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Full Length Research

Assessment of heavy metal concentrations in water and sediments at Motor Park and new bridge areas, lower River Benue, Ibi, Taraba, Nigeria

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ABSTRACT: Heavy metals concentration in water and sediment was investigated at the Motor Park Area and New Bridge Site of lower River Benue, Ibi, Taraba State. The heavy metals levels were examined using atomic absorption spectrophotometer (AAS) Buck Scientific model 210 VGP using spectrophotometry techniques. The highest mean concentration of Zn recorded in the sediment at the Motor Park Area was 0.55 mg/kg while the lowest value of 0.004 mg/kg was recorded for Cr at the Motor Park Area. The highest mean concentration of Mn recorded in the water was 0.375 mg/l at New Bridge Site while the lowest value of 0.00 mg/l was recorded for Cu. Values for Cu, Cd, Cr. Cu were generally low throughout the study period. There was no significant difference (p>0.005) in Zn concentrations in sediment at the sampled locations (Motor Park Area and New Bridge Site) throughout the study periods. However, Cr, Cd and Pb show variations (p<0.005) at the sampled locations. The concentration of Mn (0.375 mg/l) was not significantly different (p>0.05) from Mn (0.325 mg/l) in water between the two location, Pb value (0.343 mg/l) of water in December at the New Bridge Site exceeded the WHO recommended safe limit. However, all other metals were within the WHO and FMENV safe limit for portable drinking water. Since Pb value (0.343 mg/l) exceeded the WHO and FMENV safe limit for December. It shows that there is need for continuous monitoring of Lower River Benue waters at Ibi, Taraba State.

Keywords: Heavy metals, water, sediments, Lower River Benue.

INTRODUCTION

The aquatic ecosystem plays important role in the socioeconomic lives of the populace. The inhabitant living close to these areas depends on the water bodies for their livelihood, recreation among other things (Ndimele *et al*., 2011). Estuaries and inland water bodies which are major source of drinking water in Nigeria are often contaminated by the urban populations and industrial establishments (Ikponmwen *et al*., 2020). Increase in population, industrialization, agricultural and domestic activities have led to the pollution of the environment and subsequently increase of the problem of waste disposals and which has adversely affected man and the environment (Ndimele *et al*., 2011).

A lot of industrial effluents are emptied into the aquatic environment untreated; the products of treatment plants are still potentially harmful to aquatic organisms and human, a common component of these effluents is heavy metals (Ikponmwen and Asuelimen, 2023). Therefore, knowledge of the changing concentration and distribution of heavy metals in various component of the environment is a priority for good environmental management programmes all over the world and metals contaminant can persist for many years in sediment where they hold potential of affecting human and the environment (Mackeviciene *et al*., 2012). Sediments are important sink of a variety of pollutants, particularly heavy metals and may serve as enriched source of contaminant for benthic organisms and fish (Wang *et al*., 2017). The occurrence of higher levels of heavy metals in sediments found at the bottom of the water column can be a good indicator of non-induced pollution rather than natural enrichment of the sediment by geological weathering (Chang *et al*., 2020).

Heavy metals are classified as metals and metalloids with a specific gravity or density greater than 4 g/cm^3 or metal with high atomic weight and are toxic at elevated concentrations (Butu and Igiusi, 2013; Wangboje and Ikhuabe, 2015), they are chemical elements with a specific gravity that is at least five times the specific gravity of water. Specific gravity is a measure of density of a given amount of a solid substance when it is compared to an equal amount of water. Heavy metals including both essential and nonessential elements have a particular significance in ecotoxicology, since they are highly persistent and all have the potential to be toxic to living organisms (Olayinka-Olagunju*.,* 2021). Heavy metals such as copper (Cu), iron (Fe), chromium (Cr) and nickel (Ne) are essential metals since they play an important role in biological systems, whereas cadmium (Cd) and lead (Pb) are nonessential metals, as they are toxic, even in trace amounts (Ali *et al*., 2018).

