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Physico-Chemical Characteristics of Otamiri River and its Sediments in Parts of Owerri

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ABSTRACT

The physico-chemical characteristics of Otamiri River were investigated using digital meters and Atomic Absorption Spectrometer (AAS). The aim of the study was to provide information that will be useful in the sustainable development of the River. The results indicates that the mean pH concentrations of the Otamiri river obtained at four strategic gauge stations designated $SSWS_1$ - Egbu, $SSWS_2$ –Timber Market, $SSWS_3$ – FUTO and Downstream-Mbirichi were 6.45, 6.58, 6.45 and 6.50 respectively for the mean pH while the mean values for Pb^{2+} were 0.02, 0.02, 1.67 and 0.02 mg/l respectively, that of Cd^{2+} was 0.004, 0.0036, 0.004 and 0.002 mg/l respectively while the mean concentrations for Fe^{+} were 0.01, 0.016, 0.23 and 0.10 mg/l. The result of stream sediment samples indicates that the concentrations of pH were 5.8, 5.90, 6.30 and 4.45 respectively while mean concentrations values for Pb^{2+} were 0.08, 0.07, 0.06 and 0.05 mg/kg respectively while the values for Cd^{2+} were 0.32, 0.28, 0.30 and 0.25 mg/kg respectively. The values for Hg were 0.10, 0.13, 0.15 and 0.18 mg/kg. The results for both water and sediment samples with respect to pH and some heavy metal concentrations were not in conformity with World Health Organisation (2011) standard for safe drinking water as well as Federal Ministry of Environment (2006) standard for soil respectively thus, constitute a threat to the River; these are attributed to waste dumps and anthropogenic activities around the four stations The Sodium Adsorption Ratio (SAR) of the river indicates that it is excellent for irrigation purposes even though correction of the pH needed to be done. The pollution index (PI) of the river shows that it is tending towards its critical value of 1. The pH of the water can be treated using sodium bicarbonate while the sediment by liming method while the excessive concentrations of heavy metals can be treated using acornic acid.

Introduction

The impact of human activities in the urban, municipal and populated area makes surface water bodies like streams, rivers, lagoons, etc, and ground water bodies are susceptible to contamination from pollutants. Pollution of sediments and water by heavy metal occurs due to industrial wastes, application of fertilizer, corrosion of sheeting, wires, pipes, and burning of coal and wood [1]. The physico-chemical characteristics of surface water resources are constantly changing by activities within and around it. Such activities include farming, fishing, indiscriminate dumping of waste, exploration and exploitation of solid minerals etc. These activities are capable of introducing toxic substances such as heavy metals into the surface water thereby altering the resource status and usefulness.

The Otamiri River is a major fresh surface water resource of South-eastern Nigeria. The river takes its name from "Otamiri", a deity who owns all the water that are called by its name, and who is often the dominating god of Mban houses [2]. It is located on latitude 5˚23'N and 5˚30'N, and Longitude 6˚58'E and 7˚04'E (Figure 1). The river runs south from Egbu (its source) pass Owerri and through Nekede, Ihiagwa, Eziobodo, Obowuumuisu, Mgbirichi and Umuagwo (all in Imo state) to Ozuzu in Etche Local Government Area of Rivers state where it has a confluence with OramirukwaRiver; both rivers flows from there into the Atlantic Ocean. The Otamiri River is used for domestic, industrial and agricultural activities. The stream sediments on the river are used for various construction purposes. The quality of the river is exposed to threat fromindiscriminate waste disposal, fishing, oil and natural gas activities to mention a few. Therefore, constant monitoring of the quality of surface water cannot be overstressed especially now that increase in population has resulted in generation of more waste thus exposing the water to more pollutants.

Methodology

Eleven water samples were obtained along the stretch of the Otamiri River using grab method; the water samples were geo-referenced and collected with the aid of sterilized 1.5litres plastic containers. The samples were corked under water immediately after collection so as to avoid the oxidation of the constituents and later sent to the laboratory within 24hours for analysis. The stream sediments were obtained at 5 strategic locations using manual dredging method. The samples were collected into black polyethene bags and sent to the lab for analysis within 24 hours. The water samples were analysed using the Atomic Absorption Spectrophotometer (AAS). The sediment samples were first

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digested using x-ray fluorescence (XRF) method and aspirated into the Atomic Absorption Spectrophotometer (AAS). The sampling points were geo-referenced using a global positioning system (GPS). Land use elements especially waste dump sites were visited and examined. Samples were taken at a distance of 300 meters.

