DETERMINATION OF POLLUTION INDEX OF BENIN RIVER FLOWING THROUGH OGHARA INDUSTRIAL SITE OF ETHIOPE WEST L.G.A, NIGERIA

Augustine Apiamu*, Uduenevwo Francis Evuen and Mercy Akpan
Department of Biochemistry, College of Natural and Applied Sciences, Western Delta University, P.M.B. 10, Oghara, Nigeria.
*Corresponding author. E-mail: austodacademia.edu@gmail.com. Tel: +2347060440357.

Accepted 26th June, 2016

The present study was done to ascertain the pollution index of Benin River flowing through the industrial site of Oghara town for the assessment of heavy metals' concentrations in soil and water samples. The description of the study area was enhanced by means of a geographic positioning system (GPS) and geographic information system (GIS) devices of the designated sites (A, B, C) with specific distances of 100, 200 and 300 m from the industrial site (labelled D). In each case for soil and water samples whose pHs were determined, a total of twelve samples with three samples at the respective sites were collected for the evaluation of six heavy metals (Zn, Cu, Mn, Cd, Cr and Pb) using atomic absorption spectrophotometer. Although the correlation study showed no marked significant difference ($p>0.05$) among the concentrations of heavy metals obtained from the designated sites, the results of pollution indices of heavy metals in soil (A-0.26, B-0.39, C-0.39 and D-0.44) and water (A-0.11, B-0.09, C-0.07 and D-0.09) samples were less than a unit, and the quality grades of the samples were considered unpolluted and may be safe for domestic and agricultural purposes.

Keywords: Atomic absorption spectrophotometer, heavy metal, pollution index, geographic information system (GIS) and geographic positioning system (GPS).

INTRODUCTION

The tendencies for an increasing pollution index of an ecosystem owing to its rapid industrialization and urbanization may be inevitable and can be salvaged through the provision of up-to-date data for analysis and inferences about the bioaccumulation of contaminants. Most of our water sources are gradually becoming polluted due to the addition of foreign materials from the surroundings. These include organic matter of plant and animal origin, land surface washing and industrial and sewage effluents (Abida et al., 2008). Rapid urbanization and industrialization with improper environmental planning often leads to discharge of industrial and sewage effluents into water bodies. The aquatic ecosystem is complex and fragile with a self-cleaning inability, and therefore readily accumulates pollutants (Akan et al., 2012; Abida et al., 2008).

Water is an indispensable compound of life. Fresh water comprises 3% of the total water on earth. For human use, only 0.01% of this freshwater is available (Hinrichsen and Tacio, 2002; Shen et al., 2014). Unfortunately, even this small proportion of fresh water is under gigantic stress due to lithogenic and anthropogenic sources, particularly from rapid population growth, urbanization and unsustainable consumption of water in industry and agricultural activities (Li et al., 2009; Lui and Li, 2011). Predominant among them are the heavy metal high concentrations that accumulated in the aquatic system via several pathways, for example variety of bedrocks, atmospheric deposition of water drainage, runoff from agricultural and urban areas, and industrial effluents (Arnason and Fletcher, 2003; Luo et al., 2010; Lui and Li, 2011).

Furthermore, heavy metals contaminate the surface water and ground water resulting in deterioration of drinking and irrigation water such that water quality affects human health as well as the health of aquatic ecosystem (Krishna et al., 2009; Batayneh, 2012). Eminent heavy metal concentrations in different water systems may pose a risk of adverse effects such as deformities, cancer and health of aquatic animals together with their terrestrial predators (Havacar et al.,

2009; Volpe et al., 2009; Coeurdassier et al., 2010).

Soil is a crucial component of rural and urban environments, and in both places, land management is the key to soil quality (USDA, 2000). Heavy metal contamination of soil environment has been occurring for centuries now, but its extent increased remarkably for the past 50 years due to technological development and increased consumer use of materials containing these metals (Guanlin et al., 2006). These elements can accumulate in plants and animals eventually making their way into humans through food chains (Singh et al., 2006; Ganesh et al., 2010). Significant increase in soil metal content is found in areas of high industrial activity, where accumulation may be several times higher than the average content in non-contaminated areas (Geng et al., 2005).

