ASSESSMENT OF HEAVY METALS IN NKOHO RIVER RECEIVING PAINT EFFLUENT, ABIA STATE, NIGERIA

*** NWAKANMA, A. & KANU, C.**
Department of Environmental Management and Toxicology
Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.
*Corresponding Author's email: dr.nwakanmac@gmail.com kanuchidozie84@gmail.com;

Abstract
The study aimed to assess the potential impact of industrial effluents from Saclux Paint Industryon the recipient waterquality of Nkoho River in Abia state. Samples were taken at the effluent discharged point, upstream and downstream of the discharge point. *The sample collection points were geo-referenced using Global Positioning system (GPS). Results of heavy metal concentration such as Iron (Fe), Zinc (Zn), Manganese (Mn), Cadmium (Cd), Nickel (Ni), Lead (Pb), Chromium (Cr) and Copper (Cu) at different points in water and in the effluent were estimated using Atomic Absorption Spectrophotometer (AAS). The heavy metal content in the samples varied significantly ($p<0.05$) between the sampling points. Concentrations of the heavy metals fluctuated during the study period but were constantly higher than the permissible limits by Federal Ministry of Environment and World Health Organisation. These few cases of failure among many could be attributed to possible improper treatment of the effluent prior to discharge into the environment. In conclusion, it was observed that the poor quality of the water occasioned by the further deterioration by the entrance of the paint effluents which confer potentials of health hazards to users of the water.*
Keywords: Heavy metal, water quality, industrial effluent, paint industry, Abia State, pollution

Introduction

The availability and quality of water have always played important role in determining quality of life in every living thing. Water quality is also closely linked to water use and to the state of economic development (Chennakrishnan *et al*., 2008). Most of the water bodies in developing and developed countries are the end points of effluents discharged from industries. Water contaminated by effluent from many sources are associated with heavy disease burden (Okoh, 2007) and this could influence the current shorter life expectancy in the developing countries compared with the developed nations (WHO, 2002; 2004). Freshwater has become a scarce commodity due to over exploitation and pollution (Patil and Tijare, 2001). Pollution is caused when a change in the physical, chemical or biological condition in the environment harmfully affect quality of human life including other animals' life and plant (Lowel and Thompson, 1992; Okoye *et al*., 2002).

Agricultural, Industrial, sewage and municipal wastes are being continuously added to water bodies hence affect the biological and physiochemical qualities of water making them unfit for livestock and other organisms (Adigun, 2005).

Water pollution due to discharge of untreated industrial effluents into water bodies is a major problem in the global context (Mathuthu *et al.,* 1997). Effluents such as the outflow from sewage treatment plants or waste water discharged from industrial facilities are generally considered as water pollutants (Womach, 2005).

It is generally recognized that in many developing countries, industrial environmental standards are lacking, and where they do exist, the instruments of control are not efficient. This is largely explained by the absence of reliable and comprehensive system of monitoring of industrial emissions and enforcement of compliance with the industrial standards (Aluyor and Badmus, 2003). Pollution from industrial disposal and effluent discharges have remained serious environmental issues in many countries in Africa (Uzoukwu *et al*., 2004). The ultimate recipient or end point of all forms of pollution is the natural water body (Otaraku and Nkwocha, 2010).

Waste water is water affected in quality from various standard parameters due to anthropogenic influence and less frequently by natural occurrences. Waste water can be rinsed waters, including residual acids, plating metals and toxic chemicals (Husain *et al*., 2014). If the effluents are contaminated with toxic metals, it can compromise human health with acute and chronic diseases (Alam *et al*., 2007; Rahman, *et al*., 2014).

Effluent may contain considerable amounts of potentially harmful substances and heavy metals like Fe, Cu, Zn, Mn, Cd, Cr, Pb etc (Ram *et al*., 2011). Paint industries pollute the environment through effluent discharge, gas emission and waste disposal in the form of organic and inorganic substances. Bhaluro and Adeko (1981) and Lori (1991) recorded that of all the three forms of pollutants discharged by paint industries, effluents are by far the most significant due to its heavy metal compositions. Heavy metals have cumulative effects over time; hence the presence of these heavy metals in the ecosystems has increased as a result of increase in industrialization process. Health problems such as genetic mutation, deformation, cancer, kidney problems etc, have been attributed to pollution by heavy metals (Onuegbu *et al.*, 2007).

