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Industrial Effluents/Abattoir Discharge and Its Effects on Water Quality on the Receiving Woji River, Niger Delta, Nigeria.

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Abstract*: The study assessed the surface water quality of Woji River, Niger Delta of Nigeria, in order to determine the water quality index, water samples were collected at six sampling points of the River. The result revealed that the Physicochemical and heavy metals parameters exceeded the WHO and NSDWQ recommended permissible limit except for EC, Zinc, Chromium and Mercury that were within the acceptable limit. The water quality index scores of the selected locations of the surface water is bad to very bad quality of water samples, thus, Woji Abattoir (SS5) and Okwujagwu (SS6) locations were observed to be more polluted. The study recommends a consistent monitoring of anthropogenic activities around the surface water by relevant agencies.*

Keywords— Heavy metals, Water quality index; Waste discharge, Surface water.

1. INTRODUCTION

Water is an essential resource necessary for existence as such its quality should be properly maintained and not be compromised [1]. Effluent discharge from industrial plants, abattoir discharge, sewage disposals, surface runoff from mechanic garages and dockyard pollute the water bodies. The disposal of effluents into drains to Woji River poses serious health and environmental hazard to urban dwellers downstream. According to Huang et al. [2], aquatic environments like lakes, rivers and reservoirs receive heavy metals in untreated or inadequately treated wastewater from domestic, industrial, and agricultural sources. As most of the heavy metals quickly deposit into the sediment after entering the river. Heavy metals can be found in trace amount in surface waters but many of them are toxic even at very low concentrations which influences many other organisms through the food web [3; 4]. The concentration of metals in the coastal ecosystem is of concern due to their toxicity, environmental persistence and bioaccumulation in some biota [5; 6].

Among the toxic metals are arsenic, lead, cadmium, nickel, mercury, chromium, cobalt, zinc, and selenium even in very little quantity [7]. According to [6] Woji River in the Niger delta province is prone to pollution from various industrial effluents, abattoir discharge, dockyard, market located within and outside the area. The importance of water cannot be over-emphasized as it plays a significant role in enhancing human life, animal and plants [8]. Most importantly, it is used for cooking, laundry services, cleaning, agricultural (irrigation purposes) and industrial activities which the study area is known to be the industrial hub of the nation and water is also regarded as a universal solvent [9]. It is accessed from surface and groundwater sources. The groundwater sources include boreholes and hand dug wells while surface water sources include stream, rivers, and lakes. Rapid increase in population density, urbanization and industrialization has led to the contamination of water sources. The increase in unregulated discharge of untreated effluent from households, industries and abattoirs in the Niger Delta and this constitutes a major source of water pollution in the region [10] and improper management of solid waste such as electronic appliance, painting waste, used batteries, etc. when dumped with municipal solid wastes increase the heavy metals in dumpsites and dumping without adequate separation of hazardous waste can further elevate toxic environmental effects [8]. Environmental impact of land filling of municipal solid waste can usually result from the run-off of the noxious compounds into surface water and groundwater which ultimately lead to water pollution as a result of percolation of leachate [12] these contaminations can affect the clarity and the chemical constituents of the water source. Essentially, they can distort the quality of the water and even add odour thereby impacting negatively on economic activities [13]. Waterfronts in Nigeria Niger Delta Basin have suffered prolonged environmental pollution and degradation from human activities, leading to deposition of heavy metals and all sorts of environmental contaminants [14;15; 16]. In recent times, several studies have formulated various methods of assessing water quality status and their application has been strongly advocated by agencies responsible for water supply and control of water pollution . Thus, the present study aimed at the combined effect of industrial effluents and abattoir discharge on the receiving Woji River.

