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Distribution of Heavy Metals in Water and Sediment along Abonnema Shoreline, Nigeria

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Abstract The concentrations of Cd, Cr, Cu, Zn and Pb in water and sediment collected along Abonnema shoreline were determined using GBC Avanta flame Atomic Absorption Spectrophotometer version 2.02. The metal concentrations in water ranged from < 0.001 -0.0772 mg/l Cu, 0.1139 - 6.1168 mg/l Zn, 0.0002 - 0.0012 mg/l Pb, <0.001 - 0.0628 mg/l Cd and 0.0632 - 0.1836 mg/l Cr and in sediment 0.1332 - 0.6229 mg/kg Cu, 1.0535 -7.0965 mg/kg Zn, 0.0075 - 0.0520 mg/kg Pb, <0.001 - 0.0526 mg/kg Cd and 0.0762 -0.3071 mg/kg Cr. The concentrations of the metals and their pollution index values in sediment were higher than those in water. The mean metal pollution index values for Cu (0.151±0.140), Cd (0.007±0.0005), and Cr (0.153±0.059) at the high activity area higher than Cu (0.132±0.131), Cd (0.002±0.001) and Cr (0.122±0.0295) at the low activity area while Zn (1.205±1.036) high and (1.478±0.6175) low as well as Pb (0.009±0.008) high and (0.020±0.0185) low showed the reverse. The difference in metal concentrations and metal pollution index values between sediment and water as well as high and low activity areas were not significant (P>0.05). The shoreline was considered critically contaminated as the concentrations of Cr, Zn and Cu exceeded permissible limits set by Rivers State ministry of environment, Federal Environmental Protection Agency and World Health Organization and therefore pose serious environmental concern. Low pH, high commercial activities, wastes, tidal and wave actions influenced the concentrations of metals in the area. Regular monitoring and evaluation of the water, sediment and sea foods were recommended.

Keywords Heavy Metals, Abonnema, Shoreline, Water, Sediment, High Activity, Low Activity, Sombriero River

1. Introduction

Coastal areas are sites of discharge and accumulation of a range of environmental contaminants[1]. Studies on heavy metals in rivers, lakes, fish and sediments have been a major environmental focus especially during the last decade[2-6]. Heavy metals contamination of coastal water and sediment has been identified as a serious pollution resulting from industrialization. Heavy metals contamination of river water is one of the major quality issues in fast growing cities because maintenance of water quality and sanitation infrastructure do not increase along with population and urbanization growth especially in developing countries[7,8]. There are five major sources of heavy metals viz: Geological weathering, (natural phenomenon), industrial processing of ore and metals, the disposal of metals and metal components, leaching of metals from garbage and solid waste heaps and animal and human excretions[9]. The single largest source of heavy metals in most coastal ecosystems in the United States is residential waste water effluents[9]. Other sources of heavy metals are Harbour activities such as docking, vessel repair facilities, antifouling, vessel paints, anticorrosion material and petroleum exploitation which activities introduce lead (Pb), copper (Cu), zinc (Zn), Cadmium (Cd), chromium (Cr) and other metals into the coastal wasters[10-12].

Heavy metals discharged into aquatic ecosystems are likely to be scavenged by particles leading to their accumulation in sediments[13]. A large reservoir of metals in the sediments can act as a source to the overlying water column after their input to the ecosystem has ceased[14], potentially leading to adverse ecologic effects[13]. However, the extent of the risks is difficult to accurately assess because of the complexity of biologic and chemical interactions that alter the bioavailability of metals. Release from sediments may not only result from re-suspension of particulates, but also through the activities of microorganisms within the sediments and at the sediment-water interface, resulting in biotransformation to more volatile/soluble forms[15]. These soluble forms of the heavy metals may be incorporated in crustaceans, finfish and shellfish[10]. Trace metal contaminations are important due to their potential toxicity for the environment and human beings. Among environmental pollutants, metals are of particular concern due to their potential toxic effect and ability to bioaccumulate aquatic ecosystems[16]. Pb and Zn are toxic in their cationic forms

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while Hg, Cu and others are biochemically transformed by microorganisms to organic metal compounds prior to becoming toxic. These alkylated metallic compounds increase their biological availability in terms of uptake and toxicity above that expected based on their cationic behaviour[10]. In addition to being toxic, these biologically available forms of metals often are bio-concentrated readily to very high levels in finfish and shell fish. Ingestion of sea foods contaminated by steady accumulation of these heavy metals has caused human health risks as in Minamata Bay case history[10]. These heavy metals are also enzyme poisons[17]. Since the heavy metals are also enzyme poisons, they can affect the capacity of the natural self- purification instruments of the coastal waters by disabling them structurally so that can not degrade other poisonous substances carried into the coastal waters at usual rates of biodegradation. The effect is, increase in concentration of biodegradable contaminants in sea foods. Lead (Pb), copper (Cu) and zinc (Zn) are usually found around harbours in coastal, waters; also they are impurities in petroleum[11-12].

