JEAS

Journal of Engineering and Applied Sciences 10 (2014), 19-29

JOURNAL OF ENGINEERING
AND
APPLIED SCIENCES

Surface water quality degradation in Anambra State, South Eastern Nigeria

B.U. Okoro* and +N.E Nwaiwu**
Department of Civil Engineering, Nnamdi Azikiwe University, Awka, Anambra,
** Email: ugoben@gmail.com (+23408025163719)*
***Email: nknwaiwu@yahoo.co.uk (+23408025528200)*

Abstract

The study was undertaken to assess the water quality in selected rivers and lake in Anambra State, South Eastern Nigeria. A total of six surface water sources selected(including Rivers Niger,Eziche,Omambala,Obibia,Okpuno stream and Agulu Lake) were from five Local Government Areas in the State, viz.: Onitsha South, Anambra East, Anaocha, Awka North and Awka South. All the samples were analyzed for parameters which include temperature, total dissolved solids (TDS), pH and six heavy metals, viz., As, Cd, Cu, Fe, Pb, and Zn using standard procedures. The results were compared with present National and International (World Health Organisation WHO) standard, the Nigerian Standard for Drinking Water Quality NSDWQ (2007). Among the analyzed samples, all samples contained Zinc and Copper within the NSDWQ (2007), although no guideline is set by WHO (2011) for Zinc level in drinking water. Cadmium , Arsenic , Iron and Lead were above the maximum admissible and desirable limits recommended by NSDWQ (2007) and WHO (2011). Microbiological parameters, viz., total coliform, fecal coliform and the total aerobic heterotrophic bacterial count, were all above the maximum admissible and desirable limits recommended by NSDWQ (2007) and WHO (2011) for all the surface water sources selected. This is an indication of pollution hazards in the study areas, which in turn have important human health implications. In general, the results of the present study have shown that the surface water sources need to be treated before consumption. This study, therefore, recommends the government and other responsible authorities to take appropriate corrective measures.

Key words: surface water quality, heavy metals, maximum admissible limit, pollution hazards, water quality standards.

1. Introduction

Potable water should be freely accessed by everyone and in every community, state and country. This is not the case as accessibility of water is usually truncated by either insufficiency or unsuitability. Today 31 countries representing 2.8 billion people, including China, India, Kenya, Ethiopia, Nigeria and Peru confront chronic water problems. Within a generation, the world's population will climb to an estimated 8 billion people yet, the amount of water will remain the same (Bishnoi and Arora, 2007). The challenge is as clear and compelling as pristine water cascading down a mountain stream as new and equitable ways of saving, using and recycling the water must be found (Atalay et al., 2008).

With increasing urbanisation and industrialization, there has been a rapid increase in industrial effluent discharge into the stream water, leading to increased pollution load. In aquatic eco-systems, trace elements may be immobilized within the stream water and may involve complex formation and co-precipitation as oxides and hydroxides of Fe, Mn or may occur in particulate form (Awofolu *et al.*, 2005; Mwiganga and Kansiime, 2005; Srivastava *et al.*, 2008, Sabo et al, 2008).

Industrialization and human activities have partially or totally turned the environment into dumping sites for waste materials. As a result, many water resources have been rendered polluted and hazardous to man and other living systems (Bakare et al, 2003). The toxic substances discharged into water bodies are not only accumulated through the food chain but may also either limit the number of species or produce dense populations of microorganisms (Odiete, 1999).

Industrial development (either new or existing industrial expansion) results in the generation of industrial effluents, and if untreated results in water, sediment and soil pollution (Fakayode, 2005). Also of note is the increasing impact of sand mining operation on surface water bodies. These operations not only change the natural aquatic habitat, but degrade river bed, and channel, causes erosion and impact negatively on the water quality (Lawal, 2011; Phua et al, 2004; Gubbay, 2003).

Aquatic ecosystems are affected by several stresses that significantly weaken biodiversity. River pollution is an environmental problem in the world. They are subjected to various natural processes such as the hydrological cycle occurring in the environment. As a result of unprecedented development, humans are responsible for choking several aquatic ecosystems to death. Storm water runoff and sewage disposal into rivers are two common ways that various nutrients and other pollutants enter the aquatic ecosystems resulting in pollution (Sudhira and Kumar, 2000; Adeyemo, 2003).

+corresponding author

Most of the rivers in the urban areas of the developing countries are the ends of effluents discharged from the industries. African countries and Asian countries are experiencing rapid industrial growth and this is making environmental conservation a difficult task (Agarwal and Manish, 2011). The quality of water depends on various chemical constituents and their concentration, which are mostly derived from the geological data of the particular region. Industrial waste and the municipal solid waste have emerged as two leading causes of pollution of surface and ground water. In many parts of the world available water is rendered non-potable because of the presence of heavy metal in excess. The situation gets worsened during the summer season due to water scarcity and rain water discharge. Contamination of water resources available for household and drinking purposes with heavy elements, metal ions and harmful microorganisms is one of the serious major health problems.

Therefore it is necessary that the quality of drinking water be checked at regular time interval, because due to use of contaminated drinking water, human population suffers from varied forms of water borne diseases. It is difficult to understand the biological phenomenon fully because the chemistry of water reveals much about the metabolism of the ecosystem and explain the general hydro - biological relationship (Basavaraja et al., 2011). Heavy metals normally occurring in nature are not harmful to our environment because they are only present in very small amounts (Sanayei et al., 2009). However, if the levels of these metals are higher than the recommended limits, their roles change to a negative dimension. Human beings can be exposed to heavy metal ions through direct and indirect sources like food, drinking water, exposure to industrial activities and traffic (Ghaedi et al., 2005).

Very few researches have been conducted on heavy metal contamination of surface water in Anambra State. For this reason, due emphasis is given to the analysis of these contaminants. The main goal of this paper is to determine the levels/concentration of some of the heavy metals (As, Cd, Cu, Fe, Pb, and Zn), as well as microbiological contamination of surface water samples from different parts of Anambra State.

2. Description of the study area

Anambra State is drained principally by a number of rivers which include **River Niger,** Anambra River (Omambala and Eziche), Idemili and Mamu, Nkisi, Obibia etc. **Omambala** and **Eziche** rivers in Otuocha meet at a point before inflow to the Niger River. Omambala and Eziche rivers lie between (6º21´N and 6º51´E) and (6º20´N and 6º49´E) respectively.