2 MATERIALS AND METHODS

2.1 Description of Study Area

The Woji River is situated in one of the industrial area in the city located on the intersection of Latitude 4°57′4.48’N Longitude 6°55′7.05’’E where it is currently experiencing

serious alterations in its fluvial discharges and its channel [17]. It is an estuarine tidal water, a tributary of the upper Bonny River with a mean depth of 4.8m, which is tidal and gradually transits from fresh to salt water at the head [1]. Its flow originates from Okrika town to Mini-Ewa, Rumuobiakani through Woji, Oginigba, Okujagu communities and then empties into the Bonny estuaries before flowing into the Atlantic Ocean. Much of scrap metals from dockyard, abattoir discharge, and industrial effluents from within and around emptied their waste to the receiving Woji River. The river feels the impact of industrial activities on the mangrove at the coastal areas (Figure 1). It also serves as a receptor for the untreated or partially treated industrial and municipal wastes. It has a confluence with the refinery creek at Okujagu to form the main tributary which drains into the Bonny River [6].

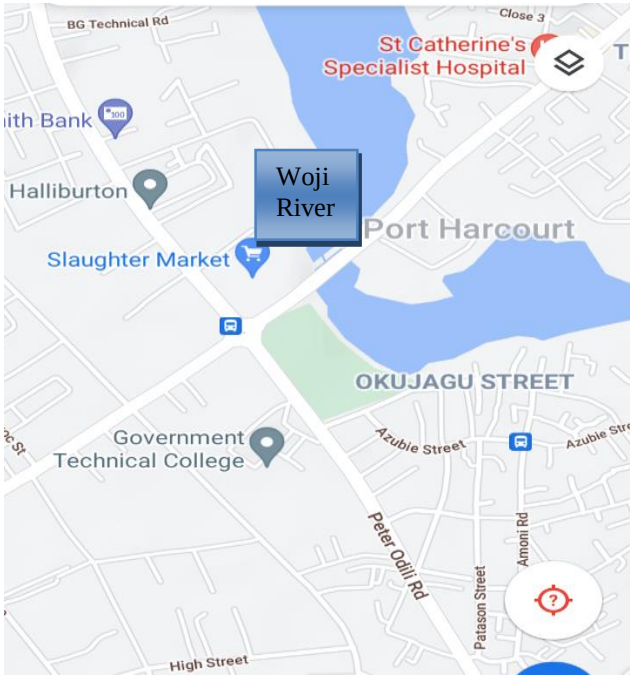

Figure 1: Map of Obio-Akpor Showing Woji River

2.2 Sample Collection

The surface water samples were collected from six different points in Woji River; Mini-Ewa, Oginigba, Okujagu, Bridge Bustop, Woji abattoir and Eliozu located in Obio/Akpor local Government of Rivers State, Niger Delta Region of Nigeria as shown in Table 1. A pre- cleaned plastic containers were used to collect water sample. The physicochemical and heavy metals parameters analyzed includes Temperature, pH, Electrical conductivity (EC), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), some heavy metals Mercury (Hg), Lead (Pb), Zinc (Zn), Cadmium (Cd) and Chromium (Cr).

2.3 Physical and Chemical Characteristics of Woji River

Selected parameters like pH, Turbidity, Electrical Conductivity and Temperature were determined in-situ using HANNA water checker (Model HI 93414) after calibrating the instrument with Standard Hanna solution. The dissolved oxygen (DO) was determined by the modified Azide or Winkler's method [18]. Biochemical Oxygen Demand (Apha-5210-B) Known portion of water sample collected was diluted with oxygenated water and incubated at 20^0c for five (5) days. At the end of the incubation period, the samples were treated in the same manner as the DO samples stated above. Chemical Oxygen Demand (COD) The chemical oxygen demand were determined by titrimetric method. Heavy Metals (Mercury Hg, Lead Pb, Zinc Zn, Cadmium Cd And Chromium Cr (APHA 3111-B (AAS) Heavy metals were determined using an Atomic Absorption Spectrometer (AA) as described in APHA 3111B and ASTM D3651. This involves the direct aspiration of the sample into an air/acetylene or nitrous oxide/acetylene flame generated by a hollow cathode lamp at a specific wavelength peculiar only to the metal programmed for analysis. For every metal investigated, standards and blanks were prepared and used for calibration before samples were aspirated [19].

