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Investigation on the Heavy Metal Concentrations and Potential Ecological Risk Assessment of Sediments from Ikpoba River, Benin City, Edo State, Nigeria

Idemudia, I., Omoigberale, M.O. and *Uyi, O.O.
Department of Animal and Environmental Biology, Faculty of Life Sciences, University of Benin, P.M.B. 1154, Benin City, Nigeria.
*osariyekemwen.uyi@uniben.edu

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ABSTRACT

This study investigated the monthly variations of the heavy metal concentrations of sediments from Ikpoba River, Benin City, Nigeria. A further objective of this study was to determine the potential ecological risk assessment of sediments from the same river. Sediments obtained from four sampling stations across the river were analysed for heavy metals between November 2016 and February 2017. Nine heavy metals in the sediment samples were determined by atomic absorption spectrophotometry (AAS). Apart from Cu, Cd, Ni and V which showed significant differences across the various stations, all other heavy metals did not differ as a function of sampling station. Heavy metal assessment and ecological risk assessment were carried out to determine the pollution and risk degree of the heavy metals in the sediments. Heavy metal assessment revealed that Cr, Cu, Cd and Pb were present in high levels across all four stations. Ecological risk assessments conducted to determine the potential ecological index (E^i_R) and comprehensive potential ecological risk index (RI) revealed that Cd had a very strong to an extremely strong degree of pollution across the study stations thus resulting in the extremely strong degree of risk in stations 1, 3 and 4. The results suggest that the studied stations in Ikpoba River are highly polluted, but whether other stations of the river are also polluted remains unclear, and therefore warrant further studies.

1. INTRODUCTION

Heavy metals are inorganic chemical elements needed for plant development in relatively small or minute quantities and hazardous in higher concentration (Egborge, 1994). They are toxic or poisonous because they are not biologically degradable and they tend to bio- accumulate in the protoplasm of the aquatic organisms (Egborge, 1994). Heavy metals originate from various sources, mostly from anthropogenic activities such as untreated effluents, sewage and domestic waste discharge into water bodies (Opeolu *et al*., 2008). Smaller proportions of heavy metals discharged into the sediment of a given water body originate from natural sources which include leaching of rocks, forest fires and vegetation (Fernandez and Olalla, 2000). Examples of heavy metals include, iron, lead and copper while others are, arsenic, mercury, cadmium, nickel, zinc cobalt and vanadium (Garbarnio *et al.*, 1995). The presence of heavy metals in aquatic environment leads to a great deal of concerns about their influences on plant and animal lives (Iwuoha *et al.*, 2012). Some of the heavy metals of significant health concern include arsenic, cadmium, chromium, lead, nickel and zinc (WHO, 2008). When the concentration of these heavy metals in water exceed environmental tolerance limits, the use of such water for agricultural purposes (irrigation and aquaculture) could result in detrimental effects to the aquatic ecosystem and humans through the food chain (Wright and Welbourn, 2002). Studies evaluating the concentrations of several heavy metals in the sediments of aquatic bodies are necessary, and also, they help in unravelling the degree of toxicity of the given water body.

Sediment constitutes loose sand, silt and other soil particles that settle at the bottom of water bodies (USEPA, 2002). Different sources such as soil erosion from run-offs over arable farm lands, plantations, and other parts of the landscape in an environment as well as decomposing matter of plants and animals supply water bodies with significant amounts of sediments, wherein they act as a natural buffer and filter systems in the material cycles of water (Jain and Sharma, 2002). Water sediment provide an essential habitat for benthic macro-invertebrates whose metabolic activities significantly contribute to aquatic productivity, and also serve as the major site for organic matter decomposition (Abowei and Sikoki, 2005). Of a suite of important macro-nutrients, nitrogen and phosphorus are continuously being interchanged between sediments and overlying water, therefore defining the integrity in benthic life (Abowei and Sikoki, 2005). Sediment structures in the intertidal zone play a major role in the distribution of the organisms that live in or on them (Ikomi *et al.*, 2005), and it is seldom unusual for sediments to act as both a carrier and potential source of contaminants in the aquatic environment; consequently leading to the development of a pool and/or reservoir capable of retaining or releasing contaminants into the water column through various processes of remobilization (Marchand *et al.*, 2006, Davies and Abowei, 2009). Sediments also serve as a reservoir for pollutants and therefore a potential source of pollutants to the water column. Organism- and ultimately human-contaminated sediments can cause lethal and sub-lethal effects to benthic and other sediment-associated organisms. Ogbeibu and Victor (1989) reported a significant impact of roads and bridge construction across Ikpoba River on sediments which resulted in a corresponding negative effect on the benthic invertebrates in the sediments.

