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Concentrations of heavy metals in two Ghanaian Lagoons

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ABSTRACT

The study was conducated in Benya and Nakwa lagoons in the Central Region of Ghana, to assess the level of heavy metal pollution of the water and its sediment, as well as in two species of fish: the black chin tilapia (Sarotherodon melanotheron) and oyster (Crassostrea tulipa) both of which constitute one of the major sources of protein for the local people of Elmina and Nakwa. It was also to find out the effect of cooking and depuration (of oysters) on the heavy metal content of the biota. The method involves collection of samples of the species with cast net, scaled and gutted. But the oyster samples were hand–picked. Each sample was divided into two, weighing 500 g. each. One portion was boiled and the other part was dried to a constant weight. The oyster sample was similarly treated. The oyster sample was divided into two, one depurated and the other half not depurated. Water and sediment samples from the lagoons were also collected for analysis at WRI of CSIR.. The results indicated that cooking significantly reduced the concentration of Pb in Crassostrea tulipa from Nakwa but increased concentration of Cd, Pb. As and Hg in S. melanotheron, significantly. Depuration significantly reduced As and Cd concentration in C. tulipa from Benya, but raised the concentration of Pb and Hg in C. tulipa from Benya.

Keywords: Heavy metals, Lagoon, One way ANOVA, Pollution, depuration.

INTRODUCTION

The accumulation of heavy metals in aquatic biota has become a major problem. This is because most humans consume fishes from these polluted water bodies. Pollutants are absorbed and are carried in the bloodstream to the liver for transformation. Pollutants transformed in the liver may be stored there or transported to excretory organs such as gills, kidneys for elimination or rather stored in fat which is an extra hepatic tissue [1]. Metals generally enter the aquatic environment through atmospheric deposition, erosion of geological milieu or due to anthropogenic activities caused by industrial effluents, domestic sewage and mining wastes.

A recent of the proportion of *Sarotherodon melanotheron* [1]in local subsistence fishing showed that 60-80% of all fish caught in the lagoons was tilapias. Among the tilapias, *S. melanotheron* constituted between 85 and 98% of catch in various lagoons. Observations made in many West American lagoons indicate a similar predominance of *S. melanotheron.* It is evident that this resource, if properly managed, might support a more important fishery, especially in Ghana [2].This is why *S. melanotheron* is the object of study.

The term "heavy metals" refers to any metallic element that has a relatively high density and is toxic or poisonous even at low concentration [3]. Heavy metals are generally a collective term which applies to the group of metals and metalloids with atomic density greater than $4g/cm^3$ or 5 times or greater than water [4-6].

Arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), silver (Ag), zinc (Zn) and the platinum group elements constitute heavy metals. Heavy metals are often used to encompass a diverse range of elements which form an important class of pollutants. Such pollutants have received the attention of many researchers all over the world and this is due to the fact that they are very harmful to living beings. There have been instances where mass deaths resulted from heavy metal toxicity. These heavy metals occur as natural constituents of the earth's crust and are non-biodegradable and so tend to be contaminants to living things in the environment. They enter into the body system through food, air and water and bio-accumulate over a period of time [3, 7].

There are three main routes through which heavy metals enter into the environment. These routes include disposal of metal enriched sewage sludge and sewage effluents into water bodies, occur as by-products from metal mining processes and deposition of atmospheric particulates. These metals are transported through water bodies as either dissolved metals in water and sometimes as an integral part of suspended sediments. The dissolved heavy metals in water have the greatest potential of causing the most deleterious effects. The metal contaminants in aquatic systems usually remain either in soluble or suspension form and finally tend to settle down to the bottom or are taken up by organisms. The progressive and irreversible accumulation of these metals in various organs of aquatic creatures ultimately leads to metal-related diseases because of their toxicity and thereby endangering the aquatic biota.

They then get stored in bed sediments of water bodies or seep into the underground water, thus causing the water sources to be contaminated. Water bodies such as rivers, lagoons get contaminated with these heavy metals through human activities like mining, manufacturing, agriculture among others. These activities introduce wastes containing some of these heavy metals into water bodies. These metals dissolve and move down stream into lower reaches of the water bodies. Some also settle into the sediments of the water bodies.

Fishes often accumulate large amounts of certain metals; they assimilate these heavy metals through ingestion of suspended particulates, food materials and sometimes by constant ion-exchange process of dissolved metals across lipophilic membranes like the gills and adsorption of dissolved metals on tissue and membrane surfaces [8, 9]. Benya lagoon serves as one of the main sources of fish for the Elmina community and neighboring towns. *S. melanotheron* constitute one of the main fishes caught in the lagoon. It is a burrower and also a suspension feeder and serves as one of the main sources of protein diet for the community.