Environmental pollution is one of the major challenges in the modern human society (Ali and Khan, 2017). Environmental contamination and pollution by heavy metals is a threat to the environment and is of serious concern (Olayinka-Olagunju*.,* 2022a). Heavy metals are persistent in the environment, contaminate the food chains, and cause different health problems due to their toxicity. Chronic2exposure to heavy metals in the environment is a real threat to living organisms (Wieczorek-Dabrowska *et al*., 2013). The use of water and sediment in heavy metals study in aquatic environment and its suitability for human use has been documented (Tukura *et al*., 2022; Ikponmwen *et al.,* 2020; Wangboje and Ikhuabe, 2015). Therefore, the objective of this study is to investigate the heavy metals concentration in water and sediment at the Motor Park Area and New Bridge Site of lower River Benue, Ibi, Taraba State.

MATERIALS AND METHODS

Collection of samples

Water samples were collected from a determined point of 15-30 cm and acidified to pH 1.5 with nitric acid after collection (APHA, 2005). They were sealed and stored in containers previously washed and rinsed with distilled water. The samples were collected monthly for a period of 3 months between October 2021 and December 2021. All samples were transported to the laboratory and stored in a deep freezer at -10°C.

Sediment samples were collected from the two sampling locations using bottom grab sampler from a determined point of 50-100 cm. They were placed in plastic bags previously soaked in nitric acid and rinsed in distilled water. Sediment samples were air- dried at a temperature of 60°C in a moisture extraction oven to constant weight. They were stored in labeled packs prior to digestion and analysis.

Digestion and analysis

The frozen water samples were allowed to thaw at room temperature (27°C) and preserved and prepared for analysis by digestion using the pre-concentrated Nitric acid method described by Wangboje *et al*. (2014), blanks were prepared using the same quantity of mixed acids.

The oven-dried sediment samples were sieved through a 200 m mesh size screen. The samples were weighed and 1 g of each sample was placed into a 250 ml flask and digested with hydrochloric acid (10 ml). The mixture was heated until a milky precipitate appears indicating complete digestion. The precipitate was then allowed to cool and made up to mark with distilled water. Blanks were prepared using the same quantity of hydrochloric acid.

Data analysis

Data were presented as means and standard deviations. Means were subjected to one way analysis of variance (ANOVA) using 9.0 statistical packages for scientist and engineers (SPSS) 2012 to determine significant differences at 5% level of probability. Significant means was subjected to Duncan Multiple Range Test (DMRT).

RESULTS

The results of heavy metals concentrations in water and sediments of lower River Benue at Ibi are presented in Table 1 to 3. The results showed mean variation of heavy metals in water and sediment, with sediments recording higher concentrations compared to water.

Mean variation of heavy metals concentrations in water between locations with time

The result of the levels of concentrations of heavy metals in lower River Benue water with time is presented in Table 2 the result showed that Mn and Zn have the highest concentration amongst other metals in both the New Bridge Site and Motor Park Area, particularly in the New Bridge Site with Mn having highest value in November (0.37 mg/l) and it least value in December (0.24 mg/l), and Zn having its highest values in October (0.10 mg/l) and its least value in November (0.05 mg/l). Cu values (0.00 mg/l) were generally lower through the study period. This study show variation with season and are lower for Pb which was

Table 1. Mean variation of heavy metals concentrations in water between locations with time.