Awka, the state capital, covers an area of approximately 560square kilometres. Climatologically, records show that the mean annual rainfall of the area is about 1524mm with a relative humidity of 80% at dawn with rainfall concentrating from April to October. Rivers that drain the state capital are Haba, Obizi , **Obibia**, **Okpuno** (6°14´N and 7°03´E),Idemili and Mamu rivers (Muoghalu and Okonkwo, 1998). Obibia river lies between latitude 6º 09´N and 7º 04´E.

Agulu Lake is a large natural inland water lake located in Agulu, Anambra State and serves as a natural boundary between Agulu and parts of Nri. Agulu Lake is the largest lenthic water body in Anambra. Agulu Lake lies within 5°15´ and 5°55´N longitude, 7°15´ and 6°55´E latitude, has an area of about 16,081m^2 and an average depth of about 5.2m. The deepest area which is about 11.2m is permanently stratified. The lake has six arms shaped like a star. The water is clear during the dry season and turbid, with a yellowish-brown colouration, during the rainy season (Anibueze ,1988; Egboka et al, 2006).

There are two main seasons in the state namely the dry season(October – March) and the rainy season (April – September) approximately corresponding to the dry and flood phase, respectively of the hydrological regime. The vegetation is derived guinea savannah (Awachie and Ezenwaji, 1981).

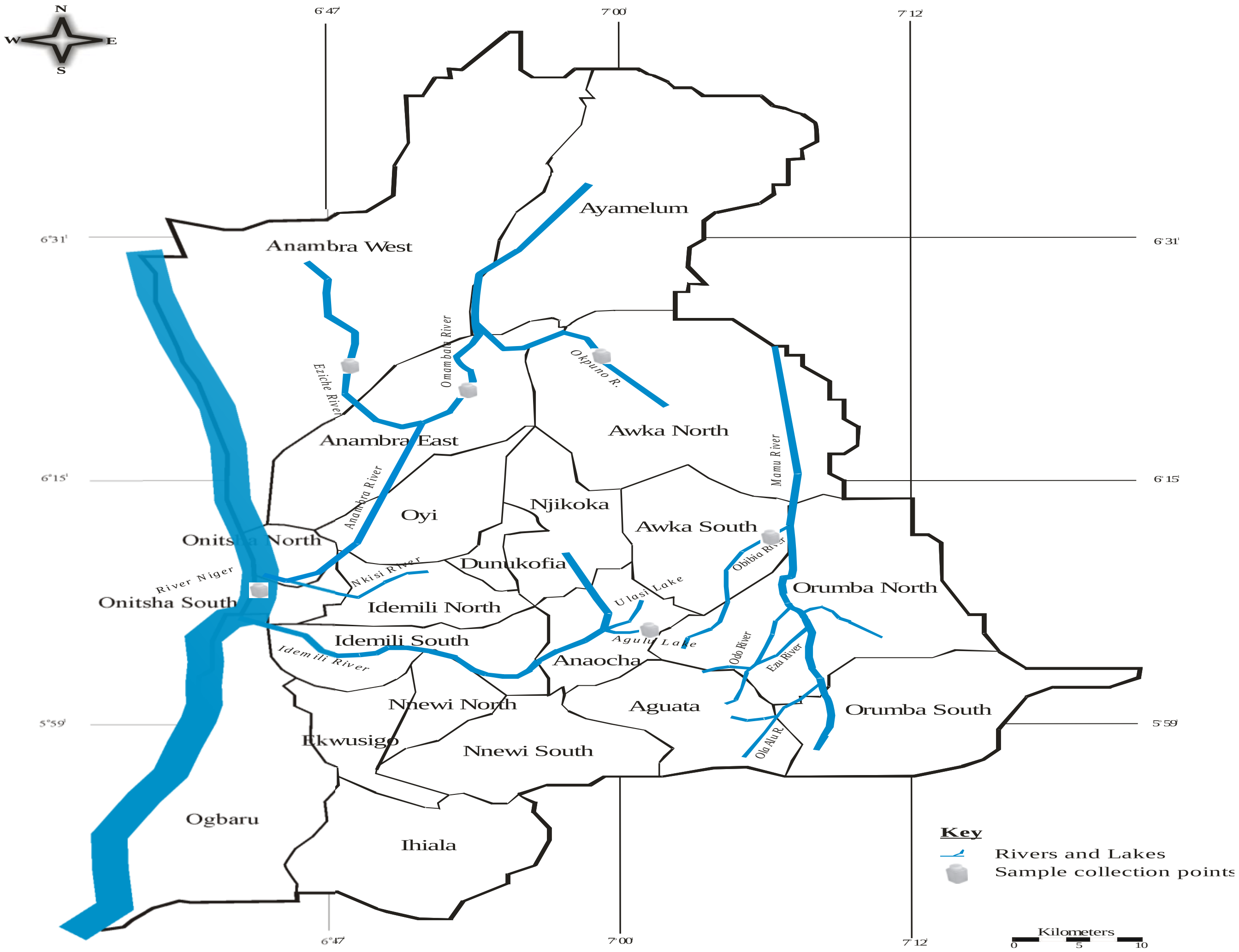

Figure 1: Map showing Anambra State with sampling collection points.

3. Methodology

Water Sample preparation and analysis

A total of six surface water samples were collected from Onitsha, Otuocha, Agulu, Awka South, and Awka North (Fig. 1). The rivers sampled include **Rivers Niger, Omambala**, **Eziche, Obibia**, **Okpuno** and **Agulu Lake.** Sample bottles were washed with non-ionic detergent, rinsed with de-ionized water prior to use, and labeled indicating source. During sampling, 1 litre plastic sample bottles with screw caps were rinsed with sample water three times and then filled to the brim at a depth of 0.4m below the water surface from each of the sampling points. Temperature was measured immediately after collection. All the samples were collected at each of the sample sites mentioned above and transported to Yitzak Rabin Biotechnology Research Centre, Nnamdi Azikiwe University, Awka for physicochemical and heavy metals analysis (within 7 days of sample collection) while the bacteriological analysis were carried out in the Department of Applied Microbiology and Brewing, Nnamdi Azikiwe University Awka (within 48 hours of sample collection).The methodologies followed were according to Reimann et al., 2003 and Tuzen and Soylak, 2006.

