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Full Length Research Paper

Heavy metals in sediments from River Ngada, Maiduguri Metropolis, Borno State, Nigeria

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The objective of this research was to determine the degree of heavy metal contamination in River Ngada and the extent to which the sediment quality of the river had deteriorated. In this study, metals such as Cu, Zn, Co, Mn, Mg, Fe, Cr, Cd As, Ni and Pb in the sediments were determined using Perkin-Elmer Analyst 300 Atomic Absorption Spectrophotometer. The extent of sediment quality deterioration was observed in all the sampling points to be higher with respect to all the metals studied. The levels of the above metals increased with an increase in distance from point S_1 to S_8. The metals also increased with increasing sediment depth, indicating age-long accumulation of heavy metals from anthropogenic sources. The study revealed that the levels of all the metals studied were higher than the WHO's standard sediment guideline limits. If this trend is allowed to continue unabated, it is most likely that the food web in this study environment might be at highest risk of induced heavy metal contamination.

Key words: Heavy metals, sediments, deterioration, food web, pollution.

INTRODUCTION

Heavy metals are elements having specific gravity greater than 4.0 that is, at least 5 times that of water. Heavy metals exist in water, in colloidal, particulate and dissolved forms (Adepoju-Bello et al., 2009). Their occurrence in water bodies are either of natural origin (eroded minerals within sediments, leaching of ore deposits and volcanism-extruded products) or of anthropogenic origin (solid waste disposal, industrial or domestic effluents, harbour channel dredging) (Marcovecchio et al., 2007). Some of the metals such as calcium, magnesium, potassium and sodium are essential to sustaining life and must be present for normal body functions. While others such as cobalt, copper, iron, manganese, molybdenon and zinc are needed at low levels as catalyst for enzyme activities (Adepoju-Bello et al., 2009). Excess exposure to these essential metals can however, be toxic. Water has unique chemical properties due to its polarity and hydrogen bonds which makes it is able to dissolve, absorb, adsorb or suspend many different compounds (WHO, 2007). Thus, in nature, water is not pure as it acquires contaminants from its surrounding and those arising from humans and animals as well as other biological activities (Mendie, 2005).

Heavy metals can cause serious health effects with varied symptoms depending on the nature and quantity of the metal ingested (Adepoju-Bello and Alabi, 2005). The most common heavy metals that humans are exposed to are aluminium, arsenic, cadmium, lead and mercury. Aluminium has been associated with Alzheimer's and Parkinson's disease, senility and presenile dementia. Arsenic exposure can cause among other illnesses or symptoms, cancer, abdominal pain and skin lesions. Cadmium exposure produces kidney damage and hypertension. Lead is a cumulative poison and a possible human carcinogen (Bakare-Odunola, 2005) while for mercury, toxicity results in mental disturbane and impairment of speech, hearing, vision and movement (Hammer and Hammer, 2004). In addition, lead and mercury may cause the development of autoimmunity in which a person's immune system attacks its own cells. This can lead to joint diseases and ailment of the kidneys and circulatory system and neurons. At higher concentrations, lead and mercury can cause irreversible brain damage.

Sediments represent significant sources of heavy metal

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pollution in the aquatic environment as a result of changes in pH, redox potential, diagenisis or physical perturbations within their primary sedimentary sinks. The occurrences of enhanced concentrations of heavy metals especially in sediments may be an indication of human-induced perturbations rather than natural enrichment through geological weathering (Davies et al., 1991; Binning and Baird, 2001; Eja et al., 2003). Heavy metals are non-biodegradable and they persist in the environment and may become concentrated up the food chain (Eja et al., 2003), leading to enhanced levels in liver and muscle tissues of fishes (Eja et al., 2003), aquatic bryophytes (Mouvet et al., 1993) and aquatic biota (Ramos et al., 1999). It therefore means that the biota and water quality of an aquatic ecosystem could determine the quantitative and qualitative levels of heavy metals in tissues of fauna and flora of the ecosystem. Heavy metal distribution and bioavailability in both sediments and the overlying water column have to be considered to obtain a better understanding of inter-actions between the organisms and their environment.

Sediments are ecologically important components of the aquatic habitat, which play a significant role in maintaining the trophic status of any water body (Singh et al., 1997). Sediments near urban areas commonly contain high levels of contaminants (Cook and Wells, 1996; Lamberson et al., 1992) which constitute a major environmental problem faced by many anthropogenically impacted aquatic environments (Magalhaes et al., 2007). Sediments in rivers do not only play important roles at influencing the pollution, they also record the history of their pollution. Sediments act as both carrier and sources of contaminants in aquatic environment (Shuhaimi, 2008). The contamination of sediments with heavy metals, may lead to serious environmental problem (Loizidou et al., 1992). Heavy metals may adsorb onto sediments or be accumulated by the benthic organisms; their bioavailability and toxicity depend upon the various forms and amount bound to the sediment matrices (Chukwujindu et al., 2007). Additionally, pollutants released to surface water from industrial and municipal discharges, atmospheric deposition and run off from agricultural, urban and mining areas can accumulate to harmful levels in sediments (Chukwujindu et al., 2007). In view of growing concern over the use of River Ngada by resident along the river banks and the fauna and flora of the ecosystem, this study is aimed at assessing the quality of sediment from River Ngada.