Sediment-associated pollutants especially heavy metals that are introduced by anthropogenic activities have the ability of causing direct effects on sediment-dwelling organisms and can indirectly contribute to adverse effects on man and other animals (USEPA, 2001). Heavy metal pollution of the sediments of water bodies is now a matter of increasing national and global concern because they result in hazardous effects on aquatic organisms due to the accumulation of these chemicals in the living tissues of such aquatic species. When released into the aquatic environment, many dangerous heavy metals accumulate in the sediments of the water where they are absorbed by aquatic organisms and are transferred through the food chain to the higher trophic levels. Heavy metals released into the water systems may become immobilized within the stream sediments by major processes such as adsorption, flocculation and co-precipitation. Hence, sediments serve as a pool that can retain trace metals or release them to the aquatic environment by different process of remobilization (Caccia *et al.*, 2003; Pekey, 2006; Marchand *et al.*, 2006).

Heavy metals present in sediments originate from anthropogenic sources which include industrial or municipal effluent discharge due to increasing levels of industrialization (Lin *et al.*, 2013, Krishna and Mohan, 2014). Acid mine drainage released from mining and smelting processes are also important sources of heavy metals in rivers (Gomez *et al.*, 2011). Also, pesticides and herbicides that are mainly needed in agricultural processes in many developing countries sometimes contain some amount of Arsenic (As) that are released into rivers through agricultural run-offs (Alves *et al.*, 2014). The occurrence of these untreated effluents in rivers prevents the receiving water from being used as a good quality water source, thus

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producing a serious adverse effect on the food chain which is detrimental to both human and animal health (Sangodoyin, 1991).

Sediments absorb and accumulates trace metals from water discharged to it and as a result, the concentrations of heavy metals are generally greater in sediment samples than in the water samples (Adeleye *et al.*, 2011; Maitera *et al.*, 2011). It has been reported that approximately 30-98% of the total metal load is in the sediments (Gibbs, 1973). Thus, sediments acting as an ecological sink, can release these heavy metals back into the surface water due to environmental changes causing toxic effects on several aquatic organisms (Superville *et al.*, 2014). Due to this, sediments of a given water body are sometimes used as indicators to monitor long term metal enrichment and to assess levels of heavy metal pollution (Alves *et al.*, 2014). Hence, studying the sediment qualities of water bodies will certainly advance the understanding of the pollution levels of sediments in these water bodies, and may further assist in explaining the population dynamics of benthic organisms. Amongst the rivers in Edo State, a fourth order stream located in the rainforest belt popularly referred to as Ikpoba River impacts significantly on the livelihoods of the Benin populace. It provides water for both agricultural and domestic purposes and serves as a recreational centre for its surrounding inhabitants. However, there are numerous ecological challenges associated with the river, some of which include: the discharge of effluents into the river, run-offs of fertilizers from farmlands which often lead to eutrophication, sewage disposal and irrational dumping of domestic waste; usually non-biodegradable which contribute to the pollution of the river and its sediment. Therefore, investigating the levels of heavy metals pollution and potential ecological risks caused by the heavy metals on the sediment of Ikpoba River will help to understand the pollution levels of the river and will provide necessary data to facilitate the management of the river and other water bodies found in Nigeria. The objective of this study was to determine the spatial variability of the heavy metal concentrations of sediments from Ikpoba River. A further objective of this study was to determine the potential ecological risk assessment of sediment from the river.

2. MATERIALS AND METHODS

2.1. Study Area

The study was carried out in Ikpoba River, Benin City, southern Nigeria, (Lat. 06° 13' 036"N; Long. 05° 46' 34"E). The river is characterized by a flat land surface which is composed of sand and laterite soil, while the river substratum is composed of coarse sand, clay and fine grain soil. Human and anthropogenic activities within and around the river consist of farming, fishing and domestic washing. Four sampling stations were chosen along a stretch of the river and visited once every month. The various designated sampling stations investigated in this study are thus described.

