International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 3 Issue 4 ǁ April 2014 ǁ PP.35-43

Health Implications of Polluting Warri-River in Delta State, Nigeria

Okoye, Chinedu O. and Iteyere, Pius O.
Department of Environmental Management, Faculty of Environmental Sciences,
NnamdiAzikiwe University, Awka, Anambra State, Nigeria.

ABSTRACT: *This study aims to investigate the health implications of polluting Warri River, Ubeji axis. It was motivated by the findings made by Iteyere (2011) on the physico-chemical properties of the River at Ubeji axis and the observed health issues arising from the people using the water. Four hundred copies of well-structured questionnaire were distributed in a simple random sampling to the residents along Ubeji axis of Warri River. Hospitals, health centers andtraditional homes were visited. Statistical analysis and data transformations were conducted using SPSS (version 15) and Microsoft Excel (version 2007). Differences between means were separated using Post HOC Duncan's New Multiple Range tests. Multiple linear regression (MLR) with correlations was carried out to measure the degree of the relationship observed between the enteric diseases (typhoid fever and dysentery) among the public and BOD, DO properties of the utility Warri River. The limit of significance was 0.05. The study showed that interrelationships exist between the BOD and DO of the river, and enteric diseases suffered by the local residents. Considerable, prevalence of keratoconjuctivitis, kidney and liver dysfunction, gastrointestinal and haematological effects exist in the area.The paper recommends regular aquatic monitoring, polluter pays principle, and tighter regulations on inflow of contaminants. The various governments 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: *Water pollution, WarriRiver, River, Pollution, and Water Diseases.*

I. BACKGROUND TO THE PAPER

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, 1998; Osibanjo, 1996).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, 1991; DWAF, 1996). 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, 1995).

Heavy metals could enter the aquatic environment from both natural and anthropogenic sources. Natural sources include weathering of rocks and soils (Merian, 1991). Anthropogenic inputs are mainly from industrial effluents, domestic effluent, rural and urban storm water runoff and spoil heaps (Agbozu and Ekweozor, 2001). In recent times, industry 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., 1993).

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, 2003). 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, 1993; DWAF, 1996) 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.

II. STATEMENT OF THE PROBLEM

There is a strong evidence of the serious reduction in biodiversity of the Warri River as a result of synergestic effects from pollution of its water. Atuma and Egborge (1986) earlier documented heavy metal concentrations in surface water of WarriRiver. Ezemonye and Egborge (1992) implicated pollution from heavy metals to the drastic reduction of fish diversity of WarriRiver. Agbozu et al. (2007) carried out a survey on bioaccumulation of heavy metals in catfish from TaylorCreek, close to WarriRiver, DeltaState and related the degenerating health of the population on the contaminated fish. A strategy of ecological restoration and management has been proposed to be implemented by the local government.

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.

Iteyere, (2011) determined the physico-chemical characteristics of Warri River at Ubeji axis. It determined the physical and chemical characteristics of Warri River, Ubeji axis in wet and dry seasons; it identified the sources of pollution and compares levels of physico-chemical properties of the river against FEPA standard. His findings showed that there are effects of season and station on some physicochemical properties of the River. Among the sampled heavy metals, station 2 showed high pollution. Turbidity, oil and grease exceeded the FEPA limit only in dry season while DO and iron parameters numerically exceeded in both seasons. Iteyere also identified the pollutant leading to the Warri River traceable to crude oil production and refining with considerable input from the logging industrial activities.

There is no doubt following Iteyere (2011) enormous discoveries that the neighboring communities of Ubeji axis of Warri River will be experiencing some health challenges. See appendix 1.This study therefore sets to investigate the health implications of polluting the Warri River, Ubeji axis in Delta State especially on the people using the water.