Heavy metals	Sampling points	Monthly concentration (mg/l)			Safe limits (WHO, 2008)
		October	November	December	
Pb	Motor Park Area	0.012 ^{c} ± 0.004	0.018 ^{b} ± 0.004	0.046 ^{a} ± 0.043	0.050
	New bridge site	0.012 ^{c} ± 0.004	0.035 ^{b} ± 0.009	0.343 ^{a} ± 0.471	
Cd	Motor Park Area	0.015 ^{b} ± 0.007	0.016 ^{a} ± 0.013	0.009 ^{c} ± 0.000	0.050
	New bridge site	0.025 ^{a} ± 0.013	0.012 ^{b} ± 0.001	0.009 ^{c} ± 0.000	
Cr	Motor Park Area	0.023 ^{a} ± 0.025	0.021 ^{b} ± 0.003	0.021 ^{b} ± 0.024	10.000
	New bridge site	0.017 ^{b} ± 0.002	0.017 ^{b} ± 0.006	0.030 ^{a} ± 0.006	
Cu	Motor Park Area	0.000 ^{a} ± 0.000	0.000 ^{a} ± 0.000	0.000 ^{a} ± 0.000	20.000
	New bridge site	0.000 ^{b} ± 0.000	0.050 ^{a} ± 0.071	0.000 ^{b} ± 0.000	
Zn	Motor Park Area	0.100 ^{a} ± 0.000	0.050 ^{b} ± 0.071	0.050 ^{b} ± 0.000	40.000
	New bridge site	0.100 ^{a} ± 0.000	0.050 ^{b} ± 0.071	0.100 ^{a} ± 0.000	

Results are expressed as Mean ± Standard deviation (SD). Means having the same letters in a row are not significantly different ($p > 0.05$).

Table 2. Mean variation of heavy metals concentrations in sediment between locations with time.

Heavy Metals	Sampling points	Monthly concentration (mg/kg)			Safe limits	
		October	November	December	FAO/WHO (2004)	USEPA (2016)
Pb	Motor Park Area	0.040 ^{a} ± 0.017	0.037 ^{b} ± 0.048	0.019 ^{c} ± 0.005	35.8	40.0
	New bridge site	0.025 ^{a} ± 0.013	0.012 ^{b} ± 0.004	0.025 ^{a} ± 0.013		
Cd	Motor Park Area	0.019 ^{a} ± 0.006	0.006 ^{c} ± 0.001	0.008 ^{b} ± 0.001	0.99	0.60
	New bridge site	0.012 ^{b} ± 0.004	0.013 ^{a} ± 0.004	0.005 ^{c} ± 0.003		
Cr	Motor Park Area	0.014 ^{a} ± 0.018	0.010 ^{b} ± 0.001	0.004 ^{c} ± 0.004	43.4	25.0
	New bridge site	0.034 ^{a} ± 0.020	0.028 ^{b} ± 0.029	0.005 ^{c} ± 0.006		
Cu	Motor Park Area	0.100 ^{b} ± 0.000	0.150 ^{a} ± 0.071	0.100 ^{b} ± 0.000		16.0
	New bridge site	0.100 ^{b} ± 0.000	0.150 ^{a} ± 0.071	0.100 ^{b} ± 0.000	31.60	
Zn	Motor Park Area	0.500 ^{b} ± 0.000	0.550 ^{a} ± 0.071	0.500 ^{b} ± 0.000	121.0	110.0
	New bridge site	0.500 ^{b} ± 0.000	0.550 ^{a} ± 0.071	0.500 ^{b} ± 0.000		
Mn	Motor Park Area	0.235 ^{a} ± 0.304	0.235 ^{a} ± 0.177	0.180 ^{b} ± 0.240		
	New bridge site	0.295 ^{b} ± 0.176	0.025 ^{c} ± 0.007	0.405 ^{a} ± 0.092	–	–

Results are expressed as Mean ± Standard deviation (SD). Means having the same letters in a row are not significantly different ($p > 0.05$).

generally higher during the study period with its highest mean value in December and least mean value in October (Table 2).

