60); Total Dissolve Solids (4.75 – 10.10); Total Suspended Solids (13.90 – 41.50); Dissolve Oxygen (4.90 – 5.80); Biochemical Oxygen Demand (1.60 – 3.20); Chemical Oxygen Demand (2.68 – 5.12).

Total Hardness, Calcium Hardness and Magnesium Hardness were also determined as shown in Figure 4.3. Total Hardness analysed ranges from 18.29 – 23.17; Calcium Hardness 4.88 – 14.63 and Magnesium Hardness 4.88 – 18.29.

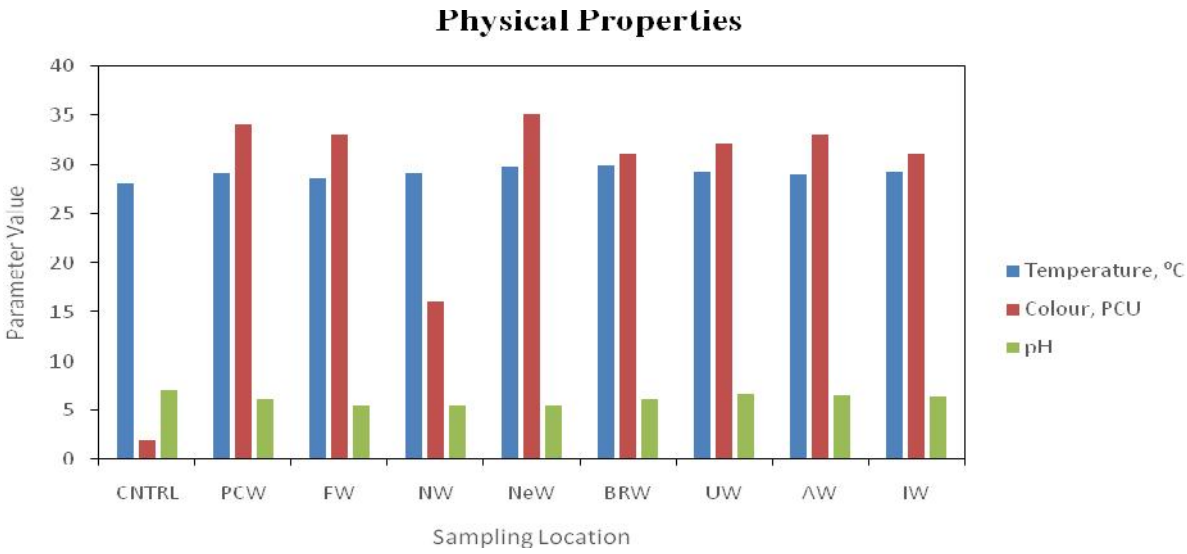


Figure 4.1: Physical properties of water sampled from the different locations.

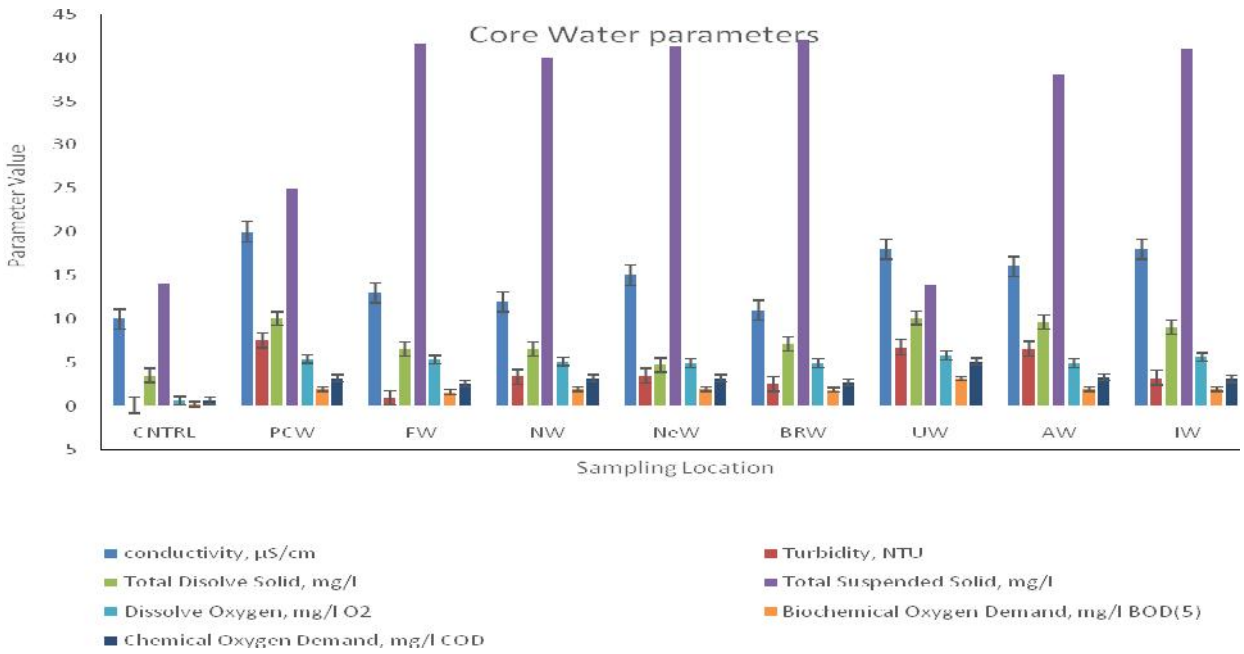


Figure 4.2: Core water parameters of water sampled from the different locations to determine conductivity, turbidity, NTU, total dissolve solid, dissolved oxygen, chemical oxygen demand and biochemical oxygen demand.

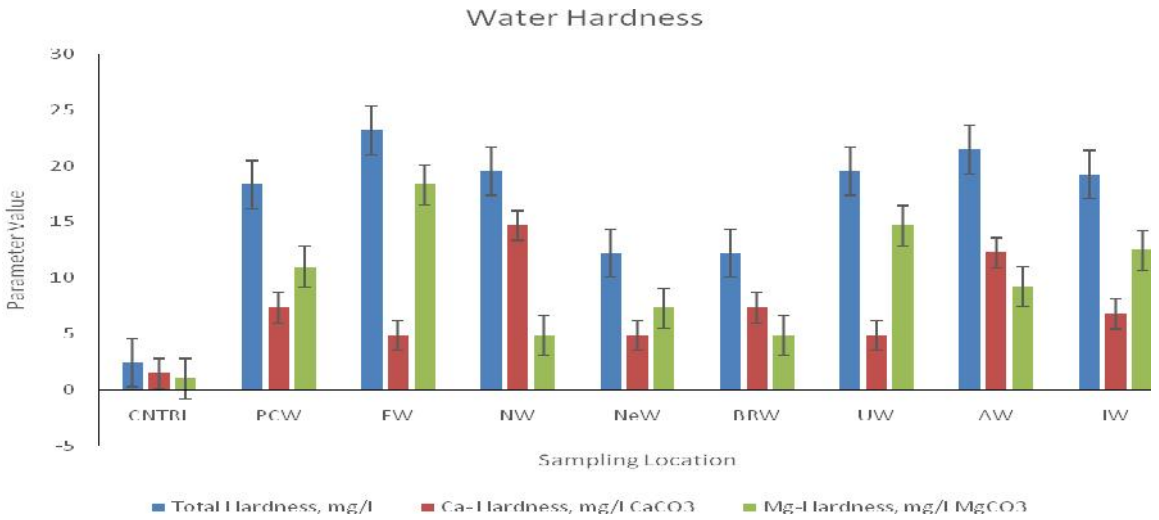


Figure 4.3: Bar chart showing the hardness of water sampled from the different locations.