The shoreline of Abonnema having served as harbour for more than two decades, before it was abandoned at the wake of the Nigerian Civil war in 1967 by the Nigerian ports Authority, by implication has the toxic heavy metal pollutants found around harbours. These heavy metals get adsorbed onto the sediment surface at different pH. Heavy metals sop onto suspended particulates; this is a concern because filter feeding organisms such as shellfish are most likely to bioconcentrate the metals associated with these particulates [10].

The coastal waters of the shoreline of Abonnema, which is the Sombriero River, leads to other oil and gas bearing communities like Idama and Soku where oil and gas exploitation activities are at the peak. The shoreline of Abonnema is occasionally inundated by spilled oil from oil spillage when it occurs. An oil spill can cause not only hydrocarbon contamination but also heavy metal contamination in extremely small concentrations such as inorganic salts, metal soaps and organic metal complex compounds[12]. The building of the Abonnema- Degema bridge contributed its share of toxic heavy metals. The heavy metal contaminants may be released from the sediment into the water column; leading to the possible contamination of benthic organisms living in contact with them and finally of all the benthic food chain[18].

This study aims to determine the levels and distribution of the toxic heavy metals lead (Pb), copper (Cu), Cadmium (Cd), Chromium (Cr) and zinc (Zn) in water and sediment of Sombriero river at the shoreline of Abonnema in the Akuku-Toru Local Government Area of Rivers State, Nigeria with a view to create awareness and establish baseline data on the present status of the river.

2. Materials and Methods

2.1. Study Area

Abonnema along whose shoreline the samples for the study were collected is an island located on the lateritic clay residual deposits in the transition or mangrove (Middle Delta) zone of the Niger Delta along the Sombriero River of Rivers State[19] (Fig. 1). This is the mangrove brackish water zone that has numerous intertidal flats and mangrove vegetation subsoil here is characterized by a typical fibrous pervious clayey mud that shows a large value of compressibility and consolidation[19]. The climate of the zone is basically that of tropical monsoon with rainfall occurring almost all through the year except the months of December, January and February, which are not completely free from rainfall in some years[19]. The zone experiences diurnal ebb and flow of the tides with maximum values obtained during the once- a-year spring tide[19]. The surface water of the Sombriero River along the shoreline of Abonnema is the sodium chloride (NaCl) subtype of the rock dominated type[20], because during the dry season a slight sparking in the river water is noticed when the water is disturbed at night by the observer in a boat. When the river water is collected and evaporated to dryness, sodium chloride (NaCl) crystals form. This salt can be used as table salt after recrystallizations to improve the purity, as practiced by most coastal communities located along the Sombriero River.

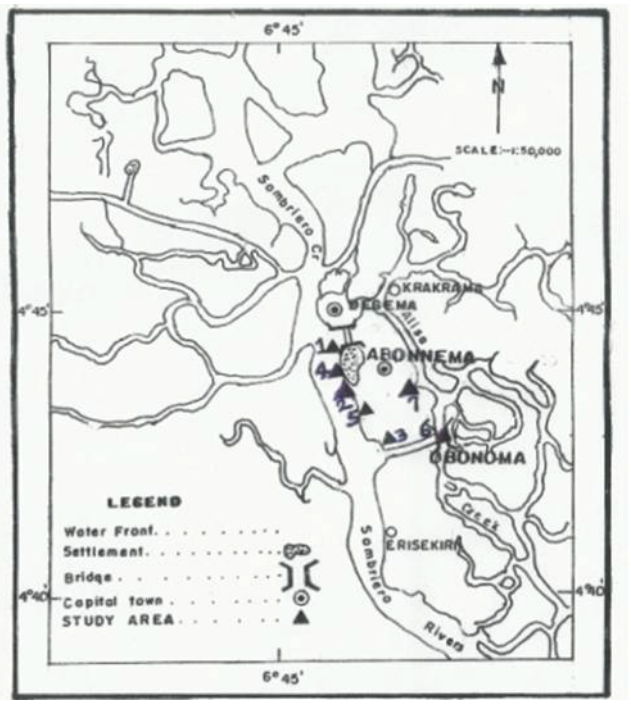


Figure 1. Map of the study area showing sampling points

2.2. Sampling Site Selection and Location

The sampling site was selected based on representativeness of the site of wastes and metal components discharge and easy accessibility. The study area was divided into High (> 100 engine boats, along Sombriero river) and Low (< 20 engine boats, along Abonnema creek) activity areas depending on the type, number and frequency of engine boats, sea trucks, etc. Water and sediment samples were collected