Mean variation of heavy metals concentrations in sediment between locations with time

The result of the levels of concentrations of heavy metals in sediment between locations during the study period is presented in Table 1. It was generally observed from Table 1 that concentrations of heavy metals at the New Bridge Site were higher in October and December than at the Motor Park Area, but the concentrations were higher at the Motor Park Area in November than the New Bridge Site. The concentrations were highest in December, followed by October and lowest in November. Zn was generally observed at both locations (Motor Park Area and New Bridge Site) to have the same highest mean value in November (0.550 mg/kg) and the same lowest value in October and December (0.500 mg/kg) while lower mean values (0.019, 0.006 and 0.008 mg/kg) were recorded for Cd in October, November and December. Cr values were also lower with the lowest 0.004 mg/kg at the Motor Park Area.

Mean comparison of heavy metals concentrations between water and sediment with time

The mean concentrations of heavy metals between water and sediment samples of lower river Benue are presented

Table 3. Mean comparison of heavy metals concentrations between water and sediment with time.

Heavy metals	Samples	Monthly concentration			Safe limits (WHO, 2008)
		October	November	December	
Pb	Sediment (mg/kg)	$0.026^{a} \pm 0.091$	$0.025^{b} \pm 0.031$	$0.022^{c} \pm 0.009$	35.8
	Water (mg/l)	$0.009^{c} \pm 0.005$	$0.027^{a} \pm 0.011$	$0.194^{b} \pm 0.323$	0.050
Cd	Sediment (mg/kg)	$0.015^{a} \pm 0.006$	$0.009^{b} \pm 0.005$	$0.006^{c} \pm 0.003$	0.990
	Water (mg/l)	$0.020^{a} \pm 0.011$	$0.014^{b} \pm 0.008$	$0.009^{c} \pm 0.005$	0.050
Cr	Sediment (mg/kg)	$0.020^{a} \pm 0.022$	$0.019^{b} \pm 0.020$	$0.005^{c} \pm 0.004$	43.40
	Water (mg/l)	$0.020^{b} \pm 0.015$	$0.019^{c} \pm 0.004$	$0.025^{a} \pm 0.016$	10.0
Cu	Sediment (mg/kg)	$0.100^{b} \pm 0.000$	$0.150^{a} \pm 0.058$	$0.100^{b} \pm 0.000$	31.60
	Water (mg/l)	$0.000^{b} \pm 0.000$	$0.025^{a} \pm 0.050$	$0.000^{b} \pm 0.000$	20.0
Zn	Sediment (mg/kg)	$0.100^{c} \pm 0.000$	$0.550^{b} \pm 0.058$	$2.750^{a} \pm 2.600$	121.0
	Water (mg/l)	$0.333^{a} \pm 0.118$	$0.050^{b} \pm 0.058$	$0.075^{c} \pm 0.050$	40.0
Mn	Sediment (mg/kg)	$0.265^{c} \pm 0.206$	$0.285^{b} \pm 0.060$	$0.293^{a} \pm 0.198$	10.0
	Water (mg/l)	$0.348^{a} \pm 0.057$	$0.333^{b} \pm 0.118$	$0.285^{c} \pm 0.060$	

Results are expressed as Mean ± Standard deviation (SD). Means having the same letters in a row are not significantly different ($p > 0.05$).

in Table 3. It was observed that generally sediment recorded the highest mean concentration (2.75 mg/kg) for Zn in December while the lowest value 0.005 mg/kg was recorded for Cr in December. In water, the highest mean value 0.348 mg/l was recorded for Mn in October while the lowest value 0.000 mg/l was recorded for Cu in October and December. Lead (Pb) levels was below the recommended limits of 0.05 mg/L in October and November for drinking water except in December while the mean value was higher (Table 3).

