Physio-Chemical Characteristics of Warri River, Delta State - Nigeria and Possible Implications

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Abstract—**This study aims to determine the Physico-chemical characteristics of Warri River at Ubeji axis and its possible implications. It was motivated by the serious reduction in local biodiversity of the Warri River as a result of synergistic effects from pollution of its water. It determines the physical and chemical characteristics of Warri River, Ubeji axis in wet and dry seasons; it identifies the sources of pollution and compares levels of the physico-chemical properties of the river against FEPA standards and the possible implications of the findings. Water samples collected for wet and dry seasons were analyzed for pH, temperature, turbidity, conductivity, biological Oxygen Demand (BOD), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Sulphate (SO42-), Nitrate (NO3-), Phosphate (PO43-), oil and grease, Lead (Pb), Iron (Fe), Cadmium (Cd), Zinc (Zn), Chromium (Cr), Copper (Cu). Effects of season and location were studied on these parameters at three distinct stations with differential pollution stress. The relationships between BOD and DO, and enteric infections (typhoid fever and dysentery) in the area were investigated together with other health effects emanating from water quality compromise. The study showed the varying effects of season and location on the physicochemical properties of the river. Interrelationships exist between the BOD and DO of the river. Crude oil production, improper disposal of rural and urban wastes, industrial effluent, logging activities and refining operation were identified as major pollution sources to the Warri River. The work recommends regular aquatic monitoring; polluter pays principle, tighter regulations on inflow of contaminants, and sanitary control of water. The various government regulatory bodies such as NESREA, DPR, NOSDRA, Federal and State Ministries of Environment and State Environmental Protection Agency, should strengthen their regulatory and compliance monitoring strategies.**

Keywords: Physio-chemical; River; Warri River; Heavy metals.

INTRODUCTION

The availability of water determines the location and activities of humans in an area, and our growing population is placing great demands upon natural freshwater resources. Technological growth has also put the ecosystem we depend on under stress and water resources at risk of being polluted Kulshreshtha [21]; Osibanjo [29].The accumulation of heavy metals and their effects on aquatic environment have direct consequences on man and the ecosystem in general. Although some metals such as copper (Cu) and Zinc (Zn) are generally regarded as essential trace metals in view of their valuable role for metabolic activities in organisms, other metals like lead (Pb), nickel and mercury exhibit extreme toxicity even at trace levels Merian [28]; DWAF [10]. However, it is of interest to note that most essential metals are toxic when supplied in concentrations in excess of the optimum levels. Heavy metal contamination of aquatic environment is of critical concern due to the toxicity and accumulation in aquatic habitats Tam and Wong [38].

Heavy metals could enter the aquatic environment from both natural and anthropogenic sources. Natural sources include weathering of rocks and soils Merian [28]. Anthropogenic inputs are mainly from industrial effluents, domestic effluent, rural and urban storm water runoff and spoil heaps Agbozu and Ekweozor [3]. In recent times, industrial activities have raised natural concentrations / levels, causing serious environmental problems. The biota that inhabits contaminated sites is generally exposed to very high concentration of these pollutants Woo et al. [45]

In terms of biological production, the Nigerian fresh waters including Ubeji axis WarriRiver have wide diversity of both flora and fauna. The fish yields of most Nigerian inland waters are generally on the decline Jamu and Ayinla [18]. The decline and threat to the sustainability of these resources have been attributed to array of causes ranging from inadequate management of the fishery resources to gross environmental degradation of the water bodies. Various physical factors such as temperature, conductivity, turbidity, pH, Dissolved Oxygen and salinity can influence the toxicity of metals in solution Dojludo and Best [9]; DWAF [10] and ecosystem hydrodynamics. As such, the lack of natural elimination processes for metal aggravates the situation and metals shifts from one compartment within the aquatic environment to another including the biota, often with detrimental effects, through sufficient bioaccumulation. Food chain transfer also increases toxicological risk in humans Mason [27].

Data provided shows evidence of selected heavy metal contamination of Chrysicthysnigrodigitatus and Pseudotolithuselongators respectively. Writing on the impact of economic activities on the environment of the Niger Delta, Agbozu [2] stated that water bodies have been heavily polluted due to the recurring incidence of oil spillage and industrial activities. Most micro-populations and invertebrates are eliminated following large – scale spillages, while sublethal levels of oil following several scale spillages have generally affected aquatic resources. The unregulated discharge of untreated effluents into WarriRiver by industries has also been reported by Egborge [12].

It is important to analyze water to determine its suitability for drinking, domestic, industrial, and agricultural uses. It is also important in water quality studies to know the quantity of oxygen required for stabilization of the water Waziri andOgugbuaja [44]. The impact of pollutants especially organics on water quality leading to enteric disease infections among the water utility population in this work is expressed in terms of the BOD, and Do, which both depend on each other Waziri and Ogugbuaja [44]. According to Onyema [30], there is a strong positive correlation between BOD, DO, phosphate, sulphate, and nitrate and the bacillariophyta abundance at IjoraRiver, these points to the fact that pollutants have the potential to affect waterbody ecosystem dynamics.

