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Impact Assessment of Cement Factory Waste Water on the Heavy Metal Contents of a Typical Low-Latitude Stream in North Central Nigeria

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Abstract
Sediment and water samples from Oinyi River were collected bi-monthly from three sampling stations and analyzed for heavy metals in order to ascertain their distribution in sediment and water of the river, and also to determine the effects of the cement factory waste water on heavy metal concentration of the studied river. Station 1, located upstream of point of discharge of cement factory waste water, served as control point. Station 2 was immediately downstream of the factory's waste water discharge point, and was designated as impact site while station 3 which was selected as the recovery site was downstream of both station 1 and 2. The cement factory waste water impacted negatively on the water chemistry and sediment of the river. Values obtained from river water sample showed that Zinc (0.05-0.054mg/l) and Copper (0.004-0.008mg/l) had their highest values at station 2 while the values of Manganese (114.8–115.8mg/kg), Zinc (6.07–6.26 mg/kg), Copper (3.3–3.39 mg/kg), Nickel (5.2–6 mg/kg), Lead (0.4–0.55 mg/kg), Chromium (0.3–0.45 mg/kg) and Cadmium (0.15–0.24 mg/kg), of river sediment, were also highest at the cement impacted site. However, there was reduction in the amount of Iron (92.4–93.8 mg/kg) in sediment sample of impacted site. These noticeable increases in the heavy metal contents of the waste water impacted site may be attributed to the cement factory effluent, and if not checked or stopped may become a matter of health issue because of the enormous human activities taking place in the site, as recorded in the study.
Keywords: cement factory; waste water; heavy metals; sediment; water quality; Oinyi River.

Introduction

Industrial effluents contain toxic and hazardous materials, and forms the wastes that settle in river water as bottom sentiments (Akaniwor *et al*., 2007. Septic systems, hazardous waste sites and landfills are major targets of pollution because rainfall and ground water leach these highly contaminated substances into rivers and streams (Asonye *et al*., 2007). Water pollution is one of the major problems attributed to industrialization and growth of human population. According to (Olajumoke *et al*., 2010), industrial activities are the major source of pollution in developing countries. Water pollution in Nigeria occurs in both rural and urban areas. In most rural communities, the predominant source of drinking water is rivers and streams which are usually polluted by organic substances from upstream users who may as well use water for some industrial and agricultural related purpose (WHO/UNEP, 1997). Hence, control of water pollution is of primary importance in developed and a number of under developed countries.

Most industries in Nigeria release their untreated effluent directly into rivers or streams, thus, in deviance or variance to the Federal Environmental Protection Agency's standard of the volume of effluent that is to be discharged per day in a given water body.

During cement manufacturing operations, effluent discharge is generated from cooling process equipment and wet scrubbing kiln stack emission for recovering cement kiln dust and as runoff water from the outdoor areas.

Heavy metals are inorganic elements essential for plant growth in traces or very minute quantities. They are toxic and poisonous in relatively higher concentrations. One of the main factor that contribute to the deleterious effects of heavy metals as environmental pollutants is that they cannot be destroyed through biological degradation as in the case of most organic pollutants. Wogu and Okaka (2011) reported that high concentration level of Iron recorded in their study on Warri River may be attributed to the Iron and Steel industry at Aladja which discharges its effluents into the river. While Lawson (2011) reported that for heavy metals such as Fe, Zn, Mn, Cd and Cr the concentration was dangerously higher than the maximum contaminant levels (MCL) recommended for unpolluted or drinking water for Lagos lagoon. Well-known examples of heavy metals include: Iron, Lead and Copper. Others include: Manganese, Cadmium, Chromium, Nickel and Zinc.