MATERIALS AND METHOD

Study area

River Ngada is located in Maiduguri Metropolis, Borno State, Nigeria. The river is used for various human activities including fishing, vegetables irrigation, bricks making and by residences along the river banks for bathing, washing and as drinking water by animals. The river originates from Rivers Yedzram and Gombole which meet at a confluent at Sambisa both in Nigeria and flows as River Ngada into Alau Dam and stretches down across Maiduguri Metropolis then empties into Lake Chad. The river receives copious amounts of wastes from residential houses and abattoirs sited along its course. Urban waste management and garbage disposal practices in the city are very poor. Treated water from the Municipal waste and Abattoir located near the river contains large amounts of heavy metals, which when in super abundance may cause disruption to the ecological balance of the river (Akan et al., 2011).

Sample area and collection points

Sediment samples from River Ngada were collected and labelled S_1 to S_8 along the river course corresponding to the points where notable discharge of wastewater into River Ngada occurs (Figure 1). Samples were collected from Alau Dam bridge (S_1); the point of discharge of wastewater from the water treatment plant (S_2) 100 m away from water treatment plant (S_3), the Lagos bridge (S_4), the Gwange bridge (S_5), the Custom bridge (S_6); the point of discharge of Abattoir wastewater into River Ngada (S_7) is 2 km after discharge of Abattoir wastewater into River Ngada (S_8). At each sampling point, sediments were collected using Van-Veen grab sampler at a depth of 0-5, 5-10, 10-15, and 15-20 cm respectively. Sediment samples were then preserved in plastic bags, transported to the laboratory and kept frozen in the refrigerator pending analyses.

Sample preparation

All the sediment samples were oven-dried at 80 to 100°C. The dry samples were gently crushed and sieved to collect the < 63 µm grain size. Two grammes of each sediment sample were weighed into a pre-weighed dry crucible. The crucibles were covered and placed in a muffle furnace and the temperature gradually increased to 500°C for 2 h (Radojevic and Bashkin, 1999). The samples were removed and cooled to room temperature in desiccators. The ash samples were placed into acid-washed glass beakers. Sediment samples were digested by the addition of 10 ml of 0.25 M HNO_3, heated to dryness and thereafter 10 ml of 0.25 M HNO_3 and 3 ml of $HClO_3$ were added. The solution was then heated in a fume chamber. Sample solutions were obtained by leaching the residues with 4.0 ml of HCl and thereafter filtered and diluted with distilled water to 100 ml mark (Radojevic and Bashkin, 1999). Blank solutions were handled as detailed for the samples. All samples and blanks were stored in plastic containers. Determination of Cu, Zn, Co, Mn, Mg, Fe, Cr, Cd As, Ni and Pb were made directly on each final solution using Perkin-Elmer Analyst 300 Atomic Absorption Spectrophotometer (AAS).

Statistical analyses

Data collected are presented as mean and standard deviation and were subjected to Pearson's correlation analysis, while one-way analysis of variance (ANOVA) ($P < 0.05$) was used to assess whether heavy metals varied significantly between sampling depths and points. All statistical analysis was performed with SPSS 9.0 for Windows (Ozdamar, 1991).

RESULTS

The concentrations of heavy metals in sediment at different depths at point S_1 are presented in Table 1. The concentrations of Cr range from 28.87±0.02 to 45.14±0.02 µg/g; Pb from 54.33±0.01 to 71.23±0.11µg/g;

