EFFECTS OF EFFLUENT DISCHARGE FROM OIL MINING ON THE PHYSICO-CHEMICAL PROPERTIES OF WARRI RIVER

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ABSTRACT

The insatiable passion for oil as a source of energy worldwide has placed enormous pressure on oil producing communities with consequent high risk of pollution of their soil and water resources. Physico-chemical parameters of Warri River by Ubeji community were assessed in May, 2012 to determine the effects of effluent discharge from oil mining on the river water quality. Samples were collected upstream of the discharge point, at the discharge point and downstream of the discharge point. The parameters were analysed using standard methods. The mean values of the parameters obtained were 44.70, 78.86, 5.38, 766.7, 12.33, 0.04 and 100.56 mg/L for Total Suspended Solids (TSS), Oil and grease, Nitrate, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Lead and Sodium, respectively. Those of Electrical Conductivity and Sodium Adsorption Ratio were 0.48 dS/m and 2.29, respectively. Results showed that values of most of the parameters were above the World Health Organization (WHO) guidelines for drinking water quality. Therefore, the water cannot be consumed without treatment. Though the quality of the water may depress aquatic development, it satisfied the criteria for irrigation.

KEYWORDS: Oil mining, Warri river, pH, effluent, irrigation.

1. INTRODUCTION

Over the years, water quality has been an important parameter used to verify the integrity of water supply. Most streams and river systems are affected by the indiscriminate disposal of effluent. These effluents could be from atmospheric deposition, runoff, and domestic and industrial sources (Lomniczi et al., 2007). More than half of the major rivers around the world today are highly depleted and polluted that they now threaten human health and poison the surrounding ecosystem.

With the high rate of population growth in the developing countries, the rate of demand for fresh water has also increased, thus making it necessary to ascertain the quality of water being supplied. About 25,000 people are estimated to die daily through the use of contaminated water, while millions of others suffer varying and frequent water borne illness (WHO, 2006). Supply of good quality water to ensure good health condition, food production of high quality and yield and sustainable development is one of the major challenges facing Nigeria. For water to be used for irrigation, drinking, and industrial processes or for recreation it must meet some basic requirements in terms of quality.

Although industrialization and waste production is quite inevitable, some major environmental degradation and pollution has been occurring in great magnitude, thereby threatening ecological and human safety. In Nigeria, about 98% of its export earnings are derived from oil resources and that accounts for about 83% of the government's total revenue (Ekundayo, 1998). Oil activities especially in the Niger Delta region is a key source of environmental pollution. With the development of oil industry, contamination of aquatic environment by crude oil and petroleum products constitute an additional source of stress to aquatic organisms (Omoregie *et al.,* 1997).

Industrialization is without doubt an avenue of improving a nation's economic standard. However, toxic elements and oil may get to surface water from day to day operations as a result of accidents, waste discharge, oil spillage, gas emission, agricultural runoff and other reasons, leading to environmental pollution and health hazards . Thus, it becomes imperative to carry out an assessment of the quality of the water bodies in order to establish the extent of contamination and hazard to the environment as a result of oil exploration.

The objectives of this study were to determine the effects of effluent discharge from oil mining activities on the physico-chemical quality of Warri river; and to compare the results obtained with internationally established standards.

2. METHODOLOGY

2.1 Study Area

Warri River by Ubeji community lies between latitude 5°30"N and 5°38"N and longitude 5°38"E and 5°45"E and is situated in Warri South Local Government Area of Delta State, Southern Nigeria. The area is typified by mangrove swamp vegetation with a very high presence of Rhizophorasis specie. The relative humidity of the area ranges between 80% and 92%, while average annual rainfall exceeds 2800mm. The period between the months of April and October is regarded as the wet season, while that between November and March is considered as the dry season. However, a measurable amount of rainfall is recorded virtually in every month of the year. Air temperature ranges between 27°C and 29°C (Egborge, 1994). Figure 1 shows the map of Nigeria indicating the study area.