Inorganic compositions from water samples from different locations is shown in Figure 4.4. The results shows the compositions of cations and anions analysed in the water samples. The values of inorganic compounds includes; calcium (1.68 - 5.05); potassium (25.00 – 40.00); magnesium (1.19 – 4.45); nitrate (10.50 – 26.20); phosphate (1.60 – 23.00) and carbonate (22.20 – 64.00).

Heavy metal contents of the water sample across the sample locations is shown in Figure 4.5. Lead was not detected in all the water sampled whereas cobalt was detected in insignificant quantities in sample locations NeW, PCW, UW, AW and IW. Magnesium was not detected in NeW and zinc in UW. Other metals were detected in all the water samples analysed.

Figure 4.6 shows the physicochemical composition of Water Sediments from the Different Sample Locations. Detailed parameters analysed and their compositions is shown in Table 4.1. Species belonging to the genus *Enterobacter*, *Klebsiella*, *Micrococcus*, *Bacillus*, *Enterococcus*, *Salmonella*, *Shigella*, *Staphylococcus*, *Pseudomonas and Escherichia coli* were isolated from some of the water and sediment samples. *Saccharomyces*, *Aspergillus*, *Mucor*, *Penicillium* and *Fusarium* were the prominent fungi isolated from some of the samples (Table 4.2).

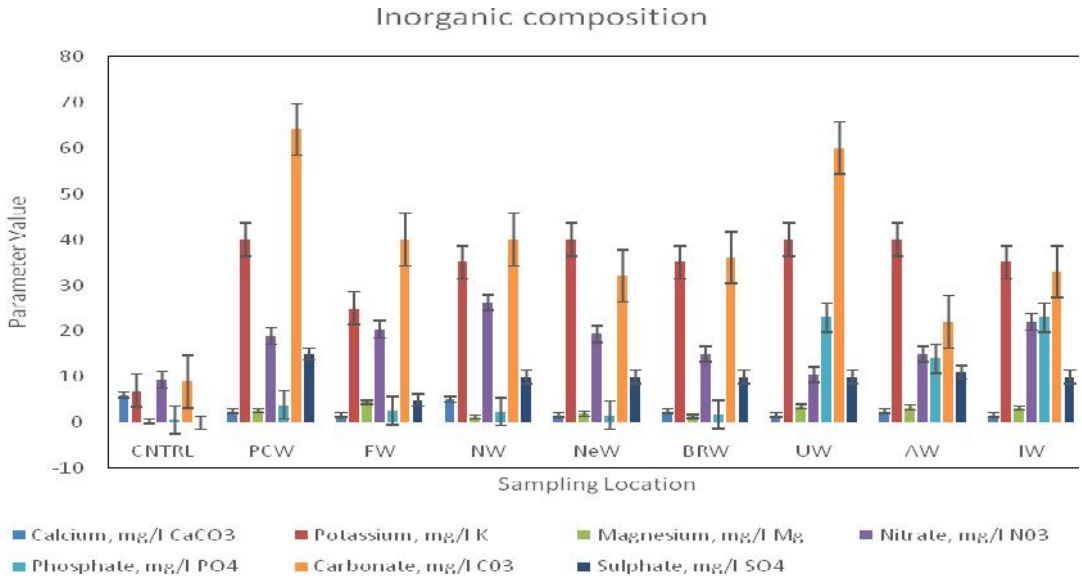


Figure 4.4: Bar chart showing the inorganic composition of water sampled from the different locations.

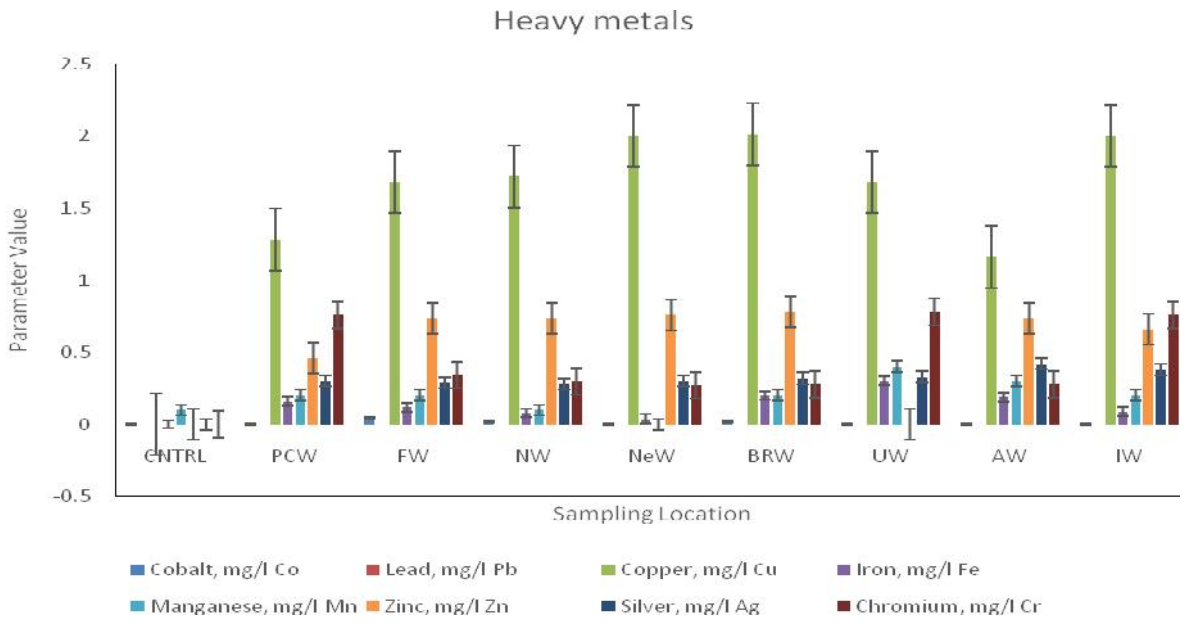


Figure 4.5: Chart showing the heavy metals composition of water sampled from the different locations.