III. CONCEPTUAL FRAMEWORK

This study is based on the concept of ecological-level-interaction, which focuses on the interdependencies within the ecosystem. The ecosystem as a basic functioning unit of nature is made up of living organisms and their non-living environment. Both components, not only interact among themselves, but are also linked by a variety of biological, physical and chemical processes. Practical ecology involves measuring factors of effect on the environment (aquatic in this research), distribution, relationship and interdependency between living organisms and these factors. A life cycle assessment is a pollution prevention programme that hinges on the evaluation of the health effects of environmental pollution. Recognizing the fact that our world is finite and that continued pollution of our environment if not detected and controlled early enough may be difficult to rectify in the future in the face of escalated consequences. The overall objective of environmental management is to minimize/or cancel out the adverse health effects caused by deviation from environmental standards. When wastes are not properly managed, the environment is impacted upon negatively. This results in the pollution of the environment. A polluted soil may loose its natural properties like strength, fertility and mineral contents. This may affect its ability to support plants growth and productivity. When this happens, all living organism that depend on the plants for food would be affected. For Example, refineries in Delta and RiversStates have a number of oil spill polluted sites that were not properly restored. These are still looking lifeless without the usual presence of green plants. Fishes die or emigrate from polluted water environment leading to poor yields. Synonymously, when air is polluted, both plants and animals are adversely affected. There are cases of air pollution, where released toxic gases resulted in the death of many plants and animal.Humans as living organisms are part of the environment- interacting with other living organisms and non-living environment within the ecosystem. The physicochemical state of the WarriRiver, Ubeji axis is always compromised through anthropogenic activities such as industrial, agricultural, urban and domestic activities. But due to ecological level interactions, the health of the dependent human population on the river becomes adversely affected. Such effects on public health are evidenced on the incidence and alarmingly, epidemiology of water-borne diseases/ infections. To ensure healthy environment, there is therefore the need to closely monitor the activities of humans before they create imbalance in the ecosystem. It is important to note that there is a high level of interactions and inter-dependencies within the complex functioning ecosystem. Therefore, any distortion through unsustainable practices within the ecosystem would have significant adverse environmental implications on the inhabiting human health.

IV. DESCRIPTION OF THE STUDY AREA

The study area is WarriRiver, 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*., 2006). 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.

V. METHODS

Four hundred (400) copies of well-structured questionnaire were distributed in a simple random fashion to the people of various occupations in the sampling areas. The researcher administered the questionnaires directly to the respondents. Some of the questionnaires were completed and collected *in situ*. The method was adopted to explain confusing points to the respondents. The questionnaire consists of Section A, which was structured to reflect the personal data of the respondents and their utility rate of the WarriRiver. There is also Section B, which portrays the anthropogenic activities and pollution sources to the WarriRiver. Section C (Parts 1 and 2) highlight the incidence of enteric diseases (typhoid fever and dysentery), which are known to be dependent on BOD and DO of water (Part1) while other water quality health related effects were shown in Part 2. Hospital, health centres and traditional healing homes were visited in the course of administering the questionnaire.Statistical analyses and data transformations were conducted using SPSS (version 15) and Microsoft Excel (2007 version). Differences between means were separated using Post Hoc Duncan's New Multiple Range tests. To examine the relationship between the enteric diseases (typhoid fever and dysentery) among the public and BOD, and DO properties of the utility Warri River, multiple linear regression (MLR) was carried out and correlations to measure the degree of the relationships observed. The limit of significance was pinned down to 0.05.

Response Categories to Section C (Part 1) of the Questionnaire

The responses to the questionnaire items on the infections of typhoid fever and dysentery, and skin rashes among the local people using the stressed river of Warri are shown in table 1. The responses recorded high incidence of the diseases investigated in the past twelve months.

Table 1: Incidence of enteric infections and skin rashes among the people in Ubeji for the past 12months

Enteric Disease	Question	Frequency	Percentage
Typhoid fever	Yes	351	87.75
	No	49	12.25
	Total	400	100
Dysentery	Yes	283	70.75
	No	117	29.25
	Total	400	100
Skin Rashes			
Skin rashes	Yes	236	59.0
	No	164	41.0
	Total	400	100

Source: Author's field survey and computations (2011)

Response Categories to Section C (Part 2) of the Questionnaire

Table 2 shows the percentage responses of the observed water quality and heavy metal related health cases among the residents using water from the Warri River by the medical/ hospital personnel interacting with them on medical visits.