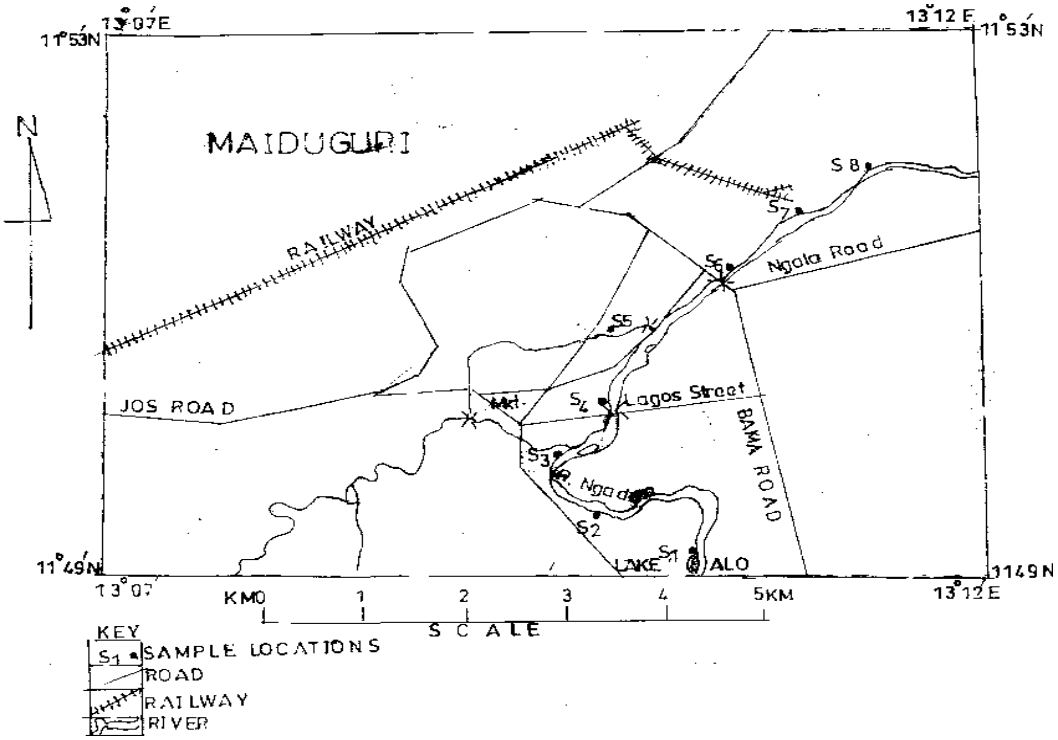

Figure 1. Map of the study area showing sample location.

Cu from 26.32±0.02 to 51.32±0.01 µg/g; Fe from 31.87±0.21 to 58.34±1.01 µg/g; Ni from 24.31±0.22 to 39.45±0.41 µg/g; Co from 12.45±0.05 to 28.34±0.21 µg/g; Mn from 43.11±0.11 to 154.34±0.10 µg/g; Cd from 7.34±0.02 to 19.34 ±0.09 µg/g; As from 12.23±0.01 to 40.67±0.76 µg/g and Zn from 132.03±0.20 to 163.45±0.06 µg/g. For point S_2, S_3, S_4 and S_5, the concentrations of heavy metals in sediment samples at different depths are as presented in Figures 2, 3, 4 and 5. The levels of Cr for points S_2, S_3, S_4 and S_5 at different depths varied between 36.00±0.67 and 82.00±3.56 µg/g; 64.00±4.56 and 97.00±0.87 µg/g Pb; 30.00±3.54 and 79.00±5.66 µg/g Cu; 43.00±1.34 and 88.00±7.56 µg/g Fe; 32.00±7.89 and 79.00±2.41 µg/g Ni; 18.00±4.67 and 64.00±6.12 µg/g Co; 54.00±4.54 and 21.00±2.01 µg/g Mn; 12.00±0.91 and 44±4.12 µg/g Cd; 15.00±0.21 and 80.00±2.81 µg/g As and 143.00±1.53 and 230.00±3.76 µg/g Zn. The concentrations of heavy metals in sediment samples at different depths for points S_6 and S_7 are as presented in Tables 2 and 3. The values of Cr ranged from 69.34±0.32 to 94.34±0.50 µg/g; 81.76±0.22 to 110.33±0.60 µg/g Pb; 48.34±0.05 to 82.55±0.06 µg/g Cu; 74.45±1.43 to 107.44±0.07 µg/g Fe; 52.23±1.01 to 91.44±0.92 µg/g Ni; 36.21±1.00 to 72.22±1.05 µg/g Co; 84.34±0.28 to 236.33±0.88 µg/g Mn; 25.23±0.55 to 56.54±0.22µg/g Cd; 33.24±0.22 to 97.67 ±0.11µg/g As and 185.45±0.87 to 248.45 ±0.87 µg/g Zn. Similarly, the levels of Cr for point S_8 ranged (Figure 6) between 74.00±0.56 and 98.00±1.03 µg/g; 89.00±7.73 and 116.00±10.56 µg/g Pb; 56.00±2.05 and 89.00±6.06 µg/g Cu; 86.00±0.87 and 118.00±2.07 µg/g Fe; 65.00±0.54 and 104.00±1.77 µg/g Ni; 53.00±3.90 and 78.00±0.88 µg/g Co; 103.00±2.63 and 243.00±2.88 µg/g Mn; 34.00±0.21 and 64.00±1.29 µg/g Cd; 45.00±0.22 and 107.00±0.66 µg/g As and 218.00±2.12 and 257.00±7.81 µg/g Zn.

DISCUSSION

Of the various sampling sites, point S_1 was found to be least polluted in relation to the heavy metals analysed. This was attributed to the fact that there were less anthropogenic activities at this point. For point S_2, the increase in concentrations of all the metals was due to the discharge of wastewater from the water treatment plant located close to it. During water processing and treatments, wastewater from the treatment plant is discharged to River Ngada, thereby increasing the levels of metals at this point. point S_3 was located 200 m away from point S_2 and had higher concentration of heavy metals when compared to point S_1 and S_2. The high levels of heavy metals at point S_3 are due to the discharged of wastewater from residential areas. Point S_4 had higher metal concentrations than points S_1 to S_3. This is due to the fact that this point is located near Lagos bridge and roads where several anthropogenic activities and discharge of sewage sludge from residential areas

Table 1. Mean concentration of heavy metals in sediment samples by depth for point S_1 of River Ngada.