## Sediment physicochemical parameters

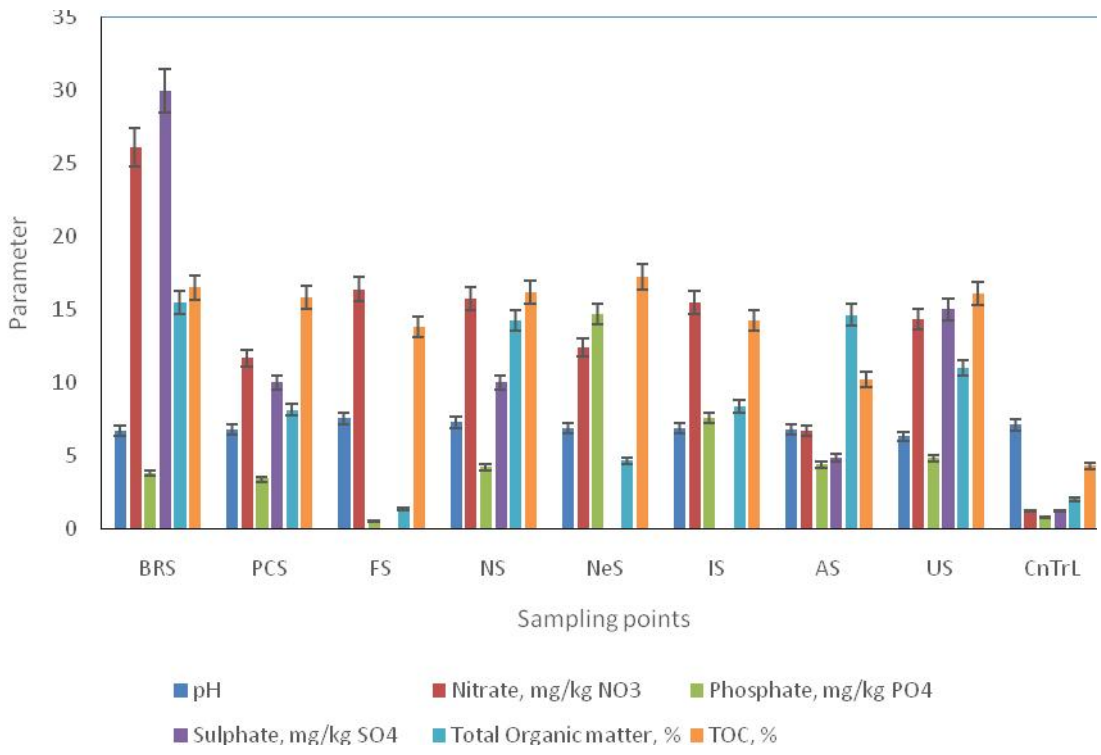


Figure 4.6: Physicochemical composition of sediments sampled from the different locations.

Figures 4.7 and 4.8 shows the microbial counts of sediment and water samples respectively. The figures revealed the logarithm of total heterotrophic bacterial (THBC) counts plotted against the hydrocarbon utilizing bacteria (HUB) isolated from the samples.

Comparative percentage composition of top water and sediment sampled from the different locations is shown in Figure 4.9 while Figure 4.10 shows the Comparative Log composition of top water and sediment sampled from the different locations.

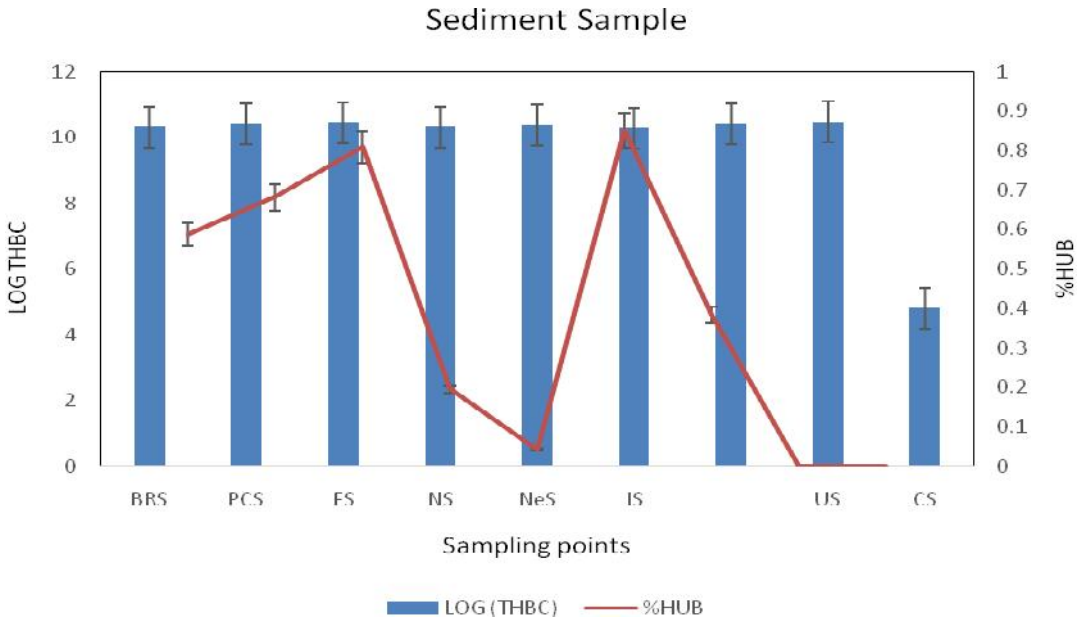


Figure 4.7: Top composition of sediment sampled from the different locations.

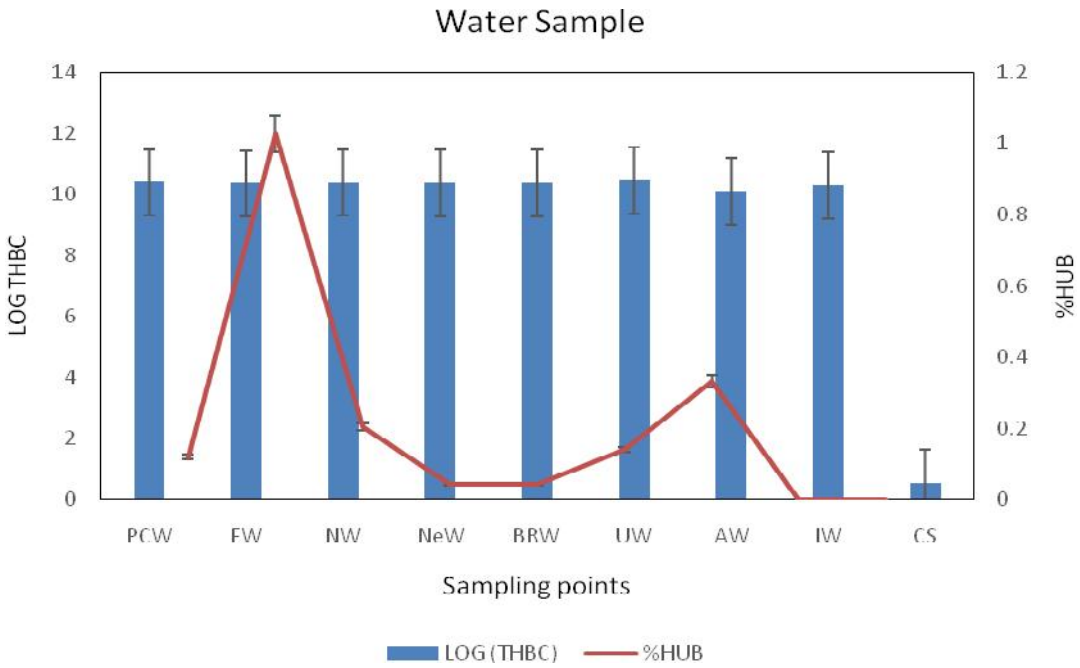


Figure 4.8: Top composition of water sampled from the different locations.

