Original Research Article

Evaluation of Heavy Metal Concentrations in Subsurface Water and Bottom Sediments of the Lower River Niger in Southern Nigeria

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Abstract

The concentrations of some heavy metals in water and sediments of the lower River Niger at three locations (Illah, Asaba and Okpai) were investigated for sixteen (16) months (January, 2014 – April, 2015). Subsurface water and bottom sediments were collected monthly and analyzed using standard methods for Chromium (Cr), Manganese (Mn), Iron (Fe), Copper (Cu), Zinc (Zn), Lead (Pb) and Cadmium (Cd). Data collected were statistically analyzed using Analysis of Variance (ANOVA) and means separated with LSD. Results showed that except for Pb and Cd, there were significant differences ($P < 0.05$) in the mean concentrations of the other metals among the stations. The mean concentrations of heavy metals in the bottom sediments (mg/kg) were higher than those of the subsurface water (mg/l). The results also showed that apart from Cadmium, where the concentration of 0.001 mg/l was lower than the 0.003 mg/l acceptable limit for drinking water, concentration of the other metals in the subsurface water and bottom sediments were above the acceptable limits for drinking water. Thus showing that water in the lower River Niger is highly polluted and not fit for drinking.

Keywords: Heavy metals, Concentrations, water, bottom sediments

Introduction

Water is an aquatic resource used beneficially by man in many areas of life, and being a universal solvent, many chemical substances dissolve in it. Anthropogenic pollutants are channeled into the aquatic environment, where they result in chronic stress conditions with the attendant negative effects on aquatic life. Amongst the pollutants are those of metals known to adversely affect the dynamics of the ecosystem (Amoo *et al.*, 2005).

The demands for metal-bearing compounds in a wide range of manufacturing industries, and the fabrication of metal artifacts have an increasing relationship with the mobilization of metals to the environment. These anthropogenic activities continuously increase the amount of heavy metals in the aquatic ecosystem. Pollution levels by these heavy metals are not only growing at an alarming rate but have become a world-wide problem, because the metals are non-degradable and so persist in the environment (Malik *et al*., 2010; Adebayo *et al.,* 2017). Heavy metal discharges, as effluents from industries, run-offs, and as domestic and agricultural wastes are deposited in coastal waters and rivers resulting in elevated levels of heavy metals in them (Okoro, 2012). Some examples of heavy metals are Lead (Pb), Zinc (Zn), Cadmium (Cd), Copper (Cu), Iron (Fe), Manganese (Mn) and Mercury (Hg). Most of these heavy metals are toxic to aquatic organisms even at low concentrations. Generally, substances which are natural products break down when they enter the environment or persist for long periods, without harm to living things or amenities. This is however not frequently the case with chemical substances such as polychlorinated biphenyls, heavy metals and the non-degradable detergents. The concentrations of heavy metals in the aquatic ecosystem may be increased beyond the natural or acceptable levels due to agricultural and industrial effluents. These metal substances find their way into water habitats, where they bond with fine insoluble particles like silt and colloids, forming complex compounds which settle to the bottom as sediments. These metal complexes may be absorbed or ingested by the aquatic flora or fauna.

Some heavy metals constitute a hazard in the food chains relationship. This occurs when they combine with organic radicals as in sludge on river or sea-beds, forming stable chemicals which are fat soluble, stable chlorinated compounds and chelating agents. While some of the heavy metals may be transported through the water bodies, others may be deposited in the sediments (Idodo-Umeh, 2005). Consequently, increasing mobilization of heavy metals and other pollutants to the riverine environment remains a cause for concern. The problem is further exacerbated by the fact that these metals are easily assimilated and bio-accumulated in the protoplasm of aquatic organisms (Wogu and Okaka, 2011). `The untold hazards are that they are ultimately transferred to man. The increasing pollution-related activities on the River Niger due to heavy metal contamination especially with respect to the water quality, bottom sediments and even the aquatic life, gives reason for much concern. In pollution studies, water and sediment are often used as indicators of the level of pollution in a water body. Thus, the aim of this study was to ascertain the level of heavy metals contamination of subsurface water and bottom sediment of the lower River Niger.

Materials and Methods

Study Area:

River Niger is one of the principal rivers in West Africa, extending over 4,180 km. It runs in a crescent through Guinea, Mali and Niger on the North border with Benin and then southwards through Nigeria (Okoro, 2012). The river has River Benue which merges with it at Lokoja as its major and most important tributary. River Niger, then flows predominantly southwards from the confluence with the Benue, and finally discharges into the Gulf of Guinea, and then into the Atlantic Ocean through a network of outlets that constitute an extensive delta known as the oil rivers. The study area is on the lower River Niger from Illah, through Asaba/Onitsha to Okpai on latitude 5^0 40’ to 6^0 25’N and longitude $6^0$37’ to 6^0 47’E of the equator. The study area is underlaid by three subsurface depositional rock strata, namely the Benin, Ogwashi-Asaba and Ameki rock formations (Okagbare, 2004). It is characterized by flowing water, and is affected by surface run-off during the rainy season from the catchment area of the river, especially in the Asaba/Onitsha axis where a lot of developmental projects are on-going. At the Okpai end, there were oil exploration activities going on. The climate of the area is stable with two distinct seasons (rainy and dry seasons).

Sampling:

Three sampling stations (Illah, Asaba/Onitsha and Okpai) along the lower River Niger, were purposefully chosen for the study. The study lasted for 16 months (January, 2014 to April, 2015). Subsurface water and bottom sediments were collected once monthly from the study stations between 8.30 and 10.00am on sampling days using a motorized canoe. Water samples were collected in 250ml polypropylene sampling bottles using a hydro-bios water sampler. Water collected was fixed with concentrated tri-oxonitrate (5) acid, stored in an iced chest and transported to the laboratory for analysis.