from seven stations (five high and two low) approximately 500 metres apart. Station 1 (Owusara) is situated between longitude 006° 46′ 23″ E and latitude 04° 44′ 24″ N, station 2 (Bulk oil produce, BOP, company area) is situated between longitude E006°″ 46′ 11″ E and latitude 04° 43′ 48″ N, station 3 (Alice-Okolo creek junction) is situated between longitude 006°″ 46′ 11″ E and latitude 04° 43′ 48″ N, station 4 (Quick-Penny water side in Georgewill compound) is situated between longitude 006°″ 46′ 9″ E and latitude 04° 43′ 59″ N, station 5 (Timber Poku i.e Timber water front) is situated between longitude 006° 46′ 19″ E and latitude 04° 45′ 32″ N, station 6 (Alice Okolo, Bridge Area) is situated between longitude 006° 46′ 36″ E and latitude 04° 43′ 31″ N, station 7 (Okolobio, between Jack and Georgewill compounds) is situated between longitude 006° 46′ 30″ E and latitude 04° 43′ 59″ N. The water and sediment samples were labelled (a) and (b) respectively at each station.

2.3. Sample Collection, Preparation and Analysis

The water samples were collected after recording the pH in-situ using portable digital pH meter and temperature using thermometer. Plastic containers were used to collect the water samples. The containers were rinsed thoroughly with the water twice before collection. The sediment samples were collected with an 'Erkman grab' sampler.

Winkler solutions I and II were added to the water samples for dissolved oxygen (DO) and kept under laboratory condition at 30℃. The sediment sample was dried, sieved and weighed.

Twenty five millilitres (25ml) of water sample was measured into porcelain crucible and 1ml of concentrated nitric acid (HNO_3) and 3ml of concentrated hydrochloric acid (HCl) were added. The sample was transferred to a steam bath and heated for about 30 minutes and cooled. The digest was made up to 50ml with distilled water and stored in plastic bottles for heavy metal analysis[21]. All water samples were treated similarly.

Ten grams (10g) of ground and sieved sediment sample was weighed into porcelain crucible. 25ml of distilled water was added followed by 1ml of concentrated nitric acid (HNO_3) and 3ml of concentrated hydrochloric acid (HCl). The sample was transferred to a steam bath, heated for about 1 hour and cooled. The digested sample was filtered and made up to 50ml with distilled water. The filtrate was stored in plastic bottles for heavy metal analysis. All sediment samples were treated similarly. The heavy metals in all the samples were determined using solar S. series Atomic Absorption Spectrophotometer (AAS).

3. Results and Discussion

3.1. Results

The results of heavy metals in water and sediment along the shoreline of Abonnema are presented in Figs. 2-6 while Figs. 7A-E show the relationship in concentrations of the metals between sediment and water.

Table 1. Levels of pH measured in Water and Sediment along the Shoreline of Abonnema

Station no.	Water	Sediment
1	7.0	6.2
2	7.1	5.9
3	7.2	6.1
4	6.81	6.5
5	6.9	7.1
6	7.06	6.3
7	6.99	6.1

The pH range of 6.81 – 7.2 was determined in the water and 5.9 – 7.1 in the sediment. The lower limit of the pH in water was determined at station 4 and the upper limit at station 3. The lower limit of the pH in the sediment was determined at station 2 and the upper limit at station 5. The pH of the water was higher in the water than in the sediment.

The concentrations of Cu ranged from <0.001 – 0.0772 mg/l in the water and 0.1332 – 0.6229 mg/kg in the sediment (Fig. 2). The lower limit of Cu in the water was determined at stations 4 5, 6 and 7 and the upper limit at station 2. The lower limit of Cu in the sediment was determined at station 4 and the upper limit at station 2. Appreciable concentrations of Cu in water were measured only at stations 1-3. (Fig. 2). The concentrations of Cu in sediment at station 6 (0.2198 mg/kg) was higher than the concentration at stations 4 (0.1332 mg/kg) and 5 (0.1424 mg/kg). Similarly the concentration at station 7 (0.3156 mg/kg) was higher than the concentrations at stations 1 (0.2971 mg/kg), 4 (0.1332 mg/kg) and 5 (0.1424 mg/kg).