Treatment of waste water prior to its discharge into the environment is desirable to avoid pollution. In Nigeria, the Federal Environmental Protection Agency (FEPA) now (FMEnv) has established guidelines and standards for industrial emissions and effluent discharges (FEPA, 1991). Industries are required by law to monitor their effluent to ensure compliance. This study examines the influence and quality of effluent discharges from a paint processing plant of SacluxPaints Nigeria Limited, to investigate if it conforms to statutory standard for industrial effluent discharges by FMEnv as a regulatory agency to ensure sustainable environment.

Study Area

This study was carried out in Nkoho at Ohokobe Afara-ukwu River which is situated in Umuahia North L.G.A of Abia State in the South-Eastern part of Nigeria as shown in figure 1. The area is located in the lowland rainforest zone of Nigeria (Keay, 1999), which lies on Latitude $05^{0}29'$ to $05^{0}42'$ North and Longitude $07^{0}29'$ to $07^{0}33'$ East. The area has an average rainfall of 2,238 mm per year that is distributed over seven months rainy season period (Nzegbule and Ogbonna, 2008). It has bimodal peaks, the first occurring in the month of June or July and the second occurring in the month of September. Its minimum and maximum temperatures are 23^{0}C and 32^{0}C respectively and a relative humidity of 60-80% (Ogbonna and Nzegbule, 2010).

The Nkoho River flows across major villages such as Afara, Ihie and Umudere villages of Afara ukwu Ibeku. The River have been subjected to human activities such as irrigation, recreation, swimming purposes, fishing activities, washing and other domestic uses. Tremendous population increase due to urbanization, industrialization, infrastructural and economic development have resulted to serious water pollution and degradation of the water body and this unabated problems of the fresh water ecosystem exist due to ignorance and inadequate information on the extent of depletion on the available consumable fresh water and diminishing global water resources. The present estimation of consumable water levels is placed at 1% with ground water levels also threatened by pollution (Nwakanma and Oleh, 2013; Watson and Cichra, 2006).