The objectives of the study were to determine: 1.Concentrations of heavy metals in cooked *S. melanotheron. 2.*Concentrations of heavy metals in uncooked *S. melanotheron* obtained from the Benya lagoon. 3.Concentration of heavy metals in the sediment of the Benya and Nakwa lagoons. 4.concentration of heavy metals in the lagoon water of Benya and Nakwa lagoons.5.Effects of cooking (heating) on heavy metal contents of tilapia and oysters from Benya and Nakwa lagoons.

6.Effects of depuration on heavy metal contents of oysters from both habitats.

MATERIALS AND METHODS

Study areas:

The study was conducted in the Benya and Nakwoa lagoons, open lagoons located at Elmina and Nakwa respectively, in the Central Region of Ghana. The lagoons lie between longitudes 0^0 and 1º 22^1 W and latitudes 5º and 5 º 0^1 6^0 N. The main occupation of the inhabitants at Elmina and Nakwa is fishing [10].

Sample Collection

Fish samples

Samples of tilapia were collected from the Benya lagoon by means of a cast net. The fish samples were purchased from one of the many fishermen fishing in the lagoon. The fishes were transferred into an ice chest containing ice cubes and transported to the laboratory. The specimens were scaled and gutted. The sample was then divided into two and one replicate was cooked and the other remained in the raw state. The cooked and uncooked specimens were then dried in an oven at a 40ºC temperature over a 24-hour period until a constant weight was obtained. The uncooked sample was then taken out of the oven and ground into fine particles using a crucible and a pestle. The same procedure was repeated for the cooked specimen. The two specimens were weighed and stored in transparent polyethylene bags and then they were well labelled.

Oyster samples,

Oyster (*Crassostrea tulipa*) samples were hand–picked from both Benya and Nakwa lagoons. These oysters from Nakwa were divided into two groups; one group was cooked and the other group was not cooked. The oysters from Benya were divided into two: one group was depurated, while the other group was not depurated (non-depurated)

Sediment samples

Sediments from the Benya lagoon were collected with a new plastic bowl into a black polyethylene bag and brought to the laboratory. It was then transferred into a flat plate and placed inside an oven at 40ºC temperature. After the sample was dried, it was transferred into a transparent polyethylene bag and labelled.

Water samples

Two 1 litre bottles were carefully washed with acetone to remove any trace of grease. They were then washed with dilute nitric acid (HNO_3) to dissolve any traces of metals and finally rinsed with distilled water. Two samples of water were collected from two different locations of the Benya lagoon into the bottles. The bottles were labelled and transported to the laboratory where they were kept in a fridge for further analysis at the Water Research Institute (WRI), Accra.

Sample preparation and analysis

Fish sample digestion and analysis

The fish sample was digested by weighing 2 g of sample into the Teflon tube. Exactly 4ml concentrated nitric acid (HNO_3) was slowly added to the contents of the Teflon tube. The tubes were closed and placed in a stainless steel bomb. The bomb was placed on a hot plate and heated at a temperature of 110ºC for 1 hour and then to 150ºC for 3 hours. The sample was then allowed to cool to room temperature and the bomb was carefully opened. The sample was transferred into 50ml graduated polypropylene tubes in a fume chamber where the tube was rinsed 3 times with distilled water and added to the latter. All remaining samples underwent the same process of digestion and were analyzed using the cold vapour atomic absorption according to Whiteside and Milner [11].

Oyster sample digestion and analysis:

The same procedure described above for fish sample was used for the oyster sample.

Sediment digestion and analysis

Sediment samples were digested by weighing 0.4g of the sample in Teflon tubes. Exactly 4ml of concentrated nitric acid (HNO_3) was slowly added to the content. The tubes were closed and placed in stainless steel bombs. The bombs were placed on a hot plate and heated aat150ºC for 7 hours and then allowed to cool to room temperature before carefully opening the bombs to release pressure. The samples were transferred into the graduated polypropylene tubes and the Teflon tubes rinsed 3 times with distilled water and added to the content of the polypropylene tube. The content was diluted to the 50ml mark of the tube with distilled water and mixed thoroughly. Analysis of sediment for the determination of heavy metals was carried out using the cold vapour atomic absorption according to Whiteside and Milner [11].

Water sample analysis

Water samples collected from the field were analyzed for the various metals using the cold vapour atomic absorption technique. 50 ml of water samples were transferred to the reaction flask. 1ml 5% stannous chloride was added to the sample. The reaction flask was then placed on the bubblier. The absorbance signal was noted and recorded after 2 minutes and the results were plotted on a graph. The values obtained were then multiplied with the dilution factor after which the digestions were calculated.

Data analyses
The experimental data from the study were subjected to statistical analyses using MINITAB software (Version 15). The normality of the data was checked using Shapiro-Wilk method (N<50).. The critical differences among the different sample types were examined using Least Significant Difference (for equal variances assumed variables) multiple comparison tests.