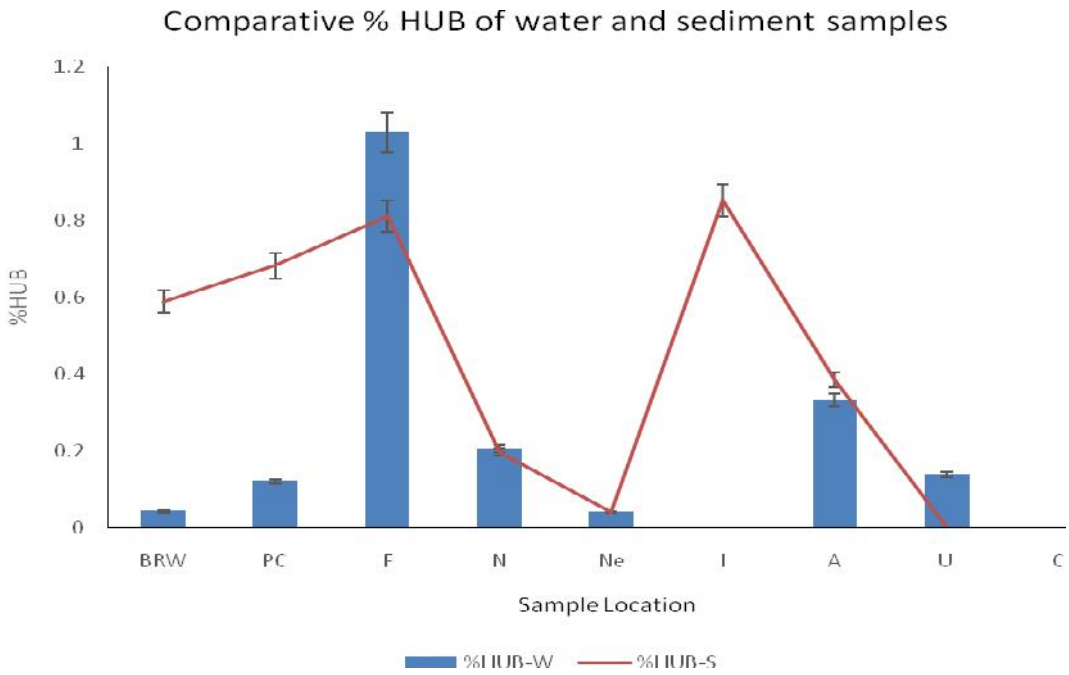


Figure 4.9: Comparative percentage of composition of top water and sediment sampled from the different sample locations.

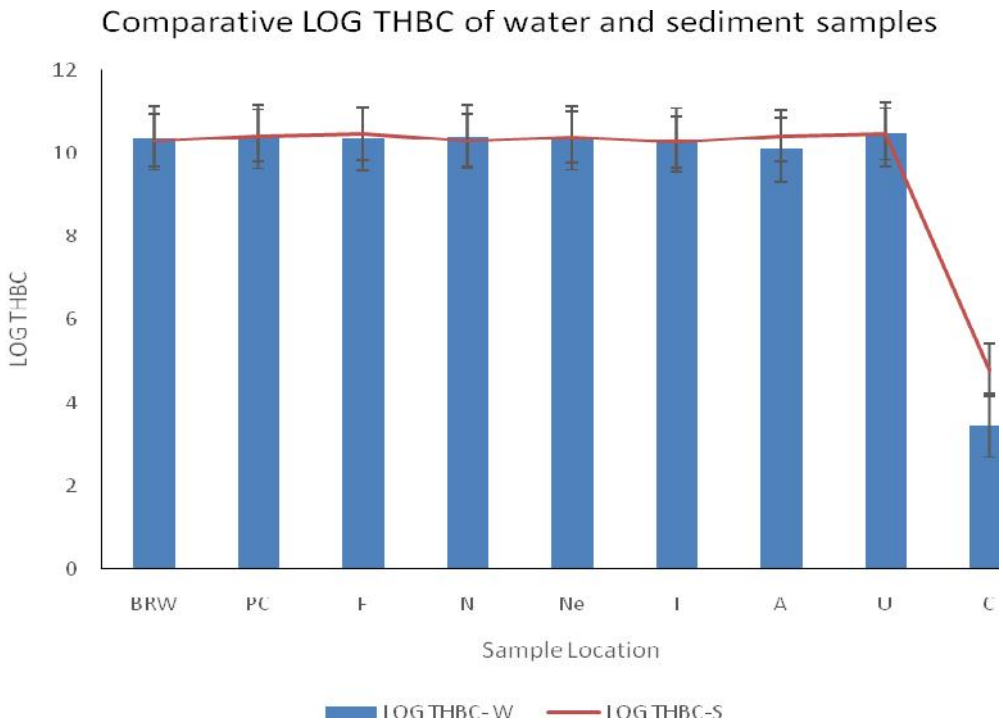


Figure 4.10: Comparative Log of composition of top water and sediment sampled from the different sample locations.