Sampling	Concentrations (µg/g)									
Depth (cm)	Cr	Pb	Cu	Fe	Ni	Co	Mn	Cd	As	Zn
0-0.5	28.87^{a}±0.02	54.33^{a}±0.01	26.32^{a}±0.02	31.87^{a}±0.21	24.31^{a}±0.22	12.45^{a}±0.05	43.11^{a}±0.11	7.34^{a}±0.02	12.23^{a}±0.01	132.03^{a}±0.20
5-10	32.89^{b}±0.33	58.98b±0.12	34.13^{b}±b0.01	36.97^{b}±0.02	29.23^{b}±0.10	23.76^{b}±0.04	78.23^{b}±0.21	12.56^{b}±0.11	30.65^{b}±0.11	138.23^{b}±0.65
10-15	38.43^{c}±0.23	63.22^{c}±0.03	41.54^{c}±0.06	43.34^{c}±1.03	33.34^{c}±0.01	18.23^{c}±0.12	126.76^{c}±0.54	16.76^{c}±0.43	32.23^{c}±0.32	154.56^{c}±0.12
15-20	45.14^{d}±0.02	71.23^{d}±0.11	51.32^{d}±0.01	58.34^{d}±1.01	39.45^{d}±0.41	28.34^{d}±0.21	154.34^{d}±0.10	19.34^{d}±0.09	40.67^{d}±0.76	163.45^{d}±0.06

Within column, mean with different letters are statistically significant $p<0.05$.

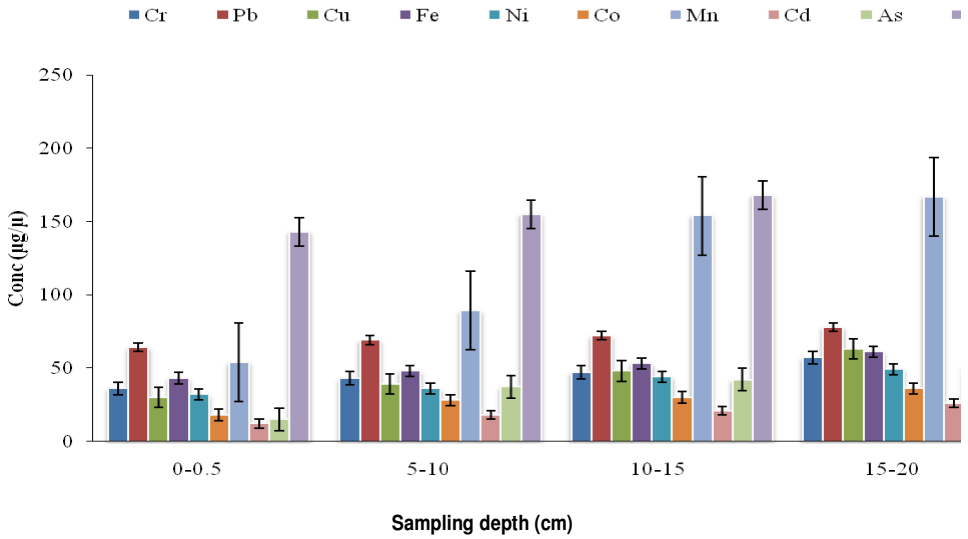

Figure 2. Mean concentration of heavy metals in sediment samples by depth for points S_2 of River Ngada.

sludge from residential areas take place. For point S_5, the levels of all the metals in the sediment samples are likely due to the discharge of wastewater from residential areas and urban garbage. Point S_6 was located at the Custom Bridge and within the market areas where there is heavy discharge of wastewater from both residential and market areas into it. Also large quantity of garbage from the Custom market is also discharged at this point which eventually contribute to high concentrations of all the metals compared to point S_1 to S_5. Also for point S_7, the concentrations of all the metals were high, which is due to the fact that this point is located at the immediate discharge of abattoir waste water into River Ngada. For all the metals studied, Zn was the highest and Mn the second highest. Pb the third highest, Fe was the fourth while Cd showed

