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Pollution along the Congo Town bay and Connaught Hospital bay, Freetown, Sierra Leone

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ABSTRACT

There is increasing concern over metal tins and scraps that litter much of the coastline, dumpsites and associated environments of Freetown as a result of poor waste management. Al, Cu and Zn were assessed for their level at two sites, back of the main central government hospital (Connaught Hospital) and the estuary of Congo Town along the Central-West coastline of Freetown. Three sets each of soil, sediment, and water samples were collected between January and August 2011. Soil and sediment samples were digested prior to metal determination in accordance to standard methods. The results were, Congo Town: Al = 20.8±4.8, Zn = 1.8±1.2, Cu = 11.4± 7.6 mg Kg^{-1} for soil samples and Al = 20.0±5.0, Zn = 2.7±0.8, Cu = 11.3±4.4 mg Kg^{-1} for sediment samples whilst for the back of Connaught hospital: Al = 8.9±8.2, Zn = 1.8±0.8, Cu = 13.7±8.8 mg Kg^{-1} for soil samples and Al = 41.0±23, Zn = 1.5±0.4, Cu = 12.2±8;9 mg Kg^{-1} for sediment samples. Metal concentration (mg/L) of water samples collected at the sites were: Al = 0.27 ± 0.1, Zn = 0.52 ± 0.4, Cu = 1.04 ± 0.6 for the Congo Town bay whilst at the Connaught Hospital bay, Al = 1.10 ± 0.3, Zn = 0.21 ± 0.1, Cu = 2.06 ± 1.5. pH of soil and sediment at both sites was relatively neutral but water samples at both sites were slightly alkaline (7.8±0.2 and 7.7±0.2 for Congo Town and Connaught respectively). Results of the study raises concern of aluminium toxicity in Freetown aquatic ecosystem.

KEYWORDS: Metal pollution, Al, Cu, Zn

INTRODUCTION

The coast of Freetown is made up of diverse landforms ranging from beaches to lagoons, bays to spits and from cuspate foreland to tombola. These different landforms serve as the habitat for humans and various animal and plant species. They are also used for various other purposes. Some of these purposes are of economic importance to the inhabitants of the coastal communities, but on the other hand a lot of the activities have led to the degradation of the natural beauty of these communities as a result of the pollutants they introduce into the environment.

In the Congo Town Bay community, the large coastal population is the main source of pressure on the neighboring marine and other coastal resources. Lack of infrastructure and treatment facilities for the large quantity of domestic sewage generated by the expanding coastal urban population, and an increasing number of other factors present a great threat to public health, coastal habitats and economic development of this community.

Overall, although industrial development in the Congo Town Community remains relatively low, there are still instances of pollution caused by the direct release of untreated effluent into the environment (Mansa-Musa, 2011). This is evident in the case of the Congo Town Bay next to the Bomeh dump site, wherein the Safari plastic manufacturing company has a pipe, which empties waste liquid from manufacturing processes. Also, the Congo Town Bay Community serves as an emptying site for major drainages in the Freetown municipality. Another major source of pollution at the Congo town bay is due to the close proximity of the Bomeh dump site which is the principal garbage collection point in the western part of the Freetown municipality (Frazer-Williams *et al*., 2010).

The Connaught hospital is the central government hospital in the centre of Freetown. Going westwards, it is located in the middle of the Bomeh dumpsite on the left and the King Jimmy market on the right. Its close proximity to the two sites renders the site vulnerable to pollutant loads. In addition, runoffs from the Kroo Bay market and a major drainage (known as Samba gutter) that receives municipal wastewater from part of the Western Area of Freetown also empties in the vicinity of the Connaught Hospital Bay.