Table 1: Sampling Stations, their Geographic Coordinates and Location Description

Sampling Stations(SS)	Coordinates	Locations	Description of Location
SS1	N 040 51' 34.9'' E 0070 01' 31.8''	Eliozu	Eliozu Car wash close to Eliozu Market
SS2	N 040 50' 27.6'' E 0070 01' 54.6''	Bridge Bus stop	Bridge bus stop along Aba-Port Harcourt
SS3	N 040 50' 15.7'' E 0070 02' 09.9''	Mini- Ewa	Mini-Ewa Police Station opposite Mobil Filling Station
SS4	N 040 49' 33.0'' E 0070 02' 08.9''	Oginigba	Wilderness/Desert in Oginigba, Trans Amadi Layout
SS5	N 040 48.6' 34.5'' E 0070 0' 33.6''	Woji Abattoir	Woji abattoir
SS6	N 040 48' 06.6'' E 0070 03' 04.7''	Okwujagwu	Sand dump in Azuabie, Okwujagwu off Peter Odili Road Trans Amadi

2.4 Water Quality Index Calculation

The WQI was calculated using standards of drinking water quality recommended by the World Health Organization (WHO) [20] and Nigeria Standard of Drinking Water Quality (NSDWQ) [21]. The weighted Arithmetic index method as cited in a related study [8] was used for the calculation of WQI in this study. Further, quality rating or sub index was calculated using the following expression.

$Qn = 100[Vn- Vi]/[Sn-Vi]$.

(Let there be (n) water quality parameters and quality rating (qn) corresponding to nth parameter is a number reflecting relative value of this parameter in the polluted water with respect to its standard permissible value).

qn – Quality rating for the nth water quality parameter.

Vn – Estimated value of the nth parameter at a given water sampling station.

Sn – Standard permissible value of the nth parameter

Vi – Ideal value of nth parameter in pure water (i.e., 0 for all other parameters except the parameters pH and Dissolve oxygen [7.0 and 14.6 mg/l respectively]. The unit weight was calculated by a value inversely proportional to the recommended standard value Sn of the corresponding parameter.

$Wn = k/Sn$

Where Wn – unit weight for nth parameter.

Sn – standard permissible value for nth parameter.

k – Proportionality constant (K=1.85445).

The overall WQI is calculated by the following equation.

$WQI = \sum qn\ Wn/\sum Wn$

The status of water quality according to WQI as shown in Table 2.

TABLE 2: Description of contaminated Water Based on the WQI [22]

Water Quality Index	Status
0 – 25	Excellent
26 -50	Good
51 -75	Bad
76 -100	Very Bad
Above 100	Unfit

3 RESULTS AND DISCUSSION

The surface water samples were examined to ascertain the extent of contamination. Selected physicochemical parameters of the surface water samples were collected at different locations and analyzed. Results obtained were compared with Nigerian Standard for Drinking Water Quality and World Health Organization [21; 20] to determine if it's safe for human consumption. The results revealed that Temperature in all location were higher than 25°C recommended standards by WHO and NSDWQ. This is an indication of foreign presence in the water bodies [2]. This work agree with [1] that high temperature causes thermal pollution and adversely affect aquatic life. It was further stated that increase in temperature also causes a decrease in the solubility of oxygen which is needed for oxidation of biodegradable wastes evidence from Table 4.

Table 3: Physicochemical Parameters of Water Samples from Different Locations of Woji River

Parameters	SS1	SS2	SS3	SS4	SS5	SS6	WHO, 2011	NSDWQ, 2015
p^H	6.28	5.84	6.1	6.8	5.77	7.25	6.5-8.5	6.5-8.5
Temperature (^oC)	26.4	27.4	29.2	28.9	26.4	26.8	25	
EC (µs/cm)	139.4	109.1	23	156.3	286	388	1000	1000
Turbidity (NTU)	9.04	6.21	5.51	8.12	78.1	85.72	5	5
TDS(mg/l)	96.8	77.4	16.3	106.8	219	254	500	500
DO(mg/l)	5.68	8.12	8.93	5.68	0	3.25	2	5
Lead(mg/l)	0.001	0	0	0	0.001	0.001	0.01	0.01
Zinc(mg/l)	0.003	0	0.004	0.005	0.004	0.004	3	3
Cadmium(mg/l)	0.004	0.004	0.004	0.004	0.005	0.005	0.003	0.003
Chromium(mg/l)	0.007	0.006	0.006	0.009	0.01	0.011	0.05	0.05
Mercury(mg/l)	0	0	0	0	0	0	0.006	0.001