The parameters analyzed are turbidity, odour, appearance, conductivity, total dissolved solid, Iron (Fe^{2+}), Calcium (Ca^{2+}), Chloride (Cl^{-}), Bicarbonates (HCO_3^{-}), total hardness and Sodium (Na^{+}) etc.

The concentrations of the major constituent cations and anions in milligram/liter (mg/l) were converted to milliequivalent/liter(meq/l) using the Equation 1 developed by [3]

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

The concentrations in meq/l were used to prepare Piper trilinear, Schoeler, Durov and Stiff diagrams as well as calculation of Sodium Adsorption Ratio (SAR). The SAR was determined using the Equation 2 [4].

$$SAR = \frac{Na^{+}}{\frac{\sqrt{(Ca2+ + Mg2+)}}{2}} \quad \text{.........(Eq. 2)}$$

The total hardness as ($CaCO_3$) of the Otamiri River water was determined using the Equation 3 developed by [3].

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

The parameters considered for the determination of the pollution index (PI) of the Otamiri River water samples were pH, Total Alkalinity, Total Hardness, Total dissolved solids (TDS), sulphate and chloride. The PI was calculated using the Equation 4 developed by [5].

$$PI = \frac{\sqrt{(\max Ci/Lj)2 + (\text{mean}Ci/Lj)2}}{2} \quad \text{....(Eq. 4)}$$

Where;

(meq/l) using the Equation 1 developed by [3]

Ci = concentration of chemical parameters

Lj = World Health Organization (2011) permissible limit.

Results and Discussion

The results of the physical and chemical characteristics of Otamiri River and its sediments are shown in Tables 3 and 4 respectively while the Pollution Index (PI), Sodium Adsorption Ratio (SAR) is shown in Tables 1 and 2 respectively.

pH

The mean pH concentrations of the Otamiri river at $SSWS_1$, $SSWS_2SSWS_3$ and Downstreamwere 6.45, 6.58, 6.45 and 6.50 respectively with a control point value of 6.60 (Table 3 and Figure 6) while for the sediments were 5.8, 5.90, 6.30 and 6.45 respectively with control point value of 6.48 (Table 4 and Figure 7). The pH values for water indicate that the Otamiri River is acidic and do not conform to the WHO (2011) standard for drinking water while that of the sediments were slightly acidic as well did not conform to the Federal Ministry of Environment (FME, 2006) standard for soil. As acidity of surface water increases, submerged aquatic plants decreases and deprives water fowls and planktons from their source of food resulting in theirdeath[6]

Electrical Conductivity and TDS

The mean concentrations of electrical conductivity of the Otamiri River at SSWS1, SSWS2, SSWS3 and Downstream were 14.83, 15.53, 11.70 and 10.30 µS/cm respectively with the control point value of 9.30 µS/cm (Table 3 and Figure 6) while the mean concentrations of total dissolved solids (TDS) were 8.89, 9.32, 11.0 and 10.05 mg/l respectively with control point value of 9.50 mg/l (Table 3 Figure 6). The concentrations of TDS and electrical conductivity conformed to WHO (2011) standard for safe drinking water. The TDS values indicates that the river is fresh [7] while the electrical conductivity values shows no salinity hazards [3].The lowest mean electrical conductivity values were obtained at SSWS3 and the lowest values for TDS were obtained at SSWS1 while the highest values for electrical conductivity were at SSWS2 and the highest values for TDS was at SSWS3.

Turbidity, Appearance and Odour

The mean values for turbidity were 10.37, 11.00, 12.95 and 8.50 NTU respectively at SSWS1, SSWS2, SSWS3 and Downstream with control point value of 4.50 NTU (Table 3 and Figure 6) which exceed the permissible limit with highest value at SSWS3 and the lowest value at SSWS1. The river is slightly turbid at SSWS1, turbid at SSWS2 and turbid at SSWS3 in terms of appearance while the control point indicates clear. Turbidity in water arises from the presence of very finely divided solids (which are not filterable by routine methods). The existence of turbidity in water will affect its acceptability to consumers and it will also affect markedly its utility in certain industries. The odour of the water is objectionable and the control point also is objectionable which shows unconformity with the WHO (2011) guideline for drinking water. Odour indicates some pollution of the river.