Bottom sediment samples were collected from each station with the aid of bottom sediment "Eckman Grab" attached to a polypropylene rope. Both subsurface water and bottom sediment samples were analyzed in the laboratory according to standard methods (APHA, 1989).

Statistical Analysis:

Data collected from subsurface and bottom sediments were analyzed using the Students t-test, while those from different locations were analyzed using analysis of variance, and means were separated using the least significant difference (LSD) (SAS, 2010). Level of probability for both tests was put at 5%.

Results and Discussion

Results of the heavy metal contents of subsurface water and bottom sediment samples, and in the different locations along the lower River Niger are presented in Tables 1 and 2. The mean concentrations of heavy metals in subsurface water (mg/l) and bottom sediment (mg/kg) (Table 1) indicate that there were significantly ($P<0.05$) lower mean concentrations of the heavy metals in subsurface water than in bottom sediments in the study area. This result is similar to that obtained

Table 1: Mean concentrations of heavy metals in bottom sediment (mg/kg) and subsurface water (mg/l).

	Concentrations of heavy metals in sediment and subsurface water							
Parameter	Cr	Mn	Fe	Cu	Zn	Pb	Cd	Hg
Bottom Sediment	0.34	5.59	35.27	6.37	4.48	0.07	0.008	ND
Subsurface Water	0.01	0.24	0.98	0.39	0.28	0.01	0.001	ND
Significance	*	*	*	*	*	*	*	ns
WHO	0.05	0.1 – 0.5	0.3	1.2	3.0	0.01	0.003	

WHO = World Health Organization; * = $p< 0.05$; ns = not significant; ND = Not detected by Opaluwa *et al*. (2012) in their study on the assessment of heavy metals in subsurface water, fish and sediments from Uke stream, Nasarawa State. They reported higher concentrations of heavy metals in the sediments compared to subsurface water. Mean values of heavy metal concentration in the bottom sediment ranged from 0.008 mg/kg to 35.27 mg/kg while those in the subsurface water ranged from 0.001 mg/l to 0.98 mg/l. The order of heavy metal concentrations in the bottom sediments were Fe (35.27mg/kg), followed by Cu (6.37mg/kg) to Cd (0.008 mg/kg) which was the least.

In the subsurface water column, the heavy metal concentrations followed the same pattern as in the bottom sediments. Fe with a concentration of 0.98 mg/l, was the metal with the highest concentration. This was followed by Cu (0.39 mg/l), while Cd (0.001 mg/l) was the least. Just like was reported by Opaluwa *et al*. (2012), mercury (Hg) was not detected in the subsurface water and bottom sediment in this study.

Presented in Table 2, are the mean concentrations (mg/kg) of the heavy metals in the three study locations of Illah, Asaba/Onitsha and Okpai. The range of heavy metal concentrations in the three locations were Illah (0.0001 mg/kg – 18.74 mg/kg), Asaba/Onitsha (0.005 mg/kg – 19.91 mg/kg) and Okpai (0.007mg/kg – 15.95 mg/kg). A comparison of the mean heavy metal concentrations, showed that there were no significant ($P > 0.05$) differences in the concentrations of Lead (Pb) and Cadmium (Cd) in the three study locations. However the other metals, Cr, Mn, Fe, Cu and Zn showed significant ($P < 0.05$) variations in concentration among the locations.

Table 2: Mean concentrations of heavy metals in the three sampling stations (mg/kg).

	Concentrations of Heavy Metals (mg/kg)							
Locations	Cr	Mn	Fe	Cu	Zn	Pb	Cd	Hg
Illah	0.18	2.76	18.74	5.86	1.78	0.03	0.0001	ND
Asaba/Onitsha	0.22	3.41	19.91	12.92	2.66	0.05	0.005	ND
Okpai	0.15	2.58	15.95	6.36	3.25	0.05	0.007	ND
LSD ($P<0.05$)	0.11	1.71	3.07	5.66	0.10	0.03	0.002	

ND = Not Detected
LSD = Least Significant Difference

Apart from Okpai station, where Zinc (Zn) with the highest mean concentration of 3.25 mg/kg was recorded, Asaba/Onitsha had the highest mean concentrations for the other heavy metals. The reason for this could be the urbanized nature of Asaba/Onitsha with its attendant industrial activities and the resultant discharge of effluents into the River Niger at that point. In all three stations, the concentrations of Iron (Fe) were higher than those of any of the other metals detected. This pattern was also reported in studies by Adebayo *et al*. (2017) on limnological assessment of heavy metal concentrations in water and sediment of Oguta Lake, south – east Nigeria, and that of Wogu and Okaka (2011), on heavy metals in surface water of Warri river, Delta State.

The high concentrations of heavy metals in the bottom sediments reported in this study followed the general principle of sediments absorbing and accumulating these metals. These metals are only released after their maximum absorption limits have been exceeded, hence the higher concentrations of the metals in the bottom sediments compared to the subsurface water samples (Adebayo *et al*., 2017). Apart from Cadmium, where the concentration of 0.001 mg/kg was lower than the 0.003 mg/kg acceptable limit for drinking water (WHO, 2003), concentrations of the other metals in the water and sediments were above acceptable limits for drinking water.

Conclusion

The results of this study have provided information on the level of pollution of the lower River Niger with heavy metals. From all indications, the lower River Niger is highly polluted, and so water from it is not fit for human and animal consumption.

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