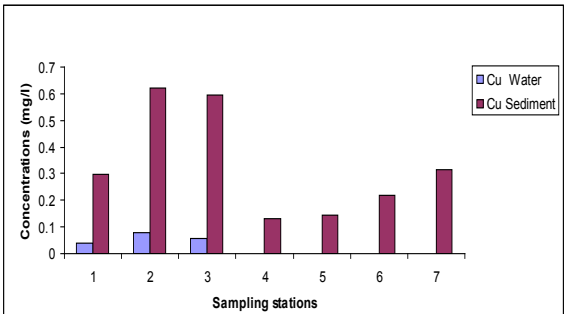


Figure 2. Variations in concentrations of Cu in water and sediment

The concentrations of Zn ranged from 0.1139 – 6.1168 mg/l in the water and 1.0535-7.0965mg/kg in the sediment (Fig. 3). The lower limit of Zn in the water was determined at station 5 and the upper limit at station 7. The lower limit of Zn in the sediment was determined at station 5 and the upper limit at station 2. The concentrations of Zn were higher in the sediment than in the water at all the stations except station 7 (Fig. 3). This could be attributed to Zn particles from suspended domestic wastes and roofs of houses close to station 7 located at Okolobio (Abonnema Creek, between Jacks and Georgewill compounds). The concentration of Zn in water at station 6 (0.1208 mg/l) was higher than the concentration at stations 4 (0.1194 mg/l), 5 (0.1139 mg/l) and the concentration at 7 (6.1169 mg/l) was greater that the concentration at

stations 1 (0.2098 mg/l), 2 (0.2098 mg/l), 3 (0.2318 mg/l), 4 (0.1194 mg/l) and 5 (0.1139 mg/l) similarly the Zn concentration in sediment at station 7 (3.6600 mg/kg) was higher that the concentration at stations 1 (1.5237 mg/kg), 4 (1.1741 mg/kg) and 5 (1.0535 mg/kg).

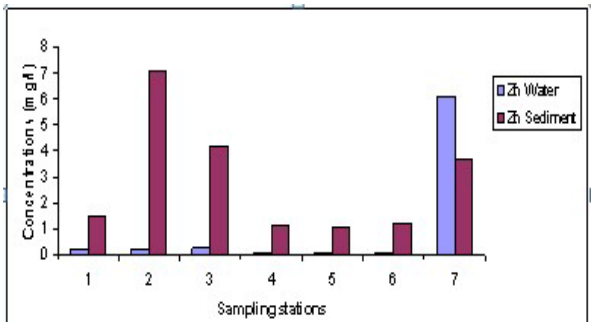


Figure 3. Variations in concentrations of Zn in water and sediment

The concentrations of Pb ranged from <0.0002 – 0.0012 mg/l in the water and 0.0075 – 0.0520 mg/kg in the sediment (Fig. 4). The lower limit of Pb in the water was determined at station 4, 5, 6 and 7 and the upper limit at station 1. The lower limit of Pb in the sediment was determined at station 1 and upper limit at station 2. The concentrations of Pb were higher in the sediment than in water. The concentrations of Pb in water at the high activity stations 1 – 5 were higher than the concentration at the low activity area. This signifies that emissions from autocrafts which frequently ply along the Somebriero River either to Abonnema or to neighbouring communities were the major source of Pb in the area. However the concentration of Pb in sediment at station 6 (0.0304 mg/kg) was higher than the concentration at stations 1 (0.0075 mg/kg), 4 (0.0076 mg/kg) and 5 (0.0107 mg/kg). Similarly the concentration of Pb in sediment at station 7 (0.0483 mg/kg) was higher than the concentration at stations 1 (0.0075 mg/kg), 3 (0.0469 mg/kg), 4 (0.0076 mg/kg) and 5 (0.0107 mg/kg).