Geochemical Models

For the purpose of interpretation using geochemical models, the following parameters were used; Na^{+}, Ca^{2+}, in milligram per liter were converted to milli-equivalent per liter and were further used to generate Piper's trilinear, Durov, Stiff and Schoeller diagrams. These geochemical diagrams also indicate that the major cation and anions during the study period were Na^{+} +K^{+} and HCO_3^{-}respectively.K^{+} and Mg^{2+} for cations while the anions were HCO_3^{-}, NO_3, Cl^{-} and SO_4^{2-}.

Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio (SAR) values of the river at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream stations were 0.97, 0.98, 1.09 and 0.68 respectively with a control point value of 0.60 (Table 1). According to [4], water resources with SAR value of between 0 and 10 (as is the case with the Otamiri River) are classified as excellent for irrigation purpose while those with SAR value of more than 26 are classified as poor for irrigation purposes.

Major Cations and Anions in Water

The mean concentrations of Ca^{2+} at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstreamwere 3.66, 3.66, 3.15 and 2.80 mg/l respectively with control point value of 6.25 mg/l while the mean concentrations of Mg^{2+} were 1.28, 1.25, 1.05 and 1.10 mg/l respectively with control point value of 0.8 mg/l. The mean concentrations of Na^{+} were 6.00, 6.03, 6.20 and 5.30 mg/l respectively with control point value of 4.30 mg/l while the mean values of K^{+} were 1.58, 1.57, 1.45 and 1.32 mg/l respectively with control point value of 0.80 mg/l (Tables 3). The relative abundance of the major constituent cations follows the trend Na^{+}> Ca^{2+}> K^{+}> Mg^{2+}. The mean concentrations of HCO_3^{-} at $SSWS_1$, $SSWS_2$, $SSWS_3$ and

Downstreamare 17, 17.17, 15.03 and 13.45 mg/l respectively with control point value of 11.00 mg/l while the mean concentrations of SO_4^{2-} are 4.83, 4.80, 4.66 and 4.00 mg/l respectively with control pointvalue of 3.00 mg/l. The mean values for NO_3^- were 6.09, 6.05, 4.83 and 4.90 mg/l respectively with control point value of 2.40 mg/l. The mean values of Cl^- were 5.20, 5.27, 4.74 and 5.30 mg/l respectively with control value of 3.50 mg/l. The major cations and anions conformed to WHO (2011) standard for safe drinking water. High concentrations of chloride can occur near sewage and other waste outlets. The relative abundance ofmajor anions follow the trend HCO_3^-> NO_3> Cl^-> SO_4^{2-}**.** The watertype is Sodium Bicarbonate ($NaHCO_3^-$) and this typical of most surface water resources in Southeastern Nigeria.

Table 1. Classification of Water Based on Sodium Absorption Ratio (SAR) [After 8].

SAR	WATER CLASS
0-10	Excellent
10-18	Good
18-26	Fair
>26	Poor

Pollution Index (PI)

The mean pollution index (PI) of the Otamiri River at$SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream stations were 0.56, 0.57, 0.56 and 0.57 respectively with Control Point value of 0.58 (Table 2). It has been noted that the critical value of pollution index is 1; hence pollution index of more than 1 indicates very high degree of pollution [5]. Although, the PI is yet to reach the critical value of 1, there is need to monitor the PI value since it is already tending to 1.

Heavy Metals and Other Metals

The mean concentrations of Fe^+ at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstreamwere 0.01, 0.016, 0.23 and 0.10 mg/l respectively with control point value of 0.008 mg/l. The mean concentrations of Cd^{2+} during the study period were 0.004, 0.0036, 0.004 and 0.002 mg/l respectively. High level of Cd^{2+} in water is toxic to the kidney [6], causes bone damage, cancer and highly toxic to aquatic life. The mean values of Pb^{2+} were 0.02, 0.02, 1.67 and 0.02 mg/l respectively with only a trace at the control point.

