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Effect of anthropogenic activities on an ecologically important wetland in Ghana

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Abstract

The objective of this research was to assess the level of pollution in the Sakumo wetland with emphasis on heavy metals contamination and their distribution in the wetland, which is being polluted from industrial, domestic and sewage effluents. Samples of water, sediment and fish were collected and analyzed for the concentration of heavy metals (arsenic, cadmium, chromium, copper, iron, mercury, nickel and zinc) using atomic absorption spectrophotometry (AAS). The sequence of order of the heavy metals in the water, sediment and fish samples observed in the wetland was as follows: Fe > Mn > Cu >Hg, Mn > Fe> V> Cr > Cu >Zn ≈ As >Co > Cd > Hg, Fe > Cu > Mn> V> Hg > Cd respectively. The results showed high levels of copper and managanese in all three samples (water, sediment and fish) however, mercury and cadmium were available in relatively low concentration in the fish samples. Sampled sediment materials revealed highest concentrations of the heavy metals. Fe, Mn, and Zn concentration in fish samples were higherr than WHO/FAO recommended values; however, these heavy metals did not pose any immediate health risk to humans. It is possible however, that, the concentration of these heavy metals may increase in wetland and subsequently in the fishes (and other animals) living within the wetland. Hence, the need for regular monitoring of these heavy metals in the wetland resources is important.

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Introduction

Wetlands like most terrestrial ecosystems are made up of soils and water as well as plants and animals. The complex interaction between these components allows wetlands to specialize in the performance of certain ecological or natural functions and generate products of socio-economic importance. The interactions of physical, biological and chemical components of a wetland, such as the soil, water, plants and animals, enable the wetland to perform many vital functions, such as water storage, storm protection and flood mitigation, shoreline stabilization and erosion control, groundwater recharge, groundwater discharge, water purification, retention of nutrients, retention of sediments, retention of pollutants, and stabilization of local climate conditions, particularly rainfall and temperature (Ramsar Convention Secretariat, 2004). The combination of these functions together with the value placed on biological diversity make wetlands useful ecosystems. Wetlands are therefore not wastelands but important ecosystems providing several ecological and production services. Wetland ecosystems, including rivers, lakes, marshes, rice fields, and coastal areas, provide many services that contribute to human well-being and poverty alleviation. Two of the most important wetland ecosystem services affecting human well-being involve fish supply and water availability. Inland fisheries are of particular importance in the Sakumo wetland and they are the primary source of employment and animal protein to rural communities in its catchment. Human activities particularly irrigated agriculture and urban development's instigating water diversions from rivers and streams have often altered the hydrology of most wetlands (Khan *et al.,* 2009).

Heavy metal pollution of aquatic ecosystems is becoming a potential global problem. Trace amounts of heavy metals are always present in fresh waters from terrigenous sources such as weathering of rocks resulting into geo-chemical recycling of heavy metal elements in these ecosystems (Muwanga, 1997). Trace elements may be immobilized within the stream sediments and thus could be involved in absorption, co-precipitation and complex formation (Mohiuddin et al., 2010).

The dumping of refuse, discharge of industrial and domestic sewage, as well as run-off from agricultural farms into surface water also increases the chemical and organic loading of the wetlands thereby decreasing the dissolved oxygen content necessary for aquatic organisms. The discharge of various forms of wastes into the wetland also creates fertile environment for microbiological and biological agents to flourish and spread disease pathogens leading to various health problems for humans and aquatic organisms (UNEP, 2006).

Rapid urban growth through the activities of real estate developers and the expansion of settlements through housing projects in the Tema Municipal Assembly as well as agricultural activities in the watershed of the wetland is equally of much concern. The amount of solid waste has been increasing with increasing population and changing socio-economic standards. The Sakumo wetland and its catchment has become home of a number of companies. Food and beverage industries have sprang up in this area. This include the Coca Cola Bottling Company, Ghabico, Kuhmesi cold stores, rush Industries, the accra abattoir, textile and chemical industries such as Printex and Johnson Wax among others (Caraco and Cole 1999). The operations of these companies impact negatively on the Sakumo wetland since their effluents and other waste waters are discharged into nearby streams that empty into the Sakumo lagoon. These discharges carry large influxes of nutrients, suspended and dissolved organic matter, contaminants, and other toxic materials into the wetland thereby affecting flora and fauna. These organic matters also contain plant nutrients, especially nitrogen and phosphorus, which when released into the water, may cause eutrophication. These developments have resulted in reduced water quality and self-purification properties of the wetland as seen in the disappearance of some key fish species from the wetland in the last ten (10) years (Koranteng *et al.,* 2000). Since fish from the wetland constitute an important source of protein for the inhabitants in and around the coastal community; there is the need to ensure that water and sediment on which the fish feed on from the catchment are toxic free. It is envisage that results from this study will generate baseline data on the influence of human interventions on the pollution status of the Sakumo Wetland, and the health risk associated with contamination of the wetland.