Cement factory effluent contain mainly processed water, dissolved solids (Potassium and sodium hydroxide, chlorides and sulphates) suspended solids (Calcium carbonate) and waste heat (EEAA, 2005). Effluent from cement industries are composed of a complex mixture of chemicals, such as Potassium and sodium hydroxide, chlorides, sulphates and Calcium carbonate, varying in composition over time. When mixed with the receiving water, these effluent may trigger a consequential change in heavy metal contents, pH, temperature, color, suspended solid, conductivity and biological oxygen demand (BOD_5) of the receiving water body thus, affecting the normal environment for aquatic biota (Osibanjo and Adie, 2007). Heavy metals are easily introduced into aquatic system as a result of chemical weathering of soil and rocks from volcanic eruptions and from a variety of human activities involving processing or using of metals and substances that contained metals. Heavy metals discharged in aquatic systems may be immobilized within the stream sediments by main processes such as co-precipitation, adsorption and flocculation. Thus, in aquatic environment sediment serves as pool that tends to store or release these heavy metals to the water column by various processes of remobilization (Pekey, 2006).

Water pollution has been a threat for viable freshwater aquatic ecosystems in developing countries. The lack of consistency in screening of water quality, of key rivers that are used for all kinds of industrial and domestic activities and the lack of monitoring river and stream’s health by the use of standardized tools, in Nigeria, also worsen the situation (Arimoro *et al*., 2015). Oinyi River serves for domestic and agricultural purposes, and it is constantly impounded by waste water from a cement factory. With respect to the resurgence of cement industries in Nigeria and tropical Africa, and the potential pollution its effluent has, this study was structured to assess the heavy metal concentration and distribution in sediment and river water and also to determine the effects of the cement factory waste water on heavy metal content of river sediment and water.

Materials and Methods

Description of study area

The cement factory is located at Obajana town in Kogi State, North Central Region of Nigeria. The central location of the factory is at latitude 7.92 (7^0 55’ 0 N) and longitude 6.43 (6^0 25’ 60 E) (Figure 1) (Meme *et al.,* 2014). The estimate terrain elevation above sea level is 140 metres. Oinyi River houses the Obajana mini-dam and characteristically, it is a third order river. The mean annual temperature is of the study area is 29^0C with mean annual relative humidity of 81%. The study area also shows characteristic tropical climate with the two prevailing climatic conditions of distinct seasons that is, the wet (runs from May – October) and dry season (runs from November to April). The origin and source of Oinyi River is Ayedebunu River in Kabba Local Government Area of Kogi State, Nigeria; from where it runs through the rocky plains and tropical rainforest of Canaja, Lokoja and Adankolo where it opens into the conference of River Benue and River Niger.

