integrity Research Journals

Journal of Bioscience and Biotechnology Discovery
Volume 8(4), pages 107-112, August 2023
Article Number: 15568AE93
ISSN: 2536-7064
https://doi.org/10.31248/JBBD2023.190
https://integrityresjournals.org/journal/JBBD

Full Length Research

Determination of some heavy metal concentrations in water and sediment of River Gidin Dorowa, at Gidin Dorowa, Taraba, North Eastern Nigeria

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Received 4th August 2023; Accepted 17th August 2023

ABSTRACT: This study examined some heavy metal concentrations in water and sediment of River Gidin Dorowa, Taraba, North Eastern, Nigeria. It was examined with atomic absorption spectrophometer (AAS) buck scientific model 210 VGP. Mean concentrations of metals in water and sediment showed significant ($p< 0.05$) during the study period between September, 2022 to February, 2023. Samples were collected upstream and downstream at River Gidin Dorowa. Higher mean value (0.3087 mg/l) was reported for lead (Pb) in October compare to other metals with lower value (0.1647 mg/l) recorded in November. Zinc (Zn) recorded higher value (0.1334 mg/l) in September. Cadmium (Cd) recorded higher value (0.0170 mg/l) in September and lower value (0.0027 mg/l) in February. Heavy metals in sediment showed variation ($p<0.05$) between metal during the study. Cadmium recorded higher value (0.0154 mg/kg) in December and lower value (0.0087 mg/kg) in January. Lead (Pb) value (0.6380 mg/kg) was higher in January while lower value (0.3707 mg/kg) were observed in October and November. Zinc (Zn) recorded a higher mean value (1.6667 mg/kg) in October. Copper value showed higher variation (0.4000 mg/kg) in October and lower value (0.2667 mg/kg) in February. Monthly variation between water and sediment during the study period showed higher variation (0.3910 mg/kg) for Lead (Pb) in the sediment and water value (0.2880 mg/l) in September. Copper (Cu) value (0.1000 mg/l) in water was lower than values in the sediment. Mean Cadmium value for water (0.0027 mg/l) and value (0.0100mg/kg) in sediment showed variations ($p<0.05$) in February from other metals considered. The levels of Zn, Cu, and Cd in water and sediment at Gidin Dorowa for this study were generally low compared to safe limits recommended by WHO and USEPA except values of Lead (Pb) in water. Therefore, routine monitoring of the heavy metals' concentrations in water and sediments of River Gidin Dorowa should be sustained.

Keywords: Heavy metals, Gidin Dorowa, sediment, water, Taraba.

INTRODUCTION

Exposure of the aquatic ecosystems to contaminants like heavy metals from both natural and anthropogenic activities is on the rise globally (Olayinka-Olagunju, 2021). Heavy metals may be essential or nonessential, however, at a higher concentration, both categories of metals may serve as contaminants (Olayinka-Olagunju, 2021; Elbeshti *et al*., 2018). Heavy metals like zinc, copper, iron, nickel, and chromium are known as essential while cadmium and lead are referred to as nonessential heavy metals and are hazardous at low concentrations (Abalaka *et al*., 2020). Although the occurrence of heavy metals in the terrestrial and aquatic ecosystem may arise from some natural activities such as parent soils or rocks, flooding, and anthropogenic activities like agriculture are however the primary cause of contamination in the aquatic environment (Olatunji-Ojo *et al*., 2019; Boscher *et al*., 2010). Pollutants are able to accumulate along the aquatic food chain with severe risk to animal and human health. However, bioaccumulation of heavy metals in fish can give an understanding of the long-term status of the aquatic ecosystem (Plessl *et al.,* 2017). Heavy metals may occur in aquatic environments from natural processes and from discharges or leachates from several anthropogenic activities (França *et al*., 2005). Contaminants can persist for many years in sediments where they hold potential of affecting human health, the environment and fish (Orowe and Ikponmwen, 2020; Ikponmwen *et al*., 2020). The occurrence of higher levels of heavy metals in sediments found at the bottom of the water column can be a good indicator of man-induced pollution rather than natural enrichment of the sediment by geological weathering (Chang *et al*., 2018). Metals may be present as dissolved specimen in water as free ions or forming organic complexes with humic and fulvic acids. Exposure of sediment-dwelling organisms to metals may then occur via uptake of interstitial waters, ingestion of sediment particles and via the food chain affect the diversity of aquatic organism and consequently accumulates in fish tissues due to bio-absorption process (Ahmed *et al.*, 2012). Studies on the mobility of heavy metals in sediments have shown that the mobility of heavy metals is strongly influenced by several factors, e.g. pH, redox potential, clay mineral content, organic matter content and water content. Various processes, e.g., adsorption-desorption, complex and ion-pair formation or activities of microorganisms are also involved and its consequential accumulation in water, sediments and fish (Gäbler *et al*., 1997; Galloway et al., 2012).