Pollution can generally be understood as the introduction of unwanted material (contaminants) into a natural environment that causes instability, harm, discomfort or disorder to the natural ecosystem which consist of both physical systems (rivers, beaches, lagoons, bays, etc.) and living organisms. Pollution can exist in a wide variety of forms such as chemical substance (e.g. heavy metals and other industrial waste materials), energy (e.g. heat, noise and light) and physical agents (e.g. litter, untreated sewage, etc). Pollution as a whole can be categorized into two classes: point source pollution and non-point source pollution. Point source pollution refers mainly to a single identifiable localized source of water, air noise, light and thermal pollution (e.g. water pollution from an oil refinery waste water discharge outlet) whilst non-point source pollution on the other hand is specifically water pollution affecting a water body from diffuse sources such as polluted run-off from agricultural areas or domestic sewage into a river or ocean, or wind-borne debris blowing out to coastal areas. Presently, little or no data is available on the state of metal pollution along the coast of Freetown. Baseline data is needed if the government and authorities involved in environmental health protection are to act decisively based on well informed knowledge. In light of the above, this study aims to primarily assess the level of metals (Aluminium, Copper and Zinc) in sediment, soil and water along the Congo Town Bay and the back of Connaught hospital Bay. Other parameters such as chloride, organic matter, cation exchange capacity and bacteriological parameters were also investigated.

MATERIALS AND METHODS

Study sites

Both study sites (i.e. the Congo Town Bay and Connaught Hospital Bay) are located in the western part of Freetown the capital city of Sierra Leone. Inhabitants of both communities depend to some extent on the nearby ocean wherein they engage themselves in activities such as fishing for economic growth. The area also serves as an entry port for small boats (canoes) that transport agricultural produce and other goods from various communities along Sierra Leone's Atlantic coast. Both communities serve as an emptying point for major drainages in the Freetown municipality. At the Congo Town Bay, waters from the Congo-cross stream from one side meet with estuarine waters from the Bay which lies adjacent to the Kingtom (Bomeh) dumpsite.

Collection of samples

The polyethylene containers that were used for sample collection were first washed with pure water, immersed in 1M Nitric acid (HNO_3) solution within a time period of 24 – 48 hours. After this, the containers were then removed from the Nitric acid solution and thoroughly rinsed with distilled water and dried in an oven (Griffin Grundy Model) at 60^{o}C.

Soil, sediments and water were collected at ~25m, ~50m and ~100m respectively from the bank of both sites in January (dry season), May (early rains) and August (mid rainy season). Portion of soil and sediment samples were used for pH and conductivity measurements according to standard procedure (APHA, 1998). The remaining samples were oven dried at 100 ± 5^{o}C to constant weight for chloride, metals, organic matter and cation exchange capacity determinations.

Determination Of Parameters

pH, Chloride Ion and Heavy Metals:

In general, the Photometric analyzer, Wagtech International Ltd, England was used for the determination of the various parameters. pH was determined using the Thermo Orion (SN 057019) combine glass electrode pH meter after calibration with pH 4, 7 and 10 buffers as indicated in the manual. Chloride was estimated by the standard argentometric titration as described in APHA (1998). This involves titrating 10ml of the sample using two drops of potassium chromate as the indicator. Titration was carried out with freshly prepared 0.02M AgNO3 solution from a burette. The first permanent reddish tinge marked the end point. Estimation for indicator organisms (E .coli as well as faecal and non-faecal coliforms) in water samples were enumerated using the field kit membrane filtration method by Wagtech International Ltd, England shortly after sample collection. In the case of the soil and sediments samples, digestion was first carried out according to amended procedure outlined in Kruis (1997) as follows: 5g of the soil/sediment sample was weighed and transferred into a digestion flask. 20 ml 3:1 HCl/HNO_3 was then added followed by one or two boiling chips and digested. When the volume reduced to about 5ml, the digestion flask was allowed to cool. After cooling, 4ml of 30% H_2O_2 (hydrogen peroxide) was added and the digestion process continued for 10 minutes. 25ml distilled water was added to the flask followed by continuous swirling and the content was heated to boiling. Finally the digestion flask was removed from the hot plate, cooled and filtered through a funnel with a Whatman No. 5 filter paper into a 250ml volumetric flask, followed by the final test for heavy metals using the photometer. In the case of the water samples no digestion was done.