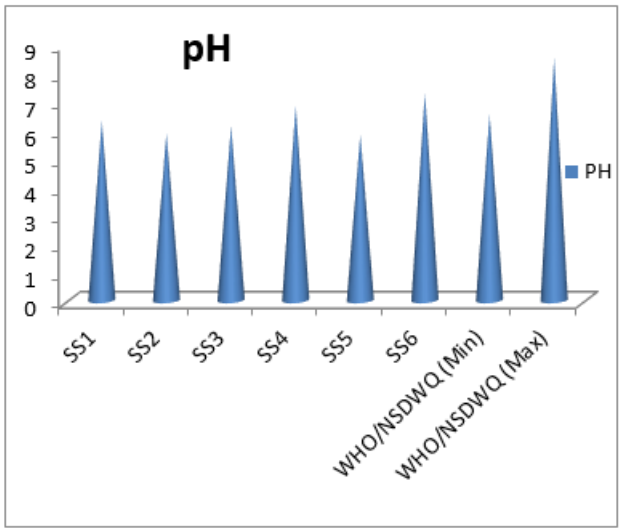

Figure 1a. pH from Sampling Points

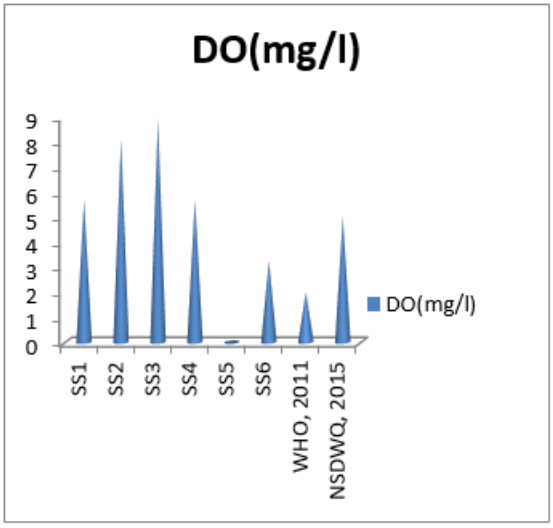

Figure 1b. Dissolve Oxygen from Sampling Points

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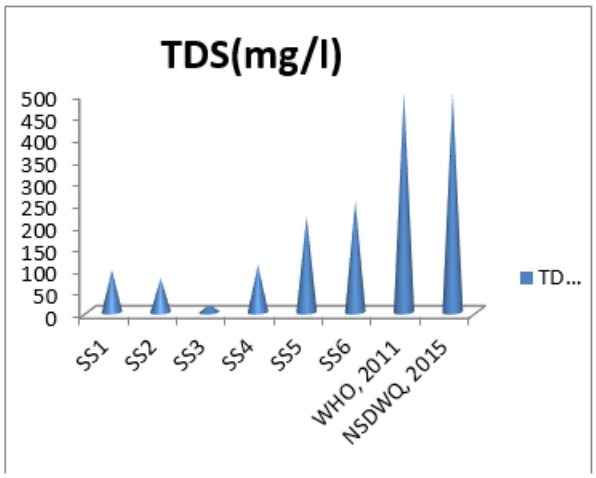