Owing to the toxicity and ill effects of heavy metals on living being, the present day researchers have developed interest in the origin and fate of these elements in the environment (Sharma et al., 2009). Soil is considered contaminated when chemicals are present or other atterations have been made into its natural environment that is often caused by accidental discharge of chemicals or the improper disposal of hazardous wastes (Srinivasa and Pradip, 2008). Soils are usually regarded as the ultimate sink for heavy metals discharged into the environment (Banat et al., 2005), and sediments can be sensitive indicators for monitoring contaminants in aquatic environments (Pekey et al., 2004). Therefore, the environmental problem of soil and sediment pollution by heavy metals has received increasing attention in the last few decades in both developing and developed countries throughout the world (Zhang et al., 2007).Some heavy metals at lower concentrations like Cu and Zn play important roles in metabolic activities of living organisms, while the high concentrations of other metals like Cd, Cr, Mn, and Pb are considered highly toxic for humans and aquatic lives, kidney problems and geno-toxic carcinogens (Gambrell, 1994). Therefore, the study focussed primarily on the potential environmental risk of heavy metals in correlation to an industrial site through the computation of pollution indices of water and soil samples obtained from the sites under survey.

MATERIALS AND METHODS

All chemicals used were of analytical grade. All solutions were prepared in deionized water. Calibration standards of each metal were prepared by appropriate dilution of stock solutions of 1000 ppm.

Description of study area

The description of study area was enhanced by "global positioning system (GPS)" and "geographic information system (GIS)". Oghara clan with a population size of over 30,962 is a community located in Ethiope West Local Government Area of Delta State, Nigeria. At the bank of Benin River, there are severally sited industries with one of the industries channelling its discharge into the river. The industrial site is situated at latitude 05° 56' 36.4"N and longitude 05°38' 53.3"E, while the sampling sites on the river, labelled A, B and C with about 100m distance from each other are located at latitude 05° 56' 17.6"N and 05° 39' 06.8"E for site A, latitude 05° 56' 20.5"N and longitude 05° 39' 0.5"E for site B, and latitude 05° 56' 21.6"N and longitude 05° 39' 0.7"E for site C respectively. The predominant occupation of the inhabitants is agriculture due to the nature of its soil, and the irrigational practice is commonly from the river. The climate of the study area is tropical with two recognizable annual seasons. The dry season lasts between November and February (4 months) while the rainy season lasts between March and October (8 months) at Oghara. The vegetation comprises predominantly of rainforest trees like rubber trees, palm trees, etc. A sketch map of the study area showing the respective sampling sites is presented in Figure 1.

Sampling

Prior to collection of samples, the plastic containers were cleaned by washing in non-ionic detergents, rinsed with tap water and later soaked in 10% HNO_3 for 24 h and finally rinsed with deionized water. During sampling, sample containers were rinsed with sample waste water from industrial site and water from the river in