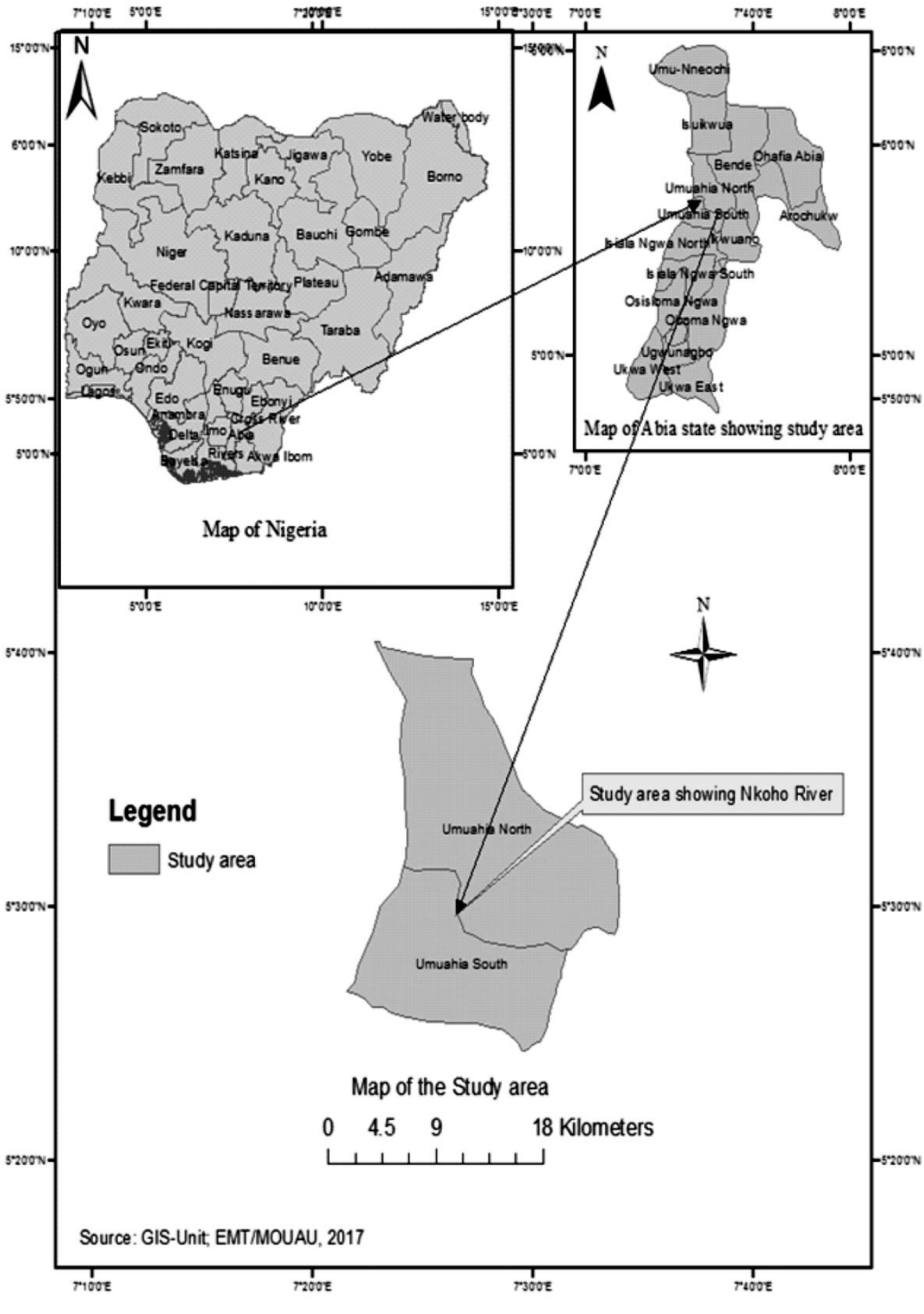

Figure 1: Map of Abia State showing the study location

Materials and Methods

Sampling Techniques

Sampling point was established and geo-referenced using Garmin Global Positioning system (GPS) at the effluent discharged point (N 05^0 29.702′ and E $007^0$29.084′), 100m upstream (N 05^0 29.759′ and E $007^0$29.062′) and 100m downstream (N 05^0 29.639′ and E $007^0$29.094′) of the discharge channel within the study area (Figure 1). Triplicate samples were collected using sterilize bottles with appropriate labels for three months, starting from October-November, 2016.

A Perkin Elmer 3100 atomic absorption spectrophotometer (AAS) was used for the determination of heavy metals including nickel (Ni), lead (Pb), zinc (Zn), iron (Fe), copper (Cu), chromium (Cr), Manganese (Mn) and cadmium (Cd) after digestion. .

Statistical Analysis

The data collected from this study was subjected to one way Analysis of Variance (ANOVA) using Statistical Package for Social Sciences (SPSS). Results obtained were statistically compared with values recommended as international minimum standards by FMEnv (2001) and WHO (2002), for domestic and aquatic uses respectively. Mean values of the water parameters over the stipulated time in the different locations was differentiated using Fisher's Least Significant Difference (F-LSD) at P-value less than 0.05 ($P<0.05$) as statistically significant.

Results

Heavy metal concentration in the effluent varies over the study period. It ranges from 3.72±0.06 to 4.83±0.25mg/l for Fe, 0.65±0.01 to 0.83±0.01mg/l for Zn, 0.11±0.01 to 0.13±0.01mg/l for Mn, 0.03±0.01 to 0.17±0.01mg/l for Cd, 0.10±0.01 to 0.19±0.01mg/l for Ni, 0.33±0.02 to 0.44±0.02mg/l for Pb, 0.23±0.01 to 0.25±0.01mg/l for Cr and 0.25±0.01 to 0.43±0.01mg/l for Cu (Table 2) in the sampling time of September to October. These values were all above the permissible limits of 1.0 mg/l, 0.05 mg/l, 0.05 mg/l, 0.05 mg/l, 0.01mg/l, 0.05mg/l and 0.01 mg/l respectively for FMEnv. This few cases of failure among many could be attributed to possible improper treatment of the effluent prior to discharge into the environment. In addition, the October and November effluents also had many more of the heavy metals above the acceptable limits especially Cadmium, Nickel and Lead.