Figure 2a.Total Dissolved Solids from Sampling Points

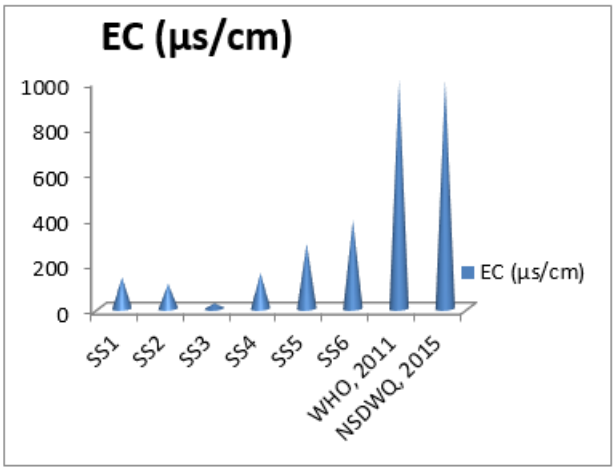

Figure 2a.Total Dissolved Solids from Sampling Points

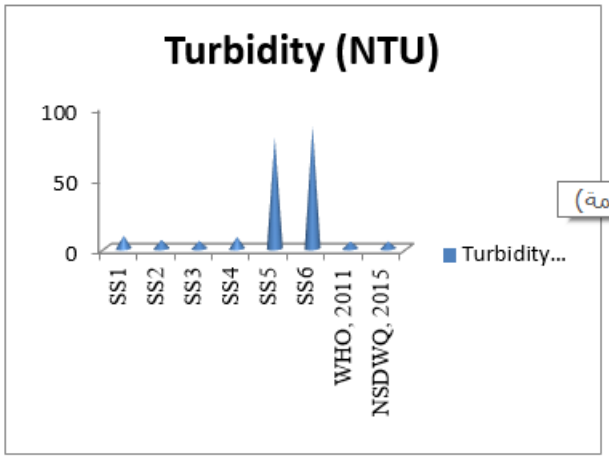

Figure 3a. Turbidity from Sampling Points

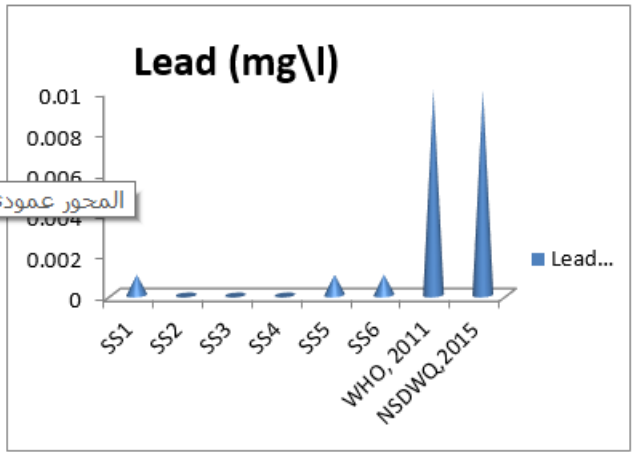

Figure 3b. Lead from Sampling Points

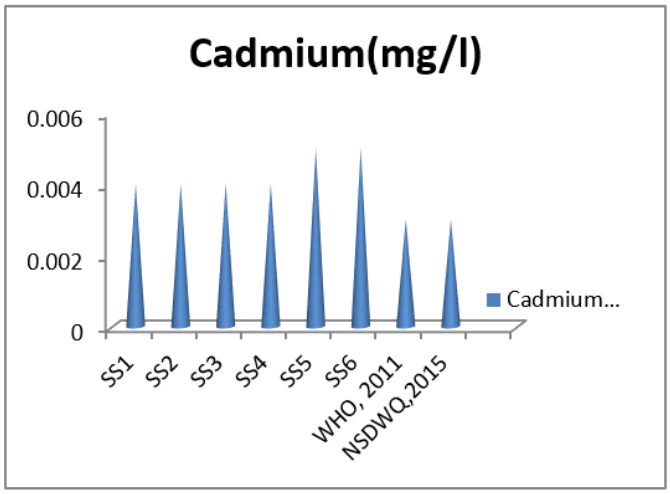

Figure 4a. Cadmium from Sampling Points

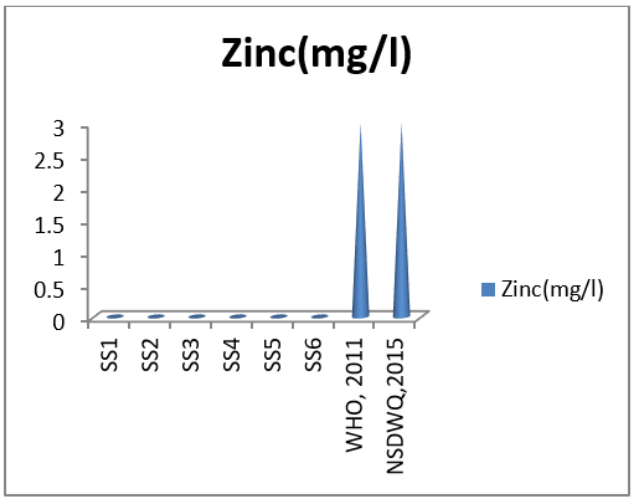

Figure 4b. Zinc from Sampling Points

Figure 1a. Shows the pH level across various sampling points with the highest in sampling point (SS4 and SS6) 6.80 and 7.25 respectively. The pH is one of the most important operational water quality parameter [20]. The surface water samples collected in all the locations were within the acceptable range of WHO and NSDWQ. High water temperature enhanced the growth of microorganisms and may increase problems related to taste, odour, colour and corrosion [20]. Figure 1b. Show the values of Dissolved oxygen for all samples exceeded the WHO and NSDWQ permissible limit of 2mg/l and 5mg/l except for SS5 (0mg/l) and SS6 (3.25mg/l) which are within the acceptable limit. The increase of Dissolved Oxygen could be due to the degree of pollution by organic substance [8].

Figure 2a. Result shows that surface water sample from all location are within the permissible range of not more than 1000mg/l. TDS is a measure of mineral content resulting from the balance between dissolution

and precipitation [1]. Figure 2b. The results indicated that EC value were by far lower across all sampling location as shown in Table 4. EC is the ability of a substance to conduct electric current, this ability depends on the presence of ions, their total concentration mobility, valence relative concentration and on the temperature [8]. The results revealed that the Woji River was not considerable ionized and has lower level of ionic concentration activities.