Station one: this station is located in Iguosa/Oluku community, between latitude 06˚27.193'N and longitude 005˚36.566'E with an elevation of 65m. This station receives industrial wastes from the 7Up bottling company located close-by. Nomadic cattle herders take their animals to drink and feed on the grasses around the river. Vegetation found around this station include Palm trees (*Elaeis guineensis*), Elephant grass (*Penisetum purpureum*), Bamboo trees (*Bambusa* spp.), and Water hyacinth (*Eichhornia crassipes*).

Station two: this station is located in Ekosodin community, between latitude 06˚25.167'N and longitude 005˚38.319'E with an elevation of 43m. The vegetation around the river at the left and right banks consist of rainforest plants and macrophytes such as *Rhizophora, Azolla* spp, Bamboo trees (*Bambusa* spp) and Elephant grasses (*Penisetum purpureum*). The major human activity that takes place at this station are farming and fishing.

Station three: station three is located in Ikpoba slope, between latitude 06˚21.072'N and longitude 005˚38.810'E with an elevation of 40m. A long pedestrian bridge (Ikpoba Bridge) is found in this station. This area is highly perturbed by human activities including laundering, dumping of waste and religious practices. Also, a car wash and an abattoir are located near-by and their wastes are emptied into the river. The major vegetation fringing this station include, palm tree *Elaeis guineensis*, bamboo tree *Bambusa bambusa*, and water hyacinth (*Eichhornia crassipes*).

Station four: this station is located in Oregbeni community, between latitude 06˚20.058'N and longitude 005˚39.816'E with an elevation of 39m. Human activities including fishing, farming, and domestic activities amongst others are clearly visible in this station. Plants found in this area include palm trees (*Elaeis guineensis*), bamboo trees (*Bambusa* spp.), mushroom (*Agaricus* spp.), macrophytes such as water lettuce (*Pistia* spp), *Azolla* spp. etc.

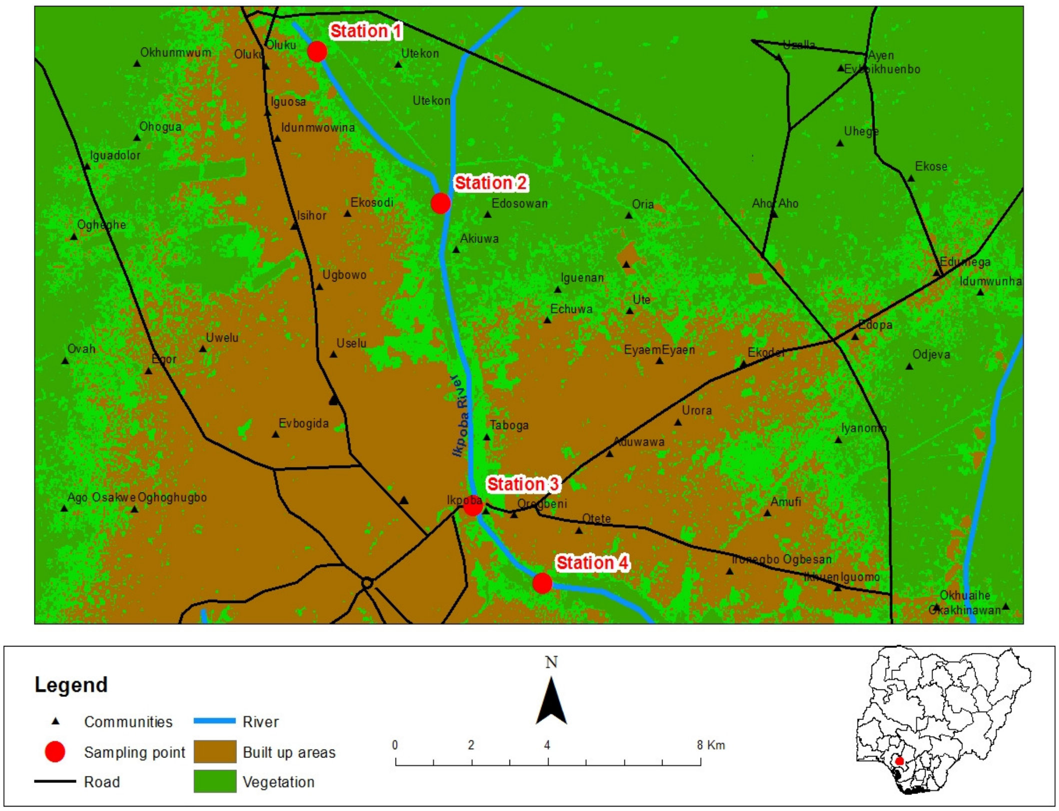

Figure 1: Map of Ikpoba River showing the study stations (Insert: map of Nigeria)

2.2. Sample Collection

The sediment samples were collected from the four sampling stations (at a depth of between 10 and 60 cm) for a duration of four months (November, 2016 – February, 2017). Samples were collected by scooping with a hand trowel in stations 1, 2 and 3, while an Ekman grab was used in station 4. The collected samples were stored properly in a foil paper and labelled with a masking tape before they were transported to the laboratory for analysis.