Heavy metal concentration of the water samples varies significantly between the upstream (control) and the effluent polluted water sampling points (mid and downstream). The values obtained showed significant difference ($P< 0.05$) in the concentrations of the metals in the water at different times. Values of the control water sample were in the range of 0.94 mg/l to 1.35 mg/l (Fe), 0.33 to 0.50 mg/l (Zn). Both metals were higher in the month of October which marked the onset of dry season. The values increased in the effluent polluted water to ranges of 1.19 to 2.18 mg/l (Fe), and 0.53 to 0.71 mg/l (Zn). However, both metals were lower in the downstream than the water sampled from the discharged point of the effluent into the river. Similarly, the value of lead was within the range of 0.12 to 0.17 mg/l, 0.05 to 0.15 mg/l (Cd) and 0.07 to 0.13 mg/l (Cr) respectively in the control water samples. Whereas, in the polluted samples, Fe was within the ranges of 0.25 to 0.27 mg/l, 0.03 to 0.11 mg/l (Cd) and 0.13 to 0.17 mg/l (Cr) respectively (Table 1).

Table 1: Heavy Metal Parameters measured for the River water in mg/l

	September				October				November				FM Env	WHO
	Up-stream	**Mid-stream**	**Down-stream**	**Effluent**	**Up-stream**	**Mid-stream**	**Down-stream**	**Effluent**	**Up-stream**	**Mid-stream**	**Down-stream**	**Effluent**		
Fe^{2+}	1.01±0.06^{a}	1.40±0.03^{c}	1.11±0.17^{b}	3.72±0.06	1.35±0.02^{b}	2.18±0.04^{c}	1.13±0.04^{b}	4.83±0.25	0.94±0.02^{a}	1.19±0.02^{c}	0.99±0.02^{b}	4.06±0.15	1.0	0.1
Zn^{2+}	0.33±0.01^{a}	0.53±0.01^{b}	0.35±0.01^{a}	0.65±0.01	0.50±0.05^{b}	0.66±0.02^{c}	0.41±0.02^{a}	0.75±0.01	0.43±0.02^{b}	0.71±0.06^{c}	0.35±0.02^{a}	0.83±0.01	5.0	5.0
Mn^{2+}	0.03±0.01^{a}	0.11±0.01^{b}	0.05±0.01^{a}	0.13±0.01	0.07±0.01^{a}	0.11±0.01^{a}	0.07±0.01^{a}	0.13±0.01	0.05±0.01^{a}	0.09±0.02^{b}	0.05±0.01^{a}	0.11±0.01	0.05	0.05
Cd^{2+}	0.05±0.00^{a}	0.12±0.01^{b}	0.05±0.00^{a}	0.03±0.01	0.15±0.01^{b}	0.03±0.01^{a}	0.15±0.02^{b}	0.11±0.02	0.05±0.01^{a}	0.11±0.01^{c}	0.07±0.01^{b}	0.17±0.01	0.01	0.01
Ni^{+}	0.04±0.00^{a}	0.09±0.01^{b}	0.05±0.00^{a}	0.10±0.01	0.2±0.03^{b}	0.09±0.01^{a}	0.47±0.01^{a}	0.11±0.00	0.07±0.01^{a}	0.10±0.02^{b}	0.09±0.01^{a} ^{b}	0.19±0.01	0.05	-
Pb^{2+}	0.12±0.02^{a}	0.25±0.01^{c}	0.15±0.01^{b}	0.40±0.03	0.17±0.01^{a}	0.25±0.01^{b}	0.19±0.01^{a}	0.44±0.02	0.15±0.03^{a}	0.27±0.01^{c}	0.21±0.01^{b}	0.33±0.02	0.05	0.01
Cr^{3+}	0.07±0.01^{a}	0.13±0.01^{b}	0.07±0.01^{a}	0.23±0.01	0.13±0.01^{a}	0.17±0.01^{b}	0.15±0.1^{a} ^{b}	0.25±0.03	0.13±0.01^{a}	0.19±0.02^{b}	0.15±0.01^{a}	0.23±0.00	-	0.05
Cu^{2+}	0.11±0.01^{a}	0.14±0.02^{b}	0.09±0.01^{a}	0.43±0.01	0.15±0.01^{a}	0.19±0.01^{b}	0.14±0.2^{a}	0.42±0.03	0.14±0.02^{a}	0.21±0.01^{b}	0.15±0.01^{a}	0.25±0.01	0.1	0.05