Figure 3a: shows the values of turbidity 5.51 to 9.04 NTU in all locations which were quite above the permissible limit for drinking water standard. This work align with [1] that high turbidity adversely affects the aquatic penetration of sunlight into water bodies. On the other hand, sunlight is needed by sea weeds for photosynthetic activities. Turbidity of above 5 NTU can harbor micro-organism protecting them from disinfection and can entrap heavy metals and biocides, even though it has no direct health effect. In addition, visibility of aquatic lives is impaired at high turbidity levels and decreased turbidity beyond a certain level promotes the growth of algae. Figure 3b**.** It is the most significant among other heavy metals, it is harmful and toxic in small concentration [4; 15] it can accumulate in the body tissue causing adverse health effect such as brain damage, cancer, mental deficiencies and even death. Results shows that lead concentration in all surface water sample location are within the acceptable limit of 0.01mg/l according to WHO and NSDWQ.

Figure 4a. Show relatively high concentration of Cadmium from different sampling location 0.004 to 0.005mg/l as against the recommended value of 0.003mg/l by WHO. High cadmium could cause agonistic and antagonistic effects on hormones and enzymes leading to several malformation such as renal damage [23]. Figure 4b. Show that Zinc concentration from the different sampling points were far below the permissible limit of 3mg/l

Table 4: Calculated Water Quality Rating (Qn) of Woji River from Six Sampling Points

Parameters	SS1	SS2	SS3	SS4	SS5	SS6
p^H	48	77.33	60	13.33	82	16.67
Temp (^oC)	105.6	109.6	116.8	115.6	105	107.2
EC (µs/cm)	13.94	10.91	2.3	15.63	28.6	38.8
Turbidity (NTU)	180.8	124.2	110.2	162.4	1562	1714.4
TDS(mg/l)	19.36	15.48	3.26	21.36	43.8	50.8
DO(mg/l)	70.79	51.43	41.51	70.79	0	25.79
Lead(mg/l)	10	0	0	0	10	10
Zinc(mg/l)	0.001	0	0.13	0.17	0,13	0.13
Cadmium(mg/l)	133.3	133.3	133.3	133.3	166.67	166.67
Chromium(mg/l)	14	12	12	18	20	22
Mercury(mg/l)	0	0	0	0	0	0

Table 5: Calculated Water Quality Unit Weight (Wn) of Woji River from Six Sampling Points

Parameters	WHO,2011	NSDWQ,2015	Wn
p^H	6.5-8.5	6.5-8.5	0.218
Temp(oC)	25		0.074
EC (µs/cm)	1000	1000	0.002
Turbidity (NTU)	5	5	0.37
TDS(mg/l)	500	500	0.004
DO(mg/l)	2	5	0.927
Lead(mg/l)	0.01	0.01	185,44