The procedure for the different heavy metals generally involves filling the graduated test-tube with the sample to the 10 ml mark, followed by crushing a tablet for the metal ion to be determined, mixed and allowed to stand for five minutes. The concentration was then read on the photometer at the specified wavelength. The reading obtained was compared with a calibration chart.

Organic Matter:

Determination of organic matter of soil and sediment was carried out by oxidising the organic matter using excess chromic acid (0.167M) in concentrated sulphuric acid which serves as an internal supplier of heat for the process. Using this method, somewhat less of the total organic matter is oxidised and this is thought to be an advantage, since the less active organic matter is not measured. In using this method, it is the percentage of organic carbon in the soil/sediment that is determined and this is multiplied by a conventional factor 1.724 to give the percent organic matter. The use of this factor is based on the assumption that the soil/sediment organic matter contains 58% carbon. To determine the organic carbon content, 10ml Potassium Dichromate (oxidising agent) is added to 0.5g soil/sediments followed by 20 ml concentrated sulphuric acid. After the oxidation is complete, the amount of unused oxidising agent is determined by back-titration with standard ferrous sulphate (Avery and Bascomb, 1987).

Cation Exchange Capacity:

The determination of the cation exchange capacity (CEC) of the soil and sediment samples was carried out according to procedure described in Bascomb (1964). 5g of air-dried soil/sediment was weighed and transferred into a polythene centrifuge bottle with a tight stopper. The soil/sediment was then treated with 100ml $BaCl_2$ for 1hour with occasional stirring. This was followed by centrifuging at 1500 r.p.m. for 15minutes. The supernatant liquid was discarded afterwards (at this point, care was taken so that the soil/sediment was not lost). The soil was further treated with 200ml buffered $BaCl_2$ and left overnight. The following day, a centrifuge process was carried out and the supernatant liquid discarded. 200ml distilled water was added to the centrifuge bottle to break up the soil/sediment cake. The centrifuge process was continued and the supernatant liquid obtained discarded. At this point the bottle was weighed with its content. 100ml of previously standardized $MgSO_4$ was pipetted into the bottle and stoppered followed by vigorous shaking at intervals of 2 hours. The content of the bottle was centrifuged for the last time and the supernatant liquid decanted into a stoppered flask. 5ml of the supernatant liquid was pipetted into a 250ml conical flask followed by 6 drops of 2N NH_4OH and 2 drops of the indicator. Titration was carried out with EDTA solution until the end point was reached (marked by a change in colour from wine red to inky blue).

RESULTS

Chemical parameters

Heavy metals

Results for heavy metals in both sites is presented (Figures 1a and 1b, Table 1). Mean concentration (mg/Kg) of metals in soil at the Congo Town Bay averaged 20.75 ± 4.8, 11.43 ±7.8 and 1.8± 1.2 for Al, Cu and Zn respectively, whilst at Connaught Hospital Bay, mean concentration (mg/Kg) in soil averaged 8.85 ± 8.2, 13.67 ±8.8 and 1.13 ± 0.8 for Al, Cu and Zn respectively. Also, mean concentration (mg/Kg) of metals in sediments at the Congo Town Bay averaged 20.0 ± 5.0, 11.27 ± 4.41 and 2.70 ± 0.75 for Al, Cu and Zn respectively and sediments at Connaught Hospital Bay mean concentration (mg/Kg) averaged 41.23 ± 23, 12.17 ± 8.9 and 1.53 ± 0.41 for Al, Cu and Zn respectively. Results of mean concentration (mg/L) of metals in water samples at the Congo Town Bay and Connaught Hospital Bay is presented (Table 1). Mean concentration (mg/L) of metals in water samples at the Congo Town Bay averaged 0.27 ± 0.1, 0.52 ± 0.4 and 1.04 ± 0.6 for Al, Zn and Cu respectively, whilst at Connaught Hospital Bay, mean concentration (mg/L) averaged 1.10 ± 0.3, 0.21 ± 0.1 and 2.06 ± 1.5 for Al, Zn and Cu. Results of organic matter (OM) in soil and sediment from both sites is presented (Table 2). Higher OM is found in sediments than in soils in both sites. Tables 3 and 4 present results of cation exchange capacity and Cl^- in soil and sediments in both sites. Table 4 presents result for chloride in soil and sediment at both sites.