## 4.2. Sediment

**Table 4.1: Composition of Water Sediments from the Different Sample Locations**

| PARAMETERS | BRS | PCS | FS | NS | NeS | IS | AS | US |
|---|---|---|---|---|---|---|---|---|
| Ph | 6.71 | 6.81 | 7.55 | 7.28 | 6.87 | 6.85 | 6.8 | 6.32 |
| Nitrate, mg/kg NO3 | 26.10 | 11.70 | 16.40 | 15.78 | 12.40 | 15.52 | 6.70 | 14.33 |
| Phosphate, mg/kg PO4 | 3.80 | 3.40 | 0.50 | 4.20 | 14.70 | 7.60 | 4.4 | 4.8 |
| Sulphate, mg/kg SO4 | 30.00 | 10.00 | ND | 10.00 | ND | ND | 4.88 | 15 |
| Total Organic matter, % | 15.5 | 8.13 | 1.37 | 14.26 | 4.62 | 8.36 | 14.63 | 11 |
| TOC, % | 16.49 | 15.80 | 13.80 | 16.18 | 17.25 | 14.29 | 10.2 | 16.1 |
| Conductivity, µS/cm | 250.00 | 340.00 | 460.00 | 622.00 | 920.00 | 830.00 | 40.00 | 120 |
| Zinc, mg/kg Zn | ND | 0.28 | ND | ND | ND | ND | 23.00 | ND |
| Lead, mg/kg Pb | ND | ND | ND | ND | ND | ND | 60.00 | ND |
| Copper, mg/kg Cu | 2.700 | 3.780 | 2.920 | 3.120 | 3.700 | 3.380 | 3.12 | 2.92 |
| Nickel, mg/kg Ni | 0.190 | 0.120 | 0.200 | 0.180 | 0.080 | 0.090 | ND | ND |
| Chromium, mg/kg Cr | 0.470 | 0.220 | 0.510 | 0.320 | 0.280 | 0.300 | 10.00 | 0.2 |
| Silver, mg/kg Ag | 0.160 | 0.180 | 0.140 | 0.130 | 0.150 | 0.160 | ND | ND |
| Manganese, mg/kg Mn | 0.300 | ND | 0.300 | 0.200 | 0.700 | 0.400 | 0.30 | 0.4 |
| Iron, mg/kg Fe | 0.060 | 0.070 | 0.090 | 0.080 | 0.040 | 0.090 | 0.40 | 0.4 |
| Potassium, mg/kg K | 85.000 | 95.000 | 370.000 | 130.00 | 60.000 | 140.00 | ND | ND |
| Calcium mg/kg Ca | 19.340 | 17.660 | 8.410 | 11.400 | 15.980 | 13.350 | 0.33 | 12.32 |
| Cobalt, mg/kg Co | 0.070 | 0.130 | ND | 0.020 | 0.045 | 0.038 | 0.04 | 0.02 |

**Key:** Pastoral Center Sediment (PCS), FUTO Sediment (FS),Nworie Sediment (NS), Nekede Sediment (NeS),Bank Road Sediment (BRS),UA Sediment (US), Awaka Sediment (AS), and Ihiagwa Sediment (IS).
*ND: Not Determined

**Table 4.2: Basic Characteristics of Microbiological Indicators of Water Flow Rates in The Studied Sites.**

| | | | | | | Eosin Methylene Blue Agar | | | |
|---|---|---|---|---|---|---|---|---|---|
| **S/N** | **SAMPLE** | **SAMPLE CODE** | **COUNT** | **df** | **SPC** | **COLONY CODE** | **COLONIAL CHARACTERISTICS** | **Gram Reaction** | **PROBABLE IDENTITY** |
| | | | | | | | **SEDIMENT** | | |
| 1 | Bank road sediment | BRS | 228 | 6 | 2.28E+09 | BRS1 | brown to blue-black, mucoid colonies with no metallic sheen | Gram negative rods | *Enterobacter*sp |
| 2 | Pastoral center sediment | PCS | 156 | 6 | 1.56E+09 | PCS1 | brown to blue-black, mucoid colonies with no metallic sheen | Gram negative rods | *Enterobacter*sp |
| 3 | FUTO sediment | FS | 94 | 6 | 9.40E+08 | FS1 | brown to blue-black, mucoid colonies with no metallic sheen | Gram negative rods | *Enterobacter*sp |
| 4 | | | | | | FS2 | Mucoid and shiny pink colonies | Thick gram negative rods in short chains | *Klebsiella*sp |
| 5 | Nworie Sediment | NS | 160 | 6 | 1.60E+09 | NS1 | brown to blue-black, mucoid colonies with no metallic sheen | Gram negative rods | *Enterobacter*sp |
| 6 | | | | | | NS2 | Mucoid and shiny pink colonies | Thick gram negative rods in short chains | *Klebsiella*sp |
| 7 | Nekede Sediment | NeS | 4 | 6 | 4.00E+07 | NeS1 | brown to blue-black, mucoid colonies with no metallic sheen | Gram negative rods | *Enterobacter*sp |
| 8 | Ihiagwa Sediment | IS | 92 | 6 | 9.20E+08 | IS1 | Regular colonies with Purple metallic sheen | Gram negative rods predominantly in singles | *Escherichia coli* |
| 9 | UA Sediment | US | 160 | 6 | 1.60E+09 | US1 | Regular colonies with Purple metallic sheen | Gram negative rods predominantly in singles | *Escherichia coli* |
| 10 | | | | | | US2 | Mucoid and shiny pink colonies | Thick gram negative rods in short chains | *Klebsiella*sp |
| 11 | Awaka Sediment | AS | 184 | 6 | 1.84E+09 | AS1 | Regular colonies with Purple metallic sheen | Gram negative rods predominantly in singles | *Escherichia coli* |
| 12 | | | | | | AS2 | Mucoid and shiny pink colonies | Thick gram negative rods in short chains | *Klebsiella*sp |
| | | | | | | | **WATER** | | |
| 1 | Pastoral Center water | PCW | 184 | 6 | 1.84E+09 | PCW | brown to blue-black, mucoid colonies with no metallic sheen | Gram negative rods | *Enterobacter*sp |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2 | FUTO water | FW | 240 | 6 | 2.40E+09 | FW1 | Regular colonies with Purple metallic sheen | Gram negative rods predominantly in singles | *Escherichia coli* |
| 3 | | | | | | FW2 | brown to blue-black, mucoid colonies with no metallic sheen | Gram negative rods | *Enterobacter*sp |
| 4 | | | | | | FW3 | Regular colonies with Purple metallic sheen | Gram negative rods predominantly in singles | *Escherichia coli* |
| 5 | Nworie Water | NW | 13 | 6 | 1.30E+08 | NW1 | brown to blue-black, mucoid colonies with no metallic sheen | Gram negative rods | *Enterobacter*sp |
| 6 | Nekede Water | NeW | 23 | 6 | 2.30E+08 | NeW1 | Mucoid and shiny pink colonies | Thick gram negative rods in short chains | *Klebsiella*sp |
| 7 | Bank road water | BRW | 96 | 6 | 9.60E+08 | BRW1 | brown to blue-black, mucoid colonies with no metallic sheen | Gram negative rods | *Enterobacter*sp |
| 8 | UA Water | UW | 144 | 6 | 1.44E+09 | UW1 | brown to blue-black, mucoid colonies with no metallic sheen | Gram negative rods | *Enterobacter*sp |
| 9 | Awaka water | AW | 252 | 6 | 2.52E+09 | AW1 | Regular colonies with Purple metallic sheen | Gram negative rods predominantly in singles | *Escherichia coli* |
| 10 | | | | | | AW2 | brown to blue-black, mucoid colonies with no metallic sheen | Gram negative rods | *Enterobacter*sp |
| 11 | | | | | | AW3 | Mucoid and shiny pink colonies | Thick gram negative rods in short chains | *Klebsiella*sp |
| 12 | Ihiagwa Water | IW | 140 | 6 | 1.40E+09 | IW1 | Regular colonies with Purple metallic sheen | Gram negative rods predominantly in singles | *Escherichia coli* |
| 13 | | | | | | IW2 | brown to blue-black, mucoid colonies with no metallic sheen | Gram negative rods | *Enterobacter*sp |
| 14 | | | | | | IW3 | Mucoid and shiny pink colonies | Thick gram negative rods in short chains | *Klebsiella*sp |