DISCUSSION

The result showed that more of the metals are concentrated in sediment compared to water, with higher concentrations of most metals in water. In the recent times, Lower River Benue, Ibi has been subjected to a lot of anthropogenic pollutant capable of impairing the healthy status of the river. The study revealed all the heavy metals investigated were present in water and sediment of Lower River Benue. However, heavy metal for this study was found to be higher in sediments compare to water. This corroborates finding by Adejare *et al*. (2011) and Ambedkar *et al*. (2012) who reported similar higher values for sediment in Lagos lagoon, Ibeshe Lagos lagoon, and Gadilam River, Tamilnadu, India respectively. Higher concentration of metals in sediment compared to surface water may also be connected with the fact that pollutants discharged into the aquatic environment does not remain in aqueous phase but instead are adsorbed onto the sediments (Ikponmwen *et al*., 2020; Oguzie and Okhabguzo, 2010). Amongst all the metals analyzed, zinc (Zn) and manganese (Mn) recorded higher concentrations in water and sediment sampled. All the metals were also observed to have mean values within the WHO and FMENV recommended limits in water and sediment samples (WHO, 2008; FMENV, 2001). The level of heavy metals (Cu, Zn, Cr, Mn and Cd) recorded in water and sediment samples in this study were generally low, when compared to the USEPA (2016), WHO (2008) and FMENV (2001) recommendation. In comparison with levels in some other water bodies in other areas, Wangboje and Ikhuabe (2015) recorded higher metal levels at River Niger at Agenebode, Edo State while Wangboje and Ekundayo (2013) reported similar higher levels in Ikpoba Resevoir, Benin city. The observed low concentrations of Cu, Pb, Cd and Cr in water in this study are consistent with the finding of Obire *et al*. (2003) who observed higher values only in Cd and Pb in Elechi Creek, Port Harcourt. The high concentration of Zinc in this study during the raining season in October maybe due to enrichment from deposited effluents at this location. It could be associated with human activities, and vehicle movement that occur in the environment. Human activities such as the use of chemicals and Zinc-based fertilizers by farmers and spent engine oil wastes and petrochemicals from the nearby maize and rice milling machines (Ikponmwen and Asuelimen, 2023), welder and automobile mechanic workshops, the use of small and big boat to transport goods and people across the river could also enhance a high concentration of this metal in soils and surrounding waters. This conforms to Mgbemena *et al*. (2011) report of runoff deposit along river course as possible sources of high heavy metal content in river. The result from this study also corroborates Shanbehzadeh *et al*. (2014) who reported high Zn concentration downstream than upstream of Tembi River. In comparison to the 40 mg/L recommended as maximum limit for water (WHO, 2008), the levels recorded in water samples in this study were low with the highest concentration (0.100 mg/l), consequently, consumption of water for domestic use and drinking from Lower River Benue could not pose any Zn-induced health hazards. It is an essential mineral of importance to both plants and animal. Its deficiency may be responsible for retarded growth, loss of taste and hypogonadism, leading to decreased fertility (Olatunji-Ojo *et al*., 2019).

The level of manganese (Mn) in water samples was high especially at the New Bridge Site (Table 2). Mn is taken directly through drinking water or indirectly from fish consumption. Mn levels in water did not exceeded the WHO (2008) recommended standards of 10 mg/L. Mn is an essential micronutrient for both plants and animals. Deficiencies of Mn result in severe skeletal and reproductive abnormalities in mammals. It does not occur naturally as a metal in aquatic ecosystems. It is frequently associated with iron deposits. Mn in aquatic environments has been attributed to detrital materials, ferromanganese minerals, clay minerals and accessory sulphide minerals (Laar *et al*., 2011). Copper (Cu) is one of the metals, which are essential to human health. Its presence in the aquatic environment may be due to accumulation of domestic and agricultural wastes. Copper combines with certain proteins to produce enzymes that act as catalyst to help in the body functions and it is also necessary for the synthesis of hemoglobin (Olayinka-Olagunju, 2022b). Copper (Cu) values for this study were below the 20.00 mg/l for water and 31.60 mg/l for sediment that is the WHO (2008) permissible limit. Lead (Pb) values were below the recommended limits of 35.8 mg/kg during the study period. Lead (Pb) and cadmium (Cd) are toxic elements which have no significant biological functions and show their carcinogenic effects on aquatic biota and humans even at low exposures. Lead (Pb) exposure is known to cause musculo-skeletal, renal, ocular, neurological, immunological, reproductive and developmental effects (Ashamo *et al.,* 2017). Cadmium (Cd) like any other substance could be absorbed via the gills and has been known to cause damage to fish gills while in man, cadmium (Cd) poisoning could lead to anemia, renal damage, bone disorder and cancer of the lungs (Ashamo *et al.,* 2017). Cd levels (Table 2) recorded in water samples from the study locations were low when compared to WHO (2008) maximum permissible limit of 0.05 mg/L in drinking water and also the levels (Table 1) recorded in sediment samples from the study locations were low when compared to WHO permissible limits of 0.99 mg/L. Cd profiles recorded in this study is lower than the permissible limits, thus, consumption of water and fish from Lower River Benue could not pose any Cd-induced health hazard.