Heavy metals investigated include Arsenic(As), Cadmium(Cd), Copper(Cu), Iron(Fe), Lead(Pb) and Zinc (Zn). After preservation at 4 ^{o}C for short period of time samples for heavy metal analysis were digested using nitric acid (65% purity). The heavy metal concentrations were determined using the Atomic Absorption Spectrophotometer (AAS) as described in the American Public Health Association(APHA) Standard Methods (1992).The bacteriological analysis was carried out according to Monica(1993).

The obtained values are to be compared with the existing standards that is, Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organisation (WHO) recommended drinking water standards. Results of water parameters of rivers and lake were analysed for descriptive statistics.

4. Results and discussion

Temperature of the samples was in the range of 29.8 ^{o}C to 33.2 ^{o}C, with minimum value from Obibia River and maximum from Eziche River. Likewise, the pH has a minimum range of 7.10 and maximum of 7.60 (Table 1).

Table 1: Descriptive Statistics of water samples collected showing maximum and minimum values for Temperature (^{o}C), pH and Turbidity(mg/l).

	N	**Range**	**Minimum**	**Maximum**	**Sum**	**Mean**		**Std. Deviation**	**Variance**
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Total Dissolved Solid (mg/L)	6	16.00	12.00	28.00	95.00	15.8333	2.50887	6.14546	37.767
Temperature (^{o}C)	6	3.40	29.80	33.20	186.60	31.1000	.47117	1.15412	1.332
PH	6	.50	7.10	7.60	44.10	7.3500	.07188	.17607	.031
Valid N	6								

These do not give an indication of which element is present but higher value may encourage bacterial growth (Orebiyi et al., 2010). Analysis of the results show that all the samples (100% of the samples) have PH, Temperature and Turbidity values less than the NSDWQ (2007) and also satisfies the WHO (2011) condition, as it must be within reduced limit (Table 2).

TDS has a mean value of 15.83mg/L respectively. Highest TDS value (28mg/L) was recorded in water sample from Okpuno Stream and lowest (12 mg/L) from River Niger and Eziche. According to WHO (2011), there is no health based limit for TDS in drinking water, as TDS occurs in drinking water at concentrations well below toxic effects may occur, but the palatability of water with TDS level of less than 500 mg/L is generally considered to be good (NSDWQ, 2007). Drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 500 mg/L. TDS with a value greater than 1200 mg/L may be objectionable to consumers and could have impacts for those who need to limit their daily salt intake e.g. severely hypertensive, diabetic, and renal dialysis patients (Landon et al., 2005). From Table 1 above, 100% were found to be within limit prescribed by the NSDWQ (2007).

Guidelines for the presence of heavy metals in drinking water have been set by different international organizations like US EPA, WHO, European Union commission (Momodu and Anyakora, 2010). Many national organizations like NSDWQ have also set their own drinking water standards (Table 2). As specified by these organizations, maximum tolerable limits for heavy metals in drinking water exists.

The concentrations of heavy metals: As, Cd, Cu, Fe, Pb, and Zn, and the microbial load in the drinking water samples analyzed are presented in Figures 2-7. Highest heavy metal concentration found for lead was (16mg/L) in water sample from Niger River.

Levels of Iron, Lead and Arsenic were above the admissible limit in all the samples. Copper and Zinc were the only heavy metal that was below the detection limit in all the samples.

Table2. Drinking water contaminants and maximum admissible limit set by NSDWQ (2007) and WHO (2011).

	TDS (mg/L)	**pH**	**Temp. (^{o}C)**	**Heavy metals**						**Microbiological parameters**		
				Zn	Fe	Pb	Cd	As	Cu	TC (cfu/ml)	FC (cfu/100ml)	TAHBC (cfu/100ml)
WHO, 2011 (mg/L)	NG*	NG*	NG*	NG*	NG*	0.01	0.003	0.01	2.00	10	0	0
NSDWQ, 2007 (mg/L)	500	6.5-8.5	NG*	3.0	0.3	0.01	0.003	0.01	1.00	10	0	0

NG* = No Guideline, because it occurs in drinking water at concentrations well below those at which toxic effects may occur.

Table 3 Bacteriological condition of sampled surface water from major rivers in Anambra State, Nigeria.

Samples	Bacteriological parameters		
	TC*	FC**	TAHBC***
Niger River	120	80	231
Eziche	64	46	202
Omambala	32	21	64
Agulu Lake	36	20	201
Obibia river	58	34	186
Okpuno stream	62	49	149
Standard(NSDWQ, 2007; WHO, 2011)	10	0	0

* - Total Coliform
**- Fecal Coliform
***-Total Aerobic Heterotrophic Bacterial Count

Table 4: Description of activities in the study areas

Sample Location	Activity/ Establishment
Niger River	Car washing bay, sand mining, residential, industrial, commercial
Eziche	Crude oil exploration, washing bay, sand mining, residential, industrial, commercial
Omambala	Crude oil exploration, car washing bay, sand mining, residential, commercial
Agulu Lake	Massive construction ongoing, fish factory, sand mining, residential, commercial
Obibia River	Car washing bay, residential, commercial
Okpuno Stream	Car washing bay, residential, commercial

A high level of Copper may lead to chronic anemia (Acharya et al., 2008). In this study, Copper and Zinc are the only metals that were within the maximum permissible level (MPL) in all the sampling areas (Figures 2 and 6) presumably due to the low Copper related industrial and mining activities in the sampling locations. The WHO (2011) maximum admissible limit of copper in drinking water is 2.0mg/L and NSDWQ (2007) is 1.0mg/L. All concentrations obtained from analysis are lower than the values in both standards. Zinc is one of the important trace elements that play a vital role in the physiological and metabolic process of many organisms. Nevertheless, higher concentrations of zinc can be toxic to the organism (Rajkovic et al., 2008; Gabriejidan and Samuel, 2011). It plays an important role in protein synthesis and is a metal which shows fairly low concentration in surface water due to its restricted mobility from the place of rock weathering or from the natural sources (Rajappa et al., 2010). Figure 2, shows a minimum value of 0.96 mg/L and maximum of 1.12 mg/L zinc concentration were recorded in water samples from Obibia and Agulu Lake respectively. Although no guideline is set by WHO (2011), a MPL of 3 mg/L for zinc was defined by NSDWQ (2007), of the samples analyzed 100% complied with the various standards of note.