Except for Ni, Cr^{6+}, Cu^{2+} and Zn^{2+}, the concentrations of other measured heavy metals (Cd^{2+}, Fe^+ and Pb^{2+}) did not conform to the WHO (2011) standard for safe drinking water and thus constitute a threat to the Otamiri River (Table 3 and Figure 8). For the Sediments, the mean concentration values of Pb at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstreamstations were 0.08, 0.07, 0.06 and 0.05 mg/kg respectively with no detection of the metal at the control point. The mean values for Hg was 0.10, 0.13, 0.15 and 0.18 mg/kg with no detection at control point. The mean concentration values for Cd at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstreamstations were 0.32, 0.28, 0.30 and 0.25 mg/kg respectively with no detection at control point. The mean values for Zn were 3.3, 4, 2.5 and 2.00 mg/kg with a control value of 1.5 mg/kg. Except for Fe, Cu and Al, the concentrations of other heavy metals did not conform to the FME (2006) standard for soil (Table 4 and Figure 9).

However, the concentrations of Zn^{2+}, Cr^{6+}, Cu^{2+} and Znwere quite significant and may exceed the permissible limit in the near future. It is important to note that these heavy metals are part of the constituents of the leachate from waste dumps and landfills around the stations which were later washed down the Otamiri River. The heavy metals owe their sources mainly from discarded electronic wastes (e-wastes) components of nearby waste dumps. Although many heavy metals are problematic environmental pollutants, nevertheless, because of their useful physical and chemical properties, some heavy metals, including, Pb^{2+}, Cd^{2+}, Zn^{2+} and Ni (to mention but a few) are intentionally added to certain consumer and industrial products such as switches, batteries, circuit boards, cell phones, and some pigments [6].

It is estimated that about 400 tons of Hg, 3000 tons of Cd, 14,000 tons of Ni, 20 tons of Cu, and nearly 100,000 tons each of Cr, Pb, and Zn are disposed in landfills in the U.S. this adds to heavy metals already residing in municipal solid waste landfill. Recently, there has been an increase in the use and disposal of electronic devices such as cell phones, mp3 players and computers, raising questions about the fate of these devices, and the metals they contain, in the landfills [9].

In Nigeria, the use of second-hand electronic wares is on the increase due to poor economy among others. This has aggravated the introduction of heavy metals into the environment, especially soil and water resources. The absence of sanitary landfill in most parts of Nigeria has worsened the situation.

Conclusion and Recommendations

The Otamiri River and its sediments have some physical and chemical constituents that do not conform to WHO (2011) standard for safe drinking water. at the four stations ($SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream) with Control Point is polluted with respect to pH and heavy metals (Pb^{2+}, Cd^{2+}, Fe^+, Ni and Hg) contents. These pollutants are attributed to the waste and effluents disposed from land at the four stations. This calls for proper waste management practices and pre-use treatment of the river water with chlorine and sodium bicarbonate in order to reduce the microbial constituents and raise the pH of the water respectively. The heavy metals of the water would be treated using acornic acid while iron can be treated using aeration method. The pH of the sediment can be treated by liming method. There is need for construction of sanitary landfills to reduce the introduction of heavy metals into the Otamiri River. The SAR values of the river indicate that it is excellent for irrigation purposes. However, the pollution index (PI) of the river is already tending to the critical value of 1.

Generally, the Otamiri River can be described as slightly acidic, soft, fresh but with excessive concentrations of certain heavy metals.

Table 2. Pollution Index of Otamiri River.

		Mean Concentration (C_{ij})					(C_{ij}/L_{ij})				
Parameters	L_{ij}	$SSWS_1$	$SSWS_2$	$SSWS_3$	DOWN.S	CON	$SSWS_1$	$SSWS_2$	$SSWS_3$	DOWN.S	CON
pH	8.2	6.45	6.58	6.45	6.50	6.60	0.786	0.802	0.786	0.79	0.80
TDS mg/l	1500	8.89	9.32	11	10.05	9.50	0.005	0.006	0.007	0.006	0.006
HCO_3^- mg/l	500	17	17.17	15.03	13.45	11.00	0.034	0.034	0.030	0.027	0.022
SO_4^- mg/l	400	4.83	4.80	4.66	4.00	3.00	0.012	0.012	0.011	0.01	0.007
Cl^- mg/l	400	5.2	5.27	4.74	3.30	2.10	0.013	0.013	0.011	0.008	0.005
Total							0.350	0.867	0.845	0.841	0.840
PI							0.56	0.57	0.56	0.57	0.58

Table 3: Physico-chemical Characteristics of Otamiri River.