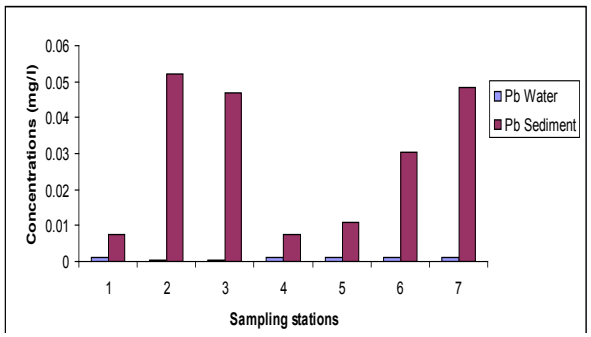


Figure 4. Variations in concentrations of Pb in water and sediment

The concentrations of Cd varied between <0.001 and 0.0628mg/l in the water and <0.001 and 0.0526 mg/kg in the sediment (Fig. 5). The lower limit of Cd in the water was determined at station 6 and the upper limit at station 3. The lower of Cd in the sediment was determined at stations 5 and 6 and the upper limit at station 3. The concentrations of Cd in the sediment were higher than in water at all the stations except stations 3 and 5 (Fig. 5). The concentration of Cd in water at station 7 (0.0018 mg/l) was higher than the concentration at station 4 (0.0014 mg/l). Similarly the Cd concentration in the sediment at station 7 (0.0082 mg/kg) was higher than the concentration at station 1 (0.0056 mg/kg), 4 (0.0024 mg/kg) and 5 (0.001 mg/kg).

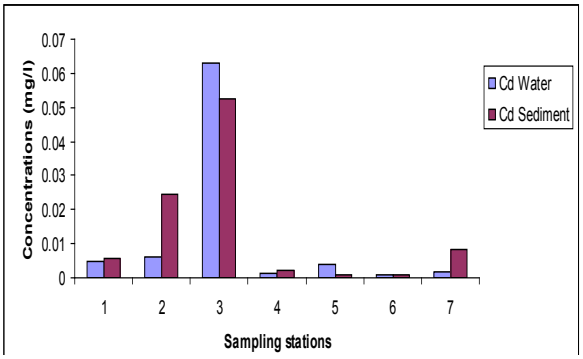


Figure 5. Variations in concentrations of Cd in water and sediment

The concentrations of Cr ranged from 0.0632 – 0.1836 mg/l in the water and 0.0762 – 0.3071 mg/kg in the sediment (Fig. 6). The lower limit of Cr in the water was determined at station 1 and the upper limit at station 2. The lower limit of Cr in the sediment was determined at station 6 and the upper limit at station 5. The concentrations of Cr in sediment were significantly higher than those in the water at all the stations except station 2. The concentration of Cr in water at station 6 (0.0762 mg/l) was higher than the concentration at stations 1 (0.0632 mg/l), 4 (0.0701 mg/l) and 5 (0.0654 mg/l). Similarly the concentration of Cr in sediment at station 7 (0.2993 mg/kg) was higher than the concentration at stations 1 (0.1445 mg/kg), 2 (0.1674 mg/kg), 3 (0.2271 mg/kg) and 4 (0.2530 mg/kg).

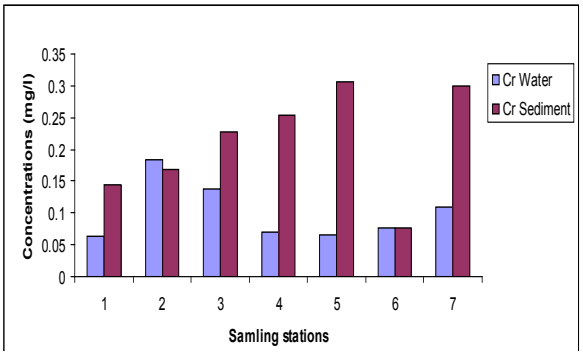


Figure 6. Variations in concentrations of Cr in water and sediment

There were variations in the concentrations of heavy metals between the high activity (Sombriero River, stations 1-5) and low activity (Abonnema creek, stations 6 and 7) areas. This could be attributed to wave actions and tidal effects which drifted heavy metals to the low activity stations. In addition the lower volume of water (Shallow) and width of the creek could have influenced the high concentrations of some metals measured at the low activity area. The presence of metal Jetties for boats and ships at stations 1 and 2 respectively greatly influenced the concentrations of metals measured there.

Table 2. Metal Pollution Index values for heavy metals in water and sediment around Abonnema

Area	Sample type	Cu	Zn	Pb	Cd	Cr	Mean
High Activity (Sombriero river; Akuku-Toru),	Water	0.011	0.169	0.001	0.006	0.094	0.0562±0.0330
	Sediment	0.291	2.241	0.017	0.007	0.212	0.5536±0.4254
	Mean ±S.E	0.151±0.140	1.205±110.36	0.009±0.008	0.007±0.0005	0.153±0.059	
Low Activity (Abonnema Creek; Okolobio)	Water	0.001	0.860	0.001	0.001	0.092	0.191±0.1682
	Sediment	0.263	2.095	0.038	0.003	0.151	0.51± 0.3989
	Mean ±S.E	0.132± 0.131	1.478±0.6175	0.020±0.0185	0.002±0.001	0.122±0.0295	