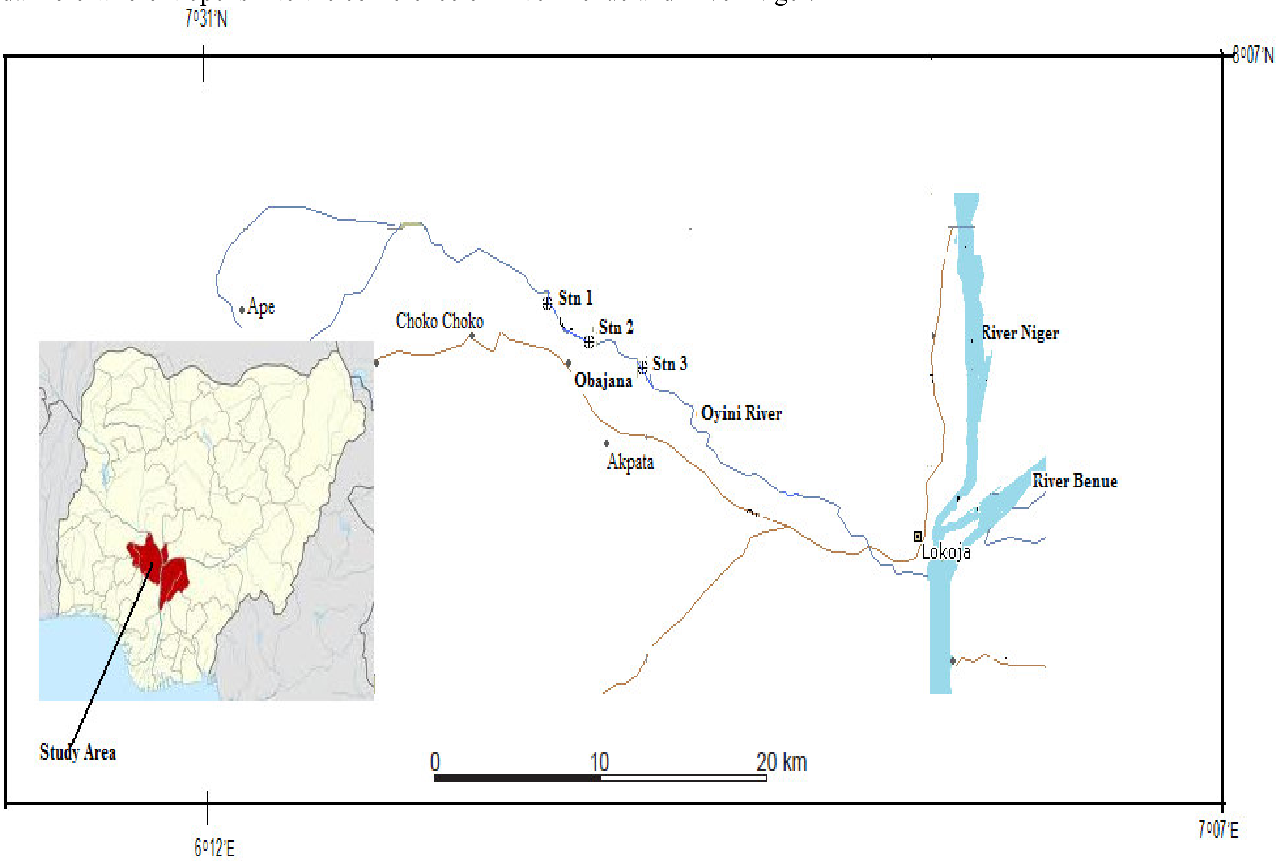

Figure 1: Study area, showing sampling stations in Oinyi River, north central, Nigeria.

Methodology

The long profile of Oinyi River was divided into three different stations and the sampling points were named Station 1, Station 2 and Station 3 throughout the study. These three stations were chosen along the river length of about 3 km apart and each sampling station was 25 m stretch along the stream. Since there are no long-term historical water quality data on the river, the sampling sites were selected carefully to provide the necessary information upon which the effects of the cement effluent could be judged and upon which also conclusion may be drawn. Nigeria really has no formal river health water-quality monitoring program, and therefore, there are no national data on historical water quality trends of the sampled river.

Situated upstream of the cement factory effluent discharge point was Station 1, and it was a centre for domestic activities, including laundry and bathing which could perhaps influence the water quality. Characterized by having a relatively high current flow, a sandy and rocky floor, Station 1 was located toward Obajana mini-dam. At the left flank of this station is the Obajana Cement Factory and water for all industrial activities for the running of the cement plants, processing of raw materials and all other day-to-day activities of the Cement factory are been extracted from this station. Major agricultural activity here is fishing and the flora composition were mainly grasses, herbs and shrubs. Located about 25m downstream of station 1 and about 3 m from the point of discharge of cement factory waste water was station directly positioned around the main bridge that leads to the query sites of the cement factory. Characterized by moderate current flow, sandy floor that has smaller rocks and aquatic rooted macrophytes, this station is surrounded by grasses, herbs and shrubs and the major agricultural activities taking place is fishing. Other human related activities include laundry works and bathing. Station 3 is located downstream of point of discharge of cement factory's effluent. The water current flow is swift which in turn influences the bottom sediment that is characteristically of fine grain. Station 3 is surrounded by trees, shrubs and many aquatic emergent macrophytes. Human and other agricultural activities are usually on the average in this station.