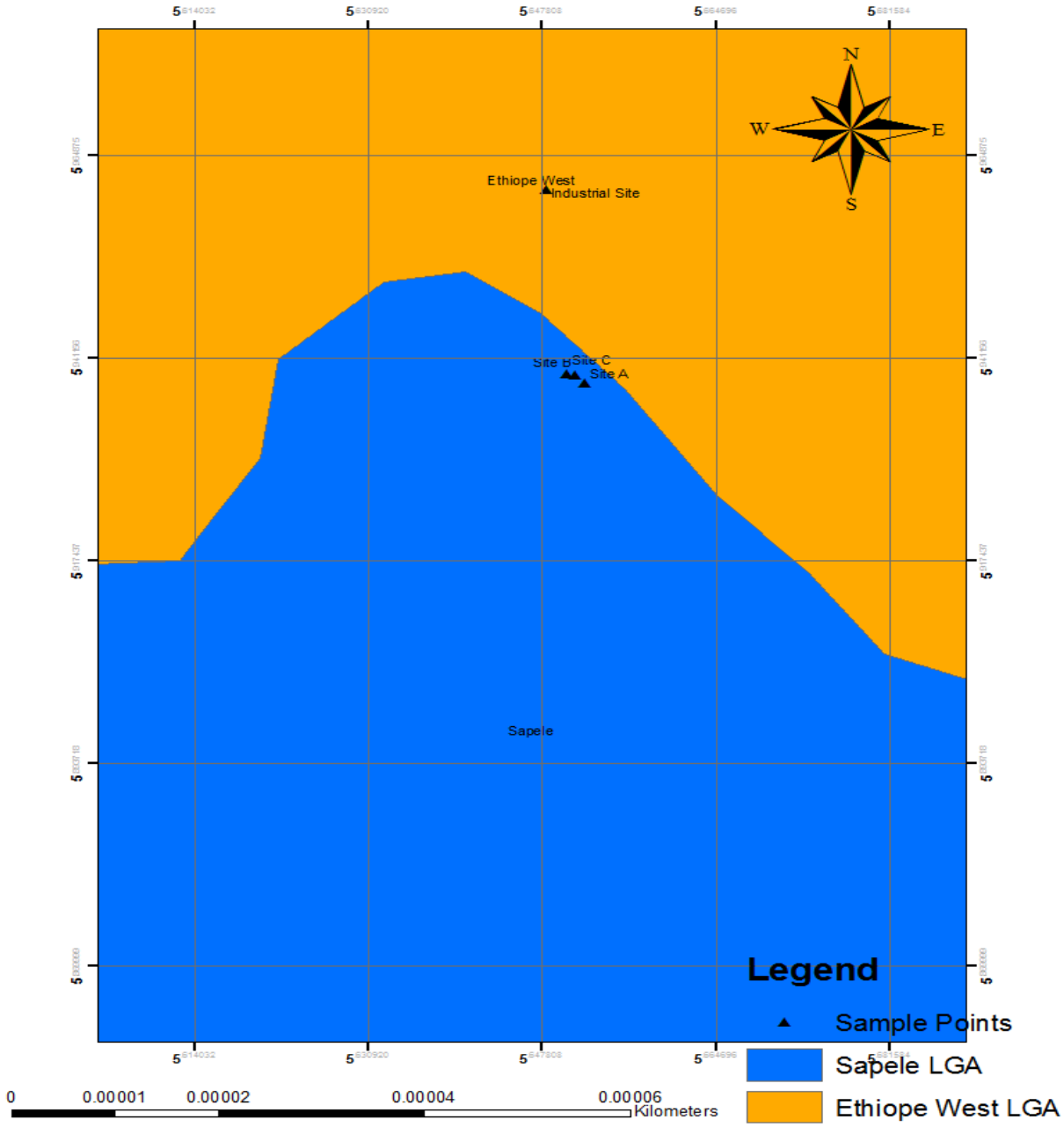

Figure 1. Sketch map of the study area showing sampling sites.

each case twice precisely and then filled to the brim. At each sampling point, water samples were collected in triplicates, making a total of twelve (12) water samples from the four designated sites. The samples were labelled, transported to the laboratory and stored in the refrigerator at 4°C prior to usage. A total of twelve soil samples were also collected in a similar fashion from the respective sites by means of a hoe from a depth of about 5-10cm. In each case, about 200 g of soil samples were stored in polyethene bags, labelled, transported to the laboratory and properly stored before its use for heavy metal analysis.

Digestion of water and soil samples for heavy metal analysis

Water samples were digested as follows: 100 cm^3 of the sample was transferred into a beaker and 5 ml concentrated HNO_3 was added.

The beaker with the content was then placed on a hot plate and evaporated to about 20 mL. The beaker was cooled and another 5ml concentrated HNO_3 was added. The beaker was covered with a watch glass and returned to the hot plate. The heating continued, and then small portion of HNO_3 was added until the solution appeared light coloured and clear. The beaker and watch glass were washed with distilled water, and the sample filtered to remove some insoluble materials that could clog the atomizer. The volume was adjusted to 100 cm^3 with distilled water (Radojevic and Bashkin, 1999).

Soil samples were air-dried in the laboratory. Any crumbs found in the samples were removed and mixed uniformly by coning, pulverization and quartering. Soil samples were sieved through a 2 mm sieve to remove coarse particles. Two grammes of the soil samples were weighed out into acid washed glass beaker. Soil samples were digested by the addition of 20 cm^3 of aqua regia (mixture of HCl and HNO_3, ratio 3:1) and 10 cm^3 of 30% H_2O_2. The H_2O_2 was added in small portions to avoid any possible overflow leading to loss of material from the beaker. The beaker was covered with a watch glass, and heated over a hot plate at 90°C for two hours. The volume of the digest was adjusted to 100 cm^3 with distilled water.