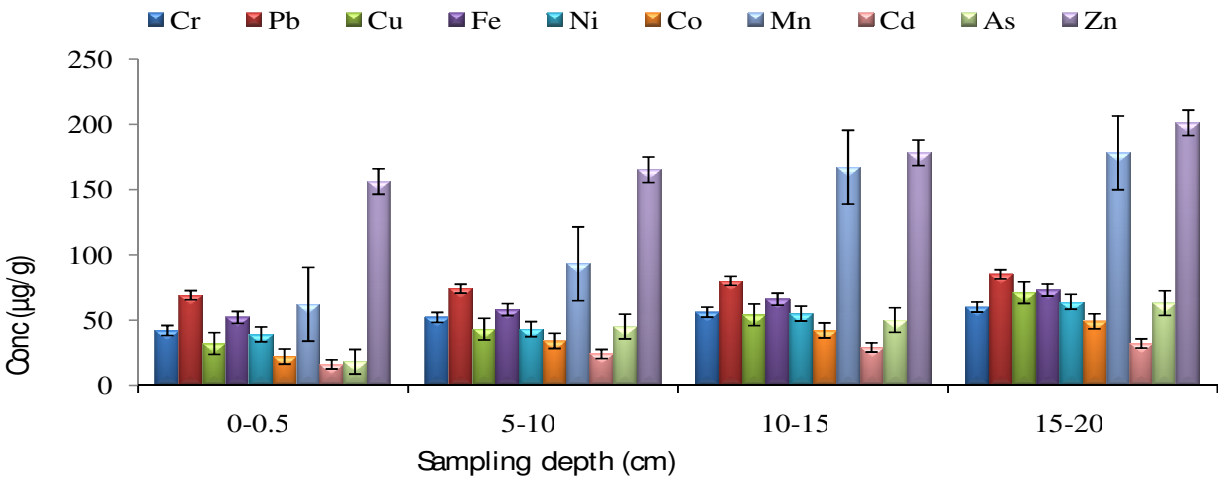

Figure 3. Mean concentration of heavy metals in sediment samples by depth for point S_3 of River Ngada.

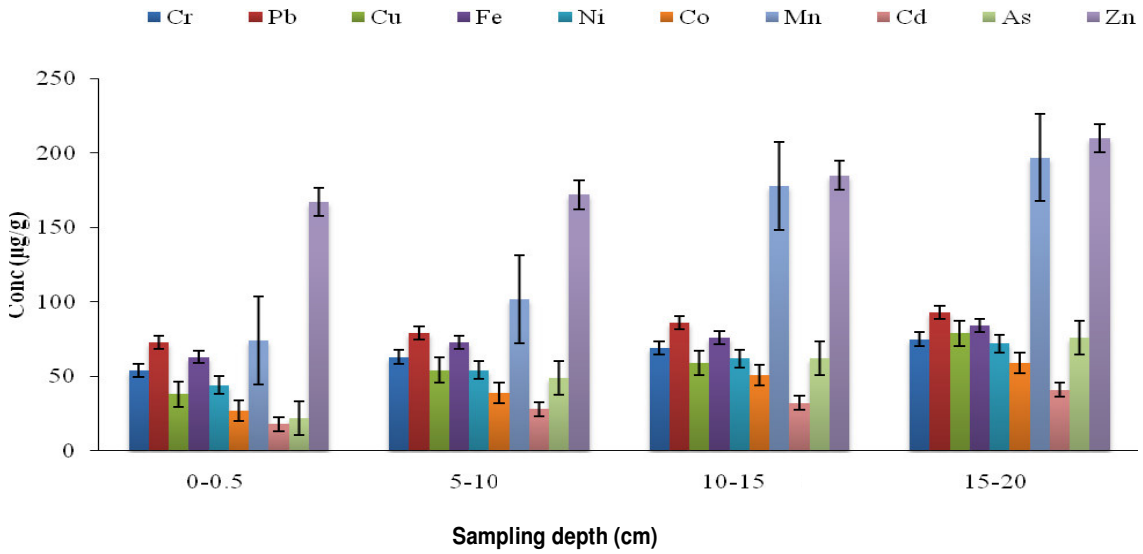

Figure 4. Mean concentration of heavy metals in sediment samples by depth for point S_4 of River Ngada.

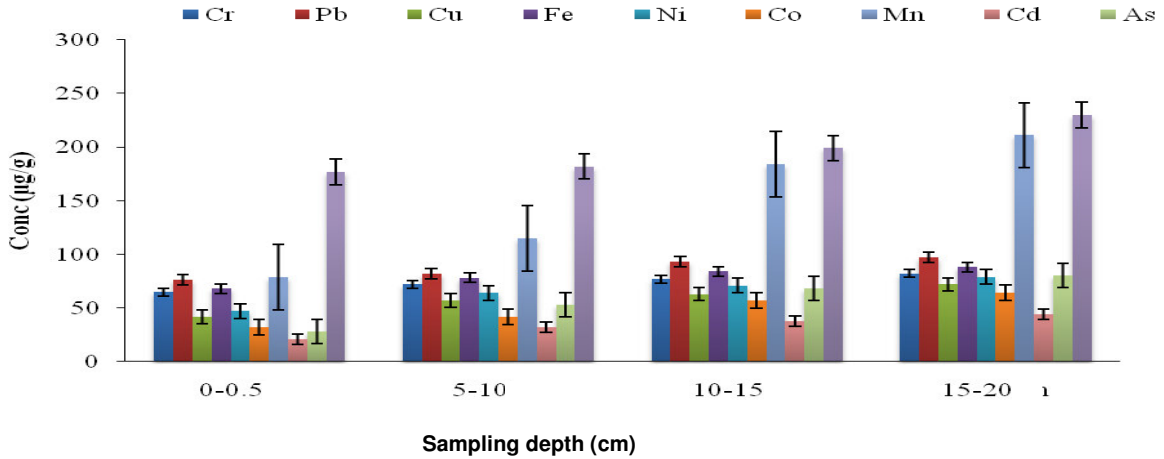

Figure 5. .Mean concentration of heavy metals in sediment samples by depth for point S_5 of River Ngada.

Table 2. Mean concentration of heavy metals in sediment samples by depth for point S_6 of River Ngada.