Field Activities

The study was carried between October 2010 and September 2011. The period of the study, which was carried out bi-monthly, corresponds to low water levels and peak flooding in the Oinyi River. Water samples were collected from the different stations of the river using 4 litres plastic kegs and 250 ml reagent bottles. The kegs and bottles were immersed below the water surface and filled to capacity, brought out of the water and then sealed properly. The samples were immediately stored in a dark cooler box on ice and were transported to the laboratory to be analyzed immediately, within twenty-four hours of collection. All analyses were based on standard methods as appropriate to each water quality parameter, prescribed in APHA (1992 and 1998). Sediment samples were wrapped with polythene bags, kept on ice and subsequently transported to the laboratory. Sediment samples were air dried and sieved with a 200µm sieve before sediment analysis.

Analysis of Heavy Metals in the Sediments

Sediment samples were collected using the Van Veen grab sampler. At the laboratory, sediment samples were air dried and then sieved using a 0.5mm sieve to extract fine particles as described by (Herr and Gray 1997a). The fine sediments were packed into sealable nylon bags, labeled and stored. One gram of sediment was weighted into a beaker which was then digested with 10ml of a mixture of nitric (HNO_3) and perchloric acids ($HClO_4$) [in the ratio 2:1]. The beaker was covered with a watch glass and set aside during which the reaction would have subsided. The beaker and contents were heated to not above 160^0C on an Aluminium Tetator digestion block for 2 hours until the volume in the beaker was about 2-5ml. The digest was allowed to cool and then transferred into a volumetric flask and subsequently diluted to a volume of 25ml using distilled water in a volumetric flask. The resultant solution was then analyzed for lead, chromium, copper, cadmium, nickel and manganese with a flame Atomic Absorption Spectrophotometer according to the methods of APHA (1992).

Analysis of Heavy Metals in the water samples

Samples for heavy metals analysis were collected in 120ml plastic container which were initially washed with detergent and rinsed with distilled water. The containers were finally rinsed with 20% Nitric acid before sampling. The samples were preserved by adding 1.5m1 of conc. HNO_3 to each 1 liter of sample and the pH adjusted to 2.0 by the use of pH meter. The samples were stored in a refrigerator at about 4^0C, where necessary, for subsequent analysis. As samples may contain particulate or organic materials, pretreatment in the form of digestion is required before analysis. Nitric acid digestion was employed in accordance with APHA (1992) and Dan'Azumi and Bichi (2010). The digested sample was taken for Atomic Absorption Spectrophotometer (AAS) analysis. The analysis begins with selection and adjustments of various units of the machine (i.e. lamp selection, wavelength selection, slit adjustment and flame adjustment) and the machine was standardized by aspirating distilled water to get zero absorbance. Standard solutions of 1000mg/l for all the metals were prepared and from them working solutions (with concentrations within the range of 0-5mg/l) were prepared by serialdilution (APHA, 1992; Dan'Azumi and Bichi, 2010). The standard solutions were taken through the same digestion technique as mentioned. After digestion, the solutions were taken to AAS and the absorbance value read and recorded. Graphs of absorbance vs. concentration (i.e. the calibration curves) were plotted. The sample was then aspirated into the machine and the absorbance value read and recorded. The concentration (in mg/l) was obtained by interpolating/extrapolating the values of absorbance from the calibration curve. The procedure was repeated for all the samples. The wavelengths set for each metal were: Pb-217.0nm, Cr-357.9nm, Cu-324.7nm, Mn-279.5nm, Fe-248.3nm and Zn-213.9nm. The procedure was repeated for all the samples.

Data Analysis

Calculation of range, mean and standard deviation of individual heavy metal obtained from the three different sampled stations were made. These data were subjected to statistical analysis to ascertain preciseness. Fixed effect ANOVAS were carried out using the data as replicates. Also, significant ANOVAS ($p < 0.05$) were followed by a post hoc (Tukey Honest (HSD)) tests to check for differences between the values of the mean of all three sampled stations, while comparison of these means were done using Tukey Honest Test. Finally, mean values of the heavy metals for the sampled stations were compared with the various permissible limits set by World Health Organization in order to ascertain those elements that attained pollution level or help to know how well the cement factory waste water had impacted the receiving river.