Table 3. Permissible limits of heavy metals in water and sediment

	Cd	Zn	Pb	Cu	Cr	References
Water (mg/l)	0.01	5	0.05	-	0.05	[22]
	0.001-0.05	0.005-0.05	2-20	0.05-0.15	0.1-0.5	[23]
	0.001-0.05	-	-	-	-	[24]
	-	-	10	-	50	[25]
	-	-	-	-	0.05	[26]
Sediment (mg/kg)	0.05	-	0.2	-	0.10	[27]
	0.05	-	0.2	-	-	[28]
	0.03-0.3	-	0.3	-	-	[29]
	0.03-0.3	50-300	2-20	20	0.5	[23]

3.2. Discussion

The lower limits of the pH range observed at stations 7 and 5 were slightly acidic; this may be as a result of high organic carbon load oxidation in those stations which produced large volumes of carbon dioxide that dissolved in the water to produce carbonic acid which lowered the pH. The pH of the water was higher than that of the sediment. Statistical analysis showed significant difference ($p<0.05$) between the pH in the water and sediment. This was due to organic carbon breakdown in the sediment. On the average the pH range was within the permissible limit of 6.5 – 8.5[23].

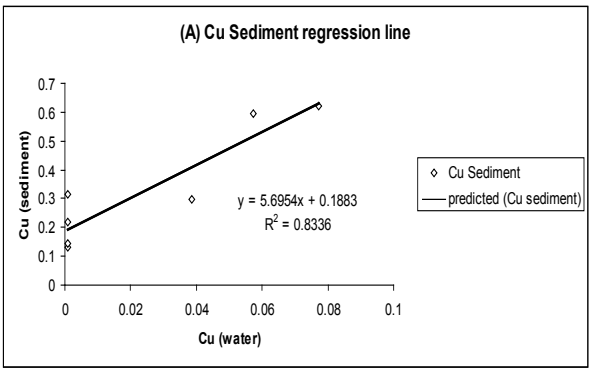
The higher concentrations of metals measured in sediment than in water indicate that lower pH favoured metal accumulation and is in agreement with report that sediments are the major depository of metals holding more than 99% of total amount of a metal present in the aquatic system[30-32].

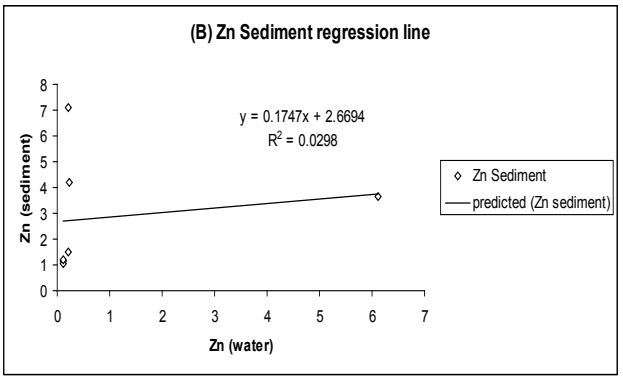
The correlation between the concentrations of metals in water and sediment fitted a linear regression equation (1) of the form:

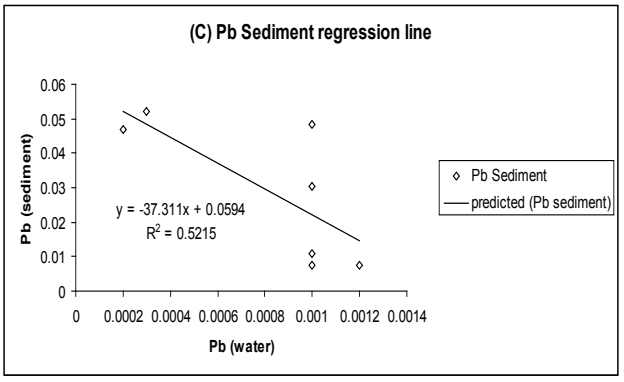
$$y = mx + c \quad (1)$$

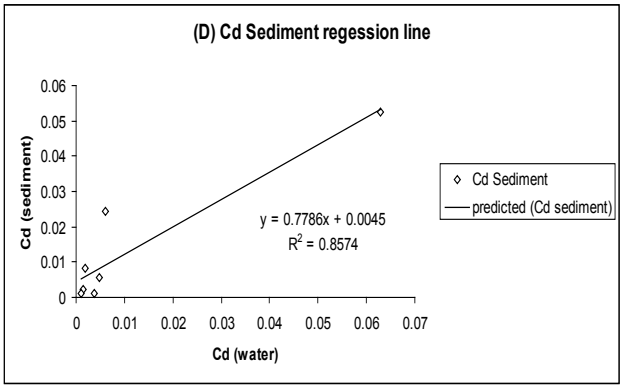
Where y = concentrations of metals in sediment, x = concentrations of metals in water;

m and c = coefficients corresponding to the slope and intercept on y axis respectively (Figs. 7A-E).