Source: Field Result, 2016; FMEnv Guidelines and Standards for Water Quality (FEPA, 1992); EGASPIN (WHO), 2002.
Means with the same alphabet are not significantly different: SD means Standard Deviation

Parameters	September	October	November	FMEnv.	WHO
Fe^{2+}	3.72±0.06	4.83±0.25	4.06±0.15	1.0	0.1
Zn^{2+}	0.65±0.01	0.75±0.01	0.83±0.01	5.0	5.0
Mn^{2+}	0.13±0.01	0.13±0.01	0.11±0.01	0.05	0.05
Cd^{2+}	0.03±0.01	0.11±0.02	0.17±0.01	0.01	0.01
Ni^{+}	0.10±0.01	0.11±0.00	0.19±0.01	0.05	-
Pb^{2+}	0.40±0.03	0.44±0.02	0.33±0.02	0.05	0.01
Cr^{3+}	0.23±0.01	0.25±0.03	0.23±0.00	-	0.05
Cu^{2+}	0.43±0.01	0.42±0.03	0.25±0.01	0.1	0.05

Table 2: Heavy Metal Parameters measured for the Paint Industrial Effluent in mg/l

Source: Field Result, 2016; FMEnv Guidelines and Standards for Water Quality (FEPA, 1992); EGASPIN (WHO), 2002.

Discussion

In the samples studied for heavy metals, iron was found to be at highly elevated levels at most of the sampling points and locations except in upstream and downstream November. Its range of measured concentration values was 1.01 – 4.83 mg/l, suggesting that the water and effluent samples were higher than the WHO and FMEnv tolerable limit of 0.1 mg/l and 1.0 mg/l respectively. The observed high concentration of iron in the water samples correlates with values obtained for the effluent samples and hence was thought to be sourced from wastewater discharged from the paint industry and other sources such as waste dump as suggested by Adeniyi and Okediyi, (2004). These measured high concentrations can potentially affect the taste of water and causes discoloration.

The range of values for zinc concentration in all the sampling points was 0.33 – 0.83 mg/l, lower than the maximum permissible value of 5.0 mg/l.

Furthermore, the range of the measured values of manganese concentration was 0.11 – 0.13mg/l, compared to the WHO permissible level of 0.05 mg/l. The observed manganese concentration at all the sampling points is believed to be sourced from the raw wastewater from the paint industry. The presence of manganese at concentrations greater than 0.05 mg/l tends to support accumulation of microbial growths in the network systems, forming coatings which may slough off as black precipitates. Cadmium has been implicated to be responsible for certain health disorders as it is a known human carcinogen and has been reported to originate from impurities in phosphate fertilizers (Onyenechere *et al.*, 2011). Cadmium is a non-essential element and it is both bioavailable and toxic. It interferes with metabolic processes in plants and can bioaccumulate in aquatic organisms and enters the food chain (Adriano, 2001). Cadmium is highly toxic and accumulates in the body and eventually causes effects such as disturbances in calcium homeostasis and metabolism (Emory *et al.*, 2001).

Conversely, the range of the measured concentration of lead was 0.09 – 0.44 mg/l for the samples compared to the permissible value of 0.01 mg/l. Lead has been reported to be toxic to both man and aquatic life, and has been recognized as pollutant to natural ecosystem even at low concentrations (Van *et al.*, 2007; Dahunsi *et al.*, 2012). Concentrations of lead in all the water samples are thought to be indicative of infiltration of paint additives from the discharged wastewater into the subsurface environment. Several authors (Needleman *et al.*, 1990; Winneke *et al.*, 1982; Smith *et al.*, 1983; Carré, 1997; Dahunsi *et al.*, 2012) have indicated that lead affects the chemistry of human red blood cells, delays normal physical and mental development in babies and young children, causes gastrointestinal disturbances and inflammation of the brain and spinal cord as well as deficits in the hearing and learning of children, and possibly carcinogenic.

Emory *et al.* (2001) reported the high toxicity of lead and its association with the hypochromic anemia with basophilic stifling of red blood cells as well as the bioaccumulation of cadmium in the body and its effects on calcium homeostasis and metabolism.Chromium is seen to be significant in all samples, as it is known to be toxic and carcinogenic and has been associated with damages to the liver and nerves (Aremu *et al.*, 2002).