Heavy metals that accumulate in water and bottom sediments not only exert deleterious effects on plant growth, but also affect the soil microbial communities and soil fertility microbial biomass and enzyme activities decreased with increasing heavy metal pollution, but decreases vary depending on the types of enzymes (Smedley *et al*., 1996).The potential hazard to the marine environment of pollutants depends mostly on their concentration and persistence (Singh *et al.,* 2004). Higher levels of heavy metals in biota can have negative effects on the ecological health water, sediment, aquatic animal species and may contribute to declines in their populations (Luo *et al*., 2014). Thus, this study examined some heavy metal concentrations in water and sediment at River Gidin Dorowa, Taraba, North Eastern Nigeria.

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 upstream and downstream at river Gidin Dorowa for a period of 6 months between September, 2022 and February 2023. All samples were transported to the laboratory and stored in a deep freezer at -5°C prior to further analysis method described by Wangboje *et al*. (2014).

Sediment samples were collected from the two sampling locations (upstream and downstream) 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.

Preparation of samples

The frozen water samples were allowed to thaw at room temperature (27°C) and preserved and prepared for analysis using the pre-concentrated Nitric acid method described by Edward *et al*. (2013). Blanks were prepared using the same quantity of mixed acids.

The oven-dried sediment samples were sieved through a 160 μm 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.

Statistical analysis

Data was presented as means and standard deviations. Means were subjected to one way analysis of variance (ANOVA) using 9.0 statistical packages for the social sciences (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 the investigation of heavy metals concentrations in water and sediments (upstream and downstream) at River Gidin Dorowa at Gidin Dorowa, Taraba, North Easter Nigeria are presented in Tables 1 to 3.

Mean variation of heavy metals concentrations in water during the study

The result of the mean concentrations of heavy metals in water from the sampling locations during the study period is presented in Table 1. It was generally observed that

Table 1. Mean monthly heavy metal variations (mg/l) in water during the study period.

Months	Concentration of heavy metals in water (mg/l)			
	Cd	Pb	Zn	Cu
September	0.0170±0.0062[a]	0.2880±0.0410[a]	0.1334±0.03341[a]	0.1000±0.00001[a]
October	0.0057±0.00208[b]	0.3087±0.0944[a]	0.1000±0.00001[a]	0.1000±0.00001[a]
November	0.0057±0.0009[b]	0.1647±0.0544[b]	0.1000±0.00001[a]	0.1000±0.00001[a]
December	0.0124±0.0035[a]	0.2264±0.074[a]	0.1000±0.00001[a]	0.1000±0.00001[a]
January	0.0080±0.0027[b]	0.1854±0.0356[b]	0.1000±0.00001[a]	0.1000±0.00001[a]
February	0.0027±0.0007[c]	0.2677±0.0740[a]	0.1000±0.00001[a]	0.1000±0.00001[a]
WHO,2008	0.05	0.05	40.0	20.0

Values are presented as mean ± S.E.M. Values with different superscript across the columns indicates a level of significance at ($p<0.05$).

Table 2. Heavy metal concentration in sediment during the study period.