Preliminary microbial survey showed high metabolic rates among macroheterotrphs in the Warri River, Ubeji axis. The community appeared to be actively assimilating labile organic matter, though the carbon respiration rates were not known. However, direct microscopic examination revealed the microheterotrphic community to be dominated by bacteria, suggesting that in this enriched habitat, nutrients may be caught in a microbial loop with relatively little assimilated up the food chain to complex organisms.

Detailed fieldworks and visits to the area revealed that the residents complained of the pollution and the declining positive impacts of the utility of the river by the industries sited haphazardly around it. Furthermore, there was complaint on the reduction of fish and other aquatic animal catch by the residents as they claim the aquatic population to be visibly declining. Visual inspection by the investigator portrayed high degree of siltation and blockage at the lower course, pale greenish coloration of the water with infestation by the water hyacinth. The indiscriminate discharge of wastes and possible pollution of this river resource has been the causative and sustaining factor of the high level of restiveness and militancy widespread among the youths of the area. Consequently, marine intrusion into the Warri River is evidenced by greenish coloration of the water with infestation by the water hyacinth. The indiscriminate discharge of wastes and possible pollution of this river resource has been the causative and sustaining factor of the high level of restiveness and militancy widespread among the youths of the area. Consequently, marine intrusion into the Warri River is evidenced by increasing density of Oligocheatedetrivores of significantly observed benthic macrofauna followed by Chironomids and then bivalves. These are exploiters or opportunistic indicator species of environmental perturbations and damage Walker et al. [42]. These observations have stimulated the interest to undertake this study. This study therefore aims to determine the physicochemical characteristics of Warri River at Ubeji axis and its possible implications. It has the following objectives:

[1] To determine the physical and chemical characteristics of Warri River, Ubeji axis in wet and dry seasons.

[2] To identify the sources of pollution to the Warri River.

[3] To compare levels of the physicochemical properties of the river against FEPA standards.

[4] To discuss the possible implications of the physicochemical properties of Warri River.

DESCRIPTION OF THE STUDY AREA

The study area is Warri River, Ubeji axis, Warri. Warri in Delta State of Nigeria is situated on the north bank of the Warri River, one of three major sinusoidal rivers, which in conjunction with their anastomosing tributary streams and creeks drain the wetlands of the Western Niger Delta Emoyan*et al*. [13]. The river stretch lies between latitudes $5^0 25^1$ and $5^0 27^1$ North and longitudes $6^0 08^1$ and $6^0 11^1$ East. The study, which is Ubeji axis of the Warri River, is located within the industrial site of Warri, South-South Nigeria. Other communities within the Warri River catchment and watershed covered are Ekpan and Ifiekporo. Ubeji is an Itsekiri settlement, Warri South local Government Area, Delta State. Traditionally it is governed under the Lordship of the Olu of Warri. The bottom of the river is mainly composed of mud, derived from decayed organic materials (Chicoco). The study area falls within the Niger Delta region of Nigeria, which covers approximately 20,000km^2 within wetlands of 70,000km^2 formed primarily by sediment deposition.

The Warri River, Ubeji axis is within the tropical swamp forest belt characterized by rainy and dry seasons. Its upstream is freshwater with dense forest vegetation. The downstream reach is however brackish and consist of scanty mangrove. The study area is also influenced by the Northeast and Southwest winds, which influence the climate of Nigeria. The study section is under the impact of intense petroleum activities. The area played host to the Warri Refinery and Petrochemical Company – WRPC, the Pipeline and Product Marketing Company PPMC, Chevron/Texaco jetties, logistics/service companies and the Nigerian Gas Company NGC. Economic and commercial activities thrive so well in Warri apart from the Oil business exploitation and utilization of silica sand, which is one of the numerous natural resources; have become big business in the area. This natural resource is a major raw material for the production of glasswares and in construction. Aquaculture and harvesting of periwinkles had contributed greatly to the economy of the study area. The women mainly practice this. Brewing of local gin called "Ogogoro," lumbering, logging, tourism, furniture making are substantial ingredients of the Warri economy.

RESEARCH METHOD

The experiment was conducted using one-way classification in a completely randomized design to test the effect of season on the concentration of the physicochemical properties {pH, temperature, turbidity, conductivity, Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), sulphate (SO_4^{2-}), nitrate (NO_3^-), phosphate (PO_4^{3-}), oil and grease, lead (Pb), Iron (Fe), Cadmium (Cd), Zinc (Zn), Chromium (Cr), Copper (Cu)} of Warri River water. Season was tested at two levels viz: wet season and dry season.