| NUTRIENT AGAR | | | | | | | |
|---|---|---|---|---|---|---|---|
| **S/N** | **SAMPLE** | **SAMPLE CODE** | **COUNT** | **df** | **SPC** | **COLONY CODE** | **COLONIAL CHARACTERISTICS** |
| **SEDIMENT** | | | | | | | |
| 1 | Bank road sediment | BRS | 204 | 7 | 2.04E+10 | BRSa | Small circular yellow colonies |
| 2 | | | | | | BRSb | Rough mucoid and slimy creamy white colonies |
| 3 | | | | | | BRSc | Pinpoint circular cream colonies |
| 4 | | | | | | BRSd | Bluish green transparent colonies |
| 5 | Pastoral center sediment | PCS | 264 | 7 | 2.64E+10 | PCSa | Rough mucoid and slimy creamy white colonies |
| 6 | | | | | | PCSb | Pinpoint circular cream colonies |
| 7 | FUTO sediment | FS | 284 | 7 | 2.84E+10 | Fsa | Bluish green transparent colonies |
| 8 | | | | | | FSb | Small circular yellow colonies |
| 9 | | | | | | FSc | Rough mucoid and slimy creamy white colonies |
| 10 | Nworie Sediment | NS | 204 | 7 | 2.04E+10 | Nsa | Small circular yellow colonies |
| 11 | | | | | | NSb | Pinpoint circular cream colonies |
| 12 | | | | | | NSc | Rough mucoid and slimy creamy white colonies |
| 13 | Nekede Sediment | 2.00E+02 | 240 | 7 | 2.40E+10 | NeSa | Bluish green transparent colonies |
| 14 | | | | | | NeSb | Small circular yellow colonies |
| 15 | | | | | | NeSc | Rough mucoid and slimy creamy white colonies |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 16 | | | | | | NeSd | Rough mucoid/blistery and slimy creamy white colonies |
| 17 | Ihiagwa Sediment | IS | 188 | 7 | 1.88E+10 | Isa | Pinpoint circular cream colonies |
| 18 | | | | | | Isb | Small circular yellow colonies |
| 19 | | | | | | Isc | Rough mucoid and slimy creamy white colonies |
| 20 | Awaka sediment | AS | 260 | 7 | 2.60E+10 | Asa | Rough mucoid and slimy creamy white colonies |
| 21 | | | | | | ASb | Small circular yellow colonies |
| 22 | | | | | | Asc | Pinpoint circular cream colonies |
| 23 | UA Sediment | US | 292 | 7 | 2.92E+10 | Usa | Pinpoint circular cream colonies |
| 24 | | | | | | Usb | Circular, moist and shiny low convex golden yellow colonies |
| 25 | | | | | | Usc | Rough mucoid and slimy creamy white colonies |
| **WATER** | | | | | | | |
| 1 | Pastoral Center water | PCW | 248 | 7 | 2.48E+10 | PCWa | Pinpoint circular cream colonies |
| 2 | | | | | | PCWb | Rough mucoid/blistery and slimy creamy white colonies |
| 3 | FUTO water | FW | 224 | 7 | 2.24E+10 | Fwa | Small circular yellow colonies |
| 4 | | | | | | FWb | Pinpoint circular cream colonies |
| 5 | Nworie Water | NW | 244 | 7 | 2.44E+10 | Nwa | Small circular yellow colonies |
| 6 | | | | | | NWb | Rough mucoid/blistery and slimy creamy white colonies |
| 7 | | | | | | NWc | Pinpoint circular cream colonies |
| 8 | | | | | | NWd | Circular, moist and shiny low convex golden yellow colonies |
| 9 | Nekede Water | NeW | 240 | 7 | 2.40E+10 | NeWa | Small circular yellow colonies |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 10 | | | | | | NeWb | Rough mucoid and slimy creamy white colonies |
| 11 | | | | | | NeWc | Pinpoint circular cream colonies |
| 12 | Bank road water | BRW | 232 | 7 | 2.32E+10 | BRWa | Rough mucoid and slimy creamy white colonies |
| 13 | | | | | | BRWb | Small circular yellow colonies |
| 14 | | | | | | BRWc | Pinpoint circular cream colonies |
| 15 | UA Water | UW | 288 | 7 | 2.88E+10 | Uaa | Bluish green transparent colonies |
| 16 | | | | | | Uab | Rough mucoid and slimy creamy white colonies |
| 17 | | | | | | Uac | Pinpoint circular cream colonies |
| 18 | Awaka water | AW | 121 | 7 | 1.21E+10 | Awa | Rough mucoid and slimy creamy white colonies |
| 19 | | | | | | Awb | Pinpoint circular cream colonies |
| 20 | Ihiagwa Water | IW | 201 | 7 | 2.01E+10 | Iwa | Small circular yellow colonies |
| 21 | | | | | | Iwb | Rough mucoid and slimy creamy white colonies |
| 22 | | | | | | Iwc | Pinpoint circular cream colonies |

**Salmonella Shigella Agar**

| S/N | SAMPLE | SAMPLE CODE | COUNT | df | SPC | COLONY CODE | COLONIAL CHARACTERISTICS |
|---|---|---|---|---|---|---|---|
| **SEDIMENT** | | | | | | | |
| 1 | Bank road sediment | BRS | 192 | 6 | 1.92E+09 | BRSx | Mucoid colonies with a characteristic |
| 2 | | | | | | BRXy | Moist, mucoid and shiny light pink colonies |
| 3 | Pastoral center sediment | PCS | 220 | 6 | 2.20E+09 | PCSx | Mucoid colonies with a characteristic |
| 4 | | | | | | PCXy | Moist, mucoid and shiny light pink colonies |
| 5 | FUTO sediment | FS | 104 | 6 | 1.04E+09 | FSx | Mucoid colonies with a characteristic |
| 6 | | | | | | Fsy | Moist, mucoid and shiny light pink colonies |
| 7 | NworieSedimment | NS | 176 | 6 | 1.76E+09 | NSx | Mucoid colonies with a characteristic |
| 8 | | | | | | Nsy | Moist, mucoid and shiny light pink colonies |
| 9 | Nekede Sediment | NeS | 136 | 6 | 1.36E+09 | NeSx | Mucoid colonies with a characteristic |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 10 | | | | | | NeSy | Moist, mucoid and shiny light pink colonies |
| 11 | Ihiagwa Sediment | IS | 200 | 6 | 2.00E+09 | Isx | Mucoid colonies with a characteristic |
| 12 | | | | | | Isy | Moist, mucoid and shiny light pink colonies |
| 13 | UA Sediment | US | 156 | 6 | 1.56E+09 | Usx | Mucoid colonies with a characteristic |
| 14 | | | | | | Usy | Moist, mucoid and shiny light pink colonies |
| 15 | Awaka sediment | AS | 172 | 6 | 1.72E+09 | Asx | Mucoid colonies with a characteristic |
| 16 | | | | | | Asy | Moist, mucoid and shiny light pink colonies |
| **WATER** | | | | | | | |
| 1 | Pastoral Center water | PCW | 232 | 6 | 2.32E+09 | PCWm | Mucoid colonies with a characteristic |
| 2 | | | | | | PCWn | Moist, mucoid and shiny light pink colonies |
| 3 | FUTO water | FW | 164 | 6 | 1.64E+09 | FWm | Mucoid colonies with a characteristic |
| 4 | | | | | | FWn | Moist, mucoid and shiny light pink colonies |
| 5 | Nworie Water | NW | 132 | 6 | 1.32E+09 | NWm | Mucoid colonies with a characteristic |
| 6 | | | | | | NWn | Moist, mucoid and shiny light pink colonies |
| 7 | Nekede Water | NeW | 228 | 6 | 2.28E+09 | NeWm | Mucoid colonies with a characteristic |
| 8 | | | | | | NeWn | Moist, mucoid and shiny light pink colonies |
| 9 | Bank road water | BRW | 138 | 6 | 1.38E+09 | BRWm | Mucoid colonies with a characteristic |
| 10 | | | | | | BRWn | Moist, mucoid and shiny light pink colonies |
| 11 | UA Water | UW | 200 | 6 | 2.00E+09 | Uwm | Mucoid colonies with a characteristic |
| 12 | | | | | | Uwn | Moist, mucoid and shiny light pink colonies |
| 13 | Awaka water | AW | 256 | 6 | 2.56E+09 | AWm | Mucoid colonies with a characteristic |
| 14 | | | | | | Awn | Moist, mucoid and shiny light pink colonies |
| 15 | Ihiagwa Water | IW | 160 | 6 | 1.60E+09 | Iwm | Mucoid colonies with a characteristic |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 16 | | | | | | Iwn | Moist, mucoid and shiny light pink colonies |