The Sakumo wetland, which is the major water body in the area receiving drainage water from the area, has been severely damaged as a result of environmental degradation from human based activities (Laar et al., 2011). The industries located in the Sakumono catchment did not have any visible waste water treatment plants hence, liquid wastes were discharged directly (untreated) into nearby storm-water canals. These releases aggravate water quality problems which result in degradation of aquatic resources in the area. The aquatic life of the lagoon has been greatly degraded due to contamination of its tributaries.

The aim of this study was to first determine the heavy metals concentration in the water, sediment and fish (Black chin tilapia) from the sakumo wetland and to compare the metal concentrations in these different compartments (water, sediment and fish) and also to eveluate the relevance of the Black chin tilapia as a metal bio-monitor of pollution.

Materials and methods

Study area

The Sakumo (II) wetland lies due east of Accra between Teshie-Nungua and Tema Township in the Greater Accra region of Ghana (Fig 1). The wetland lies between latitude 5°35' N to 6°40' N and longitude 0°00' W to 0° 10' W with an altitude of 86.9 m (286ft) and an average elevation of 45.7m. The effective catchment area of the Site is approximately 27,634ha but the water bodies including the lagoon, reservoirs and area liable to flooding is 812 ha. The catchment has a low relief, with the highest point at less than 87m above sea level and with an average elevation of 46m. Major streams within the catchment that drain into the Sakumo lagoon are the Onukpawahe, Mamahuma and Dzorwulu. However, these streams are temporary; flowing normally only during the main rainy season. The wetland is also habitat to about thirteen (13) fish species belonging to thirteen (13) genera and eight (8) families with *Sarotherodon nmelanotheron* (also known as the Black-Chin tilapia) consisting of about 97% of the total fish population (Koranteng et al., 2000). The geology of the Sakumo catchment is underlain by Dahomeyan (Pre – Cambrian) acidic schists and gneisses with minor areas underlain by intrusive granite and pyroxenite, basic gneisses and quartzite schists. Alluvium occupies the valleys of the major streams and the lagoons that drain the area (Brammer, 1967) as cited by Amatekpor, (1994).

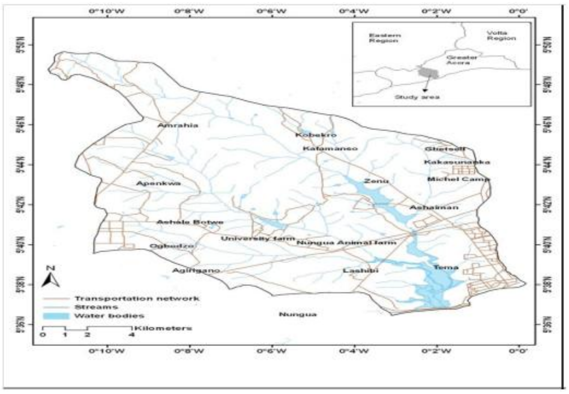

Fig. 1. Map of study area.

The predominant soils consist of black calcareous, heavy plastic clays suitable for mechanised irrigated cultivation of rice and vegetables. The vegetation consists of savannah grasses, with trees and some thickets. The area experiences a bimodal rainfall pattern, with the major rainy season occurring from mid-March/April to July and the minor rainy season starts from early September to mid – November. Average annual temperature is around 27° C.

Sample collection

Geological setting and sites were surveyed in order to choose the sampling location and site. Water samples were collected from the Sakumo (II) lagoon, three industries (alcholic beverage and non-acholic bottling company, textile industry) and surrounding feeder streams namely onupkwahe stream, mamahuma and Dzorwulu River from the Sakumono catchment within the minor raining season. The lagoon was divided into three sections with ten sampling points established (four from the northern course, three from the middle course and three from the southern course). Effluents from various industries within the catchment were also sampled at their point source before discharge into the lagoon.