Physical parameters

pH and conductivity

Results of pH for soil, sediment and water from both sites is presented (Table 5). Mean pH values were: 7.01 ± 0.1, 7.29 ± 0.1 and 7.75 ± 0.2 for soil, sediment and water respectively at Congo Town Bay and 7.03± 0.1, 7.53 ±0.2 and 7.66 ± 0.2 at the Connaught Hospital Bay. In each of the three months sampling was carried out, conductivity values from the Connaught Hospital Bay was greater than Congo Town Bay. Conductivity in both sites increase from January to August although a drop from January to May was observed for the Congo Town Bay sample.

Bacteriological parameters

Table 7 presents results for bacteriological parameters. General level of bacteriological parameters was in the order: faecal coliform > non-faecal coliform > *E. Coli* for both sites.

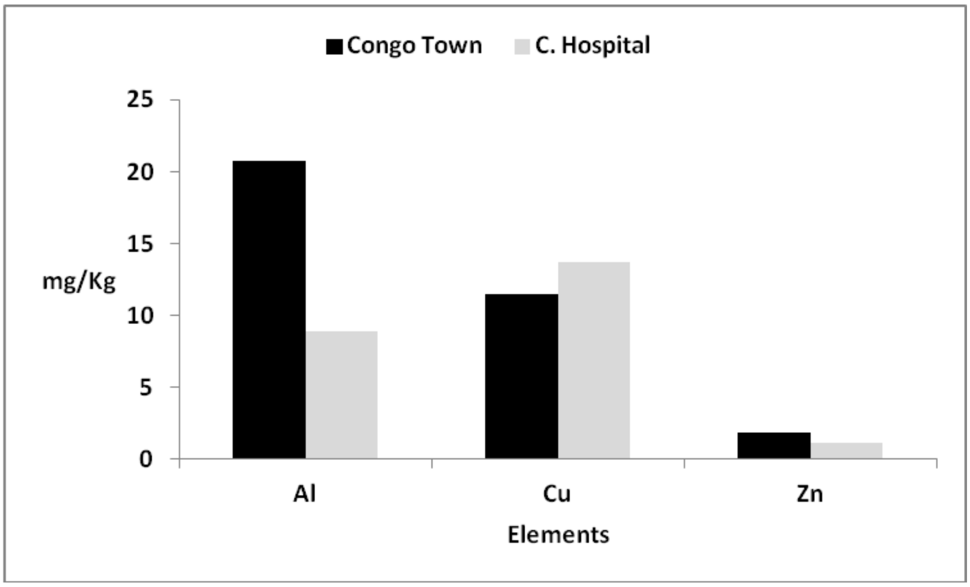

Figure 1a. Concentration (mg/Kg) of metals in soils at the Congo Town and Connaught Hospital Bays