Heavy metal analysis

Determination of Zn, Cu, Mn, Cd, Cr and Pb was made directly on each final solution using Buck Scientific-210VGP0 Atomic Absorption Spectrophotometer (AAS). Standard solution of each sample Zn, Cu, Mn, Cd, Cr and Pb was prepared according to scientific manufacturer's procedure for Atomic absorption spectroscopy to be used. A known 1000 mg/L concentration of the metal solution was prepared from their salts.

Measurement of pH

Measurement was carried out by means of an Extech pH meter (D0700), which had been previously calibrated in the laboratory. Calibration was checked by measuring a standard buffer. Calibration was repeated if reading was more than ±5% of expected reading. A known volume of sample was measured into a 250 ml glass beaker, the pH probe inserted and the displayed stable reading was taken.

Determination of pollution index (PI)

The pollution index (Håkanson, 1980), was adopted to assess the extent of pollution of soil and water samples obtained from the designated sites (A, B, C and D) in Benin River. Pollution index assesses pollution level by considering the joint effect of all the pollution metals in soil or water samples. The PI is obtained by calculating the ratios of the average metal concentration with the permissible or tolerable levels (TL). It is computed using the formula below:

$$\text{Pollution Index (PI)} = \frac{1}{n}\left(\frac{M_1}{TL_1} + \frac{M_2}{TL_2} + \ldots + \frac{M_n}{TL_n}\right) \quad 1$$

Where, M_1, M_2.....M_n are the respective average concentrations of the heavy metals, TL_1, TL_2.....TL_n are the permissible or tolerable concentration for each polluting metal and "n" is the total number of heavy metals under consideration. Therefore, the evaluation grading standards for the pollution index method can be interpreted as described by Håkanson (1980) (Table 1).

Table 1. Concentrations of heavy metal (mg/kg) of Soil Samples at designated sites.

Heavy metals	Site A	Site B	Site C	Site D
Zn	24.07±0.01	21.75±0.0	34.63±0.34	38.79±0.01
Cu	13.38±0.01	11.67±0.01	21.09±0.01	22.99±0.01
Mn	29.42±0.01	27.08±0.01	42.00±0.00	47.06±0.00
Cd	1.16±0.00	0.89±0.00	1.71±0.00	2.02±0.01
Cr	27.68±0.10	24.86±0.00	39.31±0.00	45.14±0.00
Pb	1.59±0.00	1.18±0.00	2.33±0.00	2.68±0.00

Results are expressed as Mean ± SEM (=standard error of mean) of triplicate results. All results across each row differ significantly ($p<0.05$).

Statistical analysis

Means and standard error of means were reported when appropriate. One-way analysis of variance, (ANOVA), followed by a post hoc comparison using Turkey's test, were applied to identify significant differences in measured parameters among sampling points using SPSS version 20.0. Pearson's correlation analysis was also performed to evaluate potential relationships among the different variables.

DISCUSSION

In Nigeria, environmental problems increase continually due to improper disposal of wastes. This impairs the surface of water bodies thus polluting the environment directly or indirectly. The qualities of surface water bodies are being negatively impacted as untreated effluents are discharged into them through various sources (Adeyemi-Ale, 2014).

Not until recently, Oghara was a rural settlement, where most of the local inhabitants are primarily engaged in farming and local industrial activities. The transformation of Oghara town into an urban and industrialized settlement may stand a potential risk of pollution. This may be tentative or definite as most of the localized industries, (especially industrial site D), situated at the bank of the Oghara river, (basically called Benin River), may discharge their effluents into the aquatic ecosystem. It is, therefore, a common knowledge that majority of water sources in Nigeria available to local inhabitants are either unsafe or difficult to obtain, and are stressed by poor management as reported by Galadima et al. (2011). In light of the above, the present study has revealed the varying concentrations of some heavy metals (Zn, Cu, Mn, Cd, Cr and Pb), and indicated an uncontaminated state of soil and water samples obtained from the aquatic ecosystem and the industrial site, labelled D.

