Assessment of Heavy Metals in Water and Sediments of Sakumo II, Chemu and Kpeshie Lagoons - Ghana

Louis Korbla Doamekpor[1*], Yao Abusa[1], Hilary Kwesi Ketemepi[1], Raphael Kwaku Klake[1], Mary Eyram Abla Megumi Doamekpor[2], Perpetual Aboabea Anom[1], John Obeng[1]

[1]*School of Physical and Mathematical Sciences, Chemistry Department, University of Ghana, P. O. Box LG 56, Legon, Accra, Ghana*

[2]*School of Biological Sciences, Department of Biochemistry, Cell and Molecular Biology, University of Ghana, Legon, Accra, Ghana.*

*Corresponding author email: *lkdoamekpor@ug.edu.gh*

Abstract

This study aimed at assessing the levels of heavy metal pollution in selected lagoons within the Greater Accra Region of Ghana. Water and sediment samples were collected during the dry and wet seasons from selected lagoons, namely; Sakumo II, Chemu and Kpeshie lagoons. The study areas were selected due to the reliance of the people on the lagoons for their livelihood. The lagoons also serve as habitat for diverse fish species. Analysis of the samples were done using the Fast-Sequential Atomic Absorption Spectrometer (VARIAN AA 240FS) fitted with deuterium background corrector. Results from the heavy metals determined (Cu, Pb, Fe, Ni, Zn, and Mn) were compared with the EPA, WHO and USEPA recommended limits, which indicated significant differences in concentrations between the two seasons. The concentration of Copper in the water samples ranged from 2.87-3.95 mg/L for Sakumo II lagoon, 8.32-9.39 mg/L for Chemu lagoon and 6.10-6.84 mg/L for Kpeshie lagoon during the dry season. Copper concentrations, however, increased significantly during the wet season with Kpeshie recording the highest mean concentration of 11.69 mg/L. Lead concentration for both seasons did not increase significantly within the study area. Chemu lagoon recorded the highest mean lead concentration of 0.68 mg/L. Chemu lagoon also recorded the highest concentrations of zinc and Iron with values ranging from 17.44-17.83 mg/L and 22.26-23.51 mg/L during the dry season and from 23.80-24.34 mg/L and 27.26-27.89 mg/L during the wet season respectively. Heavy metal concentrations of sediment samples varied widely within the study area with Chemu lagoon recording the highest mean concentrations of all six metals determined for both seasons. The results revealed that, concentrations of both water and sediment samples were highest during the dry season compared to the wet season. Correlations between metals in the sediment samples were statistically significant and positive with values within 0.6 and 1.0 indicating that, the metals in each combination originated from a particular source.

Introduction

The increasing rate at which squatters and industries are settling around water bodies across the globe has been of serious concern to many individuals and environmental protection agencies. This concern comes in the light of the benefits derived from water bodies by both humans and animals. Across the world, water bodies form a central part of the ecosystem.

Generally, water bodies are used by humans for agricultural, domestic, transportation, and tourism purposes. Due to the unique nature of lagoons and their contribution to human existence, they were considered in this research. Aside serving as the habitat for most fish species and beneficial algae, lagoons also form the basis for small-scale fishing and farming activities. However, the result of these activities makes the lagoons unsafe due to pollution.

According to Helmer *et al.*, (1997), water pollution is the second most significant environmental issue after air pollution. The major pollutants of most water bodies are the heavy metals (Oghenerobor, 2014). Generally, the non-biodegradable and bio-accumulative nature of heavy metals make them detrimental to human and aquatic lives upon exposure to some extent. This notwithstanding, heavy metals indirectly enter the environment through natural processes such as volcanic action, forest fires, and directly through anthropogenic activities such as release of untreated waste water into water bodies, excessive use of fertilizers and pesticides etc.

Lagoons, which form part of water bodies, are vulnerable to various anthropogenic activities (Schaffelke *et al.*, 2012; Hering et al., 2010; Green *et al*., 2008). Heavy metals include Pb, Hg, Cu, Zn and Cd as examples of inorganic contaminants (Campbell, 1994; Brown *et al.*, 1990). As inorganic contaminants, heavy metals are very toxic and pose a threat to human life especially when present in high quantities. In spite of the relatively high toxic nature of most heavy/trace metals even at low concentrations, some (e.g., selenium, manganese, iron, zinc, and copper) play essential roles in metabolism and nutrient provision when ingested in small quantities. The lagoons studied in this research were previously known as good sources of fish, especially tilapia (Essumang *et al*., 2009).

Interestingly, human activities threaten to overtake the environs of most of these lagoons, which is contributing to their deterioration and a decrease in their biodiversity (Stumpp *et al*., 2011; Adamus *et al*., 2001). Rapid urbanization has resulted in the release of heavy metals into water bodies, especially lagoons in recent times (Sin *et al*., 2001).The anthropogenic activities which have become common around the Sakumo II, Chemu and Kpeshie lagoons include the construction of roads and bridges across channels, discharge of untreated waste water into the lagoons by industries, damming of freshwater channels, over-exploitation of mangroves, over-fishing, over-grazing, over-population, refuse dumping into the lagoons to reclaim lands, and the use of pesticides for cultivation (Ramsar, 2007). Research by Klake *et al.*, (2012) revealed the presence of some heavy metals in the Sakumo Lagoon, which was greatly attributed to over-pollution caused by human activities around the lagoon.

The favorable conditions and qualities lagoons offer to coastal inhabitants , as well as, the appreciable resources for business and livelihood make lagoons indispensable in Ghana (Gordon *et al.*, 1998). The present study aims at providing base-line data for monitoring the level of heavy metal concentrations in the affected lagoons within the Greater Accra Region of Ghana. It is hoped that the results will provide vital information that would feed into a region-wide database for relevant national authorities to draw from for appropriate actions to help preserve these lagoons.

Materials and methods

Study area

The Sakumo II, Kpeshie and Chemu lagoons are located in the city of Accra about 80 km west of the Volta River. Accra is a low-lying area, about 200 m above sea level and is subject to two wet seasons in a year—May to middle of June (heavy downpours) and August to middle of November (light downpours).

The Sakumo Ramsar wetland (also called Sakumo II lagoon) is located north of the coastal front street between the urban communities of Accra and Tema. It is the third most significant site for shorebirds on the coast of Ghana (Lawson, 2013).