Parameters	WHO 4th edition (2011) Guideline Value	SSWS1			Mean	SSWS2			Mean	SSWS3			Mean	DOWNSTREAM (Mbirichi)	CONTROL POINT
pH @ 25^{0}C	8.2– 8.8	6.45	6.40	6.49	6.45	6.50	6.46	6.90	6.58	6.45	6.40	6.48	6.45	6.50	6.60
Odour	Unobjectionable	Objectionable			Objectionable	Objectionable			Objectionable	Objectionable			**Objectionable**	**Objectionable**	**Objectionable**
Appearance	Clear	Slightly turbid	Slightly turbid	Slightly turbid	Slightly turbid	turbid	turbid	Clear	Turbid	turbid	turbid	turbid	Turbid	Turbid	Clear
Total Dissolved Solid, mg/l TDS	1500	9.00	9.50	8.18	8.89	9.00	10.80	9.50	9.32	10.00	11	12	11	10.05	9.50
Conductivity, µS/cm	1400	15.00	15.87	13.64	14.83	15.00	18.00	15.83	15.53	10.50	14.00	10.60	11.70	10.30	9.30
Turbidity, NTU	1.00	10.80	9.80	11.50	10.37	11.00	11.40	4.50	11.00	10.00	11.86	11	12.95	8.50	4.50
Total Chloride, mg/l Cl^-	400	6.20	4.37	5.04	5.20	6.20	4.60	3.50	5.27	5.20	3.80	5.22	4.74	3.30	2.10
Total hardness, mg/l $CaCO_3$	100	13.40	14.90	11.30	13.20	13.35	14.89	9.53	13.13	11.10	11.17	11.30	11.19	10.50	9.53
Calcium hardness, mg/l $CaCO_3$	150	8.00	9.50	7.20	8.23	8.15	9.49	6.25	7.43	6.05	7.10	7.30	6.82	5.80	4.45
Magnesium hardness, mg/l $MgCO_3$	150	5.40	5.40	4.10	4.97	5.20	5.40	3.28	5.20	4.05	4.07	5.00	4.38	5.00	3.28
Calcium, mg/l Ca	200	4.06	3.84	3.08	3.66	4.04	3.82	2.5	3.66	3.26	2.94	3.25	3.15	2.80	2.5
Magnesium, mg/l Mg	100	1.32	1.44	1.12	1.28	1.30	1.40	0.8	1.25	0.90	1.30	1.00	1.04	1.10	0.8
Mercury, mg/l Hg	0.006	0.003	0.002	0.003	0.0026	0.004	0.002	0.001	0.003	0.004	0.003	0.002	0.003	0.002	0.001
Bi-carbonate, mg/l HCO_3^-	500	18.02	15.70	17.80	17.00	18.00	15.50	11.00	17.17	14.34	16.40	14.35	15.03	13.45	11.00
Nitrate, mg/l NO_3^-	50	6.16	5.12	7.00	6.09	6.15	5.10	2.40	6.05	5.20	4.07	5.22	4.83	4.90	2.40
Phosphate, mg/l PO^{-3}	0.05	0.10	0.07	0.06	0.07	0.05	0.05	0.01	0.053	0.04	0.03	0.04	0.036	0.54	0.01
Sulphate, mg/l SO_4^-	400	4.55	4.90	5.05	4.83	4.60	4.80	3.00	4.80	4.70	4.60	4.68	4.66	4.00	3.00
Iron, mg/l Fe	<0.1	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.016	0.02	0.20	0.30	0.23	0.10	0.008