Water samples for physico-chemical analyses were collected directly into pre-cleaned and prepared 1 L plastic containers using a sampling bottle tied to a collection pole. The samples were filtered through a 0.45 µm cellulose acetate membrane. The water samples for metal analysis were acidified to pH<2 using concentrated nitric acid (HNO_3). Sampling for DO and BOD was slowly and carefully filled with water to avoid trapping of air bubbles. Samples for DO were fixed on the spot by the addition of 2 mL each of $MnSO_4$ and alkali-oxide iodide solution. Sediment materials were sampled from the various sites water was collected from. The sediments were scraped with a hand auger between 0-10 cm depths within a 1x1 m square at the point of water collection and stored in a 500 mL polythene bags. Fish samples were purchased from fishermen after capture at the Sakumo lagoon. The fish samples were cleaned with deionized-distilled water, weighed, stored in pre-cleaned plastic bags, and kept frozen in an ice box. Thirty (30) fish samples were selected and double bagged in separate new plastic bags, sealed and labelled for analysis.

Field measurements and observations

In-situ measurments of hydrogen ion concentration was determined with a P8-11 sartorius pH meter kit whilst conductivity, total dissolved solids; salinity and temperature were measured using a mettler Toledo electrochemical probe Horiba. Alkalinity was also determined on site using the HACH alkalinity test kit. For the determination of dissolved oxygen, 300 mL plastic bottle was carefully filled with water sample to avoid trapping of air bubbles and 2 mL each of $MnSO_4$ and alkali-oxide iodide solution was added to the samples. The bottle was stoppered and inverted several times to ensure even mixing of the content. The physical characteristics of the sampled fish species were assessed by measuring the length and weight of the purchased fish samples. The ratio between the whole body weights to body length (head to tail) was examined for the fishes to identify fishes with anomalously high or low body ratios.

Laboratory analysis

Water samples were analysed by both classical and automated instrumental methods as appropriated in the standard methods for the analysis of water and waste water (APHA, 1992). For the DO concentration, iodometric tiration method was used. A flock of manganese hydroxide of higher oxidation state was formed which was allowed to settle. 2 mL of concentrated sulpuric acid was then added down the neck of the bottle, the contents were mixed by inversion until iodine was formed through redox reaction between the manganese and iodine which has been uniformly distributed. 50mL portion of the iodine solution was titrated with a standardized 0.025 M thiosulphate ($Na_2S_2O_3$) solution until a pale yellow colouration developed. The titration was continued to a final colourless end point using starch as an indicator:

$Mn^{2+}{}_{(aq)} \rightarrow Mn(OH)_2O$ (1)

then: $4Mn(OH)_2 + O_2 \rightarrow 4MnO(OH) + 2H_2O$ (2)

The I_3- produced was determined by titration w ith thiosulphate: $2S_2O_3{}^{2-} + 3I^-$ (3)

From equation I, II, and III the mole ratio of O_2 to S_2O^{2-} (1:4) can be determined and hence the mg/L of oxygen dissolved in the water samples calculate.

Trace amounts of sodium (Na) and potassium (K) in the water samples were determined in a directreading type of flame photometer at a wavelength of 589 nm and 766.5 nm respectively.

Analytical Instruments were pre-calibrated appropriately prior to measurements. Replicate analyses were carried out for each determination to ascertain the reproducibility and quality assurance. Water samples were digested to concentrate and convert metals associated with particulate to the free metal. All the samples were analysed using the varian AA240FS Flame Atomic Absorption Spectrometer. 6 mL of 65% of concentrated HNO_3, 3 mL of 35% HCl and 0.25% H_2O_2 was added to each vessel containing the sample. To ensure the reliability of the analytical method during digestion and sample preparation, a blank determination using the same procedure was performed. Cold vapour AAS was used in the determination of total dissolved mercury. The organomercury compounds in the sample were oxidized to inorganic mercury (II) compounds by heating with sulphuric acid, potassium permanganate and potassium persulphate. The mercury compounds were then reduced with stannous chloride in a hydroxylamine sulphatesodium chloride solution to elemental mercury. The mercury was sparged from solution with a stream of air and passed through an absorption cell situated in the pathway of the mercury lamp.