The average measured concentration of copper in the water samples was higher than WHO and FMEnv maximum allowable value of 0.05mg/l and >0.1mg/l respectively, for all the samples. This collaborate the suggestion that one of the major sources of copper is the industrial paint waste. Injection of copper can cause stomach and intestinal distress, as well as damage to liver and kidney. It can also impart an adverse taste in water and cause significant staining to clothes and fixtures (Reiser *et al.*, 1985).

Although there were fluctuations and variations in the concentrations of the different test heavy metals in the water, the general observation is that the water of Nkoho river did not meet the permissible limits for most of the heavy metals even before pollution with the paint industry effluent into the river as could be seen in (Table1), Fe ranges from 1.01 to 1.35mg/l, Cd 0.05 to 0.15mg/l, Ni 0.07 to 0.20mg/l, Pb 0.12 to 0.17mg/l, Cr 0.07 to 0.13mg/l and Cu 0.11 to 0.15mg/l for upstream water respectively. At the subsequent points, the discharge worsened the already bad status of the water thus making it risky for use in any domestic or recreational purposes

It was generally noted that the heavy metal content of the Nkoho River water samples were above the permissible level for both aquatic life and recreational water criteria (FEPA, 1992). This implies that the river had been polluted prior to the discharge of effluent into it and in agreement with Vilia–Elena (2006), metal wastes from diverse occupational fields (steel making, welding, cutting, glass and ceramic production etc) as well as from surface soils are washed into rivers by flood thus increasing the levels of these metals in the river water. Therefore, there should be great concern for the health of the users of this water for whatsoever purposes as most of these heavy metals are toxic and are associated with health ailments.

Conclusion

From the results of the study, effluent and water samples were above the permissible criteria by different regulatory bodies as it affects its physicochemical quality. The poor quality of the paint industry effluent was seen as an indication of non-treatment or improper treatment of the effluents prior to its discharge into the Nkoho River. Secondly, there were variations in the constituents of the effluents at the different test times (September, October and November) and these variations were attributed to possible differences in the batches of paint produced at the different test time.

The discharge of effluents into the river caused changes in the heavy metal levels of the river water. As was observed , the chemical characteristics of the Nkoho river water before the entrance of the effluent did not meet the acceptable criteria for surface water. However, the entrance of the paint effluents aggravated the already poor water quality of the river. It was also observed that the water quality characteristics, varied with sampling points (Up-stream, Mid-stream and Down-stream) and with sampling time (September, October and November).
It was finally observed that the poor quality of the water occasioned by the further deterioration following the entrance of the paint industry effluents, confer potentials of health hazards to users of the water. This raises strong public health concerns and challenge to appropriate environmental authorities to address without delay.

Recomendations

The results suggest that the effluents being discharged into the Nkoho River have considerable negative effects on the water quality in the recipient water body. The consistent discharge of the untreated or poorly treated effluents increases the load of nutrients and pollutants entering the river and this will continue to increase and further diminish the quality of water.
It is therefore recommended that careless disposal of wastes should be discouraged and there is need for the industry to install a waste treatment plant with a view to treat wastes before being discharged into the river.

There is also need for regulatory agencies like Federal Ministry of environment (FMEnv), Department of Petroleum Resources (DPR), National Environmental Standards and Regulatory Agency (NESRA) and the likes to closely monitor effluents from industries before its discharge.

References

Adeniyi, A. and Okedeyi, O. (2004). Assessing the speciation pattern of lead and zinc in surface water collected from Abegede creek ijora, Lagos. Park. J. Sci. Indus Res. 47: 430 – 441

Adriano, D.C. (2001). Trace elements in terrestrial environments: Biochemistry, bioavailability and risks of metals.

Alam, A. S. M. M., Hossain, K. M., Hossain, B., Ahmed, A. and Hoque, M. J. (2007). A Study on Industrial Waste Effluents and their Management at Selected Food and Beverage Industries of Bangladesh. *J. Appl. Sci. Environ. Manage. 11:5-9.*

Aluyor, E.O. and Badmus, O.A.M. (2003). Time Series Analysis of Pollutant Levels in Industrial Wastewater effluents – A Case Study of a Beverage Industry", *Nigerian Journal of Biomedical Engineering*, 2(1), 19-32.