Months	Concentration of heavy metals in sediment(mg/kg)			
	Cd	Pb	Zn	Cu
September	0.0127±0.0044[a]	0.3910±0.0410[a]	1.6334±0.8820[a]	0.3334±0.0334[a]
October	0.0130±0.0048[a]	0.3707±0.1554[a]	1.6667±0.0882[a]	0.4000±0.0578[a]
November	0.0150±0.0020[a]	0.3707±0.0944[a]	1.5000±0.1528[a]	0.3334±0.0334[a]
December	0.0154±0.0064[a]	0.5764±0.0204[b]	1.5334±0.0667[a]	0.3334±0.0334[a]
January	0.0087±0.0034[a]	0.6380±0.1091[b]	1.5334±0.2604[a]	0.3334±0.0882[a]
February	0.0100±0.0033[a]	0.5350±0.0742[b]	1.5334±0.1453[a]	0.2667±0.0334[b]
USEPA,2016	0.6	40.0	110.0	16.0

Values are presented as mean ± S.E.M. Values with different superscript across the columns indicates a level of significance at ($p<0.05$).

concentrations of heavy metals showed level of significant ($p<0.05$) during the study period (Table 1). Higher mean value (0.3087 mg/l) was reported for lead (Pb) in October while lower value (0.1647 mg/l) was recorded in November. Higher value (0.1334 mg/l) for Zinc (Zn) was recorded in the month of September while lower value (0.1000 mg/l) was recorded for the other months throughout the study period. Cadmium (Cd) recorded higher value (0.0170 mg/l) in September while a lower value (0.0027mg/l) was recorded in the month of February. Copper (Cu) recorded a value of 0.1000 mg/l throughout the study period (Table 1).

Heavy metal concentration in sediment during the study period

The result of mean heavy metal concentration in sediment during the study period showed that there was variation ($p<0.05$) between metal with month (Table 2). Cadmium recorded higher value (0.0154 mg/kg) in December while it recorded a lower value (0.0087 mg/kg) in January. Lead (Pb) showed higher variation (0.6380 mg/kg) in the month of January while it recorded lower value (0.3707 mg/kg) in the month of October and November. Higher mean value (1.6667 mg/kg) for Zinc (Zn) was recorded in the month of October while lower value (1.5000 mg/kg) was recorded in the month of November. Copper value showed higher variation (0.4000 mg/kg) in the month of October while it recorded lower value (0.2667 mg/kg) in the month of February (Table 2).

Mean monthly variation between water and sediment during the study period

The result of mean monthly variation between water and sediment during the study period is presented in Table 3. The result showed that higher variation (0.3910 mg/kg) for Lead (Pb) in the sediment and water value (0.2880 mg/l) in September for copper (Cu) while sediment value for Cadmium (0.0127 mg/kg) and lower variation (0.1000mg/l) in water was recorded and was observed in the month of September. Value (0.0124 mg/l) for water and sediment value (0.0154mg/kg) for the month of December showed significance ($p<0.05$) from the months of September, October, November, January and February. Cadmium mean value (0.0027mg/l) for water and value in sediment (0.0100mg/kg) showed significant difference ($P<0.05$) in February compared to other metals considered (Table 3).

Table 3. Mean monthly variation between water and sediment during the study period.