Sediment samples were air dried and all clods and crumbs removed. The dried sediments were ground in a mortar and passed through a 180 µm sieve to remove coarse particles. The fine powder sediments were then sub-sampled in preparation for chemical analysis. Sediment samples were digested in a mixture of concentrated nitric acid (HNO_3), concentrated Hydrochloric acid (HCl) and hydrogen peroxide (H_2O_2) according to the Standard examination of water and wastewaters for the analysis of heavy metals (APHA, 1992) for the determination of Ca, Cu, Mg, Mn, V, Fe, Cr, Co, Ni and Zn. A reagent blank was run for each set of six samples. The extracts were analyzed by atomic absorption spectrophotometer (Varian AA240FS). Standard reference materials (SRM) IAEA soil 7 was prepared and treated like the samples and analysed along side.

The overall health of fish samples in the lagoon was assessed using the method developed by Williams (2000). A condition factor index (K) was calculated using the equation:

$$K = \frac{100W}{L^3}$$

where, W = body weight in grams; L = body length (fork length) in cm. Fish samples were freeze-dried for 72 h using a Christ freeze-dryer and then homogenized together in a ribbed acid-free pyrex bowl with a Biospec Products blender, Model Mi33/1281-0, Fisher Scientific, Pittsburgh, PA (Moeller *et al*., 2001). 6 mL of 65% HNO_3 and 1 mL of 30% H_2O_2 were added to 0.5g of the fish material in Teflon beakers. The contents were digested in an ETHOS 900 Microwave Labstation and analysed for trace metals (Fe, Hg, Ni, Zn) using AA 240 FS. Quality assurance and quality control included the preparation of reagent blank in a similar manner as the samples without the analyte along with each set of samples and subsequently analysed for the elements of interest.

Results and discussion

Water chemistry

The physico-chemical characteristics of water have a dominant limiting effect on the aquatic environment. The chemical nature of the water determines the species that can survive and the population distribution of the species (FAO, 1983). The following physico-chemical parameters were selected for this study to ascertain the quality of water (Table 2). The pH values recorded in this study were near neutral to basic (6.9-8.1). pH values of the domestic effluents were rather basic (pH of 8.1) probably due to the presence of dissolved carbonates and bicarbonates in the waters. pH of effluents from the industries and the streams were slightly basic (pH between 7.27-7.79) and (pH of 7.79, 7.73 and 7.77, respectively). These values were however within the WHO/FAO limits for good fishing waters of 6 to 9 for fisheries and aquatic life. Temperatures recorded during the sampling period showed optimal conditions conducive for most aquatic life (27.1-34°C). The difference in tempreature was attributed to difference in sampling times of the day. However, further rise in temperature could result in some fish species migrating from the lagoon to less warmer temperatures. Salinity varied from 0.1 to 33.5 ‰. Water samples from domestic effluents and the streams were less saline (salinity range of 0.8 - 2.1‰) whiles the lagoon waters were very saline (between 15.7 to 33.5‰). The high salinity in the lagoon water could be due to the mixing of sea water and other surface waters, as well as high evaporation in the lagoon during the dry season. High salinity concentrations in the lagoon could however restrain destroying the habitat for less salt fish tolerate species thereby, reducing species diversity within the wetland. Measured conductivity values from the study area ranged from 313 to 49900 µS/cm whilst total dissolved solids (TDS) ranged from 132 to 23,200 mg/L, at the middle portions of the lagoon. The higher conductivity and TDS recorded for the lagoon (49,900 mg/L and 23,200 mg/L respectively) indicate higher ionic concentration probably resulting from the high anthropogenic activities. The high conductivity in the lagoon could however cause an increase in osmotic pressure in the fish's cell membrane; dehydrating most fish species.

Table 1. Summary of the physico-chemical compositions of some industrial effluents and surface waters in the Sakumono catchment.

Parameters	Mininmum	Maximum	Mean ± SD
pH	6.91	8.1	7.69±0.08
Salinity, ‰	0.1	33.5	11.29±2.86
Cond.µS/m	186.7	49900	19834.14±960.21
TDS, mg/L	77.9	23200	8083.26±958.91
DO, mg/L	1.4	21.2	11.32±3.29
BOD, mg/L	2.1	55	31.32±8.43

Alkalinity is important for aquatic life because it protects or buffers the water body against changes in pH (keeps the pH fairly constant) and makes water less vulnerable to acid rain and other factors that may cause these changes (Muhammad *et al.,* 2005). Alkalinity values ranged from 150 ± to 560 ± mg/l. Water samples from the three streams and the southern part of the lagoon had values exceeding the EPA (2000) limit of 400 mg/l with the highest alkalinity value of 560 ± mg/l occuring at Dzorwulu River. The alkaline nature of the feeder streams particularly the Dzorwulu River could be attributed to the influence of run-off from surrounding agricultural farms.