The ANOVA model was used for the effects determination. W-pattern sampling technique as described by US EPA was used for sample collection. Each location or station was divided into W- pattern. Water samples were collected from various points and mixed thoroughly to obtain homogenous solution, which is a true representation of the river at a given location/station. Public survey was carried out by administering well-structured questionnaire to find out the utility of the river and pollution sources. The population included all the residents of the indigenous localities, civil servants and logging/woodworkers within the axis under study.

RESULTS

The physicochemical properties of Warri River, Ubeji axis remained relatively stable irrespective of season. There was no significant difference (P>0.05) between wet and dry seasons, respectively for pH, temperature, turbidity, conductivity, biological oxygen demand (BOD), dissolved oxygen (DO), chemical oxygen demand (COD), sulphate, nitrate, phosphate, lead, iron, cadmium, zinc, chromium, and copper (Tables 1and 2). Oil and grease parameter recorded significant variation (P<0.05) in seasons with dry season being significantly higher (P<0.05) than wet season (Tables 1 and 2).

In terms of station distributions of the physicochemical properties of the WarriRiver water, there was no significant difference (P>0.05) between the stations (1, 2, and 3) for temperature, turbidity, BOD, DO, and phosphate. Though, numerical differences exist but temperature was observed to be uniform (Tables 1 and 2).

Significant differences existed between the stations in pH values obtained with station 3 recording higher (P<0.05) than stations 1 and 2. The maximum conductivity was recorded at station 1 (P<0.05) and there was difference (P<0.05) in the conductivity values obtained from the stations. In the station difference (P<0.05) of the COD, station 2 was significantly higher (P<0.05) than stations 1 and 3. Nitrate content of station 1 was higher (P<0.05) than that of stations 2 and 3. There was no variation (P>0.05) between stations 2 and 3 in both seasons of study for the nitrate parameter.

Table 1: Physicochemical properties of Warri River in wet season (Jul, 2010)

PARAMETERS	STATIONS			FEPA LIMIT
	1	2	3	
pH	4.975 ± 0.035^{b}	4.43 ± 0.212^{a}	5.30 ± 0.424^{c}	6-9
Temperature (^{o}C)	25.505 ± 0.007	25.535 ± 0.035	27.375 ± 0.021	40
Turbidity (NTU)	39.25 ± 0.071	40.50 ± 0.707	41.10 ± 0.141	10
Conductivity (ms/cm)	27.65 ± 1.626^{c}	25.31 ± 0.424^{b}	25.50 ± 0.567^{a}	NS
BOD (mg/l)	8.40 ± 0.141	6.365 ± 0.191	7.02 ± 0.113	50
DO (mg/l)	4.10 ± 0.00	3.15 ± 0.071	4.25 ± 0.212	5
COD (mg/l)	9.50 ± 0.707^{a}	10.0 ± 2.828^{c}	8.51 ± 2.121^{b}	NS
Sulphate (mg/l)	6.65 ± 0.212	4.865 ± 0.021	3.25 ± 0.354	NS
Nitrate (mg/l)	0.026 ± 0.02^{b}	0.0135 ± 0.00^{a}	0.0135 ± 0.00^{a}	20
Phosphate (mg/l)	0.58 ± 0.028	0.40 ± 0.00	0.06 ± 0.00	5
Oil & Grease (mg/l)	10.10 ± 0.14^{b}	8.40 ± 0.141^{a}	11.15 ± 0.212^{c}	10
Lead (mg/l)	0.085 ± 0.007^{b}	0.10 ± 0.00^{c}	0.055 ± 0.007^{a}	<1
Iron (mg/l)	23.30 ± 1.556^{b}	36.50 ± 0.707^{c}	21.10 ± 0.141^{a}	1
Cadmium (mg/l)	0.07 ± 0.014	0.085 ± 0.007	0.08 ± 0.00	<1
Zinc (mg/l)	0.85 ± 0.071^{a}	1.03 ± 0.014^{b}	0.85 ± 0.071^{a}	<1
Chromium (mg/l)	0.01 ± 0.00	0.045 ± 0.049	0.09 ± 0.00	<1
Copper (mg/l)	0.015 ± 0.007	0.02 ± 0.014	0.015 ± 0.007	1

Mean values followed by the superscript in each row are significantly different (P<0.05)
Source: Author's field survey, laboratory analysis and computation (2011); NS: Not specified

Table 2: Physicochemical properties of WarriRiver in dry season (Feb, 2011)