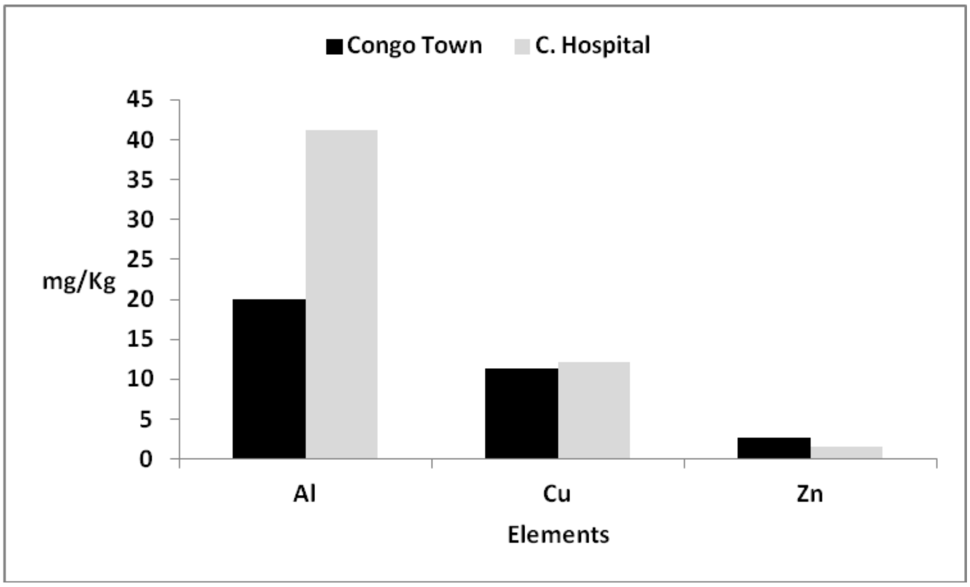

Figure 1b. Concentration (mg/Kg) of metals in sediments at the Congo Town and Connaught Hospital Bays

Table 1: Heavy metal concentration in soil, sediment and water sample at the Congo Town and Connaught Hospital Bays

		Congo Town Bay			Connaught Hospital Bay		
Month	Heavy Metal	Soil(mg/kg)	Sediments(mg/kg)	Water(mg/L)	Soil(mg/kg)	Sediments(mg/kg)	Water(mg/L)
	Aluminium	25.5	25.0	0.23	17	18.0	0.8
January	Zinc	4.2	2.0	0.0	0.2	2.3	0.04
	Copper	26.5	20.0	0.14	11	0	0.08
	Aluminium	16.0	15	0.14	0.7	64.0	1.40
May	Zinc	0.6	1.9	1.29	2.3	0.9	0.14
	Copper	2.4	8.0	2.25	0	7.0	1.10
	Aluminium	ND	ND	0.43	ND	Over range	Over range
August	Zinc	0.6	4.2	0.26	3.0	1.4	0.44
	Copper	5.4	5.8	0.72	30.0	29.50	5.0

ND – Not determined

Table 2: Percent organic matter of soil and sediment samples at the Congo Town and Connaught Hospital Bays

	Congo Town Bay		Connaught Hospital Bay	
Month	Soil	Sediments	Soil	Sediments
January	2.835	4.362	3.135	4.662
May	3.163	3.274	2.863	2.974
August	3.467	4.582	3.167	4.282

Table 3: Cation exchange capacity (meq+/100g) of soil and sediment samples at the Congo Town and Connaught Hospital Bays

	Congo Town Bay		Connaught Hospital Bay	
Month	Soil	Sediments	Soil	Sediments
January	8.43	12.67	6.02	10.83
May	18.3	21.72	16.70	19.30
August	16.61	23.94	15.10	20.67

Table 4: Chloride (g/L) of soil and sediment samples at the Congo Town and Connaught Hospital Bays

	Congo Town Bay		Connaught Hospital Bay	
Month	Soil	Sediments	Soil	Sediments
January	0.552	2.402	0.921	0.813
May	1.122	2.861	0.513	1.306
August	0.738	0.353	0.476	0.483

Table 5: pH values of water samples at the Congo Town and Connaught Hospital Bays

	Congo Town Bay			Connaught Bay		
Month	Soil	Sediments	Water	Soil	Sediments	Water
January	6.82	7.18	7.5	7.26	7.35	7.92
May	7.03	7.47	7.72	6.97	7.90	7.80
August	7.17	7.23	8.02	6.86	7.33	7.26