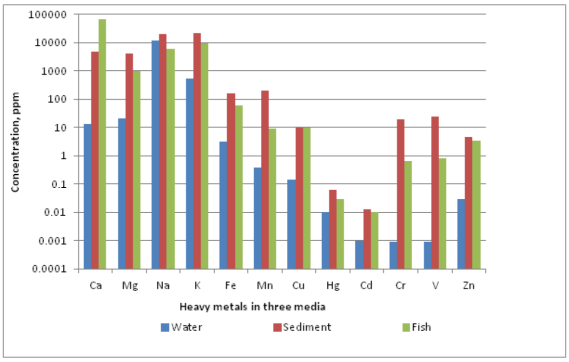

Fig. 2. Comparison of heavy metals in three environmental samples (water, sediment and fish) from the Sakumo wetland.

The solubility of oxygen in water is dependent on temperature and atmospheric pressure since DO is less soluble in saline water than in pure water (FAO, 1983). Fish, invertebrates, plants and aerobic bacteria all require oxygen for respiration. Fishes and other invertebrates will normally not survive in waters low DO (ie DO concentrations < 2). The lagoon water had optimal DO (14.4±1.98 mg/L) conducive for most aquatic organisms. Mamahuma and Dzorwulu streams had relatively low DO concentrations (ie 2.9±0.48 and 4.2±0.73 mg/L respectively) whles the Onupkawahe stream had extremely high DO concentration (12.1±1.66 mg/L). Effluents from the streams had DO concentration ranging between 7.6±1.05 and 13.1± 2.2 mg/L. This is to say that waters from the Mamahuma stream and Dzorwulu River cannot support most fish populations due to their relatively low dissolved oxygen concentration.

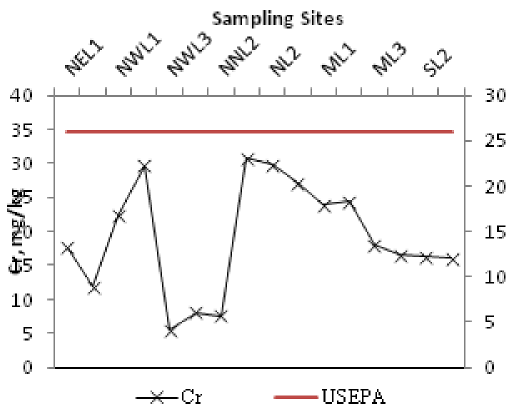

Fig. 3. Comparison of chromium levels in sediment samples with US-EPA guideline values.

All the water samples recorded BOD values higher than the WHO limit of < 3.0 (WHO, 2004). The high BOD values recorded may be due to the discharge of industrial effluents into the streams. These effluents accelerate bacterial growth and consume oxygen faster in the water. The high BOD concentrations may also be indicative of intense microbial activities at the various sampling sites. Wastes dumps (ie from domestic waste) in and around the water bodies may also contain chemicals capable of suppressing microbiological growth or activity.

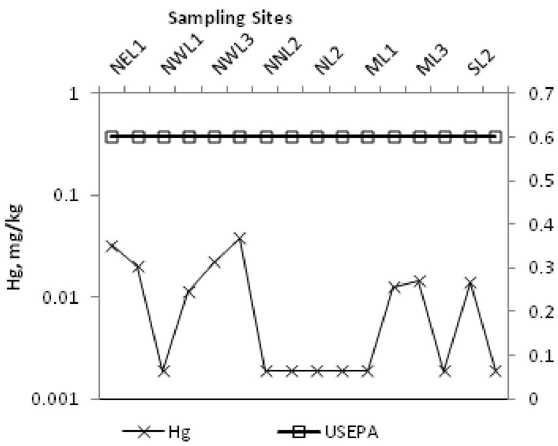

Fig. 4. Comparison of total mercury levels in sediment samples with US-EPA guideline values.

Heavy metals in water, sediments and fish samples

The contamination of sediments, water resources and biota by heavy metals is of major concern because of the toxicity, persistence and bioaccumulative nature of these metals (Ikem *et al.,* 2003). A comparison of the average total concentration of heavy metals in the water, sediment and fish samples from the Sakumo wetland is presented graphically in Fig. 2. Among the samples of water, sediment and fish, the metal concentrations were generally highest in the sediments.