PARAMETERS	STATIONS			FEPA LIMIT
	1	2	3	
Ph	4.97± 0.042 ^{b}	4.395± 0.233^{a}	5.25± 0.354^{c}	6-9
Temperature (^{o}C)	27.505 ± 0.007	27.50± 0.00	27.365± 0.191	40
Turbidity (NTU)	41.25 ±1.425	42.70 ± 0.424	41.10 ± 0.141	10
Conductivity (ms/cm)	27.65 ± 1.626^{c}	25.30± 0.424^{b}	24.50 ±0.566^{a}	NS
BOD (mg/l)	7.75± 0.071	7.00± 0.00	6.95± 0.212	50
DO (mg/l)	4.60± 0.141	3.85± 0.071	3.65 ± 0.212	5
COD (mg/l)	9.50 ± 0.707 ^{b}	10.00± 2.828^{c}	8.50± 2.121^{a}	NS
Sulphate (mg/l)	6.65 ± 0.212	4.865 ± 0.021	3.25 ± 0.354	NS
Nitrate (mg/l)	0.026 ± 0.02 ^{b}	0.014± 0.00^{a}	0.014± 0.00^{a}	20
Phosphate (mg/l)	0.38 ± 0.0311	0.40 ± 0.00	0.06 ± 0.00	5
Oil & Grease (mg/l)	11.35± 0.071^{b}	9.70 ± 0.141^{a}	12.25± 0.071^{c}	10
Lead (mg/l)	0.085 ± 0.007 ^{b}	0.10 ± 0.00^{c}	0.055 ± 0.007 ^{a}	<1
Iron (mg/l)	23.40 ± 1.556 ^{b}	36.55± 0.778^{c}	21.10 ± 0.141^{a}	1
Cadmium (mg/l)	0.07 ± 0.014	0.085 ± 0.007	0.081± 0.00	<1
Zinc (mg/l)	0.85 ± 0.071^{a}	1.04± 0.014 ^{b}	0.85 ± 0.071^{a}	<1
Chromium (mg/l)	0.01 ± 0.00	0.045 ± 0.05	0.09 ± 0.00	<1
Copper (mg/l)	0.015 ± 0.007	0.02 ± 0.014	0.015 ± 0.007	1

Mean values followed by the superscript in each row are significantly different (P<0.05)
Source: Author's field survey, laboratory analysis and computation (2011); NS: Not specified
Station 1: Ubeji Waterfront (upstream); Station 2: 100m away behind WRPC (midstream); Station 3: Ifiekporo (downstream)

Oil and grease recorded differences (P<0.05) inthe stations with station 3 being higher (P<0.05) than stations 1 and 2. Consequently, sulphate showed uniformity in concentrations (P=0.05) at the various stations in both seasons of study (Tables 1 and 2).

Among the heavy metals (Pb, Fe, Cd, Zn, Cr, and Cu), iron recorded the highest concentrations (P<0.05) in both seasons at different stations. Iron, Lead, Cadmium, and Zinc showed variations (P<0.05) in stations with station 2 being higher (P<0.05) than stations 1 and 3 for the metals, respectively. Chromium and copper exhibited uniformity in concentrations (P=0.05) over the sampled stations in both seasons with slight numerical variations (see Tables 1, 2).

Turbidity, DO, and oil and grease parameters exceeded the FEPA limits only in dry seasons but lower in wet season (P>0.05) except iron concentrations, which significantly (P<0.05) exceeded the FEPA limit in both season of the study.

Response Categories to Section B of the Questionnaire

Table 3 shows the level of agreement on the pollution sources to the Warri River.

Table 3: Percentage (%) Responses on pollution sources to the river

Question	SA	A	NS	D	SD	Total
Petrochemical industries	75.5	12.75	11.0	0.75	0	100
Crop agriculture/fishery production	3.75	14.0	4.5	3.25	74.5	100
Logging activities	31.5	29.5	33.25	4.25	1.5	100
Oil spill	78.0	18.25	2.75	1.0	0	100
Domestic/recreational uses	1.25	5.75	17.0	4.0	72.0	100
No pollution	0	0	1.5	1.75	96.75	100
SA: Strongly Agree; A: Agree; NS: Not Sure; D: Disagree; SD: Strongly Disagree; Source: Author's field Survey and computations (2011)Haematological effects such as abnormal decrease in erythrocyte, haemoglobin, and haematocrit levels, and anemia	29.0	36.0	28.0	3.0	0	100

VH: Very High; H: High; M: Moderate; L: Low; VL: Very Low; Source: Author's field Survey and computations (2011)

DISCUSSION ON THE POSSIBLE IMPLICATIONS ON FINDINGS

Distribution of the Physicochemical Properties of the Warri River

The pH of the WarriRiver, Ubeji axis varied between 4.902 and 4.872 in wet and dry seasons, respectively. There was marked variation in the stations for the sampling but no season difference. High water influx and strong tidal motion due to high buffering capacity of the system and effective flushing could cause the relatively stable pH observed in this environment. This small pH range observed could be linked to the salinity regime in the WarriRiver environment - similar observation on pH of aquatic system of the Lagos lagoon. The uniformity of water temperature readings may be linked to the shallowness of the WarriRiver and also regular tidal motion, which ensure the complete mixing of the water. This observation agreed with a work on Epie Creek of Niger Delta. Similar reports have been documented in brackish water system by Oyewo [31] on its temperature. There is no significant difference in the temperature of the two seasons and at its different stations. However, the relatively small range of variation in water temperature observed in this study area is in line with the observations of Longhurst [23]. They agreed that temperature is a stable ecological factor in shallow water environment of West Africa. It is most likely that this variation in temperature constitutes an important ecological factor in the Warri River.