Iron is the fourth most abundant element by mass in the earth's crust. In water, it occurs mainly in ferrous or ferric state (Ghulman et al., 2008). Iron in surface water is generally present in the ferric state. It is an essential and non-conservative trace element found in significant concentration in drinking water because of its abundance in the earth's crust. Usually, iron occurring in ground water is in the form of ferric hydroxide, in concentration less than 500 µg/L (Oyeku and Eludoyin, 2010). The shortage of iron causes disease called "anemia'' and prolonged consumption of drinking water with high concentration of iron may lead to liver disease called as haermosiderosis (Rajappa et al., 2010; Bhaskar et al., 2010). In this study, detected concentration of Iron was above tandard in all samples, maximum value detected being 6.54mg/L and minimum value 1.15mg/L (Figure 3). These value are above the recommended value of 0.3mg/L.

From Figure 4, Arsenic concentration is found to be a major threat in all rivers and lake, with highest concentration in Niger River (3.10mg/L) and lowest in Okpuno (0.67mg/l) respectively. All samples analyzed, were found to contain arsenic level above the WHO and NSDWQ recommended value of 0.01mg/L.

Lead is the most significant of all the heavy metals because it is toxic, very common (Gregoriaadou et al., 2001) and harmful even in small amounts. Lead enters the human body in many ways. It can be inhaled in dust from lead paints, or waste gases from leaded gasoline. It is found in trace amounts in various foods, notably in fish, which are heavily subjected to industrial pollution. Some old homes may have lead water pipes, which can then contaminate drinking water. Most of the lead we take is removed from our bodies in urine; however, as exposure to lead is cumulative over time, there is still risk of buildup, particularly in children. Studies on lead are numerous because of its hazardous effects. High concentration of lead in the body can cause death or permanent damage to the central nervous system, the brain, and kidneys (Hanaa et al., 2000). In this study, high levels of Pb (>0.01 mg/L) was found in drinking water sampled in all the water samples (Figure 5). None of the samples analyzed contained lead concentration less than the WHO (2011) and the NSDWQ (2007) Maximum Allowable Limit of lead in drinking water (0.01 mg/L).

Table 5: Descriptive Statistics of water samples collected showing range, mean, standard deviation of various heavy metals and bacteriological indicators in the study areas

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Zinc	6	.16	.96	1.12	6.24	1.0400	.02530	.06197	.004
Iron	6	5.39	1.15	6.54	18.07	3.0117	.81014	1.98443	3.938
Lead	6	8.89	7.78	16.67	61.11	10.1850	1.35142	3.31028	10.958
Cadmium	6	7.50	.00	7.50	20.00	3.3333	1.05409	2.58199	6.667
Arsenic	6	2.43	.67	3.10	9.60	1.6000	.34610	.84777	.719
Copper	6	.20	.00	.20	.70	.1167	.03073	.07528	.006
Total Coliform	6	88.00	32.00	120.00	372.00	62.0000	12.85820	31.49603	992.000
Fecal Coliform	6	60.00	20.00	80.00	250.00	41.6667	9.12384	22.34875	499.467
TAHBC	6	167.00	64.00	231.00	1033.00	172.1667	24.22866	59.34784	3522.167
Valid N	6								

Cadmium occurs mostly in association with zinc and gets into water from corrosion of zinc coated ("galvanized") pipes and fittings (danamark.com, 2008). At higher concentrations, it is known to have a toxic potential. The main sources of cadmium are industrial activities; the metal is widely used in electroplating, pigments, plastics, stabilizers and battery industries (Nassef et al., 2006). Cadmium is highly toxic and responsible for several cases of poisoning through food. Small quantities of cadmium cause adverse changes in the arteries of human kidney. It replaces zinc biochemically and causes high blood pressures, kidney damage etc (Rajappa et al., 2010). It interferes with enzymes and causes a painful disease called Itai-itai. Cadmium detected in water of Niger R, Omambala, Agulu, Obibia and Okpuno are above the WHO (2011) recommended value (0.03mg/L). Only River Eziche has a zero Cadmium level.(Figure 7).

Bacteriological results for the six samples are summarised in Table 3. All the results presented above may be due to increased anthropogenic and socio-cultural activities at different sites.(Table 4). Rapid development of town ships and industries in the surrounding vicinity, livestock grazing on nearby lands and or in water bodies as experienced in some sampling points degrades water quality and may also have added strains in the various water bodies to an extent resulting in the degradation of its water quality.Table 5 also shows the range, mean value, standard deviation of the total, fecal and the total aerobic heterotrophic bacterial count (TAHBC) counts of the samples. The TAHBC ranges from 64 cfu/ml to 231 cfu/ml. The total and fecal coliform presence in samples (Table 5), confirms microbial contamination of the rivers under consideration. The above observation indicates that the bacterial contamination varies in sampling points. McLellan et al. (2001) stated that faecal pollution indicator organisms can be used to a number of conditions related to the health of aquatic ecosystems and a potential for predicting health effects among individuals using aquatic environments. The incidence of such indicator organisms may provide indication of water-borne problems and is a direct risk to human and animal health (Belsky and Matzke, 1999; Brunson and Steel, 1996; Derlet and Carlson, 2006; Taylor et al 1989; Field and Samadpour, 2007).

5. Conclusion

The removal of metals from polluted water can be achieved by ion exchange, chemical oxidation, chemical precipitation etc (Aksu et al., 1992). For advanced purification, different physicochemical methods such as active carbon adsorption, ion exchange and reverse osmosis are used (Saha et al, 2010; Jafa and Balasubramanian, 2010; Tangjuank et al, 2009; Phuengprasop et al, 2011; Zhou and

Haynes, 2011). Recently, the method of the removal of heavy metal contaminants by means of bacteria has been focused on. Biological removal of heavy metal contaminants from aquatic effluents offers great potential when metals are present in trace amounts (Fourest and Roux, 1992; Vinita and Radhanath, 1992). Numerous low cost natural materials have been proposed as potential biosorbents. These include moss peat, algae, leaf mould, sea weeds, coconut husk, sago waste, peanut hull, hazelnut, bagasse, rice hull, sugar beet pulp, plants biomass and bituminous coal. (Dakiky et al., 2002; Johnson et al., 2002; Reddad et al., 2002; Babel and Kurniawan, 2003; Pagnanelli et al., 2003; Sekhar et al., 2003; Flora et al 2008; Suleman et al, 2007).