Aremu, D., Olawuyi, F., Metshitsuka, S. and Sridhar, K. (2002). Heavy metal analysis of groundwater from Warri. Nigeria. Int. J. Environ. Health Res. 12: 61 – 72.

Bhaluro, B.B. and Adeeko, A.B. (1981). "Pollution Survey of Some Textile Mills in Lagos State". In: *Proceedings, Federal Ministry of Water Resources (FMWR) Second National Conference on Water Pollution*. Akinyele, O.I., J.A.I. Omheti, and A.M.D. Imevbore (eds). FMWR Publication. Pp 46–59.

Carré, J.C., 1997. Impact study of paintings lacquers and varnished on the environment and Health in Port-au-Prince. Pan American Health Organization–World Health Organization–Ministry of Environment in Haiti. 50p.

Chennakrishnan, C., Stephren, A., Manju, T. and Raveen, R. (2008). Water Quality status of three vulnerable freshwater Lakes of Suburban Chennai, India. *Ind. J. Environ. Ecoplan.*, 15:591-596

Dahunsi, S.O., Oranusi S.U. and Ishola, R.O. (2012). Bioaccumulation pattern of cadmium and lead in the head capsule and body muscle of Clarias gariepinus exposed to paint emulsion effluent. *Research Journal of Environmental and Earth Sciences.* 4 (2), 166-170

Emory, E., Pattole, R., Archiobold, E., Bayorn, M. and Sung, F. (2001). Neurobehavioral effects of low level exposure in human. Neonates. Am. J. Obstet. Gynecol. 181: 5 – 11.

Federal Environment Protection Agency (FEPA), (1992). Guidelines and standards for environmental pollution control in Nigeria. Federal Government Press, Lagos Nigeria. 238p

FME (Federal Ministry of Environment) (2001). *Guidelines and Standards for Water Quality In Nigerian Publication Federal Ministry of Environment. 114 pp*.

Husain, A., Ashhar M. M. and Javed I. (2014). Analysis of industrial wastewater in Aligarh city. *J. Chem. Pharm. Res.* 6: 614-621.

Keay, R.W.J. (1999). *An outline of Nigeria vegetation* (4^{th} Edition), Government Printer, Lagos, 43 pp.

Lori, J.A. (1991). The Textile Industry and Water Pollution. In: *Book of Abstracts. Second National Environmental Seminar.* FEPA: Kaduna State, Nigeria. 11pp.

Mathuthu, A.S., Mwanga, K. and Simoro, A. (1997). Impact Assessment of Industrial and Sewage Effluents on Water Quality of receiving Marimba River in Harare. In N.A.G Moyo (Eds) Lake Chivero, a polluted lake. University of Zimbabwe Publications, Harare, Zimbabwe.

Needleman, H.L., Schell, A., Bellinger, D., Leviton, A. and Allred, E.N., 1990. The long-term effects of exposure to low doses of lead in childhood, an 11-year follow-up report. New England Journal of Medcine; 322: 88.

Nzegbule, E.C. and Ogbonna, P.C. (2008). Quantity and quality of litter fall in pure pine and pine/Gmelina mixed plantations in

Umuahia, Nigeria. *Global Journal of Agricultural Sciences 1, 93-96*

Ogbonna, P.C. and Nzegbule, E.C. (2010). Quantity and quality of litter fall in pure Gmelina arborea and pure Pinus caribea plantations in Umuahia, Nigeria. 33rd *Annual Conference of Forestry Association of Nigeria, Benin City, Edo state*.

Onyenechere, E. C., Azuwike, D.O. and Enwereuzor A.I. (2011) Effect of Rainfall Variability on Water Supply in Ikeduru L.G.A. of Imo State Nigeria. *International Multidisciplinary Journal, Ethiopia,* 5(5): 223–241.

Otaraku, I.J. and Nkwocha, A.C. (2010). Assessment of the Physicochemical Quality of Petroleum Refinery Wastewater Effluent, *ICASTOR Journal of Engineering*, 3(2), 65-174.