The level of turbidity in the zones was higher in both seasons and only exceeded the FEPA limit for turbidity in dry season. This may be linked to effluents and domestic wastes being discharged into the receptor river and high increased sand dredging leading to high turbidity but due to natural filtration, turbidity can decrease down the stream, with increasing distance away from the source of effluent and waste discharge, hence the considerably lower turbidity observed in the wet season of the study. The biological oxygen demand (BOD) observed in all the zones indicates considerably level of nutrient such as sewage. The elevated biological oxygen demand (BOD), especially at station 1 indicated that the location was moderately unclean. This agrees with the report of Van-note *et al.* [40] that rivers with high BOD have high nutrient levels in the water. Warri River, Ubeji axis receives load of municipal and industrial sewages daily, which are acted upon by the aerobic microbes. The organisms consume most of the oxygen. The BOD level measures the relative oxygen requirements of microorganisms in polluted waters (microorganisms use dissolved oxygen in the water for the oxidation of organic matter as a source of carbon). These results indicated that the rate at which microbes in the WarriRiver demanded oxygen was high. Unpolluted natural waters will have a BOD of 5mg/l or less. The non-differential capacity in BOD during the seasons at various stations is attributed to the constant effect of surface run-off, soil erosion and effluents discharge into the receiving water body Oyewo*et al*. [32].

The dissolved oxygen (DO) levels for the two seasons were generally low and below the critical level of 5mg/l by FEPA (1991). Lower dissolved oxygen concentration was usually observed at the peak of wet season during which nutrients and debris are flushed into the Warri River with influx of freshwater from the adjoining rivers and overland flow. The DO level observed in both wet and dry seasons of the study area are lower to the level recommended by Bolarin and Hatton [7] that the desired range for the culture of warm water fish is 5mg/l and above but not more than 12mg/l. The detected level of DO indicates a significant pollution load of the WarriRiver. The chemical oxygen demand (COD) of Warri River exhibited synonymous trend as that of biological oxygen demand during the sampling period. COD measures the oxygen demand created by toxic organic and inorganic compounds as well as by biodegradable substances Sawyer *et* *al*. [34]. The high level of COD with station 2 being significantly higher in concentration than stations 1 and 3 indicated that there was decomposition of organic and inorganic compounds in the water that requires high level of oxygen in the water. Similar observation was made by Wooton [46], who stated that low oxygen concentrations in water were often caused by presence of decaying organic matter, which generates toxic gases such as hydrogen sulphide and methane.

There was slight numerical variation on the nutrient level of the study area with the lower value in the dry season but this increase gradually during the wet period. This could be tied fresh water influx and overland flow into the WarriRiver. It was mainly governed by suspended sediments transportation with the fresh water influx into the study area and this usually occurs during the wet seasons. The phosphate is also of great importance an essential nutrient in aquatic system.

The nitrate values obtained are small and common to a fairly polluted river system. Nitrate is an essential nutrient but at high concentration, becomes toxic and is capable of disturbing the aquatic environment. Nitrates occur naturally in soil containing nitrogen-fixing bacteria, decaying plants, septic systems effluents, and animal manure. According to the U.S Geological Survey [39], other sources of nitrates include nitrogenous fertilizers and air-borne nitrogen compounds emitted by industries and automobiles as well as inputs from other sources Bilger and Atkinson [6]. But under normal condition, the nitrate content of surface water occurs in trace amount. Nitrates penetrate through soil and remain in groundwater for decades Spalding and Exner [35]. The nitrate levels in the test water samples fell within the FEPA limit and EPA's recommended MCL in drinking water (10mg/nitrate-nitrogen or 45mg/L nitrate) Walton [43]. The detected concentrations of oil and grease in the study were higher than FEPA standard in the dry season. The low level of dissolved oxygen in the water observed can be attributed to the high level of oil and grease detected in all the stations. A wide variety of pollutant occurred throughout the zones. In situ observation indicated that organic matter and hydrocarbons from degraded petrogenic sources were present. These could be originated from the indiscriminate oil spills in the area.

Heavy Metals

Season is a major factor that affects the concentration of heavy metals in freshwater ecosystem. Emoyan*et al*. [13] has also reported variability of heavy metal concentrations with season. It could be that as water level drops, the concentration of heavy metals in the ecosystem while the reverse is the case. There was mixed observations in the concentrations of the heavy metals detected in the WarriRiver. Only iron and cadmium were numerically higher in the dry season while other exhibited higher concentrations in wet season except lead, and copper showed uniformity in concentrations in both seasons at different stations. This trend could be explained by the factual variations in quantity and discharge rates of the effluents and waste going into the river at different time.