Zinc(mg/l)	3	3	0.62
Cadmium(mg/l)	0.003	0.003	618.15
Chromium(mg/l)	0.05	0.05	37.09
Mercury(mg/l)	0.006	0.001	309.07

Table 6. Calculation of Water Quality Index of Sampling Station (SS)1 Water Quality Index (WQI) = ∑WnQn/∑Wn =73.72

Parameters	Observed Value (Vn)	Standard Value(Vs)	Unit Weight (Wn)	Quality Rating(Qn)	WnQn
p^H	6.28	6.5-8.5	0.218	48	10.464
Temp(oC)	26.4	25	0.074	105.6	7.8144
EC (µs/cm)	139.4	1000	0.002	13.94	0.02788
Turbidity (NTU)	9.04	5	0.37	180.8	66.896
TDS(mg/l)	96.8	500	0.004	19.36	0.07744
DO(mg/l)	5.68	2	0.927	70.79	65.6223
Lead(mg/l)	0.001	0.01	185.44	10	1854.4
Zinc(mg/l)	0.003	3	0.62	0.001	0.00062
Cadmium(mg/l)	0.004	0.003	618.15	133.3	82399.39
Chromium(mg/l)	0.007	0.05	37.09	14	519.26
Mercury(mg/l)	0	0.006	309.07	0	0
			∑ Wn=1,151.965		∑WnQn=84,923.964

Table 7. Calculation of Water Quality Index of Sampling Station (SS2) Water Quality Index (WQI) = ∑WnQn/W∑n =72.02

Parameters	Observed Value (Vn)	Standard Value(Vs)	Unit Weight (Wn)	Quality Rating(Qn)	WnQn
p^H	5.84	6.5-8.5	0.218	77.33	16.85
Temp(oC)	27.4	25	0.074	109.6	8.11
EC (µs/cm)	109.1	1000	0.002	10.91	0.022
Turbidity (NTU)	6.21	5	0.37	124.2	45.95
TDS(mg/l)	77.4	500	0.004	15.48	0.062
DO(mg/l)	8.12	2	0.927	51.43	47.67
Lead(mg/l)	0	0.01	185.44	0	0
Zinc(mg/l)	0	3	0.62	0	0
Cadmium(mg/l)	0.004	0.003	618.15	133.3	82,399.39
Chromium(mg/l)	0.006	0.05	37.09	12	445.08
Mercury(mg/l)	0	0.006	309.07	0	0
			∑ Wn=1,151.965		∑ WnQn=82,963.13

Table 8. Calculation of Water Quality Index of Sampling Station (SS3) Water Quality Index (WQI) = ∑ WnQn/∑Wn =72.0

Parameters	Observed Value (Vn)	Standard Value(Vs)	Unit Weight (Wn)	Quality Rating(Qn)	WnQn

p^H	6.1	6.5-8.5	0.218	60	13.08
Temp(oC)	29.2	25	0.074	116.8	8.64
EC (µs/cm)	23	1000	0.002	2.3	0.0046
Turbidity (NTU)	5.51	5	0.37	110.2	40.77
TDS(mg/l)	16.3	500	0.004	3.26	0.013
DO(mg/l)	8.93	2	0.927	41.51	38.48
Lead(mg/l)	0	0.01	185.44	0	0
Zinc(mg/l)	0.004	3	0.62	0.13	0.081
Cadmium(mg/l)	0.004	0.003	618.15	133.3	82,399.39
Chromium(mg/l)	0.006	0.05	37.09	12	445.08
Mercury(mg/l)	0	0.006	309.07	0	0
			∑ Wn=1,151.965		∑ WnQn=82,945.541

Table 9. Calculation of Water Quality Index of Sampling Station (SS4) Water Quality Index (WQI) =∑ WnQn/∑Wn =72.23