Kpeshie lagoon seems to be divided into two as a result of a bridge constructed across it. However, this wetland has been arranged into four areas. Unfortunately, the third and fourth segments have now become extinct due to contamination. Kpeshie lagoon includes sand hills and open lagoons with a catchment area of roughly 110 km^2. Previously, this lagoon served as a remarkable fishing ground for the community of Kpeshie and other individuals outside this catchment territory (Ansah, 2006). Chemu lagoon covers a territory of approximately 26 km^2 and is located in Tema. It is characterised by various tributaries which join a main stream. The coordinates are latitude 5°37'0" N - 5°38'0"N and between longitude 0°2'0"W - 0°2'30"W for Sakumo II lagoon (Fig 1), latitude 5°34'0"N - 5°34'30"N and between longitude 6°8'0"W - 6°8'30"W for Kpeshie lagoon (Fig 2).The Chemu lagoon lies between latitude 5°38'40" W– 5°39'0"W and longitude 0°0'40"E – 0°1'20"E (Fig 3).

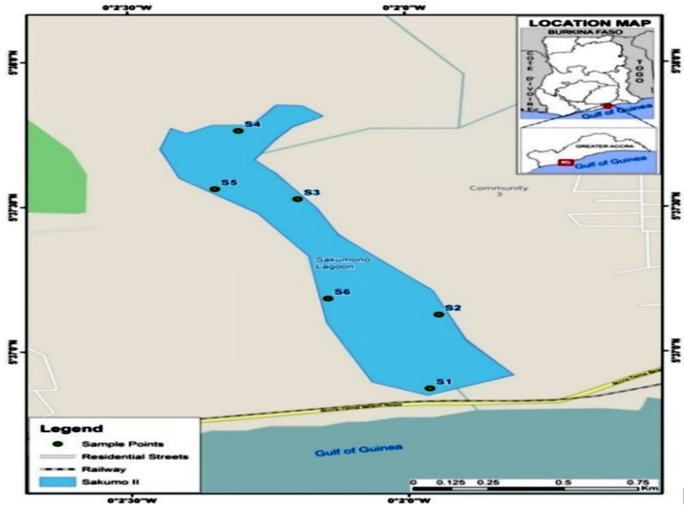

Figure 1: Map showing the catchment area of SakumoII Lagoon

Figure 2: Map showing the catchment area of Kpeshie Lagoon

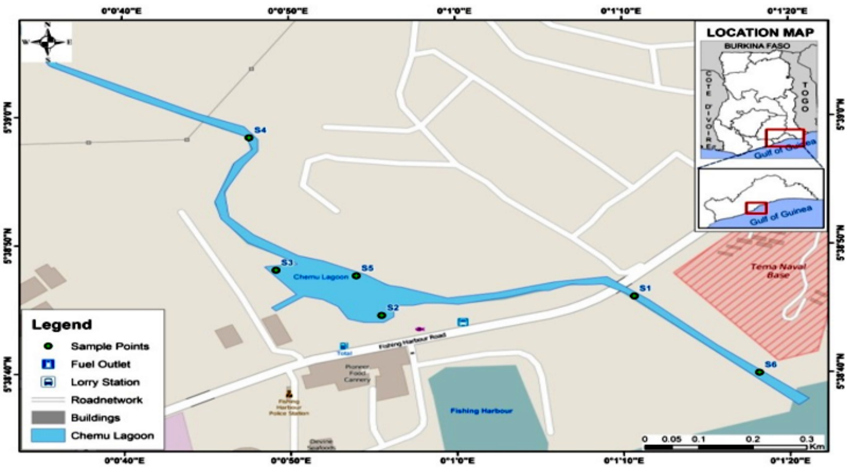

Figure 3: Map showing the catchment area of Chemu lagoon

Research facility, Quality control and Quality assurance

The Atomic Absorption Spectrophotometer (AAS), precisely the VARIAN AA 240FS was used to determine the concentrations of copper (Cu), lead (Pb), iron (Fe), nickel (Ni), zinc (Zn) and manganese (Mn) in the water and sediment samples. To minimize random error, prevent contamination of samples and ensure the accuracy of results, sampling protocols were strictly followed. Triplicate analyses were done for every determination to minimise random error and ensure reproducibility. Each reported result was the average value of triplicate measurements. Standard Reference Materials (SRMs) used were treated as the samples themselves to check for efficiency of the equipment used and further validate the procedure. The results obtained were compared with the WHO, USEPA and Ghana EPA standards for natural and effluent water.

Sampling

Water and sediment samples were taken from six different points each from the Sakumo II, Chemu, and Kpeshie lagoons in order to get a fairly representative specimen. High density polyethylene sampling bottles were thoroughly washed previously and rinsed with deionized water. At each sampling site, sampling bottles were rinsed and filled with the lagoon water at a depth of 20 cm to 30 cm and fixed in the field with 5 ml of concentrated nitric acid. The samples were kept at temperatures below 4^0 C in a refrigerator. Sampling was done on monthly basis for both dry and wet seasons. Also, a sterile 2 cm diameter polyvinylchloride (PVC) tube was used to collect sediment samples from the various sample sites into pretreated sample bags. Three samples were taken and consolidated to form a composite sample of roughly 150 g.

All samples were labeled and described in the field. They were later transported to the chemistry laboratory at Ghana Atomic Energy Commission (GAEC) for processing and further analysis (APHA, 2005; APHA, 1992).

Sample preparation

In the laboratory, 40 mL of the water sample was poured into a 100-mL beaker. 5 mL of Aqua Regia in the ratio of 4.5 mL concentrated HCl to 0.5 mL concentrated HNO_3 was added to the water sample. The beaker was covered with a cling film and placed on a hot plate and digested for 3 hours at 45 ^oC. After the acid digestion, the solution was allowed to cool to room temperature and filtered through a Whatman no. 42 filter paper into a 50 mL volumetric flask. It was then made up to the 50 mL mark with distilled water for the analysis of heavy metals (Cu, Pb, Fe, Ni, Zn and Mn) using the Atomic Absorption Spectrophotometer. Standard solutions ranging from 0.2 to 5.0 mg/L were prepared for the calibration curves of the various metals.

The sediment samples were air-dried for twenty-one days and ground in porcelain mortar and sieved using a 2 mm strainer to get rid of coarse particles. The fine powdered sediment samples were stored in double-bagged polyethylene bags with hermetic seals. Aliquots of these samples were taken and then digested for the analysis while the rest of the samples were kept in refrigerators below 5^o C.1.5 g of sediment sample was weighed in a beaker, acidified, and digested by adding aqua regia in a 1:3 molar ratio of HNO_3 and HCl respectively, followed by H_2O_2, and the content covered with a cling film and heated at 45 ^oC for 3 hours, after which similar steps were followed as the water samples.