Metals	Months of sample collection					
	September	October	November	December	January	February
Cd/W	0.017±0.0062[a]	0.0057± 0.0028[a]	0.0057±0.0009[a]	0.0124±0.0035[a]	0.0080±0.0027[a]	0.0027±0.0007[b]
Cd/S	0.0127±0.0044[a]	0.0130±0.0048[a]	0.0150±0.0020[b]	0.0154±0.0064[a]	0.0087±0.0034[a]	0.0100±0.0033[a]
Pb/W	0.2880±0.041[b]	0.3087±0.0944[a]	0.1647±0.0544[a]	0.2264±0.074[a]	0.1854±0.0356[a]	0.2677±0.0740[b]
Pb/S	0.3910±0.0410 [a]	0.3707±0.1554[a]	0.3707±0.0944[b]	0.5764±0.0204[b]	0.6380±0.1091[b]	0.5350±0.0742[a]
Zn/W	0.1334±0.0334[b]	0.1000±0.00001[a]	0.1000±0.00001[a]	0.1000±0.00001[a]	0.1000±0.00001[a]	0.1000±0.00001[b]
Zn/S	1.6334±0.8820[a]	1.6667±0.0882[b]	1.5000±0.1528[b]	1.5334±0.0667[b]	1.5334±0.2604[b]	1.5334±0.1453[a]
CuW	0.1000±0.0001[b]	0.1000±0.00001[a]	0.1000±0.00001[a]	0.1000±0.00001[a]	0.1000±0.00001[a]	0.1000±0.00001[b]
Cu/S	0.3334±0.0334 [a]	0.4000±0.0578[b]	0.3334±0.0334[b]	0.3334±0.0334[b]	0.3334±0.0882[b]	0.2667±0.0334[a]

Values are presented as mean ± S.E.M. Values with different superscript across the columns indicates a level of significance at ($p<0.05$).

DISCUSSION

Mean variation of heavy metals concentrations in water during the study

The result of the mean concentrations of heavy metals in water during the study period (Table 1) showed that concentrations of heavy metals showed level of significant ($p<0.05$) with month. Higher mean value (0.3087 mg/l) was reported for lead (Pb) in October compare to other metals while lower value (0.1647 mg/l) was recorded in November. While various metals undergo similar reactions in a number of aspects, the extent and nature of these reactions varies under particular conditions (Mulligan *et al*., 2011; Shen *et al*., 2015). Studies on the mobility of heavy metals in soils have shown that the mobility is strongly influenced by several factors, e.g seasonal variation, pH, redox potential, clay mineral content, organic matter content and water content. Various processes, e.g., adsorption-desorption, complex and ion-pair formation or activities of microorganisms are also involved and its consequential accumulation in fish (Gäbler *et al*., 1997). Simple and complex cations are the most mobile, exchangeable cations in organic and inorganic complexes are of medium mobility and, chelated cations are slightly mobile (Kelly *et al*., 2013). Higher value (0.1334 mg/l) for Zinc (Zn) was recorded in September while lower value (0.1000 mg/l) was recorded for October, November, December, January and February. Cadmium (Cd) recorded higher value (0.0170 mg/l) in September while a lower value (0.0027 mg/l) was recorded in the month of February. Copper (Cu) recorded a value of 0.1000 mg/l throughout the study period. Values obtained for Pb were generally higher during the study period compared to other metals investigated, studies have shown that Pb has numerous detrimental effects on human and animal health even at low concentrations. In addition, long-term exposure to Pb may cause death or impairment to the central nervous system, the brain, kidneys, and liver and could be genotoxic (Olayinka-Olagunju, 2021). On the other hand, in children, lead (Pb) has a poisonous effect. Results of this study corroborate the findings of other researchers (Olayinka-Olagunju *et al.,* 2021; Falowo *et al*., 2017; Ogunbileje *et al.,* 2013). However, Lead (Pb) values were higher when compared to recommendation by World Health Organization (WHO) (2008) for portable drinking water but was within the (2.0 mg/kg) recommended by Food and Agricultural Organization (FAO)/World Health Organization (WHO) (2004) for food and food products.