Sampling	Concentrations (µg/g)									
Depth (cm)	**Cr**	**Pb**	**Cu**	**Fe**	**Ni**	**Co**	**Mn**	**Cd**	**As**	**Zn**
0.0.5	69.34^{a}±0.32	81.76^{a}±0.22	48.34^{a}±0.05	74.45^{a}±1.43	52.23^{a}±1.01	36.21^{a}±1.00	84.34^{a}±0.28	25.23^{a}±0.55	33.24^{a}±0.22	185.45^{a}±0.87
5-10	78.34^{b}±0.11	86.65^{b}±0.63	61.34^{b}±0.22	88.45^{b}±2.04	68.12^{b}±0.05	46.34^{b}±0.12	123.02^{b}±1.02	38.33^{b}±0.12	56.11^{b}±0.32	193.74^{b}±0.43
10-15	81.87^{c}±0.05	97.45^{c}±0.24	68.78^{c}±0.22	92.98^{c}±0.47	77.02^{c}±0.71	61.12^{c}±0.23	193.23^{c}±2.32	42.45^{c}±1.00	73.21^{c}±0.11	224.74^{c}±2.11
15-20	87.45^{d}±0.33	103.45^{d}±0.45	79.45^{d}±0.12	99.34^{d}±0.09	85.34^{d}±0.25	65.08^{d}±0.21	221.34^{d}±0.07	49.85^{d}±0.12	85.65^{d}±0.03	237.45^{d}±0.06

Within column, mean with different letters are statistically significant p<0.05.

Table 3. Mean concentration of heavy metals in sediment samples by depth for point S_7 of River Ngada.

Sampling	Concentrations (µg/g)									
Depth (cm)	**Cr**	**Pb**	**Cu**	**Fe**	**Ni**	**Co**	**Mn**	**Cd**	**As**	**Zn**
0.0.5	72.34^{a}±0.53	84.34^{a}±0.23	53.45^{a}±0.02	79.45^{a}±0.03	58.45^{a}±0.11	42.55^{a}±0.06	92.87^{a}±0.55	30.33^{a}±1.05	37.01^{a}±0.01	205.23^{a}±0.73
5-10	83.04^{b}±0.54	92.34^{b}±1.43	65.89^{b}±0.72	93.56^{b}±0.57	74.23^{b}±0.65	53.87^{b}±0.05	136.65^{b}±0.43	45.45^{b}±0.06	64.34^{b}±0.19	212.34^{b}±0.23
10-15	88.02^{c}±0.23	104.23^{c}±0.54	74.34^{c}±0.03	97.32^{c}±0.06	86.15^{c}±0.03	64.45^{c}±0.11	204.45^{c}±0.33	47.76^{c}±0.13	87.34^{c}±0.58	231.66^{c}±0.16
15-20	94.34^{d}±0.50	110.33^{d}±0.60	82.55^{d}±0.06	107.44^{d}±0.07	91.44^{d}±0.92	72.22^{d}±1.05	236.33^{d}±0.88	56.54^{d}±0.22	97.67^{d}±0.11	248.45^{d}±0.87

Within column, mean with different letters are statistically significant p<0.05.

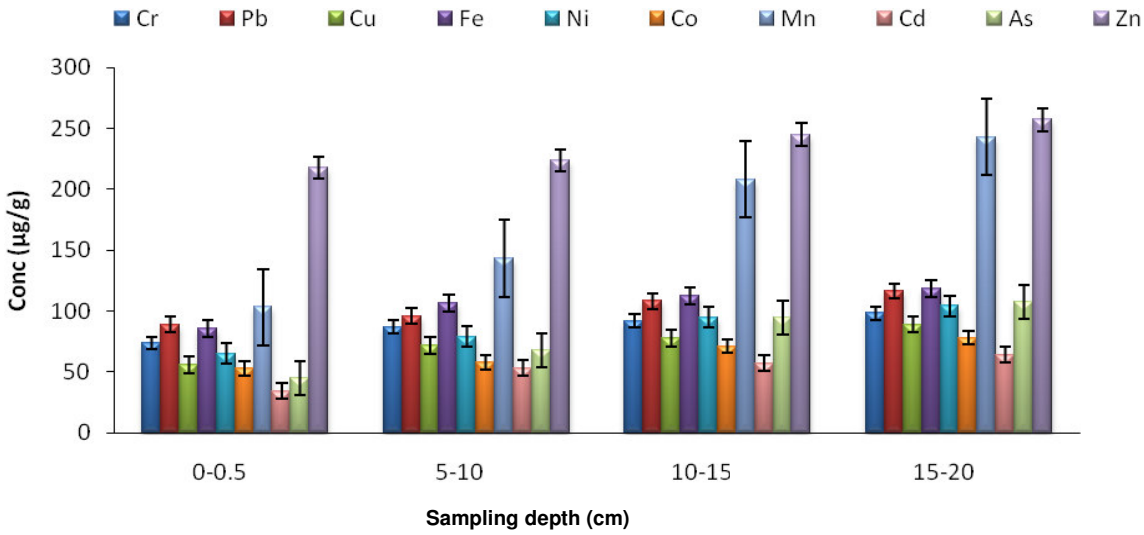

Figure 6. Mean concentrations of heavy metals sediment sample by depth for point SR of River Ngada.