Results and discussion

Water and sediment samples from three lagoons within the Greater Accra Region were analyzed for Copper (Cu), Lead (Pb), Iron (Fe), Nickel (Ni), Zinc (Zn) and Manganese (Mn) concentrations using Atomic Absorption Spectrophotometer (A Analyst 400). The results of this analysis are presented in Tables 1 to 6 and Figures 1 to 15. The tables include mean concentrations, range (minimum and maximum concentrations) and standard deviations for the three lagoons during the dry and wet seasons. The detection limits of metals on the A Analyst 400 for Cu (0.016 mg/L), Pb (0.015 mg/L), Fe (0.005 mg/L), Ni (0.006 mg/L), Zn (0.04 mg/L) and Mn (0.75 mg/L) (Ponta *et al*., 2002).

TABLE 1
Total elemental concentration (mg/L) of heavy metals in water samples from Sakumo II Lagoon during the wet and dry seasons

Metals / mg/L	Wet Season				Dry Season			
	Min	Max	Mean	Standard deviation	Min	Max	Mean	Standard deviation
Copper	2.87	3.95	3.48	0.40	5.03	6.03	5.39	0.42
Lead	0.13	0.55	0.32	0.15	0.12	0.15	0.14	0.01
Iron	4.61	5.32	5.06	0.27	5.75	6.76	6.40	0.37
Nickel	1.75	2.01	1.89	0.11	2.15	2.70	2.45	0.24
Zinc	3.53	4.01	3.74	0.17	5.04	5.27	5.14	0.11
Manganese	0.01	0.09	0.05	0.03	0.23	0.29	0.26	0.02

TABLE 2
Total elemental concentration (mg/L) of heavy metals in water samples from Chemu Lagoon during the wet and dry season

Metals / mg/L	Wet Season				Dry Season			
	Min	Max	Mean	Standard deviation	Min	Max	Mean	Standard deviation
Copper	8.32	9.39	8.65	0.41	11.23	12.03	11.69	0.30
Lead	0.52	0.59	0.55	0.03	0.65	0.70	0.68	0.02
Iron	22.26	23.51	22.86	0.49	27.26	27.89	27.48	0.25
Nickel	8.06	8.58	8.33	0.24	9.41	9.93	9.70	0.22
Zinc	17.44	18.35	17.83	0.41	23.80	24.34	24.09	0.24
Manganese	0.68	0.75	0.71	0.02	1.40	1.49	1.45	0.03

TABLE 3
Total elemental concentration (mg/L) of heavy metals in water samples from Kpeshie Lagoon during the wet and dry seasons

Metals / mg/L	Wet Season				Dry Season			
	Min	Max	Mean	Standard deviation	Min	Max	Mean	Standard deviation
Copper	6.10	6.84	6.51	0.30	8.12	8.67	8.41	0.24
Lead	0.31	0.37	0.34	0.02	0.47	0.50	0.48	0.01
Iron	17.75	18.25	17.84	0.27	20.98	22.32	21.76	0.46
Nickel	4.74	4.97	4.88	0.09	7.40	7.69	7.56	0.10
Zinc	13.10	13.48	13.19	0.14	18.58	19.11	18.87	0.18
Manganese	0.48	0.53	0.50	0.02	1.02	1.10	1.06	0.03

TABLE 4
Total elemental concentration (mg/kg) of heavy metals in sediment samples from Sakumo II Lagoon during the wet and dry seasons

Metals / mg/L	Wet Season				Dry Season			
	Min	Max	Mean	Standard deviation	Min	Max	Mean	Standard deviation
Copper	28.29	31.50	29.62	1.23	45.08	48.11	47.09	1.06
Lead	15.20	24.93	20.27	3.53	46.43	50.87	49.13	1.74
Iron	51.31	52.69	51.65	0.52	51.33	55.92	53.50	1.67
Nickel	1.93	2.68	2.25	0.29	2.95	3.32	3.11	0.15
Zinc	53.72	58.44	56.74	1.74	72.03	76.85	74.26	1.94
Manganese	91.43	96.28	94.36	1.75	102.18	123.34	114.60	8.28

TABLE 5
Total elemental concentration (mg/kg) of heavy metals in sediment samples from Chemu Lagoon during the wet and dry seasons

Metals / mg/L	Wet Season				Dry Season			
	Min	Max	Mean	Standard deviation	Min	Max	Mean	Standard deviation
Copper	76.32	83.77	80.28	2.96	95.37	101.27	98.56	2.13
Lead	30.73	33.77	31.72	1.12	62.95	67.55	64.94	1.83
Iron	91.21	99.47	95.11	3.35	123.33	130.42	127.89	2.57
Nickel	4.74	5.73	5.21	0.39	8.06	9.10	8.71	0.39
Zinc	78.26	84.19	80.40	2.12	97.27	106.55	102.44	3.35
Manganese	837.56	852.97	845.79	5.91	912.83	920.18	916.08	3.29

TABLE 6
Total elemental concentration (mg/kg) of heavy metals in sediment samples from Kpeshie Lagoon during the wet and dry seasons

Metals / mg/L	Wet Season				Dry Season			
	Min	Max	Mean	Standard deviation	Min	Max	Mean	Standard deviation
Copper	53.98	56.33	55.18	0.81	74.98	80.06	77.79	1.85
Lead	16.19	19.53	18.30	1.28	43.03	45.90	44.63	1.10
Iron	64.56	69.05	66.87	1.59	78.37	82.95	79.95	1.77
Nickel	2.89	3.34	3.05	0.16	4.45	4.83	4.63	0.15
Zinc	43.88	50.56	47.01	2.14	75.22	78.63	77.56	1.33
Manganese	330.86	360.03	344.80	12.24	529.22	568.56	550.48	14.98

Copper (Cu)

The concentration of Cu in the Sakumo II lagoon varied from 2.87 to 3.95 mg/L and 5.03 to 6.03 mg/L (Table 1) in the wet and dry seasons respectively, while the levels of Cu ranged from 11.23 to 12.03 mg/L (Table 2) and 8.12 to 8.67 mg/L (Table 3) for Chemu and Kpeshie lagoons respectively in the dry season Fig 4. The graphical representation of Cu levels in the sediment samples for both wet and dry seasons for Sakumo II, Chemu and Kpeshie lagoons is illustrated in Fig 10.