Rahman, M. S., Saha, N. A., Molla, H. and Al-Reza, S. M. (2014). Assessment of Anthropogenic Influence on Heavy Metals Contamination in the Aquatic Ecosystem Components: Water, Sediment, and Fish. Soil. Sed. Contam. *Int. J. 23:353-373.*

Ram, S., Lokhande, Pravin U.S. and Deepali, S.P. (2011). Study on Physico-Chemical Parameters of WasteWater Effluents from Taloja Industrial Area of Mumbai, India. *Int. J. Ecosys. 1:1-9.*

Reiser, S., Smith, J.C., Mertz, W., Holbrook, J.T., Scholfield, D.J., Powell, A.S., C anfield, W.K. and Canary, J.J. (1985). Indices of copper status in humans consuming a typical American diet containing either fructose or starch. American Journal of Clinical Nutrition; 42: 242.

Smith, M., Delves, T., Lansdown, R., C layton, B. and Graham, P. (1983). The effects of lead exposure on urban children: the Institute of Child Health/Southampton study. Dev. Med. Child. Neurol., 25 (Suppl. 47): 1, 83p.

Uzoukwu, B.A., Ngoka, C., and Nnaji, N. (2004). Monthly Variation of the Physicochemical Properties of Effluents from Rimco Industries, Nnewi, Nigeria", *Global Journal of Pure and Applied Sciences,* 10(1), 203-210.

Van-Dyk, J. C., Pieterse, G. M. and Van-Vuren, J. H. J. (2007). Histological changes in liver of *Oreochromis mossambicus* (Cichlidae) after exposure to cadmium and zinc, Ecotoxocol. Environ. Safety. 66, 432-440.

Vilia- Elena, S. (2006). Parkinson's disease and exposure to manganese during welding. Tech D.Welding Allied Process. 2: 106 – 111

Winneke, G., Hrdina, K.G. and Brockhaus, A., 1982. Neuro-psychological studies in children with elevated tooth-lead concentrations. I. Pilot study. Int. Arch. Occup. Environ. Health, 51: 169.

Womach, J. (2005). "Water Supply and Sanitation in the United States". Congressional Research Service Document. CWA Sections 301, 306 and 307.

World health organization (WHO), (2002). Guidelines for drinking water quality, Health criteriaand other supporting information 2ndEdition vol.2.

Watson, C. and Cichra; C. E. (2006) Department of fisheries and Aquatic Sciences florida cooperatives extension services. Institute of food and Agriculture sciences, University of florida. First edition; June 1990, second edition, 2006.

Nwakanma, C. and Oleh, K. F; Comparative Study of the Physiochemical and Microbial Evaluation of Different Brands of Bottled, Sachet, Tap, Well water in Enugu Metropolis. Proceedings of the 2nd Biennial International Conference on Biotechnology and National Development, 2013; 9-13.

Okoh, A. I. (2007). Wastewater treatment plants as a source of microbial pathogens in the receiving watershed. *Afr. J. Biotech;* 6(25): 2932-2944 (13 pages).

Onuegbu, T. U., Ajiwe, V. I. E., Arinze, R.U. and Okoye, L.O. (2007). Analysis of untreated Effluents from Guinness Brewery in Nigeria, *Journal of Applied sciences,* 10(4): 7466-7473.

WHO, (2002). Water and health in Europe: A joint report from the European Environment Agency and the WHO Regional Office for Europe. World Health Organization, WHO

Regional Publications, European Series No. 93.

WHO, (2004). Rolling revision of the WHO guidelines for drinking-water quality, Draft for review and comments. Nitrates and Nitrites in drinking-water, World Health Organization. (WHO/SDE/WSH/04.08/56).

Lowel and Thompson F., Biodiversity of vibrios. Microbiol. Mol. Biol. Rev., 1992; 68: 403-431.

Okoye, P. A. C., Enemuoh, R. E. and Ogunjiofor, J. C. (2002). Traces of heavy metals in Marine crabs. *J. Chem. Soc. Nigeria*, 2002; 27(1): 76-77.

Adigun, B. A. (2005) water quality management in aquaculture and freshwater zooplankton production for use in fish hatcheries. (pp. 12-13). New Bussa, Niger State, Niger.

Patil, D. B. and Tijare, R. V. (Dept Chem, Govt Sci Coll, Gadchiroli 442605), (2001). Investigation of pollution mystery of suspected carcinogen Cr (VI) and its control. *J Indl Polln Contl*; 17(1):43-47