Phytoremediation is an emerging technology that uses various plants to degrade, extract, contain, or immobilize contaminants from soil and water. Its various processes includes phytoextraction, phytostabilization, rhizofiltration, phytovolatization, phytodegradation, phytostimulation, (Chaney et al, 2000; Jeanna, 2000; NRMRLORD, 2000; Divya et al, 2012; Duruibe et al, 2007).

Many microbial species such as bacteria, fungi, yeast and algae are known to be capable of adsorbing heavy metals on their surface and/or accumulating within their structure (Campbell and Martin, 1990; Luef, 1991; Mitani and Misic, 1991; Vinita and Radhanath, 1992). It is possible that microorganisms can be used in the removal of toxic metal ions from the water and even in the recovery of them by using these adsorption properties of the microorganisms. Physical adsorption or ion exchange at the living or non-living cell surface is very rapid and occur in a short time after microorganisms come into contact with heavy metal ions. Accumulation which occurs in living cells is slow and related to metabolic activity (Nourbakhsh at al., 2002).

This study, therefore, recommends that all authorities involved in provision and regulation of water quality to: (1) Explore and utilize most suitable drinking water treatment techniques to reduce the current levels of heavy metals, (2) Prevent any kind of waste disposal, farming or grazing activities near rivers, canals or any reservoirs that supply domestic drinking water (3) Regulate the various industrial activities in rivers such as sand mining, crude exploration amongst others which directly impact on the quality of surface water and (4) support further study to be conducted on other physical, chemical and biological parameters of significant health concern and on identification of potential sources of the contaminants.

References

Acharya, G.D., Hathi, M.V., Patel, A.D & Parmar, K.C., 2008. Chemical properties of groundwater in Bailoda Taluka region, north Gujarat, India, viewed 06 April, 2014, <http://www.e-journals.in/PDF/V5N4/792-796.pdf>.

Adeyemo OK., 2003. Consequences of pollution and degradation of Nigerian aquatic environment on fisheries resources. The Environmentalist, 23(4), 297-306.

Agarwal, Animesh and Manish, Saxena., 2011. Assessment of pollution by Physicochemical Water Parameters Using Regression Analysis: A Case Study of Gagan River at Moradabad- India, Advances in Applied Science Research, 2(2), 185 -189.

Aksu, Zümriye; Sağ Yeşim and Kutsal Tülin., 1992. The biosorption of Copper (II) by C. vulgaris and Z. ramigera. Environmental Technology. 13, 579-586.

Anibueze CI., 1988. Studies on the Ecology of Agulu Lake (Formerly Njikoka now Anaocha Local Government Area), Anambra State. MSc Thesis, University of Nigeria, Nsukka.

APHA., 1992. American Public Health Association. Standard methods for the examination of water and wastewater. 18th Ed. Washington, D.C.

Atalay, A., Pao, S., James, M., Whitehead, B & Allen, A., 2008. Drinking water assessment at underserved farms in Virginia's coastal plain. *Journal of Environmental Monitoring and Restoration*, 4, 53-64.

Awachie, J. B. E. and Ezenwaji, H. M. G., 1981. The fisheries development of the Anambra River Basin, Nigeria. CIFA Technical Paper, 8, 212 – 224.

Awofolu, O. R.; Mbolekwa, Z.; Mtshemla, V.; Fatoki, O. S., 2005. Levels of heavy metals in water and sediments from Tyume River and its effects on an irrigated farmland. Water SA. 31 (1), 87-94

Babel, Sandhya and Kurniawan, Tonni Agustiono., 2003. Low-cost adsorbents for heavy metals uptake from contaminated water: a review. *Journal of Hazardous Materials*. 97(1-3), 219-243.

Bakare AA, Lateef A, Amuda OS, Afolabi RO., 2003. The Aquatic toxicity and characterization of chemical and microbiological constituents of water samples from Oba River, Odo-oba, Nigeria. Asian Journal of Microbiology, Biotechnology and Environmental Sciences, 5, 11–17.

Basavaraja, Simpi, S. M., Hiremath, K. N. S. Murthy, K. N. Chandrashekarappa, Anil N. Patel, E.T.Puttiah., 2011. Analysis of Water Quality Using Physico-Chemical Parameters Hosahalli Tank in Shimoga District, Karnataka, India, Global Journal of Science Frontier, Research, 1(3), 31-34.

Belsky AJ, Matzke A, Uselman S., 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. J Soil Water Conserv. 54, 419–431.

Bhaskar, C.V., Kumar, K & Nagendrappa, G., 2010. Assessment of heavy metals in water samples of certain locations situated around Tumkur, Karnataka, India', viewed 6 April, 2014, <http://www.indiaenvironmentportal.org.in/.../Assessment%20of%20heavy%20metals%20in%20water%20samples.pdf>.

Bishnoi, M & Arora, S., 2007. Potable ground water quality in some villages of Haryana, India: focus on fluoride. *Journal of Environmental Biology*, 28(2), 291-294.

Brunson MW, Steel BS., 1996. Sources of variation in attitudes and beliefs about federal rangeland management. J Range Manage. 49, 69–75.

Campbell, R. and Martin, M. H., 1990. Continuous flow fermentation to purify wastewater by the removal cadmium. Water, Air and Soil Pollution. 50, 397-408.

Chaney, R.L., Malik, M., Li, Y.M., Brown, S., Brewer, E.P., Angle, J. S., Baker, A. J.M., 1997. Phytoremediation of Soil Metals. Available [Online] http://www.soils.wisc.edu/~barak/temp/opin_fin.htm [6 June, 2000].

Chong, K.H. and Volesky, B., 2000. Metal biosorption equilibria in a ternary system. *Biotechnology and Bioengineering*. 49(6), 629-638.

Dakiky, M.; Khamis, M.; Manassra, A. and Mer'eb, M., 2002. Selective adsorption of Cr(VI) in industrial wastewater using low-cost abundantly available adsorbents. *Advances in Environmental Research*. 6(4), 533-540.

Danamark.com., 2008. Heavy metals in drinking water, viewed April 7, 2014, <http://www.danamark.com/Heavymetalsindrinking water/pdf>.