Copper (Cu) is a very common element that occurs naturally. Even at very low concentrations in water, Cu can be toxic. It is known to cause brain damage in mammals (Fatoki *et al*., 2002; DWAF, 1996). The results from Tables 1, 2 and 3 indicate that the levels of copper detected in water samples from Chemu and Kpeshie lagoons were relatively higher than that detected for Sakumo II during the wet and dry seasons. Cu levels in sediment samples from Chemu lagoon were relatively higher (Table 5) than those detected in Kpeshie (Table 6) and Sakumo (Table 4) lagoons indicating the intense domestic and industrial influence on the Chemu lagoon which may be attributed to urbanization.

The level of copper in sediment samples varied significantly from 28.29 mg/Kg – 101.27 mg/Kg with mean concentrations ranging from 29.62 mg/Kg – 80.28 mg/Kg during the wet season and from 47.09 mg/Kg – 98.56 mg/Kg during the dry season. Sakumo II lagoon recorded the least concentration of copper which was within WHO permissible limit of 30 mg/Kg (Klake *et al*, 2012) while Kpeshie and Chemu lagoons recorded values exceeding WHO permissible limit (Tables 4, 5, & 6).

Lead (Pb)

Lead (Pb) has been classified by the United States Environmental Protection Agency (USEPA) as potentially hazardous to most forms of life (USEPA, 1986). The chronic effect of Pb on human includes neurological disorders especially in foetus and children (Lansdown, 1986; Needleman, 1987). In the Sakumo lagoon, Pb concentrations detected in water ranged between 0.13 and 0.55 mg/L in the wet season and 0.12 and 0.15 mg/L in the dry season (Fig 5). Chemu and Kpeshie lagoons recorded Pb concentrations in water varying from 0.52 to 0.59 mg/L and 0.31 to 0.37 mg/L in the wet season, and 0.65 to 0.70 mg/L and 0.47 to 0.50 mg/L in the dry season respectively. Results from the study showed that the levels of Pb detected in water (Table 2) and sediment (Table 5) samples from Chemu lagoon were relatively higher than those from Kpeshie (Tables 3 and 6) and Sakumo II (Tables 1 and 4) lagoons. The relatively high detection and presence of Pb in the sediments of Sakumo II, Chemu and Kpeshie lagoons (Tables 4, 5 and 6 and Figure 11) may be due to flocculation of lead-laden effluents discharged into watercourses that eventually got washed down into the lagoons. The levels of lead in these water bodies were greater than 0.1 mg/L as per USEPA limit.

Iron (Fe)

Iron (Fe) is one of the most abundant metals on Earth and it is essential to most forms of life (Institute of Medicine, 2001). Deficiency of Fe can limit delivery of oxygen to cells. This may result in decreased immunity, poor work performance and fatigue (Institute of Medicine, 2001, Bhaskaram, 2001). Fe concentrations in water from Sakumo II, Chemu and Kpeshie lagoons ranged from 4.61 - 5.32 mg/L, 22.26 - 23.51 mg/L, and 17.57 - 18.25 mg/L, respectively in the wet season, and from 5.75 - 6.76 mg/L, 27.26 - 27.89 mg/L and 20.98 - 22.32 mg/L for Sakumo, Chemu and Kpeshie lagoons respectively in the dry season (Tables 1, 2 and 3 and Figure 6). However, the results from Tables 4, 5 and 6 and Figure 12 show that Fe values in sediment samples from Sakumo, Chemu and Kpeshie lagoons were all above the EPA limit of 5 mg/Kg. High levels of Fe in sediment samples of the study areas could be due to the discharge of iron-laden waste and effluent replete into the lagoons.

Nickel (Ni)

Nickel (Ni), is a naturally occurring element. Interestingly, it can be found ubiquitously in the air, soil, sediments, and water as a result of natural and man-made processes such as improper disposal of waste, chemicals and agricultural drainage. From Tables 1, 2 and 3, the concentrations of Ni from Sakumo II, Chemu and Kpeshie lagoons ranged from 1.75 to 2.01 mg/L, 8.06 - 8.58 mg/L and 4.74 - 4.97 respectively in the wet season and 2.15 to 2.70 mg/L, 9.41 - 9.93 mg/L and 7.40 - 7.69 mg/L in the dry season respectively. It can also be observed that Ni values of water samples were generally higher in the dry season than in the wet season (Fig 7). This could be attributed to the cleansing effect of rainfall (Ajani & Island, 2015) during the rainy season and also, the accumulation of heavy metals as a result of human activities during the dry season. Ni concentrations in the sediments from Sakumo, Chemu and Kpeshie lagoons are presented in Tables 5, 6 and Figure 13. Ni concentrations recorded from the sampling sites were all above the EPA limit of 0.14 mg/kg (Klake *et al*, 2012).

Zinc (Zn)

Zinc (Zn) is one of the commonest environmental pollutants distributed in the aquatic environment (E. O. Lawson, 2011). Zinc is an essential element for the human body. It acts as a catalytic or structural component in many enzymes that are involved in energy metabolism (Moolenaar, 1998). High doses of Zn can result in health complications such as fatigue, dizziness, and neutropenia (Hess & Schmidt, 2002).

From Tables 1 and 3, it was observed that Zn concentrations in the Chemu and Kpeshie water samples were relatively higher than their concentrations in the Sakumo II lagoon (Fig 8).This may be because of the high level of industrial activity that takes place in these two areas. The concentrations of zinc in the sediment samples of Sakumo II, Chemu and Kpeshie lagoons (Tables 4 to 6 and Figure 14) were generally low compared with that of the EPA limit of 150.00 mg/kg.

Manganese (Mn)

Manganese (Mn) is one of the most biogeochemical and active transition metals in the aquatic environment (Evans *et al.*, 1977). Mn occurs in surface water that is low in oxygen and often does so with Fe. Manganese accumulates in certain species of fish (Uthe & Blish, 1971). Tables 1, 2 and 3 show the results obtained from the analysis of Mn in water samples from Sakumo II, Chemu and Kpeshie lagoons (Fig 9). The results of Mn in sediment samples are shown in Tables 4, 5 and 6. Mn concentrations in water samples from Sakumo II, Chemu and Kpeshie lagoons varied from 91.43 – 96.28 mg/Kg, 837.56-852.97 mg/Kg and 330.86 – 360.03 mg/Kg respectively in the wet season and 102.18 – 123.34 mg/Kg, 912.83- 920.18 mg/Kg and 529.22 – 586.56 mg/Kg in the dry season (Fig 15). The Mn levels in Sakumo II, Chemu and Kpeshie lagoons could be due to deposits from methylcyclopentadienyl manganese tricarbonyl (MMT). MMT is an anti-knocking agent present in petroleum products which has Mn as an active component. MMT has a neutral charge and contains organic groups which make it highly lipophilic and soluble in petrol (Zayed, 2001; WHO, 2004).