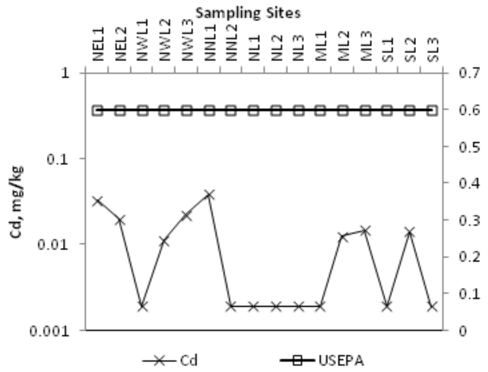

Fig. 5. Comparison of total cadmium levels in sediment samples with US-EPA guideline values.

At the time of sampling, there was no evidence of significant operation from the industries as discharge was observed to be very little and colourless. Other potentially toxic elements such as Pb, As, Cr, Cd, Co were, however below detection limit in the effluents. This could be due to the fact that the metals form insoluble precipitates in solution under specific physical and chemical conditions in the water and this may control the solubility of the metals in the water. Generally, heavy metals in the surface waters were generally in low concentrations which were attributed to dilution, adsorption and/or precipitation.

Mn occurs in surface waters that are low in oxygen and often does so with Fe. Mn accumulates in certain species of fish (Uthe & Blish, 1971). The health based guideline value is 0.4 mg/L (WHO, 2004). Mean Mn concentrations in water from the Sakumo II lagoon varied from < 2 to 0.78 ± 0.05 mg/L, with the middle portions of the lagoon recording the highest Mn value. Mean Mn concentrations in the streams varied from 0.348 ± 0.02 to 0.776 ± 0.047 mg/l, with mamahuma stream recording the highest value. The high Mn levels in the waters could be due to MMT, an anti-knocking agent present in petroleum products which has Mn as an active component (Tay *et al.*, 2010). Concentration of Mn in the sediments varied from 31.8 ±5.88 mg/kg to 903±79.04 mg/kg with the lagoon recording the highest concentration. Manganese is frequently associated with iron deposits in reducing environments. High concentration of Mn in the sediment could be due to detrital materials ferromanganese minerals, clay minerals and other accessory sulphide minerals in the sediments (Chapman, 1992). The high accumulation of the metal in the sediments could also be attributed to the release by the various processes leading to the remobilization of industrial wastes. Concentrations of Mn measured in the fish samples ranged from 0.87±0.12 mg/kg to 16.0± 2.65mg/kg (dry wt.). The relatively low concentration of the element in the lagoon fishes may be due to the high salinity content of the lagoon since uptake of manganese has been found to increase with decreasing salinity (Howe *et al.*, 2004).

The presence of the high Fe values was attributed to organic matter in the waters. Mean Fe concentrations in the waters varied from 0.89±0.25 to 1.82±0.63 mg/l, with the northern section recording highest Fe value (Fig. 3). In the waters of the feeder streams, mean Fe concentrations varied from 0.715±0.03 to 1.65 ± 0.20 mg/L, with onupkawahe stream recording the highest Fe value (Fig. 3). This may be due to natural occurrence, since the feeder streams are freshwaters which are produced from aquifers within which geochemical and biochemical processes take place, thereby, releasing Fe (WHO, 2004). Iron concentrations in the sediments varied from 63.9±15.74 mg/kg to 172±74.1 mg/kg. High concentration of Fe was observed in the lagoon sediments, especially in areas of fine-grained silts. The high Fe concentration in the sediment may be attributed to human activities such as the discharge of untreated sewage, use of the metals in industrial processes as well as the ability of the sediment to also act as a sink for the metal. Iron concentrations in fish samples were very high ranging from 25.3±5.98 to 106.8±60.05 mg/kg (dry wt.). The high concentration of Fe in the fish may be due to the fact that, fishes are carnivores and so can easily take up iron from the iron rich bed material along with other food. Fe is an essential element in aquatic species. However, in poorly oxygenated waters with low pH where Fe is present mainly in the form of soluble compounds, some fishes could be harmed by high Fe compounds since the gill surface of the fish tends to be alkaline, soluble ferrous Fe can be oxidized into insoluble ferric compounds which cover the gill lamellae and inhibit respiration (Oluwu et al., 2010).