Sodium, mg/l Na	200	6.02	5.58	6.40	6.00	6.00	5.60	6.50	6.03	6.40	5.80	6.40	6.20	5.30	4.30
Potassium, mg/l K	50- *70*	1.84	1.42	1.48	1.58	1.80	1.40	1.50	1.57	1.20	1.90	1.21	1.45	1.32	0.80
Lead, mg/l Pb	0.01	0.02	0.01	0.02	0.02	0.03	0.01	0.02	0.02	0.02	0.02	0.01	1.67	0.02	Trace
Copper, mg/l Cu	2.00	0.95	1.00	1.20	1.05	0.85	0.72	0.94	0.84	0.96	1.30	1.10	1.12	0.70	ND
Cadmium, mg/l Cd	0.003	0.004	0.005	0.004	0.004	0.003	0.004	0.004	0.0036	0.004	0.005	0.003	0.004	0.002	ND
Aluminum, mg/l Al	0.10max	0.006	0.005	0.007	0.006	0.004	0.003	0.005	0.003	0.004	0.006	0.005	0.005	0.003	0.002
Zinc, mg/l Zn	5.00	1.40	1.46	1.33	1.39	1.54	1.48	1.50	1.49	1.29	1.35	1.40	1.35	1.20	Trace
Nickel, mg/l Ni	0.07	0.05	0.04	0.05	0.046	0.03	0.05	0.06	0.06	0.04	0.05	0.06	0.03	0.01	ND
Chromium, mg/l Cr	0.05	0.02	0.03	0.04	0.03	0.03	0.04	0.03	0.033	0.02	0.04	0.03	0.03	0.01	ND

*SSWS1 – Egbu, SSWS2 – Timber Market, SSWS3 – FUTO and DOWNSTREAM – Mbirichi WHO – World Health Organization (2011)

Table 4. Physico-chemical Characteristics of Otamiri Sediment.

Parameters	**FME Standard 2006**	***SSWS$_1$**	***SSWS$_2$**	**SSWS$_3$**	**DOWNSTREAM**	**CONTROL POINT**
pH	6.5	5.8	5.90	6.30	6.45	6.48
Conductivity, µS/cm	100	11	12	15	13	10
Total chloride, mg/kg Cl^-	250	125.80	140.69	162.45	130.25	100
Iron, Mg/kg Fe	1	0.4	0.3	0.4	0.30	0.1
Lead, mg/kg Pb	0.05	0.08	0.07	0.06	0.05	ND
Copper, mg/kg Cu	2	0.55	0.88	0.95	0.80	ND
Cadmium, mg/kg Cd	0.1	0.32	0.28	0.30	0.25	ND
Aluminum, mg/kg Al	<0.01	0.006	0.005	0.004	0.003	0.002
Zinc, mg/kg Zn	5	3.3	4	2.5	2.00	1.50