Sediment samples from Chemu lagoon had higher Mn levels relative to Sakumo and Kpeshie lagoons. This could be attributed to flocculation resulting in the sedimentation of Mn in lagoons resulting from relatively high impact of human activities in the catchment areas of the Chemu lagoon as compared with the environs of Sakumo lagoon.

In general, heavy metals (Cu, Pb, Fe, Ni, Zn and Mn) concentrations obtained in sediment samples were relatively higher than heavy metals in water samples. This confirms the ability of sediments to serve as ready sinks for pollutants including heavy metals (Onyari *et al*., 2003). Also, it was generally observed that the levels of heavy metals studied were relatively higher in the dry season compared with the wet season. This could be due to the reduction in the volume of water in the lagoons during the dry season as a result of evaporation on the surface of the lagoons.

Again, using the two-tailed Pearson correlation test (Tables 7, 8 and 9), positive correlations were observed for all the heavy metals (Cu, Pb, Fe, Ni, Mn) in sediment samples from the three study areas with values above 0.50. These correlation values are indicative of the origin of individual metals showing that their sources were closely related. A high correlation was observed for Pb and Cu for Sakumo II, Chemu and Kpeshie with values 0.983, 0.960, and 0.991 respectively. A high correlation was also observed for Fe and Pb (0.970 & 0.962), and Fe and Cu (0.977 & 0.969) for Chemu and Kpeshie respectively with values above 0.8 while Sakumo II recorded correlation values less than 0.80 [Fe and Cu (0.700), Fe and Pb (0.655)]. Zinc recorded the highest correlation with Cu (0.980, 0.928, 0.987), Pb (0.973, 0.91, 0.989), Fe (0.651, 0.956, 0.969), and Ni (0.854, 0.957, 0.971) for Sakumo II, Chemu, and Kpeshie respectively. The results emphasise that the heavy metals in the sediments of Chemu lagoon might be coming from a pollution source, which is likely to be the consequence of anthropogenic activities such as effluents from industries, surface run-off and domestic wastes. The high correlation in sediments of Sakumo II lagoon could be accounted for by the geology of the area. Domestic waste and surface run-off from agricultural fields are likely to be the main factors responsible for heavy metals in the Kpeshie lagoon, since there were no industries situated around the lagoon. The correlation between the heavy metals is significant at 0.05 or 95% confidence level (2-tailed). The results obtained from the Pearson correlation for sediment samples from Sakumo II, Chemu and Kpeshie lagoons can be found in Tables 7, 8 and 9.

Conclusion

The results obtained from the analyses of heavy metals using water and sediment samples from Sakumo II, Chemu and Kpeshie lagoons were generally higher than the recommended limits of the EPA, WHO and USEPA. This could be attributed to the use of the lagoons as dumping site by most of the inhabitants and discharge of industrial pollutants into the lagoons. All the heavy metals determined [copper (Cu), lead (Pb), iron (Fe), nickel (Ni), zinc (Zn) and manganese (Mn)] recorded higher values in the dry season compared with the wet season. Sediment samples also recorded higher values during the dry season compared with the wet season. This may be due to the evaporation of water from the surface of the lagoons in the dry season which resulted in the increased concentrations of metals in the lagoons. However, a strong positive correlation exists between Cu and Pb, Cu and Fe and the other elements showing that the metals were from one source such as dump sites, industries, and agricultural lands within the environs of the lagoons. Due to increased population at the coastal zone of Ghana, there is a heavy burden on coastal lagoons which poses a threat to these natural resources.

Recommendations

It is recommended that coastal lagoons be regularly monitored and assessed by appropriate agencies like the EPA and Tema Metropolitan Assembly (TMA). This is to help control and monitor the indiscriminate release of effluents into lagoons and other important water bodies. There should be the strict enforcement of regulatory instruments to minimize the rate at which the lagoons are deteriorating.

Moreover, further research and investigations should be conducted to find out more about the presence of other inorganic and organic pollutants.

Lastly, there should be sustainable public education on management of natural resources in Ghana.

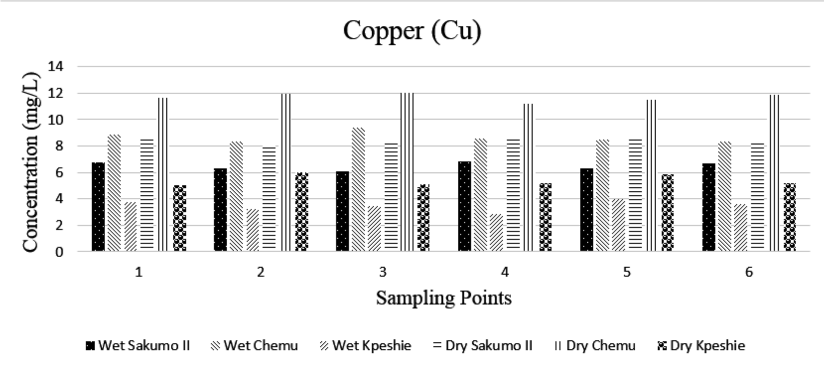

Figure 4: Seasonal variations of Copper in water samples from Sakumo II, Chemu and Kpeshie lagoons

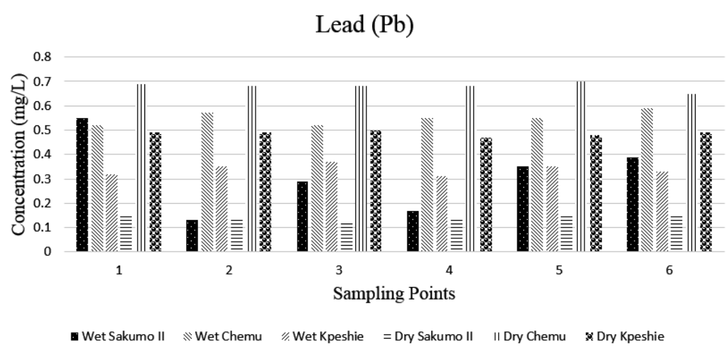

Figure 5: Seasonal variations of Lead in water samples from Sakumo II, Chemu and Kpeshie lagoons