The pH values obtained at sites; A(5.00), B(5.10), C(5.00) and D(5..5) for soil samples and A(5.4), B(5.5), C(5.4) and D(6.4) for water samples portend that the soil samples were strongly acidic and loamy-sand in nature while the water samples were acidic in nature, as described by UNEP (2008). Therefore, pH of soil and water samples may be of great impact on the accumulation of heavy metals.

Although results obtained for Zn at sites A, B, C and D (Table 1) in soil samples showed a reduced significant difference ($p<0.05$) as compared with the permissible limit of 200 mg/kg put forward by EU (2005). The concentration of Zn was highest at industrial site D (38.79 mg/kg) and lowest at site B (21.75 mg/kg). Thus, the increasing magnitude of Zn concentration at the respective sites is: site B< site A< site C< industrial site D. Moreso, the results obtained for Zn in water samples at different sites indicated a marked significant difference ($p<0.05$) with highest concentration at industrial site D (0.19 mg/l) and lowest concentration at site C (0.03 mg/l). However, the Zn concentrations at the various sites fall within the set limit of 3.0 mg/L Zn as put forward by WHO (2008) and NIS (2007). Zn plays a biochemical role in the life processes of all aquatic plants and animals; therefore, they are essential in the aquatic environment in trace amounts (Akan *et al.*, 2012). Zn is also an essential growth element for plants and animals, but at elevated levels, it is toxic to some species of aquatic life (WHO, 2008). Zn is involved in a variety of enzyme systems, which contribute to energy metabolism, transcription and translation, and is also potentially hazardous, and excessive concentrations in soil may lead to phytotoxicity as it is a weed killer (Abbasi *et al.*, 1998). Consequently and in view of the results obtained, Zn may not show any hazardous effect rather it may be biochemically advantageous to aquatic and terrestrial lives of the environment.

The marked significant difference ($p<0.05$) for Cu concentrations observed in soil samples, (Table 1.0) at the various sites, though falls within the set limits of 100mg/kg, revealed that Cu levels were highest at industrial site D (22.99 mg/kg) and lowest at site B (11.67 mg/kg). For water samples (Table 2), the results obtained for Cu concentrations at different site showed a marked significant difference at 5% confidence level, but did not exceed the permissible limit (Cu:1.00 mg/l) as stated by WHO (2008) and NIS (2007). Copper is an essential substance to human life, however, in high concentrations, it can cause anaemia, liver and kidney damage, stomach and intestinal

Table 2. Concentrations of heavy metal (mgl^{-1}) in Water Samples at designated sites.

Heavy Metals	Site A	Site B	Site C	Site D
Zn	0.04±0.00	0.05±0.00	0.03±0.00	0.19±0.00
Cu	0.21±0.90	0.02±0.00	0.12±0.00	0.12±0.00
Mn	ND	ND	ND	ND
Cd	ND	ND	ND	ND
Cr	ND	ND	ND	ND
Pb	ND	ND	ND	ND

*ND= Not detected.

rritation (Akan et al., 2012). Therefore, the drinking of water from Oghara River may not initiate any serious environmental health challenges that have to do with copper toxicity to local inhabitants of Oghara community.

Mn concentrations in soil samples (Table 1) at various sites was observed to be highest at the industrial site D (47.6 mg/kg) and lowest at site A (29.42 mg/kg) respectively. The marked significant difference ($p<0.05$) revealed that the concentrations of Mn at the sites falls within the set standard of 100 mg/kg, and therefore may not elicit any potential risk .On the hand, the concentration of Mn was below the detection limit in water samples (Table 2). Mn compounds are used in fertilizers, varnish and fungicides and as livestock feeding supplements. Mn can be adsorbed into soil; the extent of adsorption depends on the organic content and cation exchange capacity of the soil (Khan et al., 2008). It can also bioaccumulate in lower organisms (for example phytoplankton, algae, molluscs and some fish), but not in higher organisms; biomagnifications in food chains is not expected to be very significant (Khan et al., 2008). At significantly low concentration, Mn may serve as a cofactor to some enzymes, but may be toxic at high concentrations (Mahakalkar et al., 2013).