Derlet RW, Carlson JR., 2006. Coliform bacteria in Sierra Nevada wilderness lakes and streams: What is the impact of backpackers, pack animals, and cattle? J Wilderness Med. 17, 15–20.

Divya Singh, ArchanaTiwari and Richa Gupta., 2012. Phytoremediation of lead from wastewater using aquatic plants" School of Biotechnology, Journal of Agricultural Technology. 8(1), 1-11.

Duruibe, J. O, Ogwuegbu, M. O. and Egwurugwu, J. N., 2007. Heavy metal pollution and human biotoxic effects" International Journal of Physical Sciences. 2 (5), 112-118

Egboka B.C.E, Nfor B.N and Banlanjo E.W., 2006. Water Budget Analysis of Agulu Lake in Anambra State, Nigeria in Journal of Applied Sciences and Environmental Management. World Bank assisted National Agricultural Research Project (NARP) – University of Port Harcourt. ISSN: 1119-8362, 10 (3), 27-30

Fakayode SO., 2005. Impact Assessment of Industrial Effluent on Water Quality of the Receiving Alaro River in Ibadan, Nigeria. AJEAM-RAGEE, 10:1-13.

Field KG, Samadpour M., 2007. Fecal source tracking, the indicator paradigm, and managing water quality. Water Res 41, 3517–3538.

Fourest, E. and Roux, J. C., 1992. Heavy metal biosorption by fungal mycelial by-products: mechanism and influence of pH. Applied Microbiology and Biotechnology. 37, 399-403

Gebrekidan, M and Samuel, Z., 2011. Concentration of Heavy Metals in Drinking Water from Urban Areas of the Tigray Region, Northern Ethiopia. MEJS, Volume 3 (1), 105-121

Ghaedi, M., Fathi, M.R., Marahel, F & Ahmadi, F., 2005. Simultaneous preconcentration and determination of copper, nickel, cobalt and lead ions content by fame atomic absorption spectrometry. *Fresen. Environ. Bull.*,14, 1158-1165.

Ghulman, B.A., EL-Bisy, M.S & Ali, H., 2008. Ground water assessement of makkah al-mokarama. Proceedings of the 12th International Water Technology Conference, Umm Al-Qura University, Makkah, 1515-1527.

Gregoriadou, A., Delidou, K., Dermosonoglou, D., Tsoumparis, P., Edipidi, C & Katsougiannopoulos, B., 2001. Heavy metals in drinking water in Thessaloniki area, Greece. Proceedings of the 7th International Conference on Environmental Science and technology, Aristotle University, Ermoupolis.

Gubbay, S., 2003. Marine, aggregate extraction and biodiversity Wildlife Trusts, WWF-UK, UK.

Gupta, V.K.; Mohan, D. and Sharma, S., 1998. Removal of lead from wastewater using bagasse fly ash-a sugar industry waste material. *Separation Science and Technology*. 33, 1331-1343.

Hanaa, M., Eweida, A & Farag, A., 2000. Heavy metals in drinking water and their environmental impact on human health. International Conference on Environmental Hazards Mitigation, Cairo University, Egypt, 542-556.

Jafa A A, Balasubramanian S., 2010. Adsorption of Pb(II) ions on teak leaves activated carbon- a kinetic and equilibrium study", Der Chemica Sinica, 1 (2), 35-43. www.pelagiaresearchlibrary.com

Jeanna R. Henry., 2000. An Overview of the Phytoremediation of Lead and Mercury. National Network of Environmental Management Studies (NNEMS). 5, 10.

Johnson, P.D.; Watson, M.A.; Brown, J. and Jefcoat, I.A., 2002. Peanut hull pellets as a single use sorbent for the capture of Cu(II) from wastewater. *Waste Management*. 22(5), 471-480.

Landon,N., piegay H. and Bravard J.P.(1998) The Drome river incision(France):from assessment to management .Landscape and Urban Planning,43:119-131.

Lawal, P. O., 2011. Effects of sand/gravel mining in Minna Emirate Area of Nigeria on Stakeholders. *Journal of Sustainable Development,* 4(1), 193-200.

Luef, E.; Prey, T. and Kubicek, C. P., 1991. Biosorption of zinc by fungal mycelial wastes. Applied Microbiology and Biotechnology. 34, 688-692.

McLellan, S.L., Daniels, A.D., Salmore, A.K., 2001. Clonal populations of thermotolerant enterobacteriaceaes in recreational water and their potential interference with foecal Escherichia coli counts. Appl. Evniron. Microbiol. 67, 4934–4938.

Momodu, M.A & Anyakpra, C.A., 2010. Heavy metal contamination of ground water: the surulere study. *Research Journal of Environmental and Earth Science,* 2(1), 39-43.

Monica, C., 1993. Medical Laboratory Manual for Tropical Countries, Microbiology ELBS, University Press Combridge, 2ed.

Muoghalu LN, Okonkwo AU., 1998. "Effects of Urban Flooding in Awka, Capital of Anambra State, Nigeria". Environ. Rev. 2(22).

Mwiganga, M.; Kansiime F., 2005. Impact of Mpererwe landfill in Kampala Uganda, on the surrounding environment. Phys. Chem. Earth., 38 (11-16), 91-95

Nassef, M., Hannigan, R., EL Sayed, K.A & Tahawy, M.S.El., 2006. Determination of some heavy metals in the environment of Sadat industrial city. Proceeding of the 2nd Environmental Physics Conference, Cairo University, Egypt, 145-152.

National Risk Management Research Laboratory Office of Research and Development (NRMRLORD)., 2000. Introduction to Phytoremediation. U.S. Environmental Protection Agency Cincinnati, Ohio 45268 EPA/600/R-99/107 1(2), 14-19.

Nourbakhsh, Nurbaş Macit; Kiliçarslan, Serpil; Ilhan, Semra and Ozdağ, Hüseyin., 2002. Biosorption of Cr^{6+}, Pb^{2+} and Cu^{2+} ions in industrial waste water on Bacillus sp. Chemical Engineering Journal. 85, 351-355.

NSDWQ., 2007. Nigerian standard for drinking water quality. Standard Organization of Nigeria. Wuse, Abuja.