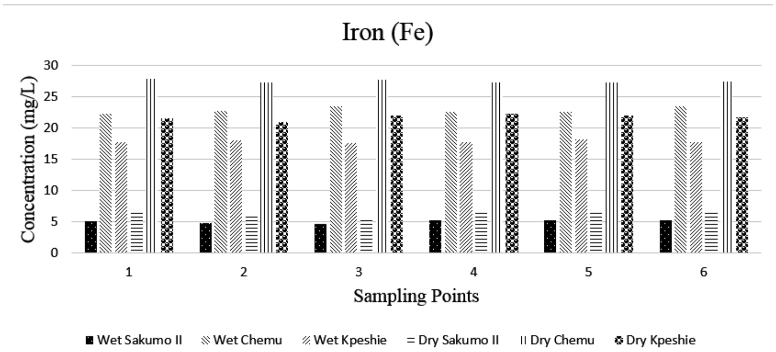

Figure 6: Seasonal variations of Iron in water samples from Sakumo II, Chemu and Kpeshie lagoons

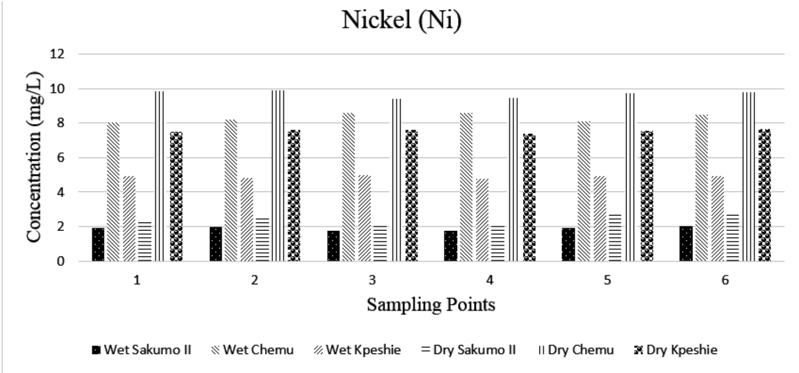

Figure 7: Seasonal variations of Nickel in water samples from Sakumo II, Chemu and Kpeshie lagoons

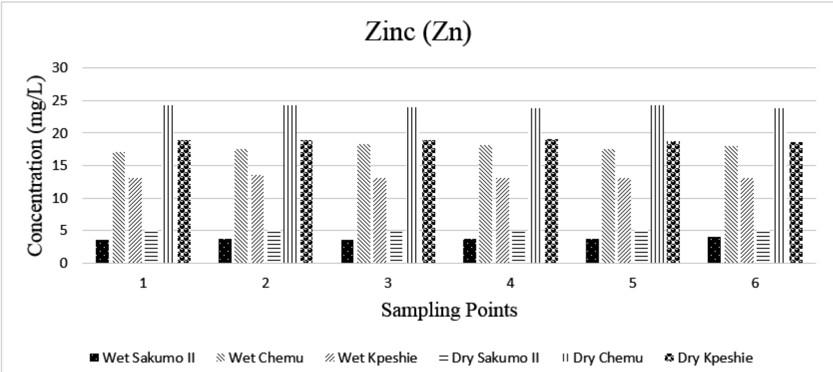

Figure 8: Seasonal variations of Zinc in water samples from Sakumo II, Chemu and Kpeshie lagoons

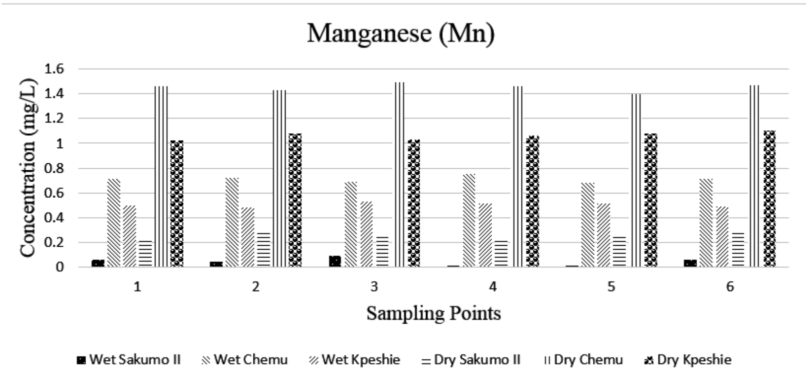

Figure 9: Seasonal variations of Manganese in water samples from Sakumo II, Chemu and Kpeshie lagoons

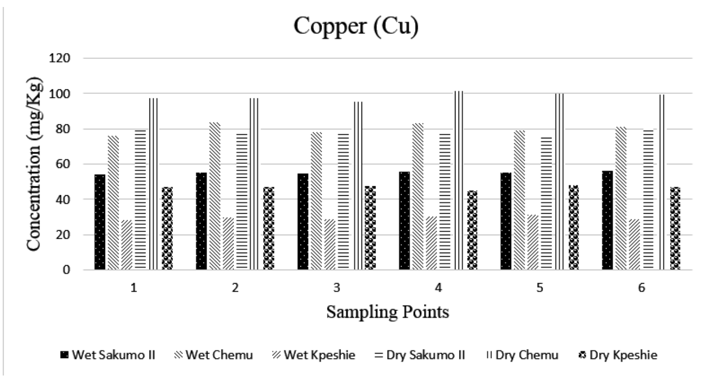

Figure 10: Seasonal variations of Copper in sediment samples from Sakumo II, Chemu and Kpeshie lagoons

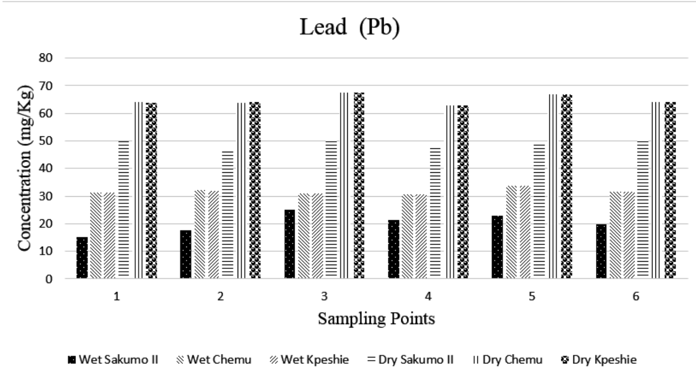

Figure 11: Seasonal variations of Lead in sediment samples from Sakumo II, Chemu and Kpeshie lagoons