Among the sampled stations in Warri River, station 2 consistently gave the higher concentration of the heavy metals sampled in the water except in chromium with copper having uniform concentrations in both seasons. It could stem from the burgeoning population, industrial, and agricultural activities surrounding the area. The various anthropogenic activities mentioned have been shown to increase the heavy metal loading of aquatic environment Kiffney and Clement [20]; Emoyan*et al*. [13]; Agbozu*et al*. [4]; Nduka [26]. The detection of cadmium in the water, though insignificant, could be attributed to rural/urban effluents along the river course and atmospheric precipitation, which supports the finding of Robinson [33]. The minute presence of chromium (Cr) and copper (Cu) in the study areas could be explained by the dumping of wood treated with chemicals made from salt of arsenic, chromium and copper in mixed soluble formulation (as copper-chrome-arsenate preservative). These chemicals were being used to prevent fungi and pest attack by the logging/ woodworkers, which could provide a potential source of chemical spills and drainage from the treated wood within and around the refinery. This supports the earlier findings of Ndiokwere [24]. Additional input of cadmium could be via agrochemicals used by farmers and fishermen and that it occurs together with zinc Varma*et al*. [41], lead and copper Lauwyers [22]. Lead (Pb), though very low in the water sourced from the study area, is a pointer to the fact that naturally, Pb is distributed in surface water due to weathering of minerals and atmospheric deposition (Merian [28]; Robinson [33]. The concentrations could be accelerated by industrial and other technical uses such as chemical pigments and alloy production and burning of fossil fuel, which agree with the earlier findings of Stoeppler [37] and Horsfall [15]. The zinc and high iron levels in the study area could be explained by high incidence of iron in Nigerian soil. Zinc occurs in nature with other metals of which iron and cadmium are the most common. Iron in the study area exceeded the maximum allowable limit of FEPA. It is noteworthy that most of these heavy metals could be made available in the freshwater system not only through industrial and domestic effluents but also through dumping of refuse Nduka*et al*. [25]

Responses from the Residents and Pollution Sources

Following the response categories, there is strong evidence on use of the WarriRiver for various activities, such as domestic, recreational and occupational uses. Earlier field survey revealed little or no alternative sources of water for the indigenes. However, greater numbers of the residents do not in any way treat the water obtained from the river before use because they believed it to be safe, which undoubtedly could expose them to possible danger of pollution impact with regard to heavy metals, especially zinc and copper. There was high agreement by the people on the pollution source to the WarriRiver traceable to petrochemical industries as well as oil spills. Follow-up questions revealed the strong animosity of the residents against the oil industries that pollute their lands. The animosity is being manifested in the prevalent insurgency witnessed in the area recently. Furthermore, they vowed tocontinue the restiveness until their lands become reclaimed. Earlier authors Atuma and Egborge [5]; Kakulu et al. [19]; Ezemonye and Egborge [14]; Egborge [11]; Ikomi and Owabor, [16]; Ikomi and Emuh [17]; Spiff and Horsfall [36]; Brades et al. [8]; Emoyan et al. [13]; and Agbozu et al. [4] have documented the pollution impacts and effects of the petrochemical industries in the Niger Delta region while Agbozu [2] stated the heavy pollution of water bodies due to recurring oil spills.

Greater proportion of the residents pointed to the logging activities as a potential source of pollution to the water since they empty their by-products into the river. Industrial wastes have been shown to be a complex admixture of several classes of pollutants such as organic and inorganic residues Oyewo [31]. The organic residues such as the wood chaffs could be increasing the BOD as well as the COD of the river with its attendant reduction of its DO. Chemical spills from the wood refinery could be a significant pollution source with copper and chromium as earlier reported by Ndiokwere [24], which account the detection of copper and chromium in the river. The residents vehemently rejected their agricultural activities, domestic, occupational, and recreational uses of the river to be loading it with pollutants that degrade its quality. They see their activities as means of livelihood and contribute less or nothing to the river loadings, seriously pointing fingers and accusations to the oil industries. Residents were also seen disposing domestic wastes into the river on daily basis. Their insistence of not contributing to the stress load of the river hinges on the ignorance of their actions and inactions over the river. Similar load of misconceptions and ignorance have been reported by Aderinola et al. [1] in Anambra River.

RECOMMENDATIONS

a) Obligatory sustainable wise use practices to conserve water resources. More river protected areas should be established not only to minimize human impacts but also to provide sites for research to better understand river processes.

b) Regular monitoring of the physicochemical properties of water at least once every four years should be instituted to ascertain the quality of water being used in the area.

c) Tighter regulations to control inflow of nutrient and physicochemicalcontaminants to river habitats coupled with enforcement of penalties imposed forillegal and unsustainable development that degradethese habitats. Polluter pays principle and penalties be adopted.