Table 2: Percentage (%) Responses on Observed Heavy Metal Related Health Effects

Question	VH	H	M	L	VL	Total
Keratoconjuctivitis (PKC)	11.0	26.0	39.0	19.0	5.0	**100**
Kidney and liver dysfunctions	21.0	32.0	24.0	17.0	6.0	**100**
Gastrointestinal effects such as nauseas, vomiting and abdominal pain/cramp	38.0	33.0	27.0	2.0	0	**100**
Haematological effects such as abnormal decrease in erythrocyte, haemoglobin, and haematocrit levels, and anaemia	**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)

Test of Research Hypothesis

Ho- there is no joint contribution of BOD and DO properties of the WarriRiver water to the incidence of the individual enteric disease (typhoid fever and dysentery) among the people of Ubeji.

The data from tables 3 and 4 (model summaries) indicate that a combination of independent variables; DO (DissolvedOxygen) and BOD (Biological Oxygen Demand) yielded coefficients of multiple regression (R^2) 0f 0.850 and 0.710 accounting for 85.0% and 71.0% of the variances in typhoid fever and dysentery infections, respectively among the people of Ubeji in the last twelve months due to their usage of water from the Warri River.

Table 3: Multiple regression analysis of contribution of independent variables on typhoid fever

Model	R	R Squared	Adjusted R Squared	Std. Error of the Estimate
1	.922[a]	.850	.750	6.94269

a. **Predictors: (Constant), X_2 (DO), X_1 (BOD)**
b. **Dependent Variable: Y (TYPHOID FEVER)**

Source: Author's field Survey and computations (2011)

Table 4: Multiple regression analysis of contribution of independent variables on dysentery

Model	R	R Squared	Adjusted R Squared	Std. Error of the Estimate
1	.843[a]	.710	.517	7.59327

a. **Predictors: (Constant), X_2 (DO), X_1 (BOD)**
b. **Dependent Variable: Y (DYSENTERY)**
Source: Author's field Survey and computations (2011)

Tables 5 and 6 show that the analyses of variance (ANOVA) for the multiple regression data in tables 3 and 4 produced F- ratio values of 8.514 and 3.680 for the typhoid fever and dysentery, respectively, which are not statistically significant at 0.05

Table 5: Analysis of variance for regression analysis on typhoid fever

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	820.730	2	410.365	8.514	.058[a]
	Residual	144.603	3	48.201		
	Total	965.333	5			

a. **Predictors: (Constant), X_2 (DO), X_1 (BOD)**
b. **Dependent Variable: Y (TYPHOID FEVER)**
Source: Author's field Survey and computations (2011)

Table 6: Analysis of variance for regression analysis on dysentery

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	424.360	2	212.180	3.680	.156[a]
	Residual	172.973	3	57.658		
	Total	597.333	5			

a. **Predictors: (Constant), X_2 (DO), X_1 (BOD)**
b. **Dependent Variable: Y (DYSENTERY)**
Source: Author's field Survey and computations (2011)

Measuring the degree of the relationship between the BOD and DO and the enteric diseases, correlation matrix showed strong positive associations (P>0.05) of r= 0.914 and 0.721 for typhoid fever and BOD, and DO, respectively. Furthermore, similar correlation analysis also revealed strong positive associations (P>0.05) of r= 0.801 and 0.745 for dysentery and BOD, and DO, respectively.
Hence, we conclude that there is a strong relationship between the enteric diseases (typhoid fever and dysentery) infections observed among the sampled population and BOD, and DO properties of the utility Warri River.

Interrelationships between Physicochemical Properties and Public Health

Relationship exists between the various physicochemical properties as studied by Iteyere (2011). As this work revealed, there was strong positive correlation (r= 0.693) between the BOD and DO of the Warri River, indicating both to be directly dependent on each other. The validity of the claim was tested with the test data results analyzed in this work and results obtained from similar waterbody (i.e. river) but in different environment (Waziri and Ogugbuaja, 2010) and the relationship were found to be similar. Consequently interactions and relationships between other physicochemical properties have been documented by Rene and Saidutta (2008), Waziri et al. (2009), and Waziri and Ogugbuaja (2010).Significant number of the sampled residents had suffered from the selected enteric diseases (typhoid fever and dysentery) in the last twelve months, which were hoped to have emanated from using water of the ecologically stressed Warri River. The observation was affirmed by the hospital personnel taking care of the visiting patients in the area of study.