2.3. Physico-chemical Parameters and Particle Size Determination

Sediment samples were air dried and further dried in an oven at 80˚C for 48 hours to remove moisture. It was then ground into very fine sediments by means of a porcelain mortar to achieve homogenous samples.

The pH and conductivity of the sediment samples were analysed using HANNA pH meter (model H18424) and HACH44600-00 Conductivity/TDS meter respectively. The samples were diluted with 50ml distilled water in a 100ml beaker to produce a ratio 1:1 mixture before inserting the probes to take the readings. The organic carbon content of the sediment sample was determined using Walkey – Black method of APHA (1995). Sand, silt and clay contents were determined using a sieve. Particles less than 0.0002 were classified as clay, between 0.002 and 0.05 as silt and between 0.05 and 0.2 as sand.

2.4. Heavy Metal Analysis

Heavy metals were first digested using Perchloric-Nitric acid-Sulphuric digestion method. Sediment samples were ground and 1g of each ground sample was placed in 250ml flask. Concentrated nitric acid (4ml) was added to the flask. After 30 minutes, 1ml of Perchloric acid and 1ml of sulphuric were added. The mixture was swirled gently and the content transferred to an electric hot plate and allowed to boil at moderate heat (98 °C) under a hood for 6 hours. In some cases, when the mixture turned black, more concentrated Nitric acid was added and heating continued. Complete digestion was indicated by white crystalline mixture obtained after the disappearance of the white chlorate fumes. The final content was allowed to cool. It was then filtered and made up to 100ml mark in a 100ml mark in 100ml standard volumetric flask containing 20ml of distilled water. Atomic absorption spectrometry was then used for the determination of heavy metals.

2.4.1. Heavy metal pollution assessment

To determine the degree of heavy metal contamination in the sediment samples, pollution index (PI) for each metal was determined for each station using heavy metal assessment grading shown in Table 1 (Yang *et al.*, 2011).

$$PI = Ci/Si \quad (1)$$

Where, Ci is the measured concentration of each metal in this study; Si is the background value in this paper.

Table 1: The grading of standard of contamination degree heavy metals (Yang *et al.*, 2011)

Pollution index (PI)	Heavy metal contamination degree
PI<1	Non-pollution
PI<2	Low level of pollution
2≤PI<3	Moderate level of pollution
3 ≤PI<5	Strong level of pollution
PI> 5	Very strong level of pollution

2.4.2. Ecological risk assessment

This study employed the Potential Ecological Risk Index (PERI) proposed by Hakanson (1980) to evaluate the potential ecological risk of heavy metals (Table 2). This method comprehensively considers the synergy, toxic level, concentration of the heavy metals and ecological sensitivity of heavy metals (Singh *et al.*, 2010; Douay *et al.*, 2013). PERI is formed by three basic modules: degree of contamination (CD), toxic-response factor (TR) and potential ecological risk factor (ER). According to this method, the potential ecological risk index of a single element (E^i_R) and comprehensive potential ecological risk index (RI) can be calculated via the following equations:

$$C_f = C_D/C_R \quad (2)$$

$$E^i_R = T^i_R \times C_f \quad (3)$$

$$R^I = \sum_{i-1}^{m} EiR \quad (4)$$

Where C_D is the measured concentration of heavy metal in each sampling station; C_R is reference value (lowest value obtained for each heavy metal was adopted). E^i_R is the potential ecological risk index of a single element; RI is a comprehensive potential ecological risk index; and T^i_R is the biological toxic factor of a single element, which is determined for Mn = 1, Zn = 1, Cr = 2, Cu = Pb = Ni = 5 and Cd = 30 (Hakanson, 1980).