The concentration of copper varied from 0.08±0.001 mg/L to 0.21±0.004 mg/L in the water samples with CCBC recording the highest concentration. Anthropogenic activities (effluents from industries and atmospheric deposition) are a major source of copper contamination (Nayaka *et al.*, 2009). Phosphate fertilizer production is a phenomenon that generates Cu in the environment. Since copper is strongly bioaccumulated, levels occuring at low concentrations can be toxic to fishes and other aquatic organisms in the lagoon. Concentrations of copper in the sediments varied from < 0.003 to 22.89±5.48 mg/kg. The elevation of copper accumulation in this study may be due to industrial and sewage wastes. The enrichment of copper in the study area may be due to its association with organic matter thereby increasing its production in the environment. Although a relatively low concentration of the metal was measured in the streams, very high concentrations were measured in the domestic effluents and some portions of the lagoon. Concentrations of Cu in the fish ranged between < 0.003 and 73.5±20.27 mg/kg. Since the waters in the lagoon were slightly alkaline (pH of 7.7), so the toxicity of Cu to the fish is also high as the fishes in the lagoon are likely to take up the element to any extent into the fish body (Alaa and Werner, 2010). Copper can combine with other contaminants such as ammonia, mercury and zinc to produce an additive toxic effect on fish (Yacoub, 2007).

The concentration of mercury in the surface water varied from < 0.001 to 0.016±0.008 mg/L. Hg enters surface water through runoff, atmospheric depositions and the discharge of mercury containing products into drains. Mercury concentrations in the lagoon sediments ranged from <0.001 to 0.080±0.05 mg/kg. High concentration of Hg in bottom sediments is a real indicator of water pollution of the metal (WHO, 2004). Accumulation of Hg from sediments may be a dominant pathway by which aquatic organisms take in the metal as it is rapidly adsorbed to soluble and particulate carbon compounds (Nartey *et al*., 2011). Concentration of Hg in the fish samples varied from < 0.01 to 0.063±0.035 mg/kg with a mean of 0.028 mg/kg. Fish and other marine organisms are often the dominant source of Hg contamination in humans, mainly in the form of methylmercury compounds (Matthesson and Jaakkola, 1979). The principal health risks associated with Hg are damages to the nervous system.

Zn is one of the earliest known trace metal and a common environmental pollutant which is widely distributed in the aquatic environment. It has been found to have low toxicity effect in man. However, prolonged consumption of large doses can result in some health complications such as fatigue, dizziness and neutropenia (Hess & Schmidt, 2002). Studies have also shown that Zn could be toxic to some aquatic organisms such as fish (Alabaster & Lloyd, 1980). Mean Zn concentrations in the surface waters varied from <0.001 to 0.17±0.01 mg/L and between 2.03 ± 0.27 to 6.52±0.86 mg/kg in the sediments. Whilst in the fish, mean Zn concentration ranged between 8.0±1.40 to 20. 46±5.11 mg/kg. The relatively high Zn levels in the sediments could be due to natural sources, resulting from the weathering of minerals and soils (Merian, 1991) and atmospheric deposition from refineries (Tay *et al*., 2009). Sewage disposal is also a major source of zinc pollution.

Measured concentration of the chromium (Cr) ranged between 5.4 mg/kg (Dzorwulu) to 30.7± 5.88 mg/kg (lagoon). The other two streams (Onukpawahe and Mamahuma) recorded relatively high concentrations of chromium, 17.7±5.29 and 22.3±5.47 mg/kg respectively. Chromium is primarily derived from the process of weathering and exists as CrO_4^{2-} in oxidized soils. Chromium is also known to be moderately to strongly reducing, whilst the solid Cr_2O_3 is stable over a wide range of pH. Concentrations of chromium in the fishes were relatively high (< 0.001 to 2.64±0.20 mg/kg). At a high pH and a high concentration of calcium, the toxicity of chromium to aquatic organisms is reduced, compared to that in soft acid water.

Zinc, nickel and iron were detected in the samples with iron having the highest concentration. The high iron content in the sediments may be attributed to the clayey material that forms the bed in the sampled area which also explained the high concentration recorded in the fish samples. The fish, being carnivores may have taken the iron from the iron rich bed material along with food from the sediments. The high concentration of the metal recorded in the sediment may be attributed also to human activities such as the discharge of untreated sewage and uses of metals and industrial materials that contain metals as well as the ability of the sediment to act as sink. Tay *et al*., (2009) also reported that iron occurs at high concentration in most Ghanaian soils.