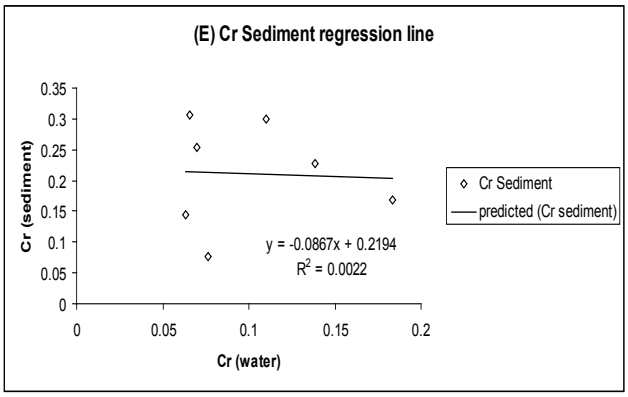


Figure 7(A-E). Regression plots showing the relationship between metals in sediment and water

The concentrations of Cu in the sediment was higher than that in the water but statistical analysis showed that there was no significant difference ($p<0.05$) between them. The concentrations of Cu in water and sediment at stations 2 and 3 were higher than the permissible limit (Table 3). This implies that the area is contaminated with copper resulting from harbour activities along the shoreline. In addition, petroleum oil spills, emissions from outboard engines, dredging activity during the building of the Abonnema – Degema Bridge may have contributed to the levels of Cu measured in the area. The relationship between the concentrations of Cu in sediment and water is shown in Fig. 7A. The slope of the equation (5.6954) was positive and greater than unity. This implies high concentration of Cu in water with high Cu in sediment. The squared correlation coefficient, R^2 (0.8336) of the linear model was significant. This implies that Cu in sediment increased with increase in Cu content of water. Figure 7A showed that 83.36% of the variation in sediment is explained by a linear relationship between sediment and water which implies very strong association between Cu in sediment and water and Cu in water contributed 0.1883mg/l Cu to the sediment.

The concentrations of Zn were higher in the sediment than in the water at all stations except station 7. However, statistical analysis showed no significant difference ($p>0.05$) between the concentrations of Zn in water and sediment. The concentrations of Zn in sediment at all the sampling stations were less than the permissible limit while the concentrations of Zn in water at all the stations were higher than the permissible limits (Table 3). This implies that while the sediment is contaminated the water is polluted with Zn. The concentrations of Zn measured could be attributed to dumping of decaying roofing sheets and metal components containing Zn, from petroleum spills, and sewage effluents. Dredging of the shoreline during the building of the Abonnema – Degema bridge may have also contributed to the high concentrations of Zn measured in the area[1]. The relationship between the concentrations of Zn in sediment and water is shown in Fig. 7B. The slope of the equation (0.1747) was positive and less than unity. This implies high concentration of Zn in water with high Zn in sediment. The squared correlation coefficient, R^2 (0.0298) of the linear model was not significant. This implies that Zn in sediment increases with increased Zn in water. Thus 2.98% of the variation of Zn in sediment was explained by a linear relationship between sediment and water; Zn in water contributed 2.6694mg/l Zn to the sediment.

The concentrations of Pb in the sediment and water were similar. Statistical analysis showed no significant difference ($p<0.05$) between the concentrations of Pb in the water and sediment. The concentrations of Pb in the water and sediment were within or below permissible limits (Table 3). This implies that the concentrations of Pb do not pose serious concern for now. The relationship between the concentrations of Pb in sediment and water is shown in Fig. 7C. The slope of the equation (-37.311) was negative and greater than unity. This implies high concentration of Pb in water with high Pb in sediment. The squared correlation coefficient, R^2 (0.5215) of the linear model was significant. This implies that Pb in sediment increases with increased Pb in water. Thus 52.15% of the variation in sediment is explained by a linear relationship between sediment and water which implies very strong association between Pb in sediment and water but Pb in water contributed 0.0594mg/l Pb to the sediment.