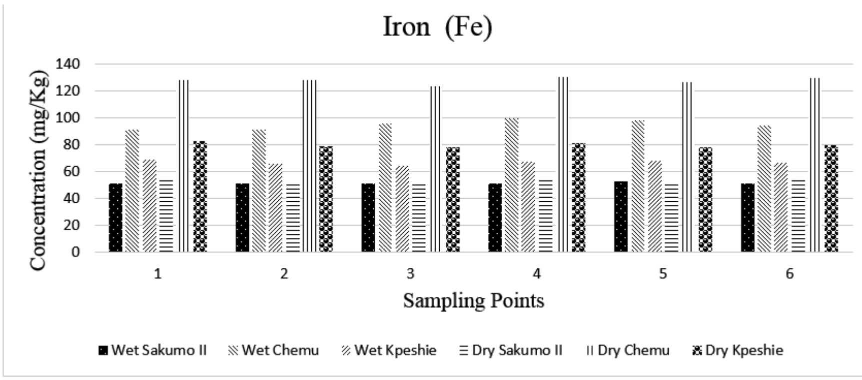

Figure 12: Seasonal variations of Iron in sediment samples from Sakumo II, Chemu and Kpeshie lagoons

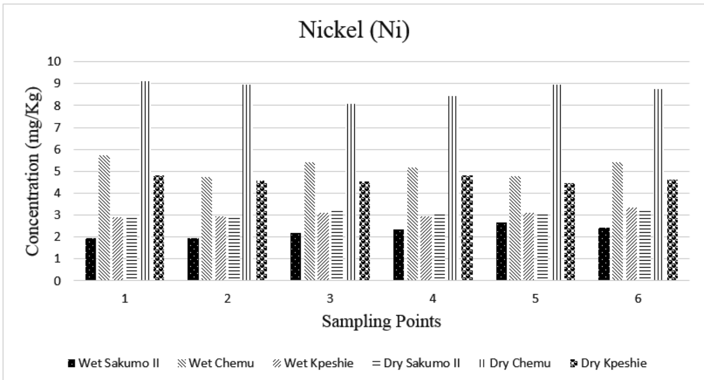

Figure 13: Seasonal variations of Nickel in sediment samples from Sakumo II, Chemu and Kpeshie lagoons

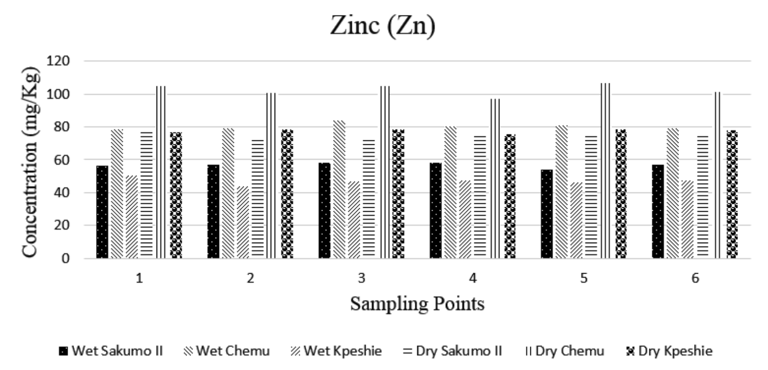

Figure 14: Seasonal variations of Zinc in sediment samples from Sakumo II, Chemu and Kpeshie lagoons

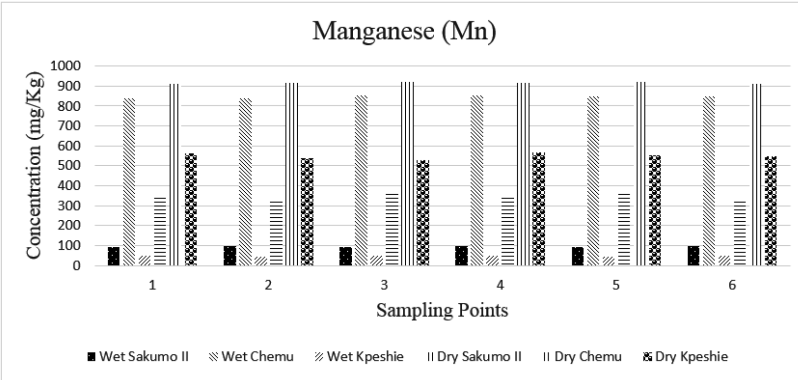

Figure 15: Seasonal variations of Manganese in sediment samples from Sakumo II, Chemu and Kpeshie lagoon

TABLE 7
Pearson correlation of heavy metal contents (mg/kg) in sediment samples from Sakumo lagoon

	Cu	Pb	Fe	Ni	Zn	Mn
Cu	1					
Pb	0.983	1				
Fe	0.700	0.655	1			
Ni	0.907	0.936	0.617	1		
Zn	0.980	0.973	0.651	0.854	1	
Mn	0.988	0.985	0.677	0.898	0.982	1

Correlation is significant at the 0.05 level (2-tailed)

TABLE 8
Pearson correlation of heavy metal contents (mg/kg) in sediment samples from Chemu lagoon

	Cu	Pb	Fe	Ni	Zn	Mn
Cu	1					
Pb	0.960	1				
Fe	0.970	0.977	1			
Ni	0.938	0.969	0.969	1		
Zn	0.928	0.981	0.956	0.957	1	
Mn	0.966	0.988	0.991	0.975	0.975	1

Correlation is significant at the 0.05 level (2-tailed)

TABLE 9
Pearson correlation of heavy metal contents (mg/kg) in sediment samples from Kpeshie lagoon

	Cu	Pb	Fe	Ni	Zn	Mn
Cu	1					
Pb	0.991	1				
Fe	0.962	0.969	1			
Ni	0.968	0.981	0.969	1		
Zn	0.987	0.989	0.969	0.971	1	
Mn	0.892	0.877	0.841	0.851	0.884	1

Correlation is significant at the 0.05 level (2-tailed)

Reference

Ansah, M., (2006). *The Use of Natural Systems for the Treatment of Greywater: A Case Study of Kpeshie Lagoon*. M.Sc Thesis, Kwame Nkrumah University of Science and Technology, Kumasi.

APHA, A., (1992). *WEF, Standard Methods for the Examination of Water and Wastewater* (18th edition.) America Publication of . Health & Association, Washington, DC.

APHA., (2005). *Standard methods for the examination of water and wastewater*. Am. Publication. Health Association.

Bhaskaram P., (2001). Immunobiology of mild micronutrient deficiencies. *British Journal of Nutrition* 2001; 85: 75-80.

Beyersmann, D., Hartwig, A., (2008). Carcinogenic metal compounds: recent insight into molecular and cellular mechanisms. *Archives of Toxicology*, 82(8), 493–512.

Department of Water Affairs and Forestry (*DWAF*), 1996. *Water Quality Guidelines, Aquatic Ecosystem Use*. Vol. 1& 2 edition. DWAF, Pretoria.