Table 2: The grading of standard of potential ecological risk and comprehensive potential ecological risk index of heavy metals in soil (Jiang *et al.*, 2014)

EiR	Pollution Degree	RI	Risk Degree
EiR<30	Slight	RI<40	Slight
$30 \leq E^i_R < 60$	Medium	40≤ RI<80	Medium
$60 \leq E^i_R < 120$	Strong	80≤ RI<160	Strong
$120 \leq E^i_R < 240$	Very Strong	160≤ RI<320	Very Strong
$E^i_R \geq 240$	Extremely Strong	RI≥320	Extremely Strong

2.5. Statistical Analysis

The one-Way Analysis of Variance (ANOVA) was used to test for significant differences in the spatial variation of the heavy metal concentration using SPSS Statistical software (version 12.0). Where significant differences ($P<0.05$) among samples means were detected, the Duncan Multiple Range (DMR) test was performed to separate the means.

3. RESULTS AND DISCUSSION

3.1. Physico-chemical Parameters and Particle Content

The summary of physico-chemical parameters and the particle sizes of the sediments from Ikpoba River, Benin City, is shown in Table 3. The pH was slightly acidic across the study stations with mean values that ranged from 4.80 in station 4 to 5.96 in station 2. DMR test revealed that station 2 was higher than stations 3, 1 and 4 which were not significantly different from each other. The mean values of electrical conductivity ranged from 199.50µS/cm in station 2 to 454.00µS/cm in station 4. DMR test revealed that station 4 was significantly higher than stations 3, 1 and 2. The mean values of organic carbon was lowest (0.66%) in station 2 and highest (4.33%) in station 4. The mean values of carbon showed a significant difference when subjected to one- way Analysis of variance (ANOVA). DMR test revealed that stations 4 and 3 showed no significant difference but were higher than stations 1 and 2. The mean concentration of clay was lowest (4.50%) in station 2 and highest (8.55%) in station 4. The mean concentration of silt ranged from 1.88% in station 2 to 3.80% in station 4 while the mean values of clay varied from 87.65% in station 4 to 93.63% in station 2. DMR test further revealed that for clay and silt, stations 4, 1 and 3 were not significantly different from each other but were higher than station 2. While for sand, DMR test showed that station 2 was significantly higher than stations 1, 3 and 4.

The values obtained for the sediment's pH levels in this study were consistent with those of Ezekiel *et al.* (2011) in the study of the sediments in Sombreiro River, River State, Nigeria and those of Ogbeibu *et al.* (2014) in Benin River, Nigeria. The results from this study is in contrast with that of an earlier study by Braide *et al.* (2004) who reported an alkaline range of 6.9-7.8 from the fresh water stream of Miniweja

Stream, Rivers State. This difference may be attributed to the fact that Miniweja Stream is in urban location characterized by land drainage pollution arising from the presence of automobile workshops and commercial activities. From this study, station 4 was the most acidic, while station 2 was the least acidic. The high level of acidity in station 4 may be attributed to the high discharge of industrial effluents into the river. The wide variation recorded in the conductivity values especially at station 4 when compared with other stations can be attributed to the high amount of ionic contents present in the river which could be as a result of wastes discharged by the industries and inhabitants of the area. The values for total organic carbon recorded in this study are similar to the values (0.98-4.58%) reported by Adesuyi *et al.* (2016) for sediment of Nwaja Creek, River State, Nigeria and those (2.02-4.1%) of Ezekiel *et al.* (2011) in Sombreiro River. Sediment is a major site for organic matter which is largely carried out by bacteria, hence the variation in organic carbon content in this study may be attributed to the difference in deposition of organic matter in the various stations. The sediments of Ikpoba River comprise sand, clay and silt. This finding compared favourably with the observation of George *et al.* (2010), who reported the sediment particle size of Okpoka Creek, River State, Nigeria to consist of sand, clay and silt. The sediment particle size of this study is also similar to the report of Ajao and Fagade, (1990), who observed a wide variety of sediments in the Lagos Lagoon ranging from fine, medium and coarse sands to admixture of silt and clay which had a wide selection of habitats. The overall results of the particle size of this study indicated that Ikpoba River had high percentage of sand, followed by clay then silt (sand>clay>silt).