Heavy metal concentrations in water, sediment and fish samples

The contamination of sediments, water resources and biota by heavy metals is of major concern because of the toxicity, persistence and bioaccumulative nature of these metals (Ikem *et al.,* 2003). A comparison of the average total concentration of heavy metals in the water, sediment and fish samples from the Sakumo wetland is presented graphically in Fig. 2. Among the samples of water, sediment and fish, the metal concentrations were generally highest in the sediments. Given the fact that sediments usually serve as sinks for mercury and other heavy metals, it is not surprising recording higher values of the heavy metals in the sediments in relation to the values in the water column and fish samples. The metal levels in the fish samples also gives an indication of the level of metal pollution of the water from which it is caught (Fig. 2).

Calcium and magnesium concentrations were generally very high in all the measured samples ranging from 7,507 mg/kg to 108,673 mg/kg and 551 mg/kg to 1,297 mg/kg (dry wt.) respectively. Calcium is an essential element for all organisms and is incorporated into the shells of many aquatic invertebrates, as well as the bones of most vertebrates. Magnesium is also important in small quantities for proper osmotic functions in fish. Both magnesium and calcium are essential to each other for proper utilization in the fish. In the case of Ca, however, the concentration was slightly higher in the fish samples, which could be due to the high calcium content in the fish bones. Potassium, like sodium, is essential for normal body function. Sodium and Potassium concentrations in all fish samples were high; varying from 4,456 mg/kg to 7,670 mg/kg and 7,225 mg/kg and 14,438 mg/kg (dry wt.) respectively.

The ATSDR review of the literature (2002) indicates that Cd may bioaccumulate in all levels of aquatic and terrestrial food chains on the contrary Cd was relatively very low in the fish samples. Chromium and mercury were also very low in the sampled fishes whilst arsenic and cobalt were not available in both the water and fish samples. Copper exhibited very high concentration in the sediment samples also attributed to effluent discharges from industries (Nayaka *et al.*, 2009). Chromium and mercury were very low in the sampled fishes whilst arsenic and cobalt were not available in both the water and fish samples. However, it was interesting to note that although Cr is less bioavailable in water its accumulation in the fish placed highest. Copper exhibited very high concentration in the sediment samples which was also attributed to effluent discharges from industries (Nayaka *et al.*, 2009).

Animals have been found to contain more zinc than most plants (ATSDR 2002). Schmitt and Brumbaugh (1990) reported a geometric mean concentration of Zn in various whole fish of 21.7µg/g (wet weight). Whole body analyses of fish for Zn showed significantly high concentrations (Fig. 2).

Vanadium was relatively high in the sediments than in the fish eventhough the metal was not available in the waters (Fig. 2). Vanadium is abundant in most soils and sediments in variable amounts, and it is taken up by plants and other aquatic organisms feeding on these sediments at levels that reflect its availability. High intake of vanadium depresses the chromium-to-vanadium ratio in the human body tissues causing visual consequences.

Conclusion and recommendations

The concentration of heavy metals measured in surface water samples, was generally low compared to those in the sediments but exceeded the background concentrations indicating contamination of the water due to the influence of industrial effluents and runoff from agricultural farms. The relatively high levels of heavy metals in the sediments did not necessarily pose negative impacts on the environment since they fell below the USEPA maximum limit, but however, suggested that industrial and agricultural activities may have led to increased levels of these elements in the wetland sediments and could possibly exceed background levels if not monitored. Based on the results of this study, it can be said that urbanization/ unplanned urban settlements, combined with the proliferation of peasant farming and the sewage from Sakumo catchment has led to the contamination of the Sakumo wetland mainly because of the discharge of effluents from chemical and metal industries that subsequently drain into the wetland.

The concentrations of heavy metals in the fish were quite variable and no patterns of distribution and behaviour were noted. However, high concentrations of some heavy metals measured in the fish tissues' inhabiting the Sakumo lagoon was related to a high influx of metals as a result of pollution from the surrounding industries thereby increased bioavailability to the fish. The high levels also suggested that the fish were capable of concentrating the metals in their bodies from the aquatic environment. The ability of the fish samples to incorporate the elements into their tissue is another important factor to consider for further study.

In other to maintain the ecological and life support functions of the wetland, regulate activities in and around the wetland to prohibite the disposal of both liquid and solid wastes into feeder streams draining directly into the lagoon.

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