The mean concentrations of Cd in soil samples, (Table 1) indicated a marked significant difference ($p<0.05$).However, the mean concentration of Cd in soil samples obtained from site C (1.71 mg/kg) and industrial site D (2.02 mg/kg) exceeded the EU (2005) permissible limit of 1.5 mg/kg, thereby resulting in contamination or pollution of the soil. In water samples, (Table 2), the concentrations of Cd at sites A, B, C and D were far below the detection limit. Although there may be traces of Cd in the water samples, but below significant levels. Higher concentration of cadmium is extremely toxic to fish population. Its effects on the growth rate have been observed even for concentrations between 0.005 and 0.01 mg/L (Akan et al., 2012). Cd is present as pollutant in phosphate fertilizers, and is also found in PVC products, colour pigment alloys and in rechargeable Ni-Cd batteries (Shen et al., 2014). These Cd-containing products are not recycled, but dumped together with household wastes, thereby polluting the environment. It has been established that an association exists between Cd exposure and chronic renal failure (Singh et al., 2006). Therefore, there may be elevated levels of Cd on the long run, which may pose serious toxic effect to aquatic lives, plants and animals respectively.

The concentrations of Cr and Pb in water samples, (Table 2.0), obtained at the respective sites were below the detection limits. However, there was marked significant difference ($p<0.05$) in the concentrations of Cr and Pb obtained at the respective sites with industrial site D having the highest values of 45.14 and 2.68 mg/kg , and site B having the lowest values of 24.86 and 1.18 mg/kg respectively. Although information regarding the permissible limits from regulatory bodies is lacking, utmost caution should be taken to avoid contamination of the soil with these metals. Cr is one of the biochemically active transition metals. Weathering of the earth crust is the primary and natural source of the chromium in soil and water. Though an essential trace nutrient and a vital component for the glucose tolerance factor, Chromium toxicity damages the liver, lungs and causes organ haemorrhages (Volpe et al., 2009) Pb on the other hand, is frequently related to soil contamination and is

potentially toxic to living organisms ((Sharma and Dubey, 2005).

The correlation between heavy metals is closely related to prediction such that the greater the association between two variables, the more accurate will be its outcome (Monitha et al., 2012).Table 3 reveals no marked significant difference at P<0.05 between heavy metals using Pearson's product moment correlation coefficient. This implies that the concentrations of heavy metals obtained at sites A, B and C were not closely related to concentrations of heavy metals obtained at the industrial site D. Despite the disparities in concentrations of heavy metals at designated sites, Table 4 clearly showed no indication of contamination of the respective sites with a definitive conclusion of no pollution of the Oghara River.

Table 3. Correlation of heavy metals in soil samples of the studied sites.

Correlation for all pairs of data series (Pearson method)						
	Zn	**Cu**	**Mn**	**Cd**	**Cr**	**Pb**
Zn	1					
CU	0.99756	1				
Mn	0.999846	0.996816	1			
Cd	0.993938	0.989435	0.992408	1		
Cr	0.999085	0.993754	0.999117	0.995388	1	
Pb	0.991297	0.989653	0.989032	0.998841	0.991325	1

*Correlation is not significant at 5% confidence interval (p<0.05) (2-tailed, n=4 sites).

Table 4. Pollution indices of water and soil samples obtained from different sites.

Sites	**Soil Samples**	**Quality grade**	**Water Samples**	**Quality Grade**
	Pollution index		**Pollution index**	
A	0.26	Unpolluted	0.11	Unpolluted
B	0.34	Unpolluted	0.09	Unpolluted
C	0.39	Unpolluted	0.07	Unpolluted
D	0.44	Unpolluted	0.09	Unpolluted

CONCLUSION

Although there was no marked significant correlation of effluents discharged from industrial site D of Benin River with other designated sites, the study succinctly revealed that the pollution index of soil and water samples was generally less than a unit. Therefore, this source of water can be considered unpolluted with respect to heavy metals, and may be safe for use by inhabitants of Oghara for domestic and agricultural purposes. However, periodic assessment of heavy metals accumulation is highly recommended for avoidance or amelioration of potential environmental risk that may be caused by rapid industrialization of Oghara community to her inhabitants. The need for the assessment of other variables of pollution in relation to the industrial site D should be put into cognisance in future studies.