**SarbroudDextrose Agar**

| S/N | SAMPLE | SAMPLE CODE | COUNT | df | SPC | COLONY CODE | COLONIAL CHARACTERISTICS |
|---|---|---|---|---|---|---|---|
| **Sediment** | | | | | | | |
| 1 | Bank road sediment | BRS | 56 | 6 | 5.60E+08 | BRS1 | Cream mucoid and slimy rough colonies |
| 2 | Pastoral center sediment | PCS | 73 | 6 | 7.30E+08 | PCS1 | Cream mucoid and slimy rough colonies |
| 3 | FUTO sediment | FS | 33 | 6 | 3.30E+08 | FS1 | Cream mucoid and slimy rough colonies |
| 4 | Nworie Sediment | NS | 12 | 6 | 1.20E+08 | NS1 | Cream mucoid and slimy rough colonies |
| 5 | Nekede Sediment | NeS | 22 | 6 | 2.20E+08 | NeS1 | Black spores on short white hyplae |
| 6 | | | | | | | Green spore enclosed in white mycelium |
| 7 | | | | | | | sparse to abundant cottony mycelium aerial mycelium, and the pigmentations were pale brown to yellowish brown with a dark brown zonation. |
| 8 | Ihiagwa Sediment | IS | 35 | 6 | 3.50E+08 | IS1 | Cream mucoid and slimy rough colonies |
| 9 | UA Sediment | US | 38 | 6 | 3.80E+08 | US1 | Cream mucoid and slimy rough colonies |
| 10 | Awaka sediment | AS | 41 | 6 | 4.10E+08 | AS1 | Cream mucoid and slimy rough colonies |
| **Water** | | | | | | | |
| 1 | Pastoral Center water | PCW | 122 | 6 | 1.22E+09 | PCW | Cream mucoid and slimy rough colonies |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | FUTO water | FW | 98 | 6 | 9.80E+08 | FW1 | Cream mucoid and slimy rough colonies |
| 3 | Nworie Water | NW | 88 | 6 | 8.80E+08 | NW1 | Black spores on short white hyplae |
| 4 | | | | | | | Green spore enclosed in white mycelium |
| 5 | | | | | | | Short white filamentous hyphae radiating out. |
| 6 | | | | | | | Cream mucoid and slimy rough colonies |
| 7 | Nekede Water | NeW | 81 | 6 | 8.10E+08 | NeW1 | Black spores on short white hyplae |
| 8 | | | | | | | sparse to abundant cottony mycelium with mycelium, and the pigmentations were pale brown to yellowish brown with a dark brown zonation. |
| 9 | | | | | | | Cream mucoid and slimy rough colonies |
| 10 | Bank road water | BRW | 73 | 6 | 7.30E+08 | BRW1 | Cream mucoid and slimy rough colonies |
| 11 | UA Water | UW | 72 | 6 | 7.20E+08 | UW1 | Cream mucoid and slimy rough colonies |
| 12 | Awaka water | AW | 69 | 6 | 6.90E+08 | AW1 | Black spores on short white hyplae |
| 13 | | | | | | AW2 | Short white filamentous hyphae radiating out. |
| 14 | | | | | | AW3 | Cream mucoid and slimy rough colonies |
| 15 | Ihiagwa Water | IW | 55 | 6 | 5.50E+08 | IW1 | Black spores on short white hyplae |
| 16 | | | | | | IW2 | Cream mucoid and slimy rough colonies |

## Discussion

The results obtained revealed the morphological changes in the Otamiri River. Changes are primarily due to diverse human activities such as farming, dumping of refuse, building structures like roads, sand mining and dredging. These activities causes the widening and narrowing of the river banks. The physical properties of the Otamiri River water from the different locations [Pastoral Center Water (PCW), FUTO Water (FW),Nworie Water (NW), Nekede Water (NeW),Bank Road Water (BRW),UA Water (UW), Awaka Water (AW), and Ihiagwa Water (IW)] showed temperature ranges between 28.6±0.40 to 30.0±0.60. In physicochemical quality of water samples, temperature is considered as a critical parameter. It has an impact on many reactions including the rate of disinfectant decay by-product formation. As the water temperature increases, the disinfectant decay by product formation, nitrification, microbial activity, algal growth, taste odour episodes, lead copper solubility increases. Moreover, calcium carbonate ($CaCO_3$) precipitation also increases (Howard *et al*., 2013). Temperature also affects water treatment (Chinedu*et al.,* 2011). If nutrients are available, the microbial activity (as measured by hetero plate count) increases significantly at water temperatures above $15^0$C in the absence of a disinfectant residual (Chinedu*et al.,* 2011). Low temperature low also reduces the risk for pathogenic proliferation survival since the optimal temperature for most pathogens is close to the human body temperature of $37^0$C (Boe-Hansen *et al.,* 2002).

The pH is acidic in the range of 5.60-6.40. The observed low pH in Otamiri River could be due to existence of compounds like chloride of iron or aluminum, which are hydrolyze in excess water to produce solutions (Lewis acids) which may have affected the pH of the river (Ekhaise and Anyasi, 2005). pH “potential hydrogen,” refers to the amount of hydrogen mixed with the water. The normal range for pH in ground water lies between 6 and 8.5 (Ekhaise and Anyasi, 2005). However, the EPA WHO recommends that public water systems maintain pH levels of between 6.5 and 8.5, a good guide for individual well owners (Obasi and Balogun, 2016).