Odiete WO., 1999. Environmental physiology of animals and pollution, 261. Diversified Resources Ltd, Lagos

Orebiyi, E.O., Awomeso, J.A., Idowu, O.A., Martins, O., Oguntoke & Taiwo, A.M., 2010. Assessment of pollution hazards of shallow well water in Abeokuta and environs, southwest, Nigeria. *American Journal of Environmental Science,* 6(1), 50-56.

Oyeku, O.T & Eludoyin, A.O., 2010. Heavy metal contamination of ground water resources in a Nigerian urban settlement. *African Journal of Environmental Science and Technology,* 4(4), 201-214.

Pagnanelli, Francesca; Mainelli, Sara; Veglio, Francesco and Toro, Luigi., 2003. Heavy metal removal by olive pomace: biosorbent characterization and equilibrium modeling. *Chemical Engineering Science*. 58(20), 4709-4717.

Phua, C., Akker, S. v. d., Baretta, M. & Dalfsen, J. v., 2004. Ecological effects of sand extraction in the North Sea. [Online] Available [Accessed 3/2/2010].

Phuengprasop T, Sittiwong J, Unob F., 2011. Removal of heavy metal ions by iron coated sewage sludge", Journal of Hazardous Materials. 186, 502-507.

Rajappa, B., Manjappa, S & Puttaiah, E.T., 2010. Monitoring of heavy metal concentration in groundwater of Hakinaka Taluk, India. *Contemporary Engineering Sciences*, 3(4), 183-190.

Rajkovic, M.B., Lacnjevac, C.M., Ralevic, N.R., Stojanovic, M.D., Toskovic, D.V., Pantelic, G.K., Ristic, N.M & Jovanic, S., 2008. Identification of metals (heavy and radioactive) in drinking water by indirect analysis method based on scale tests. *Sensors*, 8, 2188-2207.

Reddad, Zacaria; Gerente, Claire; Andres, Yves and Le Cloirec, Pierre., 2002. Adsorption of several metal ions onto a low-cost biosorbent: Kinetic and equilibrium studies. *Environmental Science and Technology*. 36(9), 2067-2073.

Reimann, C, Bjorvatn, K., Frengstad, B., Melaku, Z., Teklehaimanot, R & Siewers, U., 2003. Drinking water quality in the Ethiopian section of the east African rift valley I – data and health aspects. *The Science of Total Environment*, 311, 65-80.

Flora S.J.S., Megha Mittal & Ashish Mehta., 2008. Heavy metal induced oxidative stress & it's possible reversal by chelation therapy. Division of Pharmacology & Toxicology, Defence Research & Development Establishment, Gwalior, India, Indian J Med Res. 128(10), 501-502.

Sabo, A., Nayaya, A. J. and Galadima, A. I. 2008. Assessment of Some Heavy metals in Water, Sediment and Freshwater mudfish (*Clarias gariepinus*) from River Gongola in Yamaltu-Deba, Gombe State, Nigeria. *International Journal of Pure and Applied Science*, 2 (4), 6-12

Saha P, Datta S, Sanya S K., 2010. Application of Natural Clayey Soil as adsorbent for the Removal of Copper from Wastewater", Journal of Environmental Engineering © asce / December, 1409-1417

Sanayei, Y., Ismail, N & Talebi, S.M. 2009. Determination of heavy metals in Zayandeh rood, Isfahan-Iran. *World Applied Sciences Journal*, 6(9), 1209-1214.

Sekhar, K.C.; Kamala, C.T.; Chary, N.S. and Anjaneyulu, Y., 2003. Removal of heavy metals using a plant biomass with reference to environmental control. *International Journal of Mineral Processing*. 68(1-4), 37-45.

Srivastava, A.; Gupta, S.; Jain, V. K., 2008. Source apportionment of suspended particulate matter in coarse and fine size ranges over Delhi. Aerosol Air Qual. Res., 8 (2), 188 – 200

Sudhira HS, Kumar VS., 2000. Monitoring of lake water quality in Mysore City. In: International Symposium on Restoration of Lakes and Wetlands: Proceedings of Lake

Suleman, W.; Anwar, RS.; Muhammed, MA., 2007. Heacy Metal Uptake by Agro based Waste Materials. Electronic Journal of Biotechnology. 10(3).

Tangjuank S, Insuk N, Tontrakoon J, udeye V., 2009. Adsorption of Lead(II) and cadmium (II) ions from aqueous solutions by adsorption on activated carbon prepared from cashew nut shells", world Academy of Science, Engineering and Technology. 52, 110-116

Taylor FR, Gillman LA, Pedretti JW., 1989. Impact of cattle on 2 isolated fish populations in Pahranagat Valley, Nevada. Great Basin Nat 49, 491–495.

Tuzen, M & Soylak, M., 2006. Evaluation of metal levels of drinking waters from the Tokat-black sea region of Turkey. *Polish Journal of Environmental Study*, 15(6), 915-919.

Vinita, V. P. and Radhanath, P. D., 1992. Biorecovery of zinc from industrial effluent using native microflora. Intern. J. Enviromental Studies. 44, 251-257.

Vinita, V. P. and Radhanath, P. D., 1992. Biorecovery of zinc from industrial effluent using native microflora. Intern. J. Enviromental Studies. 44, 251-257.

WHO., 2011. Guidelines for drinking-water quality. World Health Organization Geneva Vol.1: 4 ed. ISBN 978924 1548151

Zhou Y F, Haynes R J., 2011. Removal of Pb(II), Cr(III) and Cr(VI) from Aqueous Solutions Using Alum-Derived Water Treatment Sludge”, Journal of Water Air Soil Pollution. 215, 631–643