RESULTS

A summary of the mean ± standard errors, minimum and maximum values of heavy metal concentrations in sediment of the three sampled stations of Oinyi River, Kogi State, Nigeria are shown in table 1. The results gotten from this study showed that all analyzed heavy metals were significantly different ($p<0.05$) across the stations and between the months except for Iron (Fe) which showed no significant variation ($p>0.05$) between the months but across the stations ($p<0.05$). In this study, Manganese(115.8mg/kg), Zinc (6.26mg/kg), Copper (3.39mg/kg), Cadmium (0.24mg/kg) and Lead (0.55mg/kg) Chromium (0.45mg/kg) and Nickel (4.8mg/kg) in the sediment of the river had their highest values recorded at station 2, while that of Iron (215.4mg/kg) was at station 3.

Table 1: Concentrations (mean ± standard deviation) of analysed heavy metals in the sediment sample of Oinyi River during the study period (October 2010–September 2011).

	Station 1	Station 2	Station 3
Fe (mg/kg) *	204.77 ± 1.50	93.11 ± 0.21	214.17 ± 0.35
	(200–208.6)	(92.4–93.8)	(213–215.4)
Mn (mg/kg) **	51.37 ± 0.19	115.27 ± 0.16	42.71 ± 0.22
	(50.8–52.02)	(114.8–115.8)	(42.01–43.2)
Zn (mg/kg) **	1.443 ± 0.015	6.16 ± 0.03	1.36 ± 0.02
	(1.4–1.49)	(6.07–6.26)	(1.3–1.42)
Cu (mg/kg) **	1.71 ± 0.01	3.34 ± 0.014	1.84 ± 0.02
	(1.67–1.74)	(3.3–3.39)	(1.8–1.89)
Cr (mg/kg) **	0.31 ± 0.01	0.37 ± 0.02	0.36 ± 0.01
	(0.25–0.35)	(0.3–0.45)	(0.32–0.4)
Cd (mg/kg) **	0.155 ± 0.02	0.19 ± 0.01	0.17 ± 0.02
	(0.1–0.2)	(0.15–0.24)	(0.12–0.23)
Pb (mg/kg) **	0.38 ± 0.02	0.5 ± 0.02	0.33 ± 0.01
	(0.3–0.44)	(0.4–0.55)	(0.29–0.38)
Ni (mg/kg) **	4.74 ± 0.03	5.6 ± 0.13	3.85 ± 0.08
	(4.65–4.8)	(5.2–6)	(3.5–4.03)

Note: the maximum and minimum values are given in parenthesis. Means with * are significantly different across stations or between sampling months while those with ** are significantly different across the stations and between the months.

Also, the mean ± standard error values, including the minimum and maximum values of some heavy metals in water sample of Oinyi River, Kogi State, Nigeria are presented in Table 2. Overall results of water samples showed variations ($p<0.05$) in the distributions of iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), cadmium (Cd) and chromium (Cr). Variations for iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), and chromium (Cr) were significant ($p<0.05$) across the experimental stations and not for the sampling months ($p>0.05$), whereas cadmium (Cd) was significantly different ($p<0.05$) across the stations and between the sampling months, however lead (Pb) and nickel (Ni) were found below detectable levels (0.00).

Table 2: Concentrations (mean ± standard deviation) of analysed heavy metals in the water sample of Oinyi River during the study period (October 2010–September 2011).

	Station 1	Station 2	Station 3
Fe (mg/kg) *	1.485±0.0145 (1.43-1.52)	1.625±0.0133 (1.58-1.67)	4.40±0.008 (4.38-4.43)
Mn (mg/kg) *	0.10±0.003 (0.09-0.11)	0.13±0.005 ((0.12-0.15)	0.14±0.001 (0.14-0.148)
Zn (mg/kg) *	0.04±0.001 (0.035-0.044)	0.05±0.0007 (0.05-0.054)	0.05±0.0007 (0.048-0.052)
Cu (mg/kg) *	0.00	0.0059±0.0005 (0.004-0.008)	0.00
Cr (mg/kg) *	0.004±0.0003 (0.003-0.005)	0.003±0.0003 (0.002-0.004)	0.002±0.0004 (0.001-0.004)
Cd (mg/kg) **	0.033±0.004 (0.02-0.045)	0.02±0.003 (0.01-0.031)	0.02±0.003 (0.01-0.028)
Pb (mg/kg)	0.00	0.00	0.00
Ni (mg/kg)	0.00	0.00	0.00

Note: the maximum and minimum values are given in parenthesis. Means with * are significantly different across stations or between sampling months while those with ** are significantly different across the stations and between the months.