ACKNOWLEDGMENT

The authors are very grateful to the authorities of Thermosteel Laboratories, Warri, Nigeria for the provision of equipments and demonstration of expertise in this study.

REFERENCES

Abida, B., Harikrishna, S., Irfamilla, K., Ramaiah, M., Veena, K. and Vinutha, K (2008). Analysis of Fluoride Level in Water and Fish Species at Sonkey, Bellander and Madivala Lake Bangalore. Rasayan. J. Chem., 1(3): 596 – 601.

Adeyemi-Ale, O.A. (2014). Impact of Effluent on the Physico-chemical Parametersof Gbagi Stream (Odo-Eran) Ibadan, Nigeria. Ilorin J. Sci., 1(1): 100-109.

Akan, J.C., Abbagambo, M.T., Chellube, Z.M. and Abdulrahman, E. I. (2012). Assessment of Pollutants in Water and Sediment Samples in Lake Chad, Baga, and North Eastern Nigeria. J. Environ. Protec., 3: 1428 – 4441.

Arnason, J.G. and Fletcher, B.A. (2003).A 40+ Year Record of Cd, Hg, Pb, and U deposition in Sediments of Patroon Reservoir, Albany County, NY, USA. *Environment and Pollution*, 123(3): 383 – 388.

Banat, K. M., Howari, F. M. and Al-Hamada, A. A. (2005). Heavy Metals in Urban Soils of Central Jordan: Should We Worry about Their Environmental Risks? *Environmental Research*, 97: 258–273.

Batayneh, A. (2012). Toxic Aluminium, Beryllium, Boron, Chromium and Zinc in Groundwater: Health Risk Assessment. Inter. J. Environ. Sci. Technol., 9(1): 153 – 161.

Coeurdassier, M., Scheifler, R., Mench, H., Crini, N., Vangronsveld, J. and Devaufleury, A. (2010). Arsenic Transfer and Impacts on Snails Exposed to Stabilized and Untreated As-contaminated soils. Environment and Pollution, 158(6): 2078 – 2083.

EC (European Commission) (2005). Commission Regulation (EC) No.78/2005 of 19 January, 2005 amending regulation (EC) No. 466/2001 as regards heavy metals, 116/43-45.

Galadima, A., Garba, Z. N., Leke, L., Almustapha, M. N. and Adam, I. K. (2011). Domestic Water Pollution among Local Communities in Nigeria: Causes and Consequences. Eur. J. Sci. Res., 52(4): 176-187.

Ganesh, R., Bhagure, S.R., and Mirgane, D. (2010). Heavy Metal Concentrations in Groundwaters and Soils of Thane Region of Maharashtra, India. Environmental Monitoring and Assessment. 90: 68-88.

Geng, C.N., Zhu, Y.G., Liu, W.J. and Smith, S.E. (2005). Arsenate Uptake by Seedlings of Two Rice, *(Oriza sativa L.)*, Genotypes Grown in Solution Culture. Aquatic Botany, 83: 321 – 331.

Guanlin, G., Oixinf, Z. and Lene, Q. M. (2006). Availability and Assessment of Fixing Additives for the in situ Remediation of Heavy Metal Contaminated Soils: A Review. Environmental Monitoring and Assessment, 116: 513 – 528.

Håkanson, L. (1980). An Ecological Risk Index for Aquatic Pollution Control: A Sedimentological Approach. Water Res., 14: 975–1001.

Havacar, D., Sofuoglu, A. and Sofuoglu, S.C. (2009).A Health Risk Assessment for Exposure to Trace Metals via Drinking Water Ingestion Pathway. Inter. J. Hygenic Environ. Health, 212(2): 216 – 221.

Hinrichsen, D. and Tacio, H. (2002). The Coming Freshwater Crisis is Already Here. Finding the Source: The linkages between population and water, Woodrow Wilson International Centre for Scholars, Washington, DC. and Escp Publication, Spring.

Khan, S., Cao, Q., Zheng, Y.M, Huang, Y.Z, and Zhu, Y.G. (2008). Health Risks of Heavy Metals in Contaminated Soils and Food Crops Irrigated with Wastewater in Beijing, China. Environmental Pollution; 152: 686–692.