2.2 Water Sampling and Analysis

Water samples were collected serially using 1.5litre plastic containers at a depth of between 15cm – 30cm below the water surface at different locations namely: upstream, discharge point and downstream of the Warri river. The upstream and downstream are at a distance of approximately 2.5km either away from the discharge point.

The upstream refers to the point where the search for potential underground or underwater oil fields, recovery and production of crude oil and natural gas takes place, while the downstream refers to the point where the sell and distribution of natural gas and other products derived from crude oil takes place. The discharge point refers to the region where effluents from oil mining activities are released into the river. Water sampling, preservation, transportation as well as analysis followed standard methods (APHA, 1998; ASTM, 2001). The pH, TDS and conductivity were measured in-situ using Jennway pH meter model 3510 and Jennway conductivity meter model 4520, respectively. All samples were collected mid-May, 2012.

Sodium Adsorption Ratio (SAR) was computed using equation 1.

$$SAR = \frac{Na^{+}}{\frac{\sqrt{Ca^{2+} + Mg^{2+}}}{2}} \quad (1)$$

Cations were expressed in miliequivalent of charge per litre.

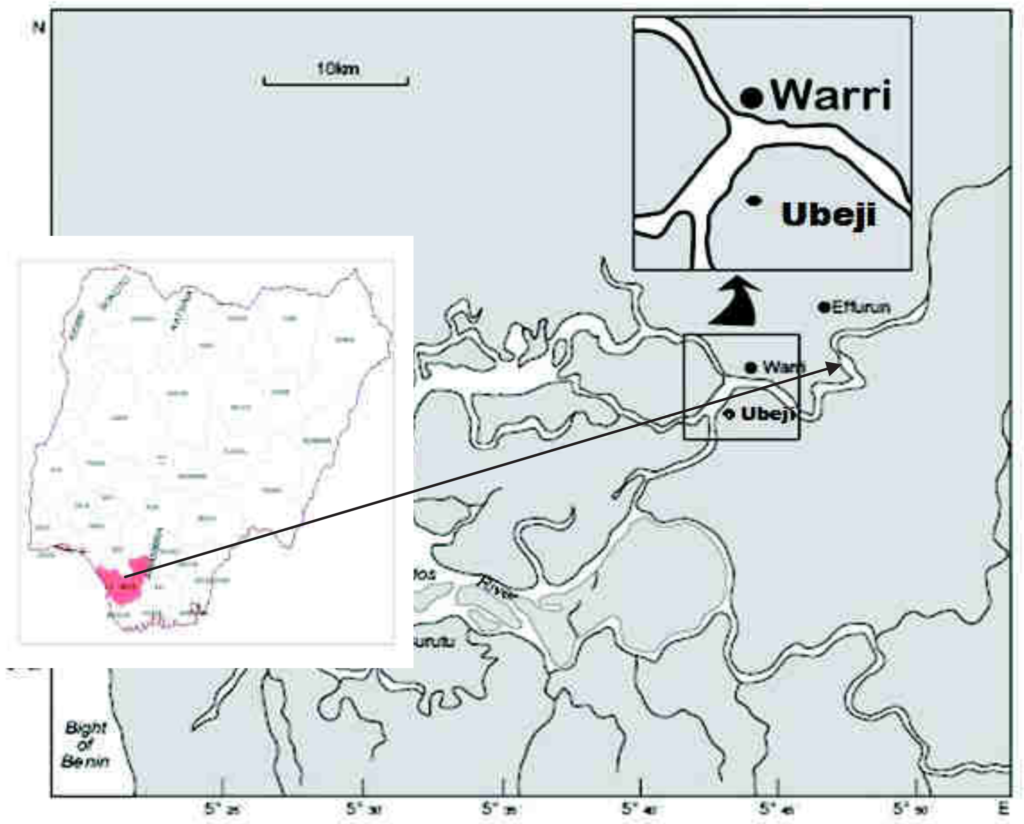

Fig 1: Map of Nigeria Showing Study Area

2.3 Statistical Analysis

Descriptive statistics were used to compute the mean, range and standard deviation, while Pearson's correlation analysis was performed among the various physico- chemical variables in order to fully understand their relationships.