Table 6: Conductivity values (µS/cm) of water samples at the Congo Town and Connaught Hospital Bays

Month	Congo Town Bay	Connaught Hospital Bay
January	629	843
May	456	1055
August	1451	1492

Table 7. Bacteriological parameters of water samples in the Congo Town and Connaught Hospital Bays (cfu/100 ml)

Month	Parameter	Congo Town Bay	Connaught Hospital Bay
	E. Coli	36	42
January	Faecal Coliform	191	186
	Non-Faecal Coliform	126	118
	E. Coli	23	30
May	Faecal Coliform	163	172
	Non-Faecal Coliform	139	132
	E. Coli	0	0
August	Faecal Coliform	125	135
	Non-Faecal Coliform	176	155

DISCUSSION

Heavy metals

Analysis of the metal result of this study show that the concentration of all three metals in both soil and sediment between the two sites is generally comparable. However, mean concentration of Al is much higher than Cu and Zn in Congo Town Bay whilst in samples collected from Connaught Hospital Bay, Al is relatively comparable to Cu but much higher than Zn (Figures 1a and 1b). Al and Cu are about 5-8 times more than Zn. Based on the results, the metal concentrations in both sites can be arrange in the order: Al > Cu > Zn (Figures 1a and 1b). A possible reason for this order is the large quantities of Al tins (empty beverage cans) that are often seen littering surrounding sites. In addition, leachates from the Bomeh dumpsites and waters from the dumpsite streams which contain dissolved Al, Cu, Pb and Zn (Frazer-Williams *et al*., 2011; Frazer-Williams *et al*., 2010) might have contributed to the metal levels as the two sites are within close proximity of the Bomeh dumpsite. Barry (2010) had earlier reported high levels of aluminium in waters and fishes of nearby ecosystem of the Kingtom dumpsite. Similar findings of the influence of dumpsite in Alexandria, Egypt on nearby environments have been reported (Rashand and Shalaby, 2007).

The results of heavy metals concentrations at both sites fell within range of reported means in the literature. To illustrate, much lower concentration (mg/Kg) for Cu (3.32 ± 2.37 in dry season and 3.38 ± 1.72 in wet season) but higher concentration for Zn (12.46 ± 4.56 in dry season and 5.62 ± 4.22) was reported in sediments of the Ase river, Niger Delta, Nigeria (Iwegbue *et al*., 2007).

Iheyen (2001) reported Cu concentrations in sediments of Benin River, Nigeria in the range 3.90 – 6.80 mg/Kg, whilst Spumy *et al*., (2002) reported Cu concentration range of 4.49 – 14.33 in sediments of Jihlava River, Czech Republic. This indicates that metal conditions in sediments depend among other things on E_h, pH, local conditions including the rate of deposition of metals from anthropogenic sources sediment deposition from runoffs etc.

With regard to metal concentration in waters, the concentration of Zn and Cu obtained in this study exceeded levels of Zn (0.035 – 0.038 mg/L) and Cu (0.04 – 0.07 mg/L) reported for polluted surface and well waters in the Sierra Rutile mining area of Mogbwemo, Southern Sierra Leone (Thullah, 2006). This indicates pollution in waters of the bay. Analysis of metal results during the period January to August reveal variation in the concentration for the various heavy metals throughout the period of investigation. This could be a direct result of anthropogenic inputs of metal scraps and metal related sources which corroded in the vicinity of the bays.

Organic matter, C. E. C and chloride

OM for sediment is consistently greater than soil in both sites. With the exception of sediment samples in Connaught Hospital Bay, highest organic matter recorded was for August. Much lower OM content had been reported in the literature. For instance, Iwegbue *et al*., (2007) reported mean OM content of sediments of the Ase River of 1.30 ± 0.33% and 1.40 ± 0.4% for dry and wet season respectively. Similar low OM content had been reported for some rivers in Niger Delta, Nigeria (Horsfall *et al*., 1999). Soil organic matter tends to have a variety of charged sites on their surfaces, some positive and some negative. The negative charges of these various soil particles tend to attract and bind the metal cations and prevent them from becoming soluble and dissolved in water.