Krishna, A. K., Satyanarayanan, M. and Govil, D.K. (2009). Assessment of Heavy Metal Pollution in Water Using Multivariable Statistical Techniques in an Industrial Area: A Case Study from Patanchetu, Medate District, Andhra Pradesh. Indian Journal of Hazardous Materials, 167(1): 366 – 374.

Li, S., Liu, W., Gu, S., Cheng, X., Xu, Z., and Zhang, Q. (2009). Spatio-temporal Dynamics of Nutrients in the Upper Han River Basin, China. J. Hazardous Materials, 162(4): 1340 – 1348.

Lui, H. and Li, W. (2011). Dissolved Trace Elements and Heavy Metals from the

Shadow Lakes in the Middle and Lower Reaches of the Yanglize River Region, China. Environmental Earth Service, 62(7): 1503 – 1512.

Luo, W., Lu, Y., Wang, T., Hu, W., Jiao, W., Naile, J.E., Khim, J.S. and Giesy, J.D. (2010). Ecological Risk Assessment of Arsenic and Metals in Sediments of Coastal Areas of Northern Bohai and Yellow Seas, China. AMBIO J. Hum. Environ, 39(5): 367 – 376.

Mahakalkar, A. S. Gupta R. R. and Nandeshwar, S. N. (2013). Bioaccumulation of Heavy Metal Toxicity in the Vegetables of Mahalgaon, Nagpur, Maharashtra (India). Current World Environment, 8(3): 453-468.

Monitha, M., Jayakumar, C. and Nagendra, G.N. (2012). Environmental Toxicology-Assessment and Remediation of Toxic metals in Soil. Inter. J. Environ. Biol., 2(2): 59-66.

Nigerian Industry Standard (NIS) (2007). Nigerian Standard for Drinking Water Quality, Abuja, Nigeria.

Pekey, H., Karakaş, D., Ayberk, S. (2004). Ecological Risk Assessment Using Trace Elements from Surface Sediments of İzmit Bay (Northeastern Marmara Sea) Turkey. Marine Pollution Bulletin, 48: 946–953.

Radojevic, M. and Bashkin, V. N. (1999). "Practical Environ-mental Analysis". The Royal Society of Chemistry, Cam-bridge, p. 466.

Sharma, P. and Dubey, R.S. (2005). Lead toxicity in plants. Brazil J. Plant Physiol., 17:35–52.

Sharma, S.K., Sehkon, N. S., Deswal, S. and Siby, J. (2009). Transport and Fate of Copper in Soils. Inter. J. Civil and Environ. Enginee., 21: 45-58.

Shen, C., Naveedullah, C., Hashmi, M.Z., Yu, C., Shen, H., Lou, L. and Chen, Y. (2014). Concentrations and Human health Risk Assessment of Selected Heavy Metals in Surface Water of the Siling Reservior Watershed in Zhejiang Province, *China.* Polland Journal of Environmental Studies, 23(3): 801 – 811.

Singh, R., Chavan, S.L. and Salake, P.H. (2006). 'Heavy Metal Contamination in Water, Sediments and Body Tissues of Red Worm (Tubifex SPP) Collected from Natural Habitats in Mumbai, India. Environmental Monitoring and Assessment, 129(3): 471 – 481.

Srinivasa, G. S. and Pradip, K. G. (2008). 'Distribution of Heavy Metals in Surface Water of Ranipet Industrial Area in Tamil Nadu, India'. Environmental Monitouring assessment, 136:197 – 207.

UNEP (2008). Desalination resource and guidance manual for environmental impacts assessment. United Nations Environmental Programme, Regional Offices of West Asia, Manama, and World Health Organization, Regional Office for the Eastern Mediterranean, Cairo.

USDA (2000). Soil Quality-Heavy Metal Soil Contamination. Urban technical Note No. 3, Washington DC.

Volpe, M., LaCara, F., Volge, E. and De Prisco, P. (2009). Heavy Metal Uptake In: The Ecological Food Chain. *Food chemistry*, 117(3): 553 – 560.

WHO (2008). Guidelines for Drinking Water Quality 3rd Ed, Recommendations, Geneva, Switzerland.

Zhang, L. P., Ye, X. and Feng, H. (2007). Heavy Metal Contamination in Western Xiamen Bay Sediments and Its Vicinity, China. Marine Pollution Bulletin, 54: 974–982.