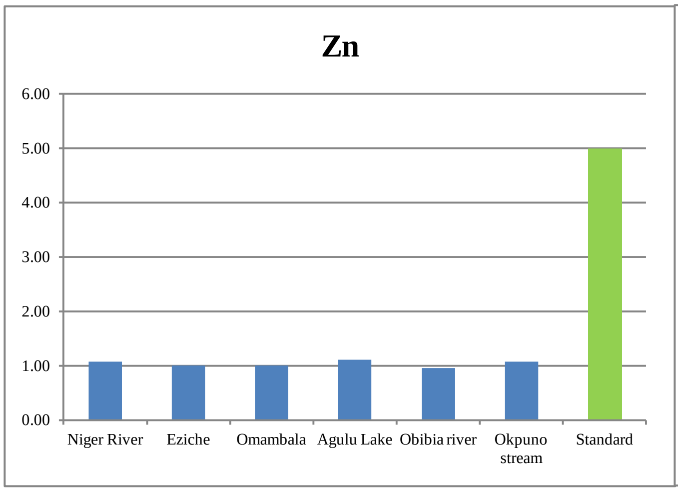

Figure 1: Zinc concentration at various sampling points

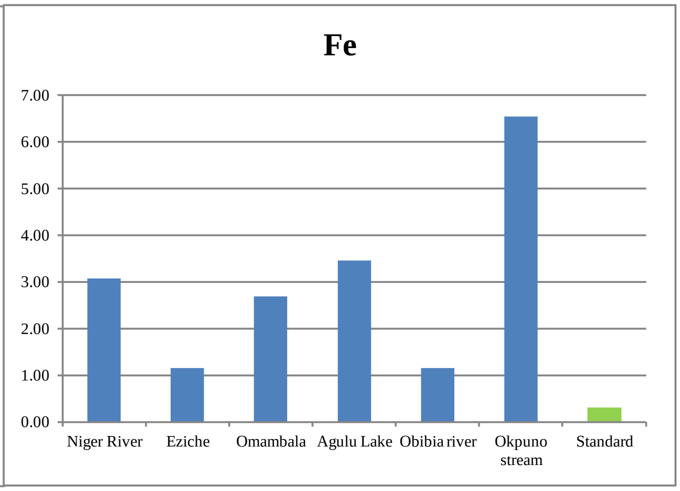

Figure 3: Iron concentration at various sampling points

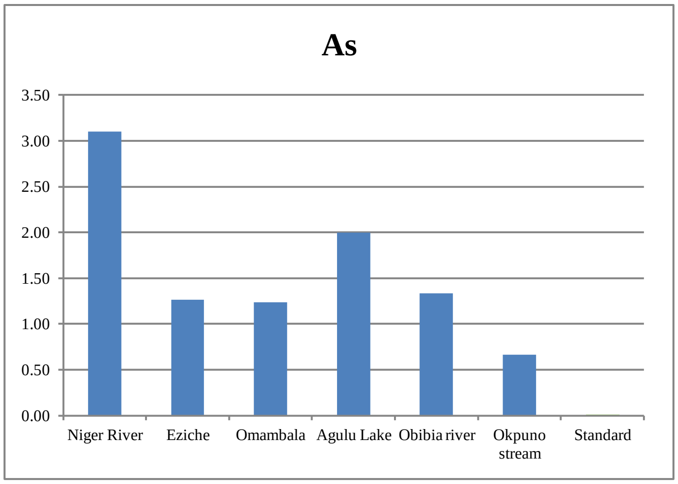

Figure 4: Arsenic concentration at various sampling points

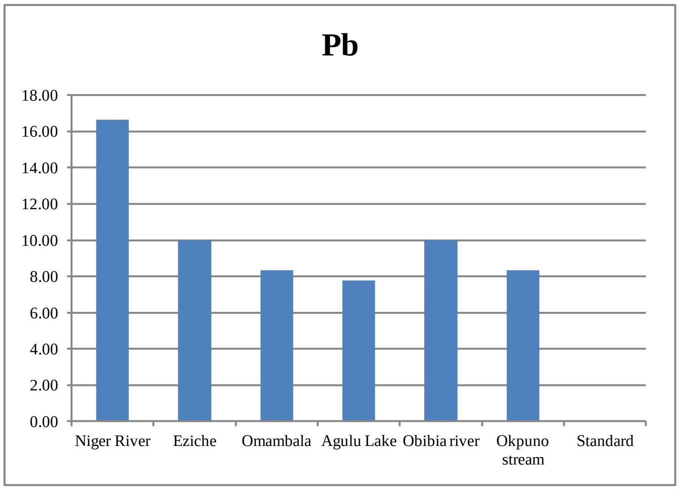

Figure 5: Lead concentration at various sampling points

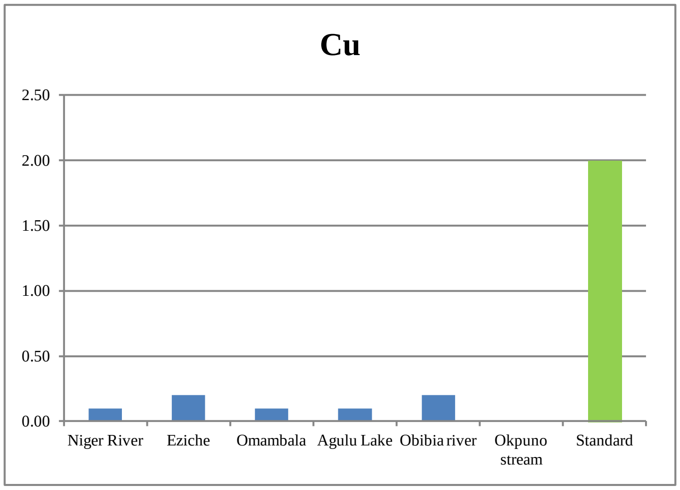

Figure 6: Copper concentration at various sampling points

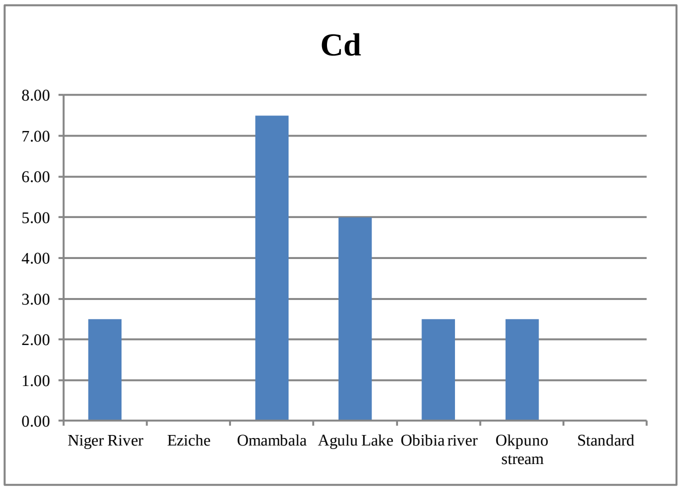

Figure 7: Cadmium concentration at various sampling points