Typhoid fever is a life threatening infection characterized by fever, headache, and variable abdominal symptoms (Jawetz et al., 2001). The infection is very common, especially in developing countries, where associated mortality rate is high (Jawetz et al., 2001). Public health prevention through fostering good hygiene and providing sanitary water and food supplies is of utmost importance (Blacklow and Greenberg, 1991). Dysentery is also transmitted by water, food and direct exposure. Caused by Shigella, dysentery can spread widely, since humans are the main recognized host of pathogenic shigellae (Jawetz et al., 2001).The incidence and possibly epidemiology of these enteric diseases all depend on the physicochemical properties of water especially the BOD and DO that account for the activities of the microorganisms causing the diseases. Regression analyses carried out in this work revealed strong relationship between the BOD and DO of WarriRiver and incidence of the enteric infections among the people using the water. Morgan (1997), Nadakavukaren (2000), Wallace (2000) and Jawetz et al. (2001) have made similar observational relationships and documented the interdependencies of enteric infects (i.e. typhoid fever and dysentery) on the BOD and DO of water. On the issue of skin rashes among the people as portrayed in the questionnaire items, greater proportion attested having it, though not severe or life threatening. Zinc detection in the water from the WarriRiver could be resulting to that, which has been similarly reported by Brown et al. (1998).

Based on the health implications of the physicochemical properties of Warri River sourced from the medical personnel, keratoconjuctivitis (PKC) has considerable prevalence in the area. This public health effect has been earlier reported to be high in children randomly selected from Warri, Ekpan, and Aladja, DeltaState. Present public health epidemiological survey agrees with that reported data. The authors equally drew attention to lead toxicosis resulting from rapid urbanization, drilling, production, and refining of crude oil and production of petrochemicals. Other health effects of lead have been reported by Needleman (1993), Yule and Rutter (1985), and Graziano et al. (1991). The detection of cadmium and chromium in the water from the WarriRiver could explain the high prevalence of kidney and liver dysfucntions in the area. There is extensive body of evidence of these metals inducing renal, hepatic, and testicular injuries (Suzuki et al., 1989), tubular and liver dysfunctions (WHO, 1992; Praydot, 1999). Cadmium half-life in bone has been reported and their carcinogenic capacities (i.e. Cd and Cr) by Lemen et al. (1976), Lee and Steinert (2003).

Gastrointestinal effects were revealed to be prevalent among the people sampled. Various factors could result to such effects including bacterial invasions with symptomatic diarrhoea. The Shigelladysenteriae type 1 produces heat-lable exotoxin that affects the gut as well as Salmonella typhi and both produce diarrhoea as clinical manifestation. But the proliferation of these water-borne enteric organisms depend on the physicochemical properties of the inhabiting water especially BOD and DO. Moreover, heavy metals have been implicated to be accelerating the incidence of gastrointestinal effects such as nausea, vomiting, abdominal pain/ cramp(Anonymous, 1983; Samman and Roberts, 1987; Gotteland et al., 2001; Pizarro et al., 1999, 2001). Synonymous effects have been reported in children by Anonymous (1983), Knobeloch et al. (1994), Lewis and Kokan (1998), Gill and Bhagat (1999).

Consequently, excluding other factors, heavy metals detected in the water could be accounted for the prevalence of the haematological effects in the area. These effects were revealed by the laboratory personnel of the hospital surveyed at Ubeji. Nevertheless, zinc has been extensively implicated in various haematological disorders (Broun et al., 1990; Stroud, 1991; Gyorffy and Chan, 1992; Summerfield et al., 1992 and Salzman et al., 2002). Furthermore, other heavy metal effects on haematological parameters have been documented by Walsh et al. (1977).

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 for illegal and unsustainable development that degrade these habitats. Polluter pays principle and penalties be adopted.
d) Detection of subclinical cases and carriers, particularly food and water handlers to forestall further incidence.
e) Antibiotic treatment of infected individuals.

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] Agbozu, I.E and Ekweozor, I.K.E (2001).Heavy metals in a non-tidal freshwater swamp in the Niger Delta areas of Nigeria. African Journal of Science., 2, pp. 175 -182.