The values of the heavy metals analyzed in this study showed that bioaccumulation has occurred in the sediment but not in alarming rate. Also, the phenomenon that different metals are accumulated at different concentrations in the two locations was observed in this study. The difference in the levels of accumulation in the different locations can primarily be attributed to the differences in various activities carried out in the different locations and the effects of physiological parameters on the concentration of the metal (Ahmed *et al.,* 2014). Higher concentration of heavy metals in sediments may be due to sediments acting as sink to heavy metals and inability of the metals to dissolve in water thus got deposited in the sediment (Edward *et. al*., 2016). The New Bridge Site location has the highest concentration of all the metals, while the Motor Park Area location recorded the least value and is thus the least preferred site for bioaccumulation. This may be as a result of heavy metals leaking into the water body from the ongoing bridge construction. This study show variation with season and are lower for Pb which was generally higher during the study period with its highest mean value in December and least mean value in October (Table 2). this study corroborates with the report for heavy metal in water and sediments reported in Ovia River by Ikponmwen *et al*. (2020). These variation in values may be attributed to the large volume of effluents discharge from domestic waste and runoff from pesticide, fertilizer and diesel products which has accumulated overtime (Afzal *et al*., 2018). The concentrations of heavy metals (Cr, Pb, Cd and Cu) in this study were generally low during the study in both water and sediment. This finding corroborate report by Oguzie and Okhagbuzo (2010) at Ovia River who reported low levels of heavy metals in water compare to sediment except for Mn and Zn recorded higher levels in the water, which this may be due to dilution effect caused by rain during rainy period.

The mean heavy metals concentrations in lower River Benue showed a given pattern based on location during the study period. Generally, results showed that more of the metals were concentrated at the New Bridge Site downstream compared to the Motor Park Area, upstream. Mean metals value recorded at the new bridge site were higher compare to most values gotten at the Motor Park Area. This finding corroborated report by Mgbemena *et al*. (2011) who reported higher heavy metals downstream compare to upstream. Values obtained for Pb were generally lower during the study period except for the month of December where the limit (0.05 mg/l) recommended by WHO (2008) for portable drinking water and the (2.0 mg/kg) recommended by FAO/WHO (2004) for food and food products were exceeded.

Conclusion

The result from this study supplied valuable information on the concentrations of metals in water and sediment at the Motor Park Area and the New Bridge Site of lower River Benue, Ibi, Taraba State. Metal concentrations were within the recommended permissible limits for drinking water and sediment outlined by WHO (2008) and FMENV (2001) except lead (Pb) value (0.343 mg/l) in December which exceeded the safe limit in water. The results of this finding present a valuable baseline data on the heavy metals in the water and sediments from Lower River Benue, Ibi, Taraba State, Nigeria.

Recommendation

In line with this study, it is recommendations that regular monitoring of the heavy metals' concentrations of the water of Lower River Benue should be encouraged and carryout monthly. Usage of herbicides, pesticides should not be encouraged closed to the River.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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