CONCLUSION

The various government regulatory bodies such as National Environmental Standards Regulatory and Enforcement Agency (NESREA), Department of Petroleum Resources (DPR), National Oil Spill Detection and Responses Agency (NOSDRA), Federal and State Ministries of Environment and State Environmental Protection Agencies should strengthen their regulatory and compliance monitoring strategies

REFERENCES

1. O.J. Aderinola, E.O. Clarke, M.O. Olarinmoye, V.Kusemiju, and M.A. Anatekhai, "Heavy metals in surface water, sediments, Fish and Periwinkles of Lagos Lagoon". American-Eurasian Journal of Agriculture & Environmental Sciences, 5 (5): pp. 609-617, 2009
2. I.E. Agbozu, "Impact of economic activities on the environment of Niger Delta". Envisafe Global Environmental and safety memoirs. GESM, 1999, pp. 99-100.
3. I.E. Agbozuand , I.K.E. Ekweozor, "Heavy metals in a non-tidal freshwater swamp in the Niger Delta areas of Nigeria". African Journal of Science., 2, pp. 175 -182., 2001
4. I.E. Agbozu, I.K.E. Ekweozor and K. Opuene, "Survey of heavy metals in the Catfish synodontisclarias". International Journal Environmental Science Technology 4(1): pp. 93-97., 2007
5. S.O. Atuma and A.B.M. Egborge (1986), "Insecticide and metals in surface water-WarriRiver". International Journal of Environmental studies, 27:pp. 131-142., 1986
6. R.W. Bilger and M.J. Atkinson, "Effect of nutrient loading on mass transfer rates of a coral reef community". Limnol.Oceanogn., 49(2): pp. 279-289., 1997.
7. J. Bolarin and, J.D Hatton. Tilapia –A guide to their biology and culture in Africa unit of Aquatic pathology, Sterling University 1981, p.174.
8. S.A., Braide, W.A.L. Izonfuo, P.U. Adiukwu, A.C Chindah and C.C. Obunwo, "Water quality of miniweja stream, A swamp forest stream receiving non-point source waste discharges in eastern Niger Delta," Nigeria Scientic Africana, 3: pp. 1-8., 2004.
9. J.R. Dojludo and G.A.L. Best, Chemistry of water and water pollution. Ellis Horwood limited, Great Britain. 1993.
10. DWAF,"South Africa water quality guidelines", vol. 7: Aquatic ecosystem 1st edn., Department of water affairs and forestry.1996.
11. A.B. Egborge, Water pollution in Nigeria (i) Biodiversity and Chemistry of Warri River. Ben Miller Publisher, Warri. 1994.
12. A.B.M. Egborge, Government, oil companies, the people and the Niger-Delta Environment: 4th convocation lecture of Delta State University, Abraka, Nigeria. 2000
13. O.O. Emoyan, , F.E Ogban and E Akarah, "Evaluation of heavy metals wading of River Ijana in Ekpan- Warri," Nigeria. Journal of Applied Science Environmental Management, 10 (2): pp. 121-127. 2006
14. L.I.N. Ezemonye and A.B.M. Egborge, Heavy metal concentration in water, sediment and selected fish species in WarriRiver and its tributaries. Proc. 3rd national seminar on petroleum. Petroleum Training Institute, Effurun, Nigeria, 3: pp. 91-112. 1992
15. M. Horsfall Jr., Advanced environmental chemistry. La Limesters, PortHarcourt, Nigeria: pp. 130-159. 2001.
16. R.B. Ikomi and N. Owabor, "The status and seasonality in the physicochemical hydrology of River Orogodo at Agbor, Nigeria". Bulletin of Science Association of Nigeria, 21: pp. 167-175. 1997.
17. R.B. Ikomi and Emuh (2000), "The status of the physicochemical hydrology of upper Warri River, Nigeria". Journal of science and Environment, 2: pp. 75-86. 2000.
18. D.M. Jamu and A.O. Ayinla (2003), Potential for the development of agriculture in Africa. NAGA 26 (3): pp. 9-13. 2003.
19. S. E., Kakulu, O. Osibanjo and S.O. Ajayi, Trace metal content of fish and shellfishes of the Niger Delta Area of Nigeria. Environmental Institute. 13, pp. 247-251. I987.
20. P.M. Kiffney and W.H. Clement, Bioaccummulation of heavy metal by Benthic invertebrates at the Arkansas River, Colarado. Environmental Toxicology and Chemistry, 12 (98): pp. 1507-1517. 1993.
21. S.N. Kulshreshtha, A global outlook for water resources to the year 2025, Water Resources Management. 12(3): 167-184. 1998.
22. R.R. Lauwerys, Health effects of cadmium. In: Di Ferrante E, ed. Trace Metals: Exposure and Health Effects.Oxford, England, Pergamon Press: Pp. 43–64. 1979.
23. A.R. Longhurst, An ecology survey of the West African Marine Benthos. colonial office Fisheries publication 11: 102p. 1958.
24. C.L. Ndiokwere, Chemistry and environment. Inaugural lecture series 73, University of Benin. UNIBEN Press, Nigeria: pp.33-37. 2004.
25. J.K.C. Nduka, O.E. Orisakwe, L.O. Ezenweke, C.O. Abiakam, K.C. Nwanguma and J.M.U. Maduabuchi, Metal contamination and infiltration into the soil at refuse dumpsites in Awka, Nigeria. Arch Environ &occup. Health, 61 (5): pp.197-204. 2006.
26. J.K. Nduka (2009). "Heavy metal pollution in Nigeria.Ph.D seminar presentation". Nnamdi Azikiwe Univerisity, Awka, Anamnra State, Nigeria. pp. 7-19.
27. C.F Mason, Biology of freshwater pollution. 2nd Edition; Longman New York. 351p.1991
28. E. Merian (1991), Metals and their compounds in the environment. occurrence Analysis and biological relevance. UCH, Weintrein – New York. 1991.
29. O. Osibanjo (1996), Present water quality status in Nigeria. In: E.O.A. Aina and N.O. Adedipe eds. Proceedings of the national seminar water quality and environmental status in Nigeria. Federal Environmental Protection Agency, FEPA Monograph. pp.35- 59. 1996.
30. I.C. Onyema, "The phytoplankton composition, abundance and temporal variation of a polluted estuarine Creek in Lagos, Nigeria". Turkish Journal of Fisheries and Aquatic Sciences.7: pp.89-96. 2007.