3. RESULTS AND DISCUSSION

The results of the physico-chemical analysis of Warri river are presented in Table 1. Correlation coefficients between various physico-chemical parameters are shown in Table 2. The results were compared with WHO and FAO guidelines for drinking water and irrigation water quality to ascertain the suitability of the water for both drinking and irrigation.

Table 1: Physico-Chemical Properties of Warri River by Ubeji Community.

Parameters	Upstream discharge point	Discharge point	Stations Downstream discharge point	Range	Mean	Stdev limits	WHO limits	FAO limits
T S S (mg/L)	33	62	39	33-39	44.7	15.31	30.00	-
EC (uS/cm)	389	566	493	389-493	483	88.9	1000	200-250
TDS (mg/L)	192	293	239	192-293	241.33	58.31	1000	200-500
pH	5.92	5.11	5.36	5.11-5.92	5.50	0.41	7.0-8.50	200-500
Oil and grease (mg/L)	11.34	207.11	18.1	11.12-207.11	78.86	111.12	10	-
Nitrate (mg/L)	1.6	9.75	4.0	1.6-9.75	5.38	4.11	0.2	≤ 30
Nitrate (mg/L)	0.16	0.96	0.21	0.16-0.96	0.44	0.45	50	0 – 10
Phosphate (mg/L)	BDL	0.26	BDL	0 – 0.26	0.26	0.15	0.30	0.1
Sulphate (mg/L)	10.21	13.22	9.89	9.89 - 13.22	11.11	1.84	250	0 – 20
Iron (mg/L)	0.36	0.63	0.49	0.36 – 0.63	0.5	0.31	0.30	-
Chloride (mg/L)	64.83	94.33	73.1	64.83 – 94.33	77.45	15.21	200	0 – 30
BOD (mg/L)	8	17	12	8-17	12.33	4.51	< 4	-
COD (mg/L)	320	1600	380	320-1600	766.7	722.31	< 10	-
Total Hardness (mg/L)	22	31	26	22 - 31	26.33	4.51	100	-
Copper (mg/L)	< 0.001	< 0.001	< 0.001	-	-	0.00	0.05	0.2
Zinc (mg/L)	0.03	0.10	0.05	0.03 – 0.10	0.06	0.03	5	2.0
Manganese (mg/L)	< 0.001	< 0.001	< 0.001	-	-	0.00	0.05	0.2
Lead (mg/L)	0.02	0.06	0.04	0.023 – 0.0	0.04	0.02	0.001	-
Sodium (mg/L)	81.04	117.92	102.71	81.04 – 117.92	100.56	18.53	200	0 – 40
Calcium (mg/L)	56.38	82.03	71.45	56.38 – 82.03	69.95	12.90	75	0 – 20
Magnesium (mg/L)	36.69	53.40	46.51	36.69 – 53.40	45.53	8.40	200	30 , 50

BDL = Below detection limit; Stdev = Standard deviation

Table 2 Pearson's correlation coefficients between the physico-chemical parameters