Figure 1: Location and Accessibility Map of the Study Area

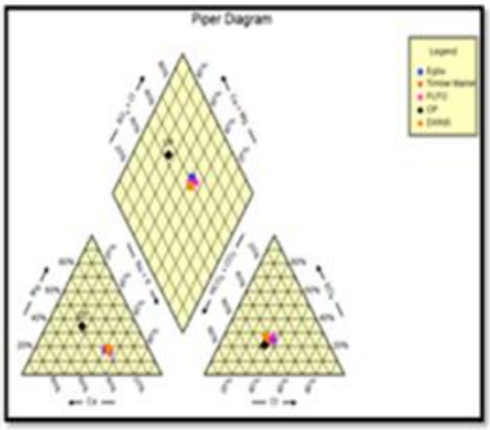

Figure 2 Piper Diagram Showing the major Cations and Anions

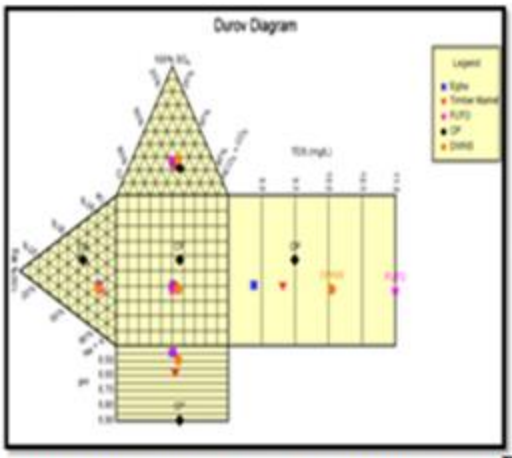

Figure 3: Durov Diagram Showing the major Cations

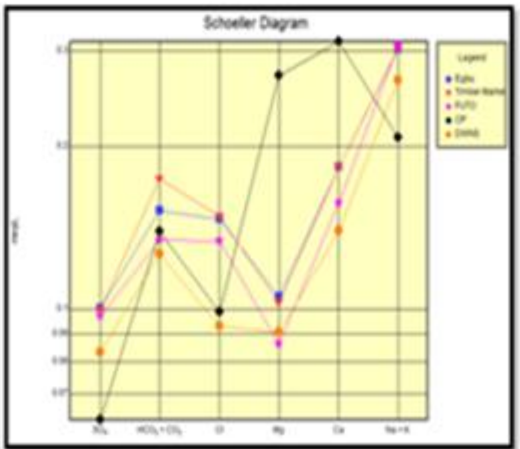

Figure 4: Schoeller Diagram Showing the major Cations and Anions

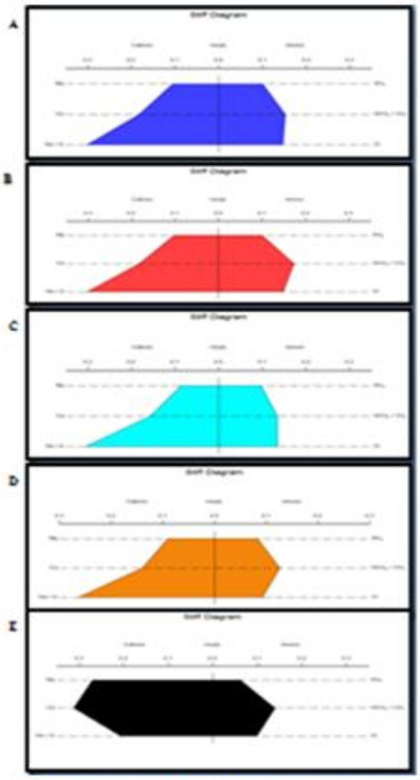

Figure 5: Stiff Diagrams for representing each stations; A-SSWS$_1$, **B-**SSWS$_2$, **C-**SSWS$_3$, **D-**Downstream and **E-**Control Point