The concentrations of Cd in the sediment and water were similar. Statistical analysis showed no significant difference ($p>0.05$) between the concentrations of Cd in the water and sediment. The concentrations of Cd in water and sediment at all the stations except station 3 were below the permissible limits (Table 3). The concentrations of Cd in the area may have resulted from petroleum oil spills and pigment for painting sea vessels. The relationship between the concentrations of Cd in sediment and water is shown in Fig. 7D. The slope of the equation (0.7786) was positive and less than unity. This implies high concentration of Cd in water with high Cd in sediment. The squared correlation coefficient, R^2 (0.8574) of the linear model was significant. This implies that Cd in sediment increased with increase in Cd in water. Thus 85.74% of the variation in sediment is explained by a linear relationship between sediment and water which implies very strong association between Cd in sediment and water but Cd in water contributed negligible amount, 0.0045mg/l Cd to the sediment.

The concentrations of Cr in the sediment and water were similar. Statistical analysis showed that there was no significant difference ($p<0.05$) between the concentrations of Cr in the water and in the sediment. The concentrations of Cr in the water at all the stations and sediment at all the stations except station 6 were above permissible limits of (Table 3). The concentrations of Cr could have resulted from previous and present harbour activities along the shoreline, petroleum oil spills and dredging activity during the construction of the Abonnema – Degema Bridge. The relationship between the concentrations of Cr in sediment and water is shown in Fig. 7E. The slope of the equation (0.0867) was negative and less than unity. This implies high concentration of Cr in water with high Cr in sediment. The squared correlation coefficient, R^2 (0.0022) of the linear model was not significant. This

implies that Cr in sediment increases with increased Cr in water. Thus 0.22% of the variation in sediment was explained by a linear relationship between sediment and water which implies negligible association between Cr in sediment and water with Cr in water contributing 0.2194 mg/l Cr to the sediment.

Equation 2 reported by[33,34] was used to obtain the metal pollution index (MPI) for the metals in water and sediment at the high and low industrial areas around Abonnema.

$$MPI = (Cf_1 \text{ x } Cf_2 \text{ x } \text{----------} \text{ } Cf_n)^{1/n} \quad (2)$$

Where Cf_1 = concentration of metal in water/sediment for sampling stations 1 – n and n = number of stations the samples were collected.

The MPI is a very useful tool in evaluating overall pollution of water bodies with respect to heavy metals[35, 36]. The critical pollution index value above which the overall pollution level should be considered on acceptable is 100[35].

At the two activity areas (High and low) the MPI values of the metals in sediment were higher than those in water (Table 2). The difference between them was not significant ($P > 0.05$). The correlation coefficient for metals in water and sediment at high and low activity areas r = 0.8777 and 0.9905 respectively while between high and low activity areas, r = 0.9043 for water and 0.9996 for sediment. This observation agrees with the earlier report that sediment is a depository of metals in the aquatic system[30-32]. The mean MPI values for Cu, Cd and Cr at the high activity area were higher than those at the low activity area (Table 2). The reverse was the case for Zn and Pb. Zinc was the most prevalent metal in the study area since it had the highest MPI value at both locations. This is attributed to the fact that until recently, Zn was the only roofing sheet used in the study area. The higher MPI values of Zn and Pb at the low activity area (Okolobio, Creek) could be attributed to closeness of most metal scraps and waste dumps, all rounds (up and down) Zn buildings (huts), topography of the area, leaching and run off of rain water which scavenges automobile emissions into the creek. In addition, metals such as Pb from engine boats and other sources on the high activity Somebriero River drift and settle on the mangrove swamp and sediment at the low activity area during tidal and wave actions. The levels of Cu, Cd and Cr in the sediment were mainly contributed by deposits of abandoned metals parts during Timber processing and shipping activities. The MPI at the high activity area followed the order of Zn > Cr > Cu > Pb > Cd which is in line with the order of intercept in the regression plots while the order of Zn > Cu > Cr > Pb > Cd was observed at the low activity area.

4. Conclusions

The findings of this study showed that sediment in the ultimate sink for heavy metals in the aquatic system. The water body surrounding Abonnema island is contaminated with heavy metals especially Zn, Cr, Cu and Cd which can contaminate sea foods and hence humans. The MPI values indicate that the sediment and Zn in water from the river are critically contaminated with respect to heavy metals and therefore pose serious environmental concern. Abandoned metals parts and effluents from industrial and commercial activities such as fishing (nets, hooks, etc) shipping, timber processing and outboard engine boats influenced the levels of metals along the Sombriero River axis of Abonnema while domestic activities (such as building materials, solid wastes), run offs, tidal and wave actions influenced the metal levels along the Abonnema creek. The area is contaminated with heavy metals and requires creation of awareness, periodic monitoring and evaluation of sea foods since most communities along the Sombriero River depend on sea foods and use the water for salt production after crystallization.

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