Discussion

Metals are reported to be well concentrated in the sediments (Olomukoro and Azubuike, 2009; Popoola and Otalekor, 2011) and water (Lawson, 2011) of rivers. Heavy metals are important indices of pollution in a particular water body because of their high toxicity to human and aquatic life (Omoigberale and Ogbeibu, 2005; Wogu and Okaka, 2011). When present in trace amount, Heavy metals may play important role in the biochemical processes of aquatic organism, some as enzyme co-factor. However, their sublethal concentrations become lethal to these aquatic organisms when the duration of exposure to these metals is prolonged (Lawson, 2011). Olomukoro and Azubuike (2009) and Wogu and Okaka (2011) have linked the high concentrations of heavy metals in the aquatic ecosystems with effluents from industries, refuse and sewage. Metal enrichment of sediment is reflected by the sedimentation of metal ions when they compete with H^+ absorption sites in the aquatic environment (Oguzie, 2002). All analyzed heavy metals were significantly different ($p<0.05$) across the various sampling stations and between the months except for Iron (Fe) which showed no significant variation ($p>0.05$) between the months but across the stations ($p<0.05$). Iron (215.4mg/kg), Manganese (115.8mg/kg), Zinc (6.26mg/kg), Copper (3.39mg/kg), Cadmium (0.24mg/kg) and Lead (0.55mg/kg) had their highest values recorded at station 3 while that of Chromium (0.45mg/kg) and Nickel (4.8mg/kg) were recorded at station 1. Peak values recorded for heavy metal concentrations of sediment sample, of Oinyi River, at station 3 and station 1 may be due to the lesser effects of sediment inflow throughout the study, thus the reduced values recorded for station 2, which is the effluent receiving site may be due to the influx of fine sediment brought about by the steady erosional flow of industrial waste water from the largest cement factory in West Africa.

The results for analysis of heavy metals of water samples from Oinyi River showed variations ($p<0.05$) in the distributions of iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), cadmium (Cd) and chromium (Cr). Variations for iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), and chromium (Cr) were significant ($p<0.05$) across the stations and not for the sampling months ($p>0.05$), whereas cadmium (Cd) was significantly different ($p<0.05$) across the stations and between the sampling months, however lead (Pb) and nickel (Ni) were found below detectable levels (0.00). High levels of iron in water samples in the present study as detected in all three sampling stations. The level has exceeded both the FEPA and WHO recommended maximum limit of 0.3 mg/l. The high level of iron concentration recorded in the study can be attributed to possible dissolution of iron bearing rock beneath the river-bed in addition to infiltration into the river-bed. It can also be observed that the level of iron increases significantly within the three stations under study and this must have a strong connection with iron discharge from industrial effluents. This result corroborates with the report of Dan'Azumi and

Bichi (2010). This result indicates that Oinyi River is highly contaminated with Fe. The concentration values of Lead (Pb), Nickel (Ni), Chromium (Cr) and Copper (Cu) were below the FEPA standards but for Manganese (Mn), Zinc (Zn) and Cadmium (Cd) were above the FEPA standards.