	pH	EC	TDS	TSS	O&G	COD	BOD	Ph	NO_3	NO_2	SO_4	Cl	TH	Fe	Zn	Pb	Na	Mg	Ca
pH	1.00																		
EC	-0.993	1.0																	
TDS	-0.954	0.912	1.00																
TSS	-0.856	0.910	0.660	1.00															
O&G	-0.758	0.829	0.526	0.986	1.00														
COD	-0.765	0.835	0.536	0.988	1.00**	1.00													
BOD	-0.961	0.986	0.832	0.966	0.909	0.914	1.00												
Ph	-0.738	0.811	0.500	0.981	1.00*	0.999*	0.896	1.00											
NO_3	-0.942	0.975	0.797	0.980	0.933	0.937	0.998*	0.922	1.00										
NO_2	-0.744	0.843	0.548	0.990	1.00*	1.00**	0.920	0.998*	0.942	1.00									
SO_4	-0.676	0.757	0.423	0.960	0.993	0.992	0.854	0.996	0.844	0.990	1.00								
Cl^-	-0.895	0.941	0.719	0.997	0.969	0.972	0.984	0.962	0.993	0.975	0.934	1.00							
TH	-0.961	0.986	0.832	0.966	0.909	0.914	1.00**	0.896	0.998*	0.920	0.854	0.984	1.00						
Fe	-0.996	0.978	0.977	0.804	0.694	0.702	0.931	0.672	0.907	0.712	0.605	0.850	0.931	1.00					
Zn	-0.837	0.895	0.633	0.999*	0.991	0.993	0.956	0.987	0.972	0.994	0.969	0.993	0.956	0.782	1.00				
Pb	-0.992	1.00**	0.906	0.916	0.836	0.842	0.989	0.819	0.978	0.850	0.766	0.945	0.989	0.975	0.901	1.00			
Na	-0.993	1.00**	0.912	0.910	0.829	0.835	0.986	0.811	0.975	0.843	0.757	0.941	0.986	0.978	0.895	1.00**	1.00		
Mg	-0.993	1.00**	0.912	0.910	0.829	0.835	0.986	0.811	0.975	0.843	0.757	0.941	0.986	0.978	0.895	1.00**	1.00**	1.00	
Ca	-0.993	1.00**	0.912	0.910	0.829	0.835	0.986	0.811	0.975	0.843	0.757	0.941	0.986	0.978	0.895	1.00**	1.00**	1.00**	1.00

* Correlation is significant at $p < 0.05$ level (2- tailed) ** Correlation is significant at $p < 0.01$ level (2- tailed)

3.1 Drinking Water Quality

Values of pH are important in ascertaining the suitability of water for different purposes, including toxicity to man and plants. The pH values obtained from the upstream, discharge point, downstream and their mean are 5.92, 5.11, 5.36 and 5.46, respectively. None of the values obtained fell within the permissible limit prescribed by WHO (2006) as shown in Table 1. The discharge of the effluent had a marked effect on the acidity of the river leading to lowered pH. Chetana and Somasekhar (1997) in a similar study of River Cauvery, observed the same trend. Correlation analysis showed that pH exhibited significant negative correlation with EC, Fe, Pb, Na, Mg and Ca (r=-0.993, -0.996, -0.992, -0.993, -0.993, -0.993, respectively).

The values of electrical conductivity obtained at the upstream (389µS/cm), discharge point (566 µS/cm), and downstream (493 µS/cm) were all within the permissible limit set by WHO. Conductivity however increased after the discharge of the oil effluent. The increased level of conductivity and the cations after effluent discharge indicates the effect of decomposition and mineralization of organic materials as reported by Abida and Harikrisha (2008). Electrical conductivity showed a significant positive correlation with lead, sodium, magnesium and calcium ($r = 1.00$ for each at $p < 0.01$), and total dissolved solids, total hardness ($r = 0.912$ and 0.986, respectively). This result is in agreement with the findings of Venkatesharaju et al. (2010).

When the electrical conductivity concentration of water is too high or too low, it may limit the survival, growth or reproduction of aquatic organisms.

The TDS for the upstream (192mg/L), discharge point (293mg/L), the downstream (239mg/L) and the mean (241.33mg/L) of the study area all fell within the allowed limit set by WHO , and is therefore not considered a threat to human health. TDS is not regarded as a primary pollutant to water, but it is used as an indication of the aesthetic quality of drinking water.

The concentrations of the total suspended solids obtained were higher than the maximum limit of <30mg/L recommended by WHO as shown in Table 1. The high value of TSS may reduce water clarity, affect photosynthesis appreciably and depress plankton development. TSS showed a significant positive correlation with zinc ($r = 0.999$ at $p < 0.05$).