3.2. Heavy Metal Pollution Assessment and Ecological Risk Assessment

The summary of the heavy metals (iron, manganese, zinc, copper, chromium, cadmium, lead, nickel and vanadium) analysed across the various stations are shown in Table 4. The mean concentration of iron ranged from 177.55mg/kg in station 2 to 378.53mg/kg in station 4. The manganese mean value varied from 15.92mg/kg in station 2 to 35.00mg/kg in station 4. The mean value of zinc was lowest (24.75mg/kg) in station 2 and highest (55. 38mg/kg) in station 4. The mean concentration of chromium was lowest (1.98mg/kg) in station 2 and highest (10.78mg/kg) in station 4. The mean values of lead ranged from 1.74mg/kg in station 2 to 10.25mg/kg in station 4. Analysis of variance (ANOVA) revealed that these values showed no significant difference across the study stations. The mean values of cadmium varied from 1.91 mg/kg in station 2 to 9.34 mg/kg in station 4. The mean copper value was lowest (2.79 mg/kg) in station 2 and the highest (12.91mg/kg) in station 4. The mean concentration of nickel ranged from 0.41 mg/kg in station 2 to 1.98mg/kg in station 4. The mean value of vanadium was lowest (0.35 mg/kg) in station 2 and highest (1.39 mg/kg) in station 4. Analysis of variance these heavy metals showed significant difference from each other. Further analysis using DMR test showed that for copper and cadmium, stations 4 and 3 were not significantly different from each other than but were higher than stations 1 and 2. Also, DMR test revealed that for nickel and vanadium, station 4 was significantly higher than stations 3, 1 and 2 which were not significantly different from each other.

Heavy metal pollution assessment was carried out across the study stations for the various heavy metals analysed in the water sediment using the grading of standard of contamination degree of heavy metals by Yang *et al.* (2011). The Pollution Index (PI) values calculated for the heavy metals across the study stations ranged from values below 2 to values above 5, indicating that the sediments of the Ikpoba River is polluted (Table 5). Cadmium (Cd) and Lead (Pb) had values that were above 5 across the various stations. Thus, the sediments of Ikpoba River has very strong levels of pollution for Cd and Pb. Also, potential ecological risk (E^i_R) and comprehensive potential risk indices (RI) were calculated on the heavy metals using the grading standard by Jiang *et al.* (2014) across the study stations. The E^i_R ranged from slight degree of pollution to extremely strong degree of pollution (Table 6). Cadmium had values that were above 120, signifying that the sediments from the above study stations of Ikpoba River showed increase levels of pollution for Cadmium. This explains the reason for the high values recorded for RI, especially at stations 3 and 4.

Heavy metal pollution of rivers is a matter of great concern in any ecosystem due to their human toxicity and bio-accumulative effect. Due to this, studying the heavy metal pollution of Ikpoba River is of paramount concern. The mean concentration of iron (Fe) recorded in this study were lower when compared with the values obtained in the Benin River (Ogbeibu *et al.*, 2011) and higher when compared with the reported values obtained in Orogodo River Sediments, Delta State (Puyate *et al.*, 2007), sediments of River Ngada, Maiduguri (Akan *et al.*, 2010) and in the sediment quality of Benin River (Ogbeibu *et al.*, 2014).

Table 3: A summary of the physico-chemical parameters and particle contents of sediments from Ikpoba River

Parameters	Station 1 $\bar{x}$±SD (Min-Max)	Station 2 $\bar{x}$±SD (Min-Max)	Station 3 $\bar{x}$±SD (Min-Max)	Station 4 $\bar{x}$±SD (Min-Max)	F-value	P-value
pH	5.29±0.60^{b} (4.51-5.96)	5.96 ±0.18^{a} (5.78-6.11)	5.30 ±0.11^{b} (5.17-5.39)	4.80±0.25^{b} (4.53-5.01)	$F_{3,15}$=7.825	**0.004**
EC (µS/cm)	278.50±30.64^{b} (250.00-322.00)	199.50±36.70^{c} (162.00-250)	346.00±84.19^{b} (220.00-396.00)	454.00±60.40^{a} (370.00-498.00)	$F_{3,15}$=14.283	**0.0001**
Organic C	2.18±0.32^{b} (1.73-2.41)	0.66±0.39^{c} (0.38-1.24)	3.17±1.78^{a} (0.64-4.83)	4.33±1.36^{a} (2.28-5.10)	$F_{3,15}$=7.306	**0.005**
Clay	6.45±0.99^{a} (5.50-7.80)	4.50±0.42^{b} (4.00-4.90)	7.48±1.82^{a} (5.10-9.50)	8.55±2.25^{a} (5.40-10.40)	$F_{3,15=}$4.995	**0.018**
Silt	2.60±1.00^{b} (1.50-3.90)	1.88±0.70^{b} (1.10-2.80)	2.95±0.37^{ab} (2.50-3.40)	3.80±0.43^{a} (3.20-4.20)	$F_{3,15}$=5.644	**0.012**
Sand	90.95±1.92^{b} (88.30-92.50)	93.63±0.63^{a} (92.90-94.20)	89.58±1.68^{b} (87.50-91.50)	87.65±2.16^{c} (86.10-90.80)	$F_{3,15}$=8.748	**0.002**