31. E.O. Oyewo, Industrial sources and distribution of heavy metals in Lagos Lagoon and their biological effects on estuarine Animals. Ph.D Thesis, University of Lagos, Nigeria, pp.230-274. 1998.
32. E.O.Oyewo, T.O. Ajayi, G.O. Dublin – Green, E.A. Ajao and L.F.Anosike, Impact of Pollution in Aquatic Living Resources in Africa. Proceedings of the 5th session of the inter-African committee Oceanography, Sea and inland Fisheries. 1999.
33. J. Robinson, Evaluation of Health assessment index with reference to bioaccumulation of Metals in Oreochromismassambicus (Peters, 1852) and aspects of the morphology of LernaaCyrinacea(Linnaeus, 1758). Thesis, Rand Afrikaans University, South Africa. 1996.
34. C.N. Sawyer, P.L. Mc Carty and G.F. Parkin, "Chemistry for environmental engineering", 4th Ed. McGraw- Hill Int. Editions. Sewerage. A Suggested Standard of Practice; Journal. Institute of public health Engineer. Vol Xliii, 4th Ed. p. 205. 1994.
35. R. Spalding and M. Exner (1993), Occurrence of nitrate in groundwater. J. Environ. Qual., 22: pp. 392-402.
36. A.I. Spiff and M. Horsfall Jnr., Trace metal concentrations in inter-tidal sediments of the upper new Calabar River in the Niger Delta area of Nigeria. Scientific African, 3: pp. 19-28. 2004.
37. M. Stoeppler, Cadmium In: Metal and their compounds in the environment: occurrence, analysis and biological relevance. Merian, E (Ed.) VCH, New York: pp. 803-851. 1991.
38. N.F.Y. Tam and Y.S Wong, Spatial and temporal variations of heavy metal contamination in sediments of a mangrove swamp in Hong Kong- marine pollution bulletin, 11. pp. 254-261. 1995.
39. U.S Geological Survey (USGS), Nutrients in the nation's waters: too much of a good thing? Denver, C.O: USGS, USGS Cir. 1136. 1996.
40. Van-note et al. (1980). In: Ayoola, S.O. and Kuton, M. P (2009). "Seasonal variation in Fish abundance and physicochemical parameters of Lagos Lagoon, Nigeria". African Journal. of Environmental Science and Technology 3 (5), pp. 149-156, Available online at http://www.academicjournals.org/AJEST
41. M.M. Varma, S.G. Serdahely and H.M Katz, Physiological effects of trace elements and chemicals in water. J. E.II., 39(2): pp. 90-100. 1976.
42. C.H. Walker, S.P. Hopkin, R.M. Sibly and D.B. Peakau, Principles of ecotoxicology. 2ndEdn. Taylor and Francis Group, Fetter lane, London. 2003.
43. G. Walton, "Survey of literature relating to infant methemoglobinemia due to nitrate-contaminated water". Am. J.PublicHealth.1: pp. 986-996.water pollution, Lagos. Pp. 187-207. Water-WarriRiver International Journal of Environmental studies, 27:pp. 131-142. 1951.
44. M. WaziriandV.O. Ogugbuaja, "Interrelationship between physicochemical water pollution indicators: A Case Study of River Yobe-Nigeria". American Journal of Scientific and Industrial Research 1 (1): pp. 76-80. 2010.
45. P.T.K. Woo; Y.M. Sin and M.K. Wong, Environmental biology of Fishes, 37: Pp.67-74. 1993.
46. R.J. Wooton. Fish Ecology: Tertiary level biology. Blackie New York. p.212. 1992.