All sulphate concentrations obtained were within the WHO limit as shown in Table 1, and thus poses no health problems. Sulphate concentration in excess of 250mg/L may give water a bitter taste and also has a laxative effect on individuals that are not adapted to using such water.

Total phosphorous was below detection level both at the upstream and the downstream, while the discharge point concentration (0.26mg/L) was also below the limit specified by WHO as shown in Table1. Absence of phosphorus in the study area will limit aquatic plant growth. The total hardness concentrations recorded for the study sites were all within the permissible limit set by WHO (Table 1).

The total hardness concentrations obtained does not pose any health hazard to human health. Values above the prescribed limit causes poor leathering with soap, skin irritation and formation of scales. Hardness of water also helps to reduce metal toxicity to fishes by preventing them from absorbing toxic metals like lead, arsenic and cadmium.

The nitrate and nitrite concentrations obtained in the study sites were below the maximum limit set by WHO (Table 1). High concentration of nitrate can cause methemoglobenia (blue baby syndrome), a condition commonly found in infants below 6 months.

The presence of high nitrite concentration in the blood encourages the conversion of hemoglobin to methemoglobin which causes methemoglobania (blue baby syndrome). Pregnant women and adults with insufficient stomach acidity, and people with inadequate enzymes that changes methemoglobin back to hemoglobin can suffer severe methemoglobenia which can result to brain damage and death.

The concentrations of oil and grease in the water at the sampled stations far exceeded the permissible limit of 10 mg/L (Table 1). The discharge point recorded the highest concentration of 207.11mg/L, the upstream concentration was 11.34mg/L, and the downstream was 18.12mg/L. The high values implies that aquatic species are at risk of being killed directly through coating and asphyxiation, contact poisoning or from water soluble components when exposed to them. This is because aerobic oxidation of oil required large quantities of oxygen. Oil and grease exhibited significant positive correlation with COD ($r = 1.00$ at $p<0.01$), phosphorus and nitrite ($r = 0.05$ at $p < 0.05$, respectively).

The values of BOD obtained were higher than the maximum permissible limit of 4mg/L (Table 1). The discharge point had the highest concentration of 17mg/L, followed by the downstream (12mg/L), and the upstream (8mg/L). High value of BOD implies a high rate of oxygen depletion and thus less oxygen available for higher form of aquatic life, as aquatic organism become stressed, suffocate and die. BOD showed significant positive correlation with nitrite and total hardness ($r = 0.998$ at $p < 0.05$ and $r = 1$ at $p < 0.01$, respectively).

Chemical oxygen demand (COD) value determines the quantity of organic matter in water and dictates the level of oxidation of reduced chemicals. COD concentration observed was higher than the WHO recommended value of 10mg/L (Table 1). High COD levels in the study area could be attributed to an increasing level of organic and inorganic substances being added from the environment, which may be due to oil pollution. Chemical oxygen demand was found to have significant positive correlation with phosphorus ($r = 0.999$ at $p < 0.05$), nitrite ($r = 1.00$ at $p <0.01$) and oil and grease ($r = 1.00$ at $p < 0.01$), respectively.

Two heavy metals Fe and Pb were above the permissible limits (Table 1), while Zn and Cu, were below the limits. High iron concentration in water causes slight toxicity and makes water to have a stringent taste and causes laundry and porcelain stain. Pregnant women with elevated blood lead level are susceptible to lead poisoning and thus could give birth prematurely or to a child with low birth weight. High lead concentration also affects the mental development in infants, it causes cancer and it is also established to be toxic to the central and peripheral nervous system.

Calcium concentration at the discharge point (82.029mg/L) exceeded the permissible limit, while the upstream (56.337mg/L) and downstream (71.449mg/L) values were below the permissible limit (Table 1). Calcium concentration above the acceptable maximum limit encourages incrustation of pipes, poor leathering and cloth quality deterioration. When calcium is absorbed in excess, the excess intake is excreted by the kidney in most healthy individuals.