[2] Agbozu, I.E and Ekweozor, I.K.E and Opuene, K (2007).Survey of heavy metals in the catfish synodontisclarias. International Journal Environmental Science Technology 4(1): Pp. 93-97.

[3] Atuma, S.O and Egborge, A.B.M (1986). Insecticide and metals in Surface water-WarriRiver International Journal of Environmental studies, 27:Pp. 131-142.

[4] Blacklow, N.R and Greenberg, H.B (1991).Viral gastroenteritis. N. Engl. J. Med 325: 252p.

[5] Brown, E.J; Kohdor, H; Hider, R.C and Rice-Evans (1998). Structural Dependence of Flavonoids Interactions with Copper (11) ions. Oklahoma State University Annual Science Journal, 33: p.78.

[6] Broun ER, Greist A, Tricot G, et al. (1990). Excessive Zinc Ingestion: A Reversible Cause of Sideroblastic Anemia and Bone Marrow Depression. JAMA 264: Pp. 1441-1443.

[7] Dojludo, J.R and Best, G.A.L (1993).Chemistry of water and water pollution.EllisHorwood Limited, Great Britain.

[8] DWAF (1996). South Africa Water quality guidelines, vol. 7: Aquatic ecosystem 1stedn., Department of water Affairs and Forestry.

[9] Emoyan, O.O., Ogban, F.E and Akarah, E (2006).Evaluation of heavy metals wading of River Ijana in Ekpan- Warri, Nigeria.Journal of Applied. Science Environmental Management, 10 (2): Pp. 121-127.

[10] Ezemonye, L.I.N and Egborge, A.B.M (1992).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.

[11] Gill, J.S, Bhagat CI. (1999). Acute Copper Poisoning from Drinking Lime Cordial Prepared and Left Overnight in an old urn.Med J Aust 170(10): 510p.

[12] Gotteland, M., Araya M, Pizarro F, et al. (2001). Effect of Acute Copper Exposure on Gastrointestinal Permeability in Healthy Volunteers.Dig Dis Sci 46(9): Pp. 1909-1914.

[13] Graziano, J.H., Slavkovic, V., factor-Litvak, P., Popovac, D., Ahmedi, X. and Mehmeti, A. (1991).Depressed Serum Erythropoietin in Pregnant Women with Elevated Blood Lead.Arch environ Health, 46: Pp. 347-350.

[14] Gyorffy, E.J, Chan H. (1992). Copper Deficiency and Microcytic Rnemia resulting from Prolonged Ingestion of over-the-Counter Zinc.Am J Gastroenterology 87(8): Pp. 1054-1055.

[15] Iteyere, P.O (2011) Physico-Chemical Characteristics of Warri River, Delta State and the Health Implications. An Unpublished M.Scthesis.Departmentof Environmental Management, NnamdiAzikiwe University- Awka.

[16] Jamu, D.M and Ayinla, A.O (2003).Potential for the development of Agriculture in Africa. NAGA 26 (3): Pp. 9-13.

[17] Knobeloch, L., Ziarnik M, Howard J, et al. (1994). Gastrointestinal Upsets Associated with Ingestion of Copper-Contaminated Water. Environ Health Perspect 102: Pp. 958-961.

[18] Kulshreshtha, S.N (1998). A Global Outlook for Water Resources to the year 2025, Water ResourcesManagement.12(3): 167-184.

[19] Lee, R.F. and Steinert, S (2003).Use of the Single Cell Gel Electrophoresis/Comet Assay for Detecting DNA Damage in Aquatic (Marine and Freshwater) Animals.Mutation Research, 544: Pp. 43-64.

[20] Lemen, G; Avner, A and Yaner, S (1976).Methods for the Examination of Water and Wastewater.American Public Health Journal. 5th ed. U.S.A. Pp. 230-241.

[21] Lewis, M.R, Kokan L. (1998). Zinc Gluconate: Acute Ingestion. J ToxicolClinToxicol 36: Pp. 99-101.

[22] Merian, e. (1991).Metals and their compounds in the Environment.Occurrence Analysis and Biological Relevance. UCH, Weintrein – New York.

[23] Morgan, M. (1997).Environmental Health, 2nd edition. Englewood, CO: Morton Publishing Company.