Eaton, A. D., Clesceri, L. S., Rice, E. W., Greenberg, A. E., & Franson, M. A. H. (2005). Standard Methods for the examination of water and wastewater. *Centennial Edition., APHA, AWWA, WEF*, Washington, DC.

Essumang, D. K., Adokoh, C. K., Afriyie, J., & Mensah, E., (2009). Source Assessment And Analysis of Polycyclic Aromatic Hydrocarbon (PAH ' s) in the Oblogo Waste Disposal Sites and Some Water Bodies in and around the Accra Metropolis of Ghana, 2009 (December), 456–468.

Evans, D.W., N.H., Cutshall, F.H. Cross and D.A. Wolfe., (1977). Manganese cycling in the Magnesium Newport estuary, North Carlifonia. Estuar. Coast. *Marine Sciences*, 5: 71-80.

Fatoki, O. S., Lujiza, N., & Ogunfowokan, A. O. (2002). Trace metal pollution in Umtata River. *Water SA*, 28(2), 183–190.

Fianko, J. R., Laar, C., Osei, J., Anim, A. K., Gibrilla, A., & Adomako, D. (2013). Evaluation of some heavy metal loading in the Kpeshie lagoon, Ghana. *Applied Water Science*, 3(1), 311–319.

Gordon, C., Yankson, K. A., Biney, C. A., Amlalo, D. S., Tumbulto, J. W., & Kpelle, D. (1998). Wetland typology: Contribution to the Ghana National Wetland Strategy. Ghana Wildlife Department, Coastal Wetlands Management Project, Accra.

Helmer, R., Hespanhol, I., Supply, W., Council, S. C., & Organization, W. H. (1997). Water pollution control: a guide to the use of water quality management principles. E & FN Spon London.

Hering, D., Borja, A., Carstensen, J., Carvalho, L., Elliott, M., Feld, C. K., Pont, D., (2010). The European Water Framework Directive at the age of 10: a critical review of the achievements with recommendations for the future. *Science of the Total Environment*, 408(19), 4007–4019.

Institute of Medicine (2001). Food and Nutrition Board. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium and Zinc. Washington, DC: National Academy Press.

Klake, R. K., Nartey, V. K., Doamekpor, L. K., & Edor, K. A. (2012). Correlation between Heavy Metals in Fish and Sediment in Sakumo and Kpeshie Lagoons, Ghana. *Journal of Environmental Protection*, 03(09), 1070–1077.

Koranteng, K. A. (2002). 14 Fish species assemblages on the continental shelf and upper slope of Ghana. *Large Marine Ecosystems*, 11, 173–187.

Lansdown, R., (1986). Lead, intelligence attainment and behavior. In: Lansdown R and Yule W (eds.) The Lead Debate. Croom Helm, London-Sydney. 235-270.

Lawson, E. O. (2011). Physico-Chemical Parameters and Heavy Metal Contents of Water from the Mangrove Swamps of Lagos Lagoon , Lagos , Nigeria. *Advances in Biological Research*, 5(1), 8–21.

Lawson, E. T. (2013). Your Leisure, My Space: Using Residents' Perceptions as Indicators in Sustainable Coastal Tourism Development in Ghana.

Marquette, C. M., Koranteng, K. A., Overå, R., & Aryeetey, E. B.-D. (2002). Small-scale fisheries, population dynamics, and resource use in Africa: the case of Moree, Ghana. AMBIO: A J*ournal of the Human Environment,* 31(4), 324–336.

Moolenaar, S. W. (1998) Sustainable Management of Heavy Metals in Agroecosystems. Landbouwuniversiteit Wageningen

Needleman, H.L., (1987). Low level lead exposure and children"s intelligence: A quantitative and critical review of mo dern studies. Proc. 6th Int. Conf. on Heavy Metals in the Environment, New Orleans. Volume 1. CEP Consultants Ltd., Edinburg. 1-8.

Oghenerobor B.A., Ohiobor G.O.,, Olaolu T.D., (2014). Heavy Metal Pollutants in Wastewater Effluents: Sources, Effects and Remediation. *Advances in Bioscience and Bioengineering*.Vol.2, No.4, pp. 37-43. doi: 10.11648/j.abb.20140204.11

Onyari M. J,. Muohi A. W., Omondi G., and Mavuti K. M., (2003). Heavy metals in sediment from Makupa and Port-Reitz Creek systems: Kenyan Coast. *Envir. Int.* 28(7): 639–647.

Ponta, M., Frentiu, T., Rusu, A-M., Cordos, E.A., (2002). Traces of Cu, Mn and Zn in aquatic animals and sediment from the Cris River basin, West Romania. *Croatica chemica acta (CCACAA)*. 75(1) 291-306.

Ramsar, C. S,. (2007). River basin management: integrating wetland conservation and wise use into river basin management, Ramsar Handbooks for the Wise Use of Wetlands, vol. 7. In Ramsar Convention Secretariat, Gland, Switzerland (p. 62).

Sin, S. N., Chua, H., Lo, W., & Ng, L. M. (2001). Assessment of heavy metal cations in sediments of Shing Mun River, Hong Kong. *Environment International,* 26(5), 297–301.

Soylak, M., & Erdogan, N. D. (2006). Copper (II)–rubeanic acid coprecipitation system for separation–preconcentration of trace metal ions in environmental samples for their flame atomic absorption spectrometric determinations. *Journal of Hazardous Materials,* 137(2), 1035–1041.

State, L., Sanyaolu, V. T., & Adeniran, A. A. (2014). Determination of Heavy Metal Fallout on the Surrounding Flora and Aquifer : Case Study of A Scrap Metal Smelting Factory in Odogunyan, 3(4), 93–100.

Stumpp, M., Wren, J., Melzner, F., Thorndyke, M. C., & Dupont, S. T. (2011). CO_2 induced seawater acidification impacts sea urchin larval development I: elevated metabolic rates decrease scope for growth and induce developmental delay. Comparative Biochemistry and Physiology Part A: *Molecular & Integrative Physiology*, 160(3), 331–340.

United States Environmental Protection Agency (USEPA)., (1986). Quality Criteria for Water. United States Environmental Protection Agency office of Water Regulations and Standards. DC, 20460.

Uthe, J., Blish E.G., (1971). Preliminary survey of heavy metal contamination of Canadian fresh water fish. *Journal of Fishery Resources Board of Canada*, 28: 786-788.

Wetlands, A. N., & Strategy, C. (1999). Republic of Ghana Managing Ghana's Wetlands :, 1999.

Zayed, J., 2001. Use of MMT in Canadian Gasoline: Health and Environmental Issues. *America Journal of Industry.* Med., 39: 425-433.