Zinc is present in large amount in natural water and next to Iron in terms of concentrations in this study. This corroborates with the reports of Lawson (2011). Cement effluent discharge from the industry increased the mean level of zinc in the river from 0.04mg/l upstream (station 1) to 0.0528mg/l at station 2 and the value then dropped to 0.05mg/l downstream (station 3). The relatively high Zn level is suggestive of the influence of industrial waste water or rather it could also be attributed to industrial effluents. The river water did show slight ability of recovery at the downstream station. This trend of river recovery was also reported by Dan'Azumi and Bichi (2010) for Challawa River and Tamburawa old Waterworks, and for this study, it may be due to dilution effects of Oinyi River. Level of Zinc in samples from all stations of study was also on the high side, exceeding the WHO maximum permissible limit. The concentration of Manganese varied from 0.09 to 0.15 mg/l with an overall mean ± standard error value of 0.123±0.003mg/l. Station

2 (0.13±0.005mg/l) had the highest value of 0.15mg/l while station 1 (0.10±0.003mg/l) had the lowest value of 0.09mg/l. The Manganese levels from this study were above the recommended or acceptable level for unpolluted water (0.05mg/l). There was an apparent recovery of the river waters between the stations 2 and 3. This apparent recovery could be the result of a combination of factors. According to Wogu and Okaka (2011), these factors include: storage in bottom sediments; reduced industrial activity; self-purification activities of the river; speciation; adsorption of ions and bioaccumulation. Mean level of copper of the present study increased from 0.00mg/l at station 1 to 0.008mg/ at station 2 and the level dropped to 0.0mg/l at station 3. The sudden rise in the level of copper to 0.008mg/l at station 2 which is the effluent discharge point is within the limit of 1.0 mg/l set by FEPA and WHO. However, the rise in value may be attributed to the effects of cement effluent discharged into the water body from that particular station. River water showed significant recovery pattern in relation to levels of copper from upstream to downstream of sampling station. Also, the mean Cadmium concentrations in this study varied from 0.02±0.003mg/l at station 1 to 0.033±0.004mg/l at station 3 (Table 2). The values were higher than the limit of 0.01mg/l set by FEPA. This is an indication that the water from Oinyi River is contaminated and slightly polluted with Cadmium. Sources of Cadmium in water include weathering of minerals and soils, discharge of domestic effluents and urban storm-water runoff containing Cadmium-laden materials. In this study the concentrations of Chromium were as low as 0.002±0.0004mg/l at station 3 and as high as 0.004±0.0003mg/l at station. These values were lesser than the maximum contaminant level (MCL) of 0.01mg/l recommended by FEPA for unpolluted water. The concentrations of Lead and Nickel in the present study were below the detectable level. The study showed that the concentrations of Lead (Pb) and Nickel (Ni) were very low and could not be detected in water samples from Oinyi River. A probable source of Lead to aquatic environment could be from the used dry-cell batteries and tires from dump sites. However, absence of dry cell battery manufacturing industry from areas of Oinyi River might probably be responsible for the non-detectable level of Lead in water.

Conclusion

Data of environmental variables of Oinyi River (physicochemical parameters including heavy metals) revealed clear distinction between the effluent discharge site (station 2) and those of the upstream and downstream sites (station 1 and station 3). The non-stop and continuous discharges of cement waste water into the river lessened water quality with significant or corresponding effect on the biota of the studied area, thus paving way for clear assertion that the deterioration noticed in the water quality was as a result of the impacts of cement factory waste water.

Recommendation

This study recommends that consistent inquiry in the status of the study area is necessary for sustainability of the study area and that the impact of cement factory waste water on Oinyi River must be checked to avoid further deterioration of water quality, as this study has pointed out, and to allow for full recovery of the already deteriorating system. Furthermore, detailed study with more stations upstream and downstream of the impacted sites is required to fully document changes in water quality and river's biota, and to ascertain the extent and duration of such changes so as to better understand pollution processes in the river. Thus helping to create or improve regulations and policies development. Finally, results from this study also illustrate the need for careful consideration of the water quality in restoration programs.

References

Akaniwor, J.O., Anosike, E.O. and Egwim, O. (2007). Effect of Indomie industrial effluent discharge on microbial properties of new Calabar River *Sci Res Essays* 2 (1):001-005.

American Public Health Association (APHA) (1992) Standard *methods for the examination of water and waste water* 19th edition. Pp472.