[24] Nadakavukaren, A. (2000). Our Global Environment, 5th edition. Prospect Heights, IL: Waveland Press.

[25] Needleman H.L (1993). The Current Status of Childhood Low-Level Lead Toxicity.Neurotoxicology, 14: Pp. 161–166.

[26] Osibanjo, O (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 ProtectionAgency, FEPA Monograph.35-59.

[27] Pizarro, F., Olivares M, Araya M, et al. (2001). Gastrointestinal Effects Associated with Soluble and Insoluble Copper in Drinking Water. Environ Health Perspect 109(9): Pp. 949-952.

[28] Pizarro, F., Olivares M, Uauy R, et al. (1999).Acute Gastrointestinal Effects of Graded Levels of Copper in Drinking Water.Environ Health Perspect 107(2): Pp. 117-121.

[29] Praydot, P. (1999). Comprehensive Giude to the Hazard Properties of Chemical Substances, 2nd Edition. John Wiley and Sons Inc., Canada. Pp. 614-624

[30] Rene, E.R. and Saidutta, M.B (2008).Prediction of Water Quality Indices by Regression Analysis and Artificial Neural Networks.Int. Journal of Environmentalresearch.2(2): 183-188.

[31] Salzman, M.B., Smith E.M., Koo C. (2002). Excessive Oral Zinc Supplementation.J PediatrHematolOncol24(7): Pp. 582-584.

[32] Samman, S., Roberts DCK. (1987). The Effect of Zinc Supplements on Plasma Zinc and Copper Levels and the Reported Symptoms in Healthy Volunteers. Med J Australia 146: Pp. 246-249.

[33] Stroud, S. (1991). Too Much Zinc has a Domino Effect. Am J Nurs 91(2): 61p.

[34] Summerfield, A.L., Steinberg FU, Gonzalez JG. (1992). Morphological Findings in Bone Marrow Precursor Cells in Zinc Induced Copper Deficiency Aanemia. Am J ClinPathol 97(5): Pp. 665-668.

[35] Suzuki, Y., Morital, J. and Yamane, Y (1989). Cadmium Stimulates Postglandis in Enzyme Production and Bone Resorption in Cultural Fetal Mouse, Calvarias calvarias. Biochem.Biophys Res. Commum, 158: Pp. 503-518.

[36] Tam, N.F.Y and Wong, Y.S (1995) Spatial and temporal variations of heavy metal contamination in sediments of a mangrove swamp in Hong Kong-Marine pollution Bulletin, 11, Pp. 254-261.

[37] Wallace, R. (2000). Maxcy-Rosenau-Last Public Health and Preventive Medicine.Stamford, CT: Appleton & Lange.
[38] Walsh, F.M., Crosson FJ, Bayley J, et al. (1977). Acute Copper Intoxication. Am J Dis Child 131: Pp. 149-151.
[39] Waziri, M and Ogugbuaja, V.O (2010). 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.
[40] Waziri, M. Ogugbuaja, V.O. and Dimari, G.A (2009). Heavy metal concentrations in Surface and groundwater samples from Gashua and Nguru areas of Yobe State- Nigeria.Int. Jour.of Sci. and Eng.8(1): 58-63.
[41] WHO (World Health Organization) (1992).Environmental Health Criteria, Vol. 134. Cadmium: GenevaSwitzerland World Health Organization.
[42] Yule, W. and Rutter, M. (1985).Lead Effect on Children's Behaviour and Cognitive Performance: A Critical review. In Mahaffey R, ed. Dietary and Environmental Lead: Human Health Service. New York, NY:
[43] Woo, P.T.K; Sin, Y.M and Wong, M.K (1993). Environmental Biology of Fishes, 37: Pp.67-74.

APPENDIX 1

Table 1: Physicochemical properties of WarriRiver 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 (°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: Iteyere (2011), laboratory analysis and computation (2011); NS: Not specified

Table 2: Physicochemical properties of Warri River 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:Iteyere (2011), laboratory analysis and computation (2011); NS: Not specified
Station 1: Ubeji Waterfront (upstream); Station 2: 100m away behind WRPC (midstream); Station 3: Ifiekporo (downstream)