The colour range was steady almost across all River water collected (32.00±3.00), except that of Nworie water (16.00). Water colour may have a direct or indirect relationship with turbidity and total dissolved solids of the water body.

Physicochemical parameters also affects the quality of the Otamiri River. Dissolved Oxygen (DO) is an important parameter in water quality analysis, because it reflects the physical and biological processes prevailing in the water. The ideal standard for dissolved oxygen is 14.6mg/l. The DO of all water samples of the Otamiri River fall below the ideal standard ranging from 4.90 – 5.80.Dissolved oxygen is an important element in water because most aquatic organisms use it for respiration. The values obtained from the results showed that the stretches of the Otamiri River is very low in DO and may affect aquatic respiration.

The level of conductivity ranges from 11.00 – 20.00. Electrical conductivity is the capacity of water to conduct current. It is caused by the presence of salts, acids bases, called electrolytes, capable of producing cations and anions. The major ions present in water causing EC are chlorides, sulphates, carbonates, bicarbonates, nitrates, calcium, magnesium, sodium and potassium. Lester and Birkett(2009) opined that as the conductivity is directly related to the presence of dissolved salts, its magnitude can give a fair idea of the levels of dissolved solids. Changes in conductivity over time may indicate changing water quality and salinity.

Turbidity was lowest in FW (0.96), slightly lower in four points, Brw (2.57), NeW (3.44), Nw (3.38) and IW (3.26) but high at the remaining points (6.60±1.00). Turbidity in water is caused by suspended matter such as clay, silts, finely divided organic inorganic matter, soluble coloured organic compounds, planktons other microscopic organisms. Turbidity measurements relate to the optical property of water that causes

light to be scattered and absorbed rather than transmitted in straight lines through the sample. Turbidity can be considered as indirect indicator for the presence of microbes (Howard *et al.*, 2013).

Total suspended solids recorded is in the range of 13.90 – 41.50. It was observed to be lowest in UW (13.90), a bit higher in PCW (25.00) and highest in the remaining points (38.00 – 42.00). Total Dissolve Solids ranges between the values of 4.75 – 10.10.

The term "total dissolved solids" (TDS) is the sum of the cations and anions in water. Ions and organic compounds making up TDS usuallyinclude carbonate, bicarbonate, chloride, fluoride, sulphate, phosphate, nitrate, calcium, magnesium, sodium, and potassium. TDS concentrations are used to evaluate the quality of freshwater systems. Sources of TDS include agricultural run-offs, urban run-offs, industrial wastewater, and sewage natural sources such as leaves, silt, and plankton rocks. Piping or plumbing may also release metals into the water (APHA, 2008). Conductivity test provides an estimate of TDS concentration levels.

Biochemical Oxygen Demand (BOD) varies between the values of 1.60 - 3.20, while Chemical Oxygen Demand (COD) is between the values of 2.68 - 5.12 for samples analysed. The BOD is used as an approximate measure of the amount of biochemically degradable organic matter present in a sample (Ademoroti, 2016). Unpolluted water has a BOD in order of 0.7 mg/L, which is considerably less than the saturated value of 8.7 mg/L at $25^0$C. This set the standard to determine if water is polluted. BOD values range widely, generally, pristine waters have a value below 1 mg/L, moderately polluted water 2-8 mg/L, and treated municipal sewage 20 mg/L. COD is a water quality measure used not only to determine the amount of biologically active substances such as bacteria but also biologically inactive organic matter in water. It is an important and rapidly measured variable for characterizing water bodies, sewage, industrial wastes, and treatment plants. COD of not more than 120 mg/L or exceeding 400 mg/L is acceptable for drinking water, Otamiri River contains varying levels of inorganic elements such as; calcium (1.68 - 5.05); potassium (25.00 – 40.00); magnesium (1.19 – 4.45); nitrate (10.50 – 26.20); phosphate (1.60 – 23.00) and carbonate (22.20 – 64.00). High concentrations of phosphate in surface waters indicate the presence of pollution largely responsible for eutrophic conditions (Venkatesharaju*et al.,* 2010). Nitrate is a compound of nitrogen oxidation which shows the effect of organic pollution on water quality. The WHO the European Union have set the standard for nitrate in drinking water at 11.3 mg/l measured as total nitrogen (mg N/l) that corresponds to 50 mg/l $NO_3^-$. Extensive application of nitrogen fertilizers has caused an increase in nitrate concentrations over large agricultural areas. Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals. The presence of iron in river water is an indication of possible contamination from geology of the river channel, rock mineral type's present and waste inflows. High concentration of Iron in water can lead to the formation of *blue baby syndrome* in babies and goitre in adults (Kola and Akinbile, 2004; Shyamala *et al.*, 2008). Calcium is an important dietary mineral for cell physiology and bone formation.

Total Hardness is due to the concentration of alkaline earth metals. Calcium and magnesium ions are the principal cations impacting hardness (Sharma*et al.*, 2011; Raut*et al.*, 2011). Water hardness (7.32 – 19.22) was detected in the rivers studied. The water hardness can be attributed to the eroding of the soil with bicarbonate, carbonate or hydroxide compounds into the river (APHA, 2005).

## Conclusion

Water and sediments from Otamiri River receives wastes from various sources resulting in the pollution of the water bodies. Wastes from industries, domestic, hospital and agriculture are emptied into the river. This is evidence in the high concentrations of inorganic ions, heavy metals,

turbidity and physicochemical compounds. Low dissolved oxygen indicates that the water may not support aquatic resources. The BOD and COD is below the standard recommended by various environmental monitoring agencies. The pH is acidic and could be detrimental to aquatic organisms.

Aquatic organisms are frequently exposed to harsh environmental conditions resulting from toxic and hazardous wastes from the industries, domestics and hospital. Agricultural wastes often results in eutrophication and depletion of dissolved oxygen and increased biological oxygen demand. Increased temperature reduced the survival of fishes while high turbidity reduces sunlight penetration thereby hampering photosynthesis and other activities at the benthic region of the river.

The microbial load is very high, especially, heterotrophic bacteria and fungi. Hydrocarbon utilizing bacterial load is low suggesting little or no pollution from petroleum products. The presence *Escherichia coli*, *Salmonella* species and other faecal coliforms indicates contamination from human faeces. *Bacillus, Pseudomonas* and *Micrococcus* species are common inhabitants of water, sediment and soil. Species of *Aspergillus, Penicillium*and *Mucor* are dominantand spread by means of spores dispersed by air currents during soil excavation and tilling.

**Recommendation**

Indiscriminate discharge of wastes into water bodies should be given serious attention. Proper and adequate wastes treatment should be enforced before disposal into water bodies. Stringent laws and measures should be put in place to monitor and apprehend defaulters. By so doing, contamination will be reduced to a minimum.

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