Parameters	**Observed Value (Vn)**	**Standard Value(Vs)**	**Unit Weight (Wn)**	**Quality Rating(Qn)**	**WnQn**
p^H	6.8	6.5-8.5	0.218	13.33	2.9
Temp(oC)	28.9	25	0.074	115.6	8.55
EC (µs/cm)	156.3	1000	0.002	15.63	0.031
Turbidity (NTU)	8.12	5	0.37	162.4	60.09
TDS(mg/l)	106.8	500	Zinc(mg/l) 0.004	21.36	0.004 0.085 3
DO(mg/l)	5.68	2	Cadmium(mg/l) 0.927	70.79	0.005 65.62 0.003
Lead(mg/l)	0	0.01	Chromium(mg/l) 185.44	0	0.01 0 0.05
Zinc(mg/l)	0.005	3	Mercury(mg/l) 0.62	0.17	0 0.1 0.006
Cadmium(mg/l)	0.004	0.003	618.15	133.3	82,399.39
Chromium(mg/l)	0.009	0.05	37.09	18	667.6
Mercury(mg/l)	0	0.006	309.07	0	0
			∑ Wn=1,151.965		∑ WnQn=83,200.1366

Table 10. Calculation of Water Quality Index of Sampling Station (SS5) Water Quality Index (WQI) = ∑WnQn/∑Wn =92.21

Parameters	**Observed Value (Vn)**	**Standard Value(Vs)**	**Unit Weight (Wn)**	**Quality Rating(Qn)**	**WnQn**
p^H	5.77	6.5-8.5	0.218	82	17.88
Temp(oC)	26.4	25	0.074	105	7.77
EC (µs/cm)	286	1000	0.002	28.6	0.057
Turbidity (NTU)	78.1	5	0.37	1562	577.94
TDS(mg/l)	219	500	0.004	43.8	0.1752
DO(mg/l)	0	2	0.927	0	0
Lead(mg/l)	0.001	0.01	185.44	10	1,854.40

Table 11: Summary of Water Quality Index of Different Sampling Points of Woji River

Sampling Point	**WQI**	**Status**
SS1	73.72	Bad
SS2	72.02	Bad
SS3	72	Bad
SS4	72.23	Bad
SS5	92.21	Very Bad
SS6	92.33	Very Bad

Table 11. Calculation of Water Quality Index of Sampling Station (SS6) Water Quality Index (WQI) = ∑WnQn/∑Wn =92.33

Parameters	Observed Value (Vn)	Standard Value(Vs)	Unit Weight (Wn)	Quality Rating(Qn)	WnQn
p^H	7.25	6.5-8.5	0.218	16.67	3.63
Temp(oC)	26.8	25	0.074	107.2	7.93
EC (µs/cm)	388	1000	0.002	38.8	0.078
Turbidity (NTU)	85.72	5	0.37	1714.4	634.3
TDS(mg/l)	254	500	0.004	50.8	0.2
DO(mg/l)	3.25	2	0.927	25.79	23.91
Lead(mg/l)	0.001	0.01	185.44	10	1,854.40
Zinc(mg/l)	0.004	3	0.62	0.13	0.081
Cadmium(mg/l)	0.005	0.003	618.15	166.67	103,027.06
Chromium(mg/l)	0.011	0.05	37.09	22	815.98
Mercury(mg/l)	0	0.006	309.07	0	0
			∑ Wn=1151.965		∑ Wn=106,367.57

CONCLUSION

The study examined the physicochemical and heavy metals properties of surface water samples of Woji River in Obio/Akpor local government area of Rivers State, Nigeria. There were changes in some physicochemical parameters like temperature, turbidity, and dissolved oxygen that were above the permissible range of WHO and NSDWQ. However, pH, Electrical Conductivity, and Total Dissolved Solids were within the accepted limit. The metal concentration in Woji River such as Lead, Zinc, Chromium, and Mercury were within the recommended acceptable limit except for Cadmium 0.003m/gl that was slightly higher than WHO recommended limit. The study revealed that sampling point 1 to sampling point 4 were bad in terms of water quality index determined on the sample, whereas sampling point 5 and sampling point 6 were very bad. The study provides a baseline information on the physicochemical and heavy metal conditions of Woji River. Proper treatment should be carried out on the discharges of effluents to water bodies to avert depletion of dissolve oxygen thereby endangering the aquatic life.

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