Heavy metal concentration in sediment during the study period

The result of mean heavy metal concentration in sediment during the study period showed that there was variation ($p<0.05$) between metal with month (Table 2). Cadmium recorded higher value (0.0154 mg/kg) in December while it recorded a lower value (0.0087 mg/kg) in January. Lead (Pb) showed higher variation (0.6380 mg/kg) in the month of January while it recorded lower value (0.3707 mg/kg) in the month of October and November. Persistent pollutants, such as heavy metals, can remain in the environment unchanged for years and thus may pose a threat to man and other organisms. Many of the heavy metals are toxic to organisms at low concentrations. However, some heavy metals, such as copper and zinc are also essential elements (Plessl *et al.,* 2017). Concentrations of essential elements in organisms are normally controlled, with uptake from the environment regulated according to nutritional demand. Effects on the organisms are manifest when this regulation mechanism breaks down as a result of either insufficient (deficiency) or excess (toxicity) metal (Duffus, 2012). Copper is one of several heavy metals that are essential to life despite being as inherently toxic as non-essential heavy metals exemplified by Lead (Pb) and Mercury (Hg) (Scheinberg, 2011). Higher mean value (1.6667 mg/kg) for Zinc (Zn) was recorded in the month of October while lower value (1.5000 mg/kg) was recorded in the month of November.

Copper value showed higher variation (0.4000 mg/kg) in the month of October while it recorded lower value (0.2667 mg/kg) in the month of February. All the metals were also observed to have mean values within the WHO and USEPA recommended limits in water and sediment samples (WHO, 2008; USEPA, 2016).

Mean monthly variations of heavy metals concentrations in water and sediment of River Dorowa

Heavy metals concentrations in water and sediments from River Gidin Dorowa shows that heavy metals concentrations were higher in sediments compare to water during the study period (Table 3). The ranking order of metals in this study for surface water was Pb>Zn>Cd >Cu while sediments was Zn>Pb>Cu>Cd. These results are consistent with those of Adesuyi *et al.* (2015) and Onjefu *et al*. (2017) except in water where Lead (Pb) value recorded higher value. This study corroborate report by Olayinka-Olagunju (2022) who also observed higher concentrations of heavy metals in sediment compare to water sample. This study implied that all benthic organism in this site might be affected by Cd, Pb and Zn. This study however differs from the opinion of Olayinka-Olagunju *et al.* (2021) who reported moderate level of heavy metals in water and sediments samples examined at Ogbese River. The result showed higher variation (0.3910 mg/kg) for Lead (Pb) in the sediment and water (Table 3). Values recorded for heavy metal for this study showed higher concentration (0.3910 mg/kg) for lead (Pb) in sediments compare to water. This corroborates the findings of Abalaka (2015) and Ladigbolu *et al*. (2011) who reported similar higher values metals for sediment in Lagos lagoon, Ibeshe Lagos lagoon, and Gadilam River, Tamilnadu, India respectively. Lead (Pb) has been shown to be linked to anthropogenic activities such as cement production, battery, e-waste, etc (Ogunbileje *et al.,* 2013). Results from this study also showed copper (Cu) value in water was 0.2808 mg/l while value for sediment was 0.0127 mg/kg. Cadmium value in sediment showed lower variation (0.1000 mg/l) compare to water during the month of September. Mean value (0.0027 mg/l) in water and sediment value (0.0100 mg/kg) of Cadmium for water showed significant difference ($p<0.05$) in February from other metals under consideration. Sediment has been known to be the major depository of metals holding more than 99 percent of total amount of a metal present in the aquatic system (Ikponmwen *et al*., 2020; Smedley *et al.,* 1996). Higher concentration of metals in the sediment more than in 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. Amongst all the metals analyzed, Zn and Cu were observed to have the highest concentrations in all the water and sediment samples. All the metals were also observed to have mean values within the WHO and USEPA recommended limits in water and sediment samples (WHO, 2008). The level of heavy metals (Zn, Cu and Cd) in water and sediment for this study were generally low compared to values recommended by World Health Organization (WHO) (2008) in water and United States Environmental Protection Agency (USEPA) (2016) for sediments except for lead (Pb) values in water which were higher.

Conclusion

Conclusively, to avoid serious environmental risk with time, there is a need to institute proper water pollution control measures and management at River Gidin Dorowa. With this in mind, the following recommendations are necessary, monitoring of the heavy metals' concentrations of the water of River Gidin Dorowa should be encouraged and carryout regularly. The use of herbicides, pesticides and fertilizers close to River Gidin Dorowa should be discouraged because agricultural runoff may likely be a major source of heavy metals contamination of the river.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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