The concentrations of manganese and sodium in the study area were all below the maximum permissible limit prescribed by WHO (Table 1), and thus are not source of health problems. Sodium correlated positively with conductivity and lead.

The mean concentrations of magnesium at the upstream (36.689mg/L), discharge point (53.396mg/L) and the downstream (46.509mg/L) were all above the maximum recommended limit by WHO (Table 1). Sulphate values were found to be below the permissible limit. Magnesium correlated positively with EC, Pb and Na. Drinking water high in magnesium and sulphate concentration causes laxative effect.

3.2 Suitability for Irrigation

The pH values of the discharge point and downstream point of the study area all fell below the FAO recommended range of 5.5 - 6.5 for irrigation (Table 1). The upstream figure, however, is within the accepted limit with a value of 5.92. The result shows that effluent discharge from oil mining impacted acidity to the river. Acidic water can cause some nutritional problems that affect plant growth.

Table 3 shows the calculated values for the electrical conductivity in decisiemens per meter (dS/m) and sodium adsorption ratio for the study area, while Table 4 presents irrigation water quality standards based on FAO (Ayres and Westcott,1985) and the Canadian Council of Ministers of the Environment (CCME, 1999) guidelines.

Table 3: Calculated Values for Electrical Conductivity and Sodium Adsorption Ratio

	Upstream	Discharge point	Downstream	Mean
Electrical conductivity (dS/m)	0.339	0.566	0.493	0.483
Sodium adsorption ratio	2.056	2.479	2.314	2.293

Table 4 Standard irrigation water quality values.

Parameter	pH	Electrical conductivity (dS/m)	Sodium adsorption ratio
Limiting Values	5.5-6.5	< 0.7	0 – 3
FAO	6.5-8.5	< 1	< 4
CCME			

Salinity is usually evaluated using the electrical conductivity (dS/m) and/or the total dissolved solids. Electrical conductivity is a reliable indicator of total dissolved solids (salts) content of water. The addition of irrigation water to soils adds to the concentration of salts in the soil. Concentration of these salts will give rise to increased osmotic potential in the soil solution, thus interfering with extraction of water by the plants. Toxic effects may also result with increased salinity. Comparing the figures in Table 3 with that of the irrigation water quality guidelines (Table 4) shows that each study site had no potential of causing salinity hazard as they are within the recommended range. The only perceived hazard is the acidity impacted on the river by the effluent discharge which lowered the pH values at the discharge point and downstream of the discharge point, respectively.

Sodium adsorption ratio is an indicator of sodium hazard of water. Excess sodium in relation to calcium and magnesium concentration in soils destroys soil structure and may lead to reduced infiltrability of water into the soil. Sodium in excess may be toxic to some crops.

Based on the irrigation water quality guidelines (Table 4), the Warri river by Ubeji community has no sodicity problem but can be used for irrigated agriculture with caution because of the high acidity of the effluent.

4. CONCLUSIONS

The study assessed the effect of effluent discharge from oil mining activities on the physico-chemical qualities of Warri river. The results indicate that Warri river by Ubeji community is highly polluted and not safe for human consumption without treatment. This assertion is based on the high concentration of parameters obtained at the discharge point which were much higher than those at both the upstream and the downstream sites of the study area.

The results revealed that the discharge effluent quality fell short of standard requirements critical to the provision of safe drinking water such as pH and organic waste (measured as TSS, BOD, COD, nitrate and nitrite). The results also indicated that the effluent discharge impacted acidity to the river system. The results of this study has shown that the discharge effluent could pose serious health and environmental challenges to Ubeji community dwellers who rely on the river water for their domestic use without treatment and may also affect aquatic life in the receiving water. The suitability of the river water for irrigation is not in doubt as it satisfied the basic irrigation water quality requirements. Arising from this study is the need for continuous quality monitoring of surface waters in rural areas similar to Warri river.

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