American Public Health Association, American Water Works Association and Water Environment Federation (APHA, AWWA and WEF), (1998) *Standard Methods for the Examination of Water and Wastewater*, 20th ed. Washington, D.C. Pp 112-113.

Arimoro, F.O. Odumeb, O.N. and Meme, F.K. (2015) Environmental drivers of head capsule deformities in *Chironomus spp*. (Diptera: Chironomidae) in a stream in north central Nigeria. *Zoology and Ecology* (In press). http://dx.doi.org/10.1080/21658005.2014.1002208

Asonye, C.C., Okolie, N.P., Okenwa, E.E. and Iwuanyanwu, U.G. (2007) Some physicochemical charasteristics and heavy metal profiles of Nigerian rivers, streams and waterways. *Afr. J. Biotechnol*.6(5):617-624.

Dan'Azumi, S. and Bichi, M.H. (2010) Industrial pollution and heavy metals profile of Challawa River in Kano, Nigeria. *Journal of Applied Sciences in Environmental Sanitation,* 5 (1): 23-29.

Egyptian Environmental Affairs Agency (EEAA) (2005) *Environmental impact assessment guidelines for cement manufacturing plants*. Ministry of State for Environmental Affairs, Environmental Management Sector. Arab Republic of Egypt. Pp 54.

Herr, C. and Gray, N.F. (1997a) Sampling riverine sediments impacted by acid mine drainage: problems and solutions. *Environmental Geology* 29:37- 45.

Lawson, E.O. (2011) Physico-Chemical Parameters and Heavy Metal Contents of Water from the Mangrove Swamps of Lagos Lagoon, Lagos, Nigeria. *Advances in Biological Research* 5 (1): 08-21.

Meme, F.K. Arimoro, F.O. and Nwadukwe, F.O. (2014) Analyses of Physical and Chemical Parameters in Surface Waters nearby a Cement Factory in North Central, Nigeria. *Journal of Environmental Protection*, 5, 828-836.http://dx.doi.org/10.4236/jep.2014.510085

Oguzie, F.A. (2002) Variations of the pH and heavy metal concentrations in the lower Ikpoba River in Benin City, Nigeria. *African Journal of Applied Zoology,* 2: 13-16.

Olajumoke, A., Oluwatosin, A., Olumuyiwa, O. and Abimbola, F. (2010) Impact assesment of brewery effluent on water quality in Majawe,Ibadan, Southwestern Nigeria. *Researcher* 2(5):21-28.

Olomukoro, J.O. and Azubuike, C.N. (2009) Heavy Metals and Macroinvertebrate Communities in Bottom Sediment of Ekpan Creek, Warri, Nigeria. *Jordan Journal of Biological Sciences* 2(1):1-8.

Omoigberale, M.O. and Ogbeibu, A.E. (2005) Assessing the environmental impacts of oil exploration and production on the Osse river, Southern Nigeria, I. Heavy metals. *Afri. J. of Environ. Pollution and Health* 4(1), 27-32.

Osibanjo, O. and Adie, G.U. (2007) Impact of effluents from Bodija abattoir on physicochemical parameters of Osunkaye Stream Ibadan City, Nigeria. *Afr.J. Biotechnol*. 6(15):1806-1811.

Pekey, H (2006). The Distribution and Sources of Heavy Metals in Izmit Bay Surface Sediments affected by Polluted Stream. *Marine Pollution Bulletin 52(10):1197-1208*

Popoola, K.O.K. and Otalekor, A. (2011) Analysis of Aquatic Insects' Communities of Awba Reservoir and its Physico-Chemical Properties. *Research Journal of Environmental and Earth Sciences* 3(4): 422-428.

WHO/UNEP (1997) *Water pollution control: Nigeria as a case study*. Retrieved from: www.epa.gov/safewater/contaminants/index.html. (Accessed on: January 19,2012).

Wogu, M.D. and Okaka, C.H. (2011) Pollution studies on Nigerian rivers: heavy metals in surface water of warri river, Delta State. *Journal of Biodiversity and Environmental Sciences* 1(3):7-12.