the least concentrations. The high levels of Zn, Mn, Pb and Fe might be due to the disposal of solid waste from residential areas which might contain higher levels of these metals. The increase in concentrations of heavy metals with depth might be due to leaching effect, since sediments usually serve as repository of elements in aqueous environment. This conforms to report by Stephen et al. (2001) that sediment could act as sink for a wide range of contaminants including heavy metals from various sources. Based on the results obtained from this study, the concentrations of heavy metals in sediment sample for point S_1 was slightly polluted, while the levels for other points were heavily polluted. Statistical analysis using analysis of variance shows that, there was significant variation in the levels of heavy metals from points S_1 to S_8 ($p< 0.05$).

The highest chromium level of 98.00 µg/g was observed in point S_8 (15-20 cm depth), while the least level of 28.87 µg/g was also observed at point S_1 (0.5-5.0 cm depth). Generally, it was observed that the levels of chromium increased significantly with increase in depth. Also there was a significant increase in concentrations of chromium from point S_1 to S_8. Chromium exists in four valency states viz: Cr (II), Cr (III), Cr (IV) and Cr (VI) and reaches water supplies primarily from the discharge of industrial wastes. While Cr^{3+} is considered a minor problem, Cr^{6+} is very toxic and carcinogenic (ATSDR, 2000). Eczematous dermatitis due to trivalent Cr compounds has also been reported. Chromium and its compounds are known to cause cancer of the lung, nasal cavity and paranasal sinus and suspected to cause cancer of the stomach and larynx (ATSDR, 2000). Chromium (III) had been described as an essential nutrient that helps the body use sugar, protein, and fat (Hati et al., 2005). However, under certain environmental conditions (Awan et al., 2003) and certain metabolic transformations, chromium (III) may readily be oxidized to chromium (VI) compounds that are toxic to human health (ATSDR, 2000). According to WHO/USEPA guideline value for sediment, the concentration of 25 µg/g, Cr is acceptable (Radojevic and Bashkin, 1999). For concentrations exceeding 25 µg/g, a condition known as allergic dermatitis could result (EPA, 1999). From the results of these analyses, the concentrations of chromium in the sediment samples exceeded the regulating limits, indicating severe contamination of sediments of River Ngada by chromium.

The highest concentration of 116 µg/g for lead was observed at point S_8, and the lowest level of 54.33 µg/g at point S_1. Lead is also used in the production of lead acid batteries, solder, alloys, cable sheathing, pigments, rust inhibitors, ammunition, glazes and plastic stabilizers. Tetraethyl and tetramethyl lead are important because of their extensive use as antiknock compounds in petrol (Abbasi et al., 1998; Sharma and Pervez, 2003; WHO, 2004). Lead toxicity leads to anaemia both by impairment of haemobiosynthesis and acceleration of red blood cell destruction. Both are dose related. Lead also depresses sperm count (Anglin-Brown et al., 1995). In addition, Pb can also produce a damaging effect on the kidney, liver and nervous system, blood vessels and other tissues (Anglin-Brown et al., 1995; Sharma and Pervez, 2003). Lead is toxic to humans and may originate in water from contact with the ground, industrial wastes and from water piping itself. Lead is a cumulative poison and has been known to cause ‘plumbism’ or lead poisoning at a concentration of 10 g/day, It produces damaging effects on the organs and tissues to which it comes into contact. The consequences of excess lead in the human body range from low intelligent quotient in children and high blood pressure in adults by (Ottaway, 1978). The levels of lead in the analyzed sediment samples showed that the limiting values by USEPA of 40 µg/g (EPA, 1999) was

exceeded, indicating contamination of River Ngada sediment and this may pose a hazard to the aquatic biota.

The maximum concentration of 89.00 µg/g for copper was observed for point S_8, while the minimum level of 26.32 µg/g was detected in point S_1. Copper is widely used in electrical wiring, roofing, various alloys, pigments, cooking utensils, piping and in the chemical industry. Copper is present in amunitions, alloys (brass, bronze) and coatings. Copper compounds are used as or in fungicides, algicides, insecticides and wood preservatives and in electroplating, azo dye manufacture, engraving, lithography, petroleum refining and pyrotechnics. Copper compounds can be added to fertilizers and animal feeds as a nutrient to support plant and animal growth. Copper compounds are also used as food additives (Abbasi et al., 1998; Eaton, 2005; WHO, 2004). In addition, copper salts are used in water supply systems to control biological growths in reservoirs and distribution pipes and it forms a number of complexes in natural waters with inorganic and organic ligands (WHO, 2004). Copper is an essential substance to human life, however, in high concentrations, it can cause anaemia, liver and kidney damage, stomach and intestinal irritation (Turnland, 1988). Copper is generally remobilised with acid-base ion exchange or oxidation mechanism (Gomez et al., 2000). The levels of copper in the sediment samples were above the (WHO, 2004) standard values of 25 µg/g for the survivor of aquatic organism.