Cation exchange capacity (CEC) is the maximum quantity of total cations, of any class, that a soil/sediment is capable of holding, at a given pH value, for exchanging with the soil/sediment solution. CEC is used as a measure of fertility, nutrient retention capacity, and the capacity to protect groundwater from cation contamination. In both sites, there is a general increase in CEC from January to August. Furthermore, CEC for sediments was consistently greater than soil and CEC for Congo Town Bay was also consistently greater that their Connaught Hospital Bay counterpart. Overall, average CEC for Congo Town Bay was greater than that of Connaught Hospital Bay. Closely related to cation exchange capacity is the base saturation (Turner and Clark; 1966) which is the fraction of exchangeable cations that are base cations (Ca, Mg, K and Na). It can be expressed as a percentage, and called percent base saturation. The higher the amount of exchangeable base cations, the more acidity can be neutralised in the short time perspective. Thus, a site with high cation exchange capacity takes longer time to acidify (as well as to recover from an acidified status) than a site with a low cation exchange capacity (assuming similar base saturations).

Average level of chloride in sediment is greater than that present in soil. At the Congo Town Bay, the mean chloride for sediment samples (i.e. 1. 872 g/dm^3) is more than two folds (~2.3 times) that of the soil sample (i.e. 0.804 g/dm^3), whilst at the Connaught Hospital Bay, mean chloride for sediment (0.867 g/L) is 1.36 times that of soil (0.637 g/L). The higher chloride concentration for the sediment could be attributed to the presence of salty estuarine waters always present in sediment. Sediment are mostly wet compared to soil which is mostly dry.

pH and conductivity

The pH values were in general near neutral and may not pose any serious impact to soil reaction. However, it is worth mentioning the trend in pH values observed. In soil and water samples, pH increase from January to August in both sites whilst for the sediment sample, there was an increase from January to May followed by a decrease in August. Although pH of water samples at both sites are comparatively higher than the soil and sediment samples, overall, there is no statistical significant difference between pH values (ANOVA, $p<0.05$). pH values are within range of acceptable limits of pH in all quality standards (e.g. WHO standard for drinking water is 6 – 8).

Conductivity of a substance is the ability to conduct or transmit electricity. It is noted conductivity generally increased from January to August corresponding to increase in rainfall from January to August. Possible explanation for this is that as rainfall increases, the amount of dissolve ions that have leached out of soils, and those carried by runoffs increases.

Bacteriological parameters

All three bacteriological parameters (*E. coli*, faecal coliform and non-faecal coliform) for both sites show the same pattern between January and August. To illustrate, in January and May, the level of bacteriological parameters is in the order: faecal coliform > non-faecal coliform > *E. Coli* for both, whilst in August, the level of non-faecal coliform is greater than the faecal coliform for both sites. Possible reason for the increase in non-faecal coliform over faecal coliform in August may be due to the absence of *E. coli* in both sites. By definition, several bacteria can be classified as coliform, and are commonly found in soil, on the surface of leaves, in decaying matter, and can grow in water bodies as well. These types of coliform bacteria are not faecal contamination related, and do not necessarily indicate unsafe water. Also it should be noted that, the presence of faecal coliforms in water may not be directly harmful, and does not necessarily indicate the presence of faeces.

CONCLUSION

A study to investigate the nature and extent of pollution along the Congo Town Bay and Connaught Hospital Bay was conducted. All pollutants determined were present in greater quantities in sediment compared to soil. The result of this study showed that both sites are contaminated with Al, Cu and Zn. The order of occurrence of the three metals in both soil and sediment can generally be placed in the order Al> Cu> Zn. The results raises concerns of Al toxicity in Freetown aquatic ecosystem. The fluctuation in concentration of metal during the study period can be as a result of anthropogenic inputs.

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