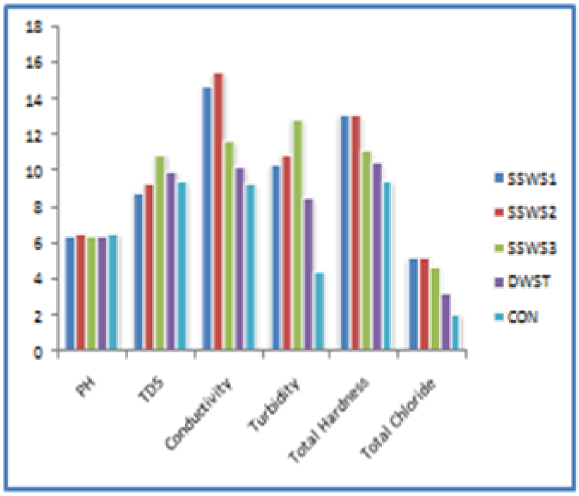

Figure 6: Bar Chart of some physiochemical parameters for water

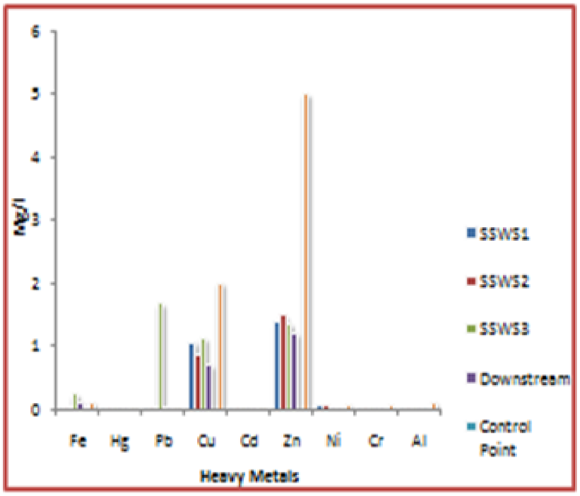

Figure 8: Relative Abundance of Heavy Metals in water

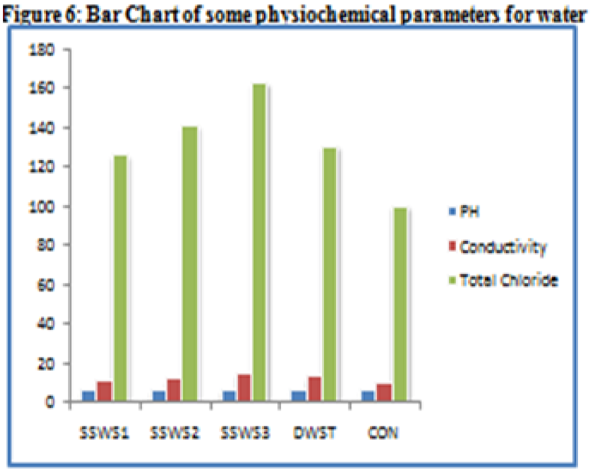

Figure 7: Bar Chart of some physiochemical parameters for sediments

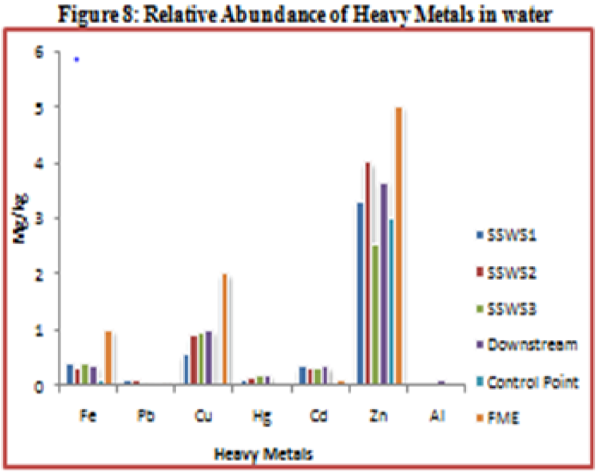

Figure 9: Relative Abundance of Heavy Metals in sediment

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References

[1] P.O. Nwankwoala and P.O. Ekpewerechi, Human Activities and Heavy Metal Concentrations in Aba River, Abia State, Nigeria. *British J Earth Sciences Research* 5(1): 26-36. 5(9): 492-500, 2007, ISSN 1991-81.

[2] A.E. Ihenyen and A.E. Aghimien, A Study of Trace Heavy Metal Levels in Warri Soils and Vegetables, Southern Nigeria. *African Journal of Environmental Pollution Health*, I, 72-82, 2002.

[3] D.K.Todd, Grounwater hydrology. John Wiley and Sons Inc., New York, 2nd Edition, p. 524, 1980.

[4] L.V. Wilcox, Classification and use of irrigation waters, usda (United States Department of Agriculture Technology and Engineering), Circular 969, Washington DC; Pp.1-19, 1955.

[5] R. K. Horton, An Index Number System for Rating Water Quality, *Journal of the Water Pollution Control Federation*, Vol. 37, No. 3, 1965, pp. 300-306; 1965.

[6] C. A. Ahiarakwem The impacts of Njoku sawmill landfill on the water quality of the Otamiri River, Owerri metropolis, Niger Delta Basin, Southeastern Nigeria. *International Journal of Engineering Inventions* e-ISSN: 2278-7461, p-ISBN: 2319-6491 Vol. 2, Issue 2, 2013.

[7] D. Carol, Rain water as a chemical agent of geological process. A review,US Geological Survey water supply papers. Nos.15 & 16, pp. 336-338, 1962.

[8] United States Department of Agriculture, Classification of water for Irrigation Purposes based on Sodium Ad-sorption Ratio (SAR).P 20, 1965.

[9] M. Aucott, The fate of heavy metals in landfills. Newsletter of New York, New Jersey Harbour Estuary Program.Pp. 1-2, 2008.

[10] WHO, Guidelines for Drinking-Water Quality, 4th ed.; World Health Organisation: Geneva, Switzerland, 2011; pp. 155–202.