The maximum concentration of 118.00 µg/g for iron was observed for point S_8, while the minimum level of 31.87 µg/g was detected in point S_1. The USEPA guideline value (30 µg/g of Fe in sediment is acceptable (Radojevic and Bashkin, 1999). Above 30 µg/g, a condition known as haemo-chromatosis could result. From the result of this study, the concentration of iron in the sediment samples exceeded the guideline limit indicating severe pollution of River Ngada.

The level (104.00 µg/g) of nickel in the sediment samples was highest at point S_8, while point S_1 showed the least concentration (24.31 µg/g). Nickel is used mainly in the production of stainless steels, non-ferrous alloys and super alloys. Other uses of nickel and nickel salts are in electroplating, as catalysts, in nickel-cadmium batteries, in coins, in welding products and in certain pigments and electronic products. It is estimated that 8% of nickel is used for household appliances (WHO, 2004). Nickel is also incorporated in some food supplements, which can contain several micrograms of nickel per tablet (Abbasi et al., 1998; Eaton, 2005; WHO, 2004). The WHO guideline value of 20 µg/g showed that the concentrations of Ni in River Ngada is very high and indicate possible pollution. However, nickel limiting levels were exceeded and River Ngada could be said to be contaminated by nickel.

The maximum concentration for manganese (243.00 µg/g) was observed for point S_8, while the minimum level (43.11 µg/g) was detected in point S_1. The common aqueous species found in water is predominantly Mn^{2+} and Mn^{4+}. Manganese is essential for plants and animals. Manganese dioxide and other manganese compounds are used in products such as batteries, glass and fire-works. Potassium permanganate is used as an oxidant for cleaning, bleaching and disinfection purposes. Other manganese compounds are used in fertilizers, varnish and fungicides and as livestock feeding supplements. Manganese can be adsorbed onto soil, the extent of adsorption depends on the organic content and cation exchange capacity of the soil. It can bioaccumulate in lower organisms (e.g., phytoplankton, algae, molluscs and some fish) but not in higher organisms; bio-magnification in food chains is not expected to be very significant (Abbasi et al., 1998; Eaton, 2005; WHO, 2004). The levels of manganese in the sediment samples exceeded the USEPA limit of 30 µg/g,

The highest concentration (64.00µg/g) for cadmium was observed in point S_8, while the minimum level (7.34µg/g) was detected in point S_1. Cadmium metal is used mainly as an anticorrosive and electroplated on steel. Cadmium sulphide and selenide are commonly used as pigments in plastics. It is also used in electric batteries and in various electronic components and inorganic fertilizers produced from phosphate ores which constitute a major source of diffuse cadmium pollution (Anglin-Brown et al., 1995; Eaton, 2005). Moreover, when ingested by humans, cadmium accumulates in the intestine, liver and kidney (WHO, 2004). The kidney cortex is regarded as the most sensitive organ. Cadmium adsorbs strongly to sediments and organic matter (Sanders et al., 1999). Cadmium has a range of negative physiological effects on organisms such as decreased growth rates and negative effects on embryonic devel-opment (Newman and McIntosh, 1991). The levels of cadmium in the sediment samples were above the WHO, 2004 standard value of 6 µg/g.

Arsenic is a highly toxic metalloid element (Rodriguez et al., 2003; Pizzaro et al., 2003). The maximum concentration (107.00 µg/g) for arsenic was observed in point S_8, while the minimum level (12.23µg/g) was detected in point S_1.The levels of arsenic in the analyzed sediment samples exceeded the WHO, 2004 standard limit of 27 µg/g, indicating contamination of River Ngada.

Excessive intake of Zn may lead to vomiting, dehydration, abdominal pain, nausea, lethargy and dizziness (ATSDR, 1994). The maximum concentration (257.00 µg/g) for zinc was observed in point S_8, while the minimum level (132.03 µg/g) was detected in point S_1. Zinc is used in a number of alloys including brass and bronze, batteries, fungicides and pigments. Zinc is an essential growth element for plants and animals but at elevated levels it is toxic to some species of aquatic life (WHO, 2004). In addition, Zn is involved in a variety of enzyme systems which contribute to energy metabolism, transcription and translation. Zinc is also potentially hazardous and excessive concentrations in soil lead to phytotoxicity as it is a weed killer (Anglin-Brown et al., 1995;

Abbasi et al., 1998; WHO, 2004). Zinc is used in galvanizing steel and iron products. Zinc carbonates are used as pesticides (Anglin-Brown et al., 1995). The levels of zinc in the sediment samples exceeded the WHO guideline value of 123 µg/g.

Conclusion

From the above observations, it is clear that the concentrations of all the metals showed pronounced levels of pollution. The study therefore indicates the increasing levels of all the metals from points S_1 to S_8. The study also revealed a significant increase in the levels of all the metals with sediment depth. The results of this study proved that the activities within the metropolis might have been responsible for the elevated levels of all the metals in the sediment samples. The levels of all the metals in the sediment samples were higher than the sediment guideline limits. If this trend is allowed to continue unabated, it is most likely that the food web in this study environment might be at highest risk of induced heavy metal contamination.

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