*Values in bolds are significantly different; *Means with different letters along the same rows are significantly different

Table 4: A summary of the heavy metal concentrations of sediments from Ikpoba River

Parameters	Station 1 $\bar{x}$±SD (Min- Max)	Station 2 $\bar{x}$±SD (Min- Max)	Station 3 $\bar{x}$±SD (Min- Max)	Station 4 $\bar{x}$±SD (Min- Max)	F-value	P-value
Fe (mg/kg)	243.48±146.16 (114.90-411.40)	177.55±21.92 (149.00-195.30)	255.80±105.37 (154.60-391.40)	378.53±101.36 (268.60-481.10)	$F_{3,15}$=0.2.601	0.100
Mn (mg/kg)	23.01±15.35 (5.12-42.11)	15.92±4.91 (9.46-21.40)	23.40±15.19 (10.20-43.90)	35.00±17.82 (17.70-51.50)	$F_{3,15}$=1.236	0.340
Zn (mg/kg)	31.20±20.69 (13.40-59.20)	24.75±6.53 (16.70-31.50)	41.40±15.59 (21.60-59.00)	55.38±20.27 (17.70-51.50)	$F_{3,15}$=2.538	0.106
Cu (mg/kg)	5.74 ± 4.41^{b} (1.26-10.50)	2.79 ± 2.52^{b} (1.13-6.52)	7.25± 4.33^{a} (3.14-13.20)	12.91 ± 6.09^{a} (7.25-19.60)	$F_{3,15}$=3.542	**0.048**
Cr (mg/kg)	4.87±6.96 (1.11-15.30)	1.98±1.77 (0.49-4.23)	4.21±2.45 (1.68-6.67)	10.78 ± 5.07 (4.93-17.30)	$F_{3,15}$=2.713	0.092
Cd (mg/kg)	3.16± 3.77^{b} (0.35-8.56)	1.91 ± 2.36^{c} (0.38-5.39)	6.44 ± 1.91^{a} (3.94-8.42)	9.34 ± 2.68^{a} (5.88-11.50)	$F_{3,15}$=5.871	**0.010**
Pb (mg/kg)	5.34 ± 6.44 (0.40-1.28)	1.74± 1.81 (0.31-4.36)	5.84 ± 3.29 (2.34-9.13)	10.25 ± 3.04 (6.27-13.20)	$F_{3,15}$=3.006	0.072
Ni (mg/kg)	0.72 ± 0.39^{b} (0.44-1.28)	0.41± 0.38^{b} (0.00-0.82)	0.80 ± 0.27^{b} (0.50-1.06)	1.98 ± 0.82^{a} (1.43-3.19)	$F_{3,15}$=7.294	**0.005**
V (mg/kg)	0.51 ± 0.40^{b} (0.25-1.10)	0.35±0.33^{b} (0.00-0.74)	0.76 ± 0.13^{b} (0.59-0.91)	1.39±0.20^{a} (1.25-1.69)	$F_{3,15}$=10.312	**0.001**

*Values in bolds are significantly different; *Means with different letters along the same rows are significantly different

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Table 5: Heavy metal pollution Index sediments from Ikpoba River

Station	Pollution Index								
	Fe	Mn	Zn	Cu	Cr	Cd	Pb	Ni	V
Station 1	2.12	4.49	2.33	5.08	9.94	9.04	17.21	4.00	3.17
Station 2	1.55	3.11	1.85	2.47	4.05	5.44	5.60	3.04	2.88
Station 3	2.23	4.57	3.09	6.42	8.58	18.39	18.85	4.42	4.72
Station 4	3.29	6.84	4.13	11.42	22.01	26.67	33.05	10.99	8.69

Table 6: Potential ecological risk index and comprehensive potential ecological risk index

Heavy metal	Potential ecological risk index			
	E^i_R Station 1	E^i_R Station 2	E^i_R Station 3	E^i_R Station 4
Mn	4.49	3.11	4.57	6.84
Zn	2.33	1.85	3.09	4.13
Cu	25.38	12.35	32.09	57.11
Cr	19.89	8.09	17.16	44.01
Cd	271.07	163.29	551.79	800.14
Ni	20.00	15.19	22.08	54.93
Pb	86.05	27.98	94.23	165.24
RI	429.21*	231.85*	725.02*	1132.41*

Values with asterisks are comprehensive potential ecological risk index

The high values of iron recorded in this study may be due to anthropogenic contamination of the river with wastes disposed by the community which found their ways to river bottom. This observation agrees with the report of Iwuegbue *et al.* (2006) that wastes discharged into the river can lead to increased iron concentration. The values of manganese (Mn) obtained in this study were quite high when compared with the values recorded by Ogbeibu *et al.* (2014) in the sediments of Benin River. The high concentration of manganese in the sediments could be due to increased rate of effluents discharged into the river which then accumulate at the river bottom. The values of zinc recorded did not compare favourably with the mean values obtained by Iwegbue *et al.* (2007) in Ase River, Delta State. High zinc values were obtained in station 4 and this could be due to run-off water or effluent sources containing zinc compound. Copper (Cu) is found in the surface water, water sediments and underground water. Increased levels of copper have been known to cause anaemia, kidney and liver problems, stomach and intestinal irritation (Priju and Narayana, 2007). The concentration of copper in this study was low and this could be attributed to the absence of heavy industries around the study stations. In a similar study, the concentration of copper in water sediments was relatively low due to domestic wastes discharged into the river (Ayaeze, 1998). Chromium (Cr) enters the water bodies primarily from the discharge of industrial wastes and disposal of products containing the metals (Akan *et al.*, 2010). High intake of Chromium can be carcinogenic according to the World Health Organization. The high values of chromium obtained from this study, could be as a result of anthropogenic contamination of the river with clay pots containing chicken eggs and animal blood. Other sources could be from pigments for textile glass, oxidising agents and corrosion inhibitors etc. In a similar study by Okoye *et al.* (1991) on the Lagos Lagoon, it was discovered that the concentrations of chromium in the sediments collected were relatively high due to anthropogenic contamination which is mainly due to the deposition of sacrificial materials into the lagoon.

Cadmium (Cd) and its compound find their ways into the environment only from geological or human activities (metal mining, smelting and fossil fuel combustion). Cadmium and its compounds are blacklisted materials, which by international agreement may not be discharged or dumped into the environment as it is a cumulative poison that lead to liver and kidney diseases. The increased levels of cadmium in the Ikpoba

River could be attributed to the high rate of anthropogenic activities by inhabitants of the area. Lead (Pb) is toxic to humans and its major anthropogenic sources include the use of petrol additives, run-off from the cities, discharge of improperly treated waste effluents, sewage sludge and the use of pesticides containing lead components (Radojevic and Bashkin, 1999). The high concentration of lead recorded in station 4 might be due to the nature of anthropogenic activities such as the use of pesticides containing lead components. Nickel (Ni) concentrations in groundwater depend on the soil use, pH, and depth of sampling. Acid rain increases the mobility of nickel in the soil and thus might increase nickel concentrations in groundwater. Station 4 had the highest value when compared to the other stations. This can be attributed to the increased rate of anthropogenic contamination of the river with domestic waste and improper effluent discharge. High values of vanadium (V) were recorded in station 4 and this was due to domestic wastes disposal into the river by the inhabitants of the community.

Heavy metal assessment and ecological risk assessment were carried out on sediments of Ikpoba River to assess the pollution contamination of the heavy metals in the sediments. The result of the evaluation showed that the sediments of Ikpoba River is polluted with heavy metals. Extremely strong level of cadmium pollution risk has been recorded across the study stations. This poses a serious threat and pollution contamination of the benthic communities resulting in a serious adverse effect on the organisms found at the different levels of the food chain. As a result of this, there is need for continuous assessment of the Ikpoba River to reduce the risk factor of potential health hazards of the communities located close-by that depend on the river for their domestic uses.

4. CONCLUSION

The results of this study suggest that the sediments from the sampled stations in Ikpoba River are highly polluted, but whether other stations of the river are also polluted remains unclear, and therefore warrant further studies. There is need for governments and environmental agencies to take the issue of sediment degradation in Ikpoba River into serious consideration as it may pose a serious threat to the sediment communities and the surrounding environments which may further exacerbate the already worsened environmental issues in the country.

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work

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