RESULTS

Effect of Heat and depuration on metal concentrations
The differences in the concentrations of Cd and Pb in water, sediment, uncooked and cooked C. *tulipa*; were statistically significant (P-value<0.05). Cooking significantly reduced the concentration of Pb in the C. *tulipa* samples from Nakwa lagoon. However, the average concentrations of Cd, As and Hg increased in the cooked C. *tulipa* samples from Nakwa lagoon and the difference was significant (p-value<0.05).

The average concentrations of Cd, Pb, As and Hg in the cooked S. *melanotheron* samples were significantly lower than the concentrations recorded in the uncooked S. *melanotheron* (P-value<0.05). This observation suggests that cooking has a reduction effect on the concentrations of these metals in S. *melanotheron* from Benya lagoon.

Table1. Mean concentration (±SD) of metals in samples

Lagoon	Samples	Cd(mg\kg)	Pb(mg\kg)	As(mg\kg)	Hg(mg\kg)
Nakwa	*C. tulipa* (uncooked)	1.171±0.01	10.5±1.01	0.732±0.03	0.343±0.01
	C. tulipa (cooked)	1.634±0.01	7.968±0.97	3.221±0.01	0.355±0.01
	water	0.131±0.05	0.583±0.01	0.004±0.00	0.001±0.00
	sediment	2.083±0.03	13.797±1.97	4.899±0.82	0.255±0.07
Benya	Cooked (*S. melanotheron*)	0.364±0.13	12.154±0.59	1.022±0.66	0.334±0.14
	Uncooked (*S. melanotheron*)	0.881±0.15	18.709±0.02	1.259±0.89	0.479±0.13
	Depurated *C. tulipa*	12.035±0.15	0.338±0.07	1.53±0.08	4.833±0.52
	Non Depurated *C. tulipa*	14.766±0.71	0.317±0.01	2.973±0.01	1.218±0.08
	sediment	0.847±0.23	29.871±1.89	9.087±1.74	0.373±0.18
	water	0.13±0.01	0.672±0.01	0.058±0.05	0.002±0.00

Table 2. One-way ANOVA results for studied samples and metals

Lagoon	Compared samples	Parameter	Cd	Pb	As	Hg
Nakwa	*C. tulipa* (uncooked), *C. tulipa* (cooked), water & Sediment	F value	127000	3713000	148739.1	90521.1
		Df	3	3	3	3
		P-value	0.000	0.000	0.000	0.000
Benya	Cooked (S), uncooked (S), Depurated *C. tulipa*, Non Depurated *C. tulipa*, water , & sediment	F-value	8675.9	4216.8	52.1	868.5
		Df	5	5	5	5
		P-value	0.000	0.000	0.000	0.000

Table 3. Multiple comparisons of metals levels in samples from Nakwa lagoon

Metal	(I) Sample_type	(J) Sample_type	Mean Difference (I-J)	Sig.
Cd	*C. tulipa* (uncooked)	C. *tulipa* (cooked)	-0.462	0.000
		water	1.040	0.000
		Sediment	-0.909	0.000
	C. *tulipa* (cooked)	C. *tulipa* (uncooked)	0.462	0.000
		water	1.502	0.000
		Sediment	-0.448	0.000
	water	C. *tulipa* (uncooked)	-1.040	0.000
		C. *tulipa* (cooked)	-1.502	0.000
		Sediment	-1.950	0.000
	Sediment	C. *tulipa* (uncooked)	0.909	0.000
		C. *tulipa* (cooked)	0.448	0.000
		water	1.950	0.000
Pb	C. *tulipa* (uncooked)	*C. tulipa* (cooked)	2.532	0.000
		water	9.917	0.000
		Sediment	-3.297	0.000
	C. *tulipa* (cooked)	C. *tulipa* (uncooked)	-2.532	0.000
		water	7.385	0.000
		Sediment	-5.829	0.000
	water	C. *tulipa* (uncooked)	-9.917	0.000
		C. tulipa (cooked)	-7.385	0.000
		Sediment	-13.214	0.000
	Sediment	C. *tulipa* (uncooked)	3.297	0.000
		C. *tulipa* (cooked)	5.829	0.000
		water	13.214	0.000
As	C. *tulipa* (uncooked)	C. *tulipa* (cooked)	-2.489	0.000
		water	0.7163	0.000
		Sediment	-4.167	0.000
	C. *tulipa* (cooked)	C. *tulipa* (uncooked)	2.489	0.000
		water	3.2053	0.000
		Sediment	-1.678	0.000
	water	C. *tulipa* (uncooked)	-0.7163	0.000
		C. *tulipa* (cooked)	-3.2053	0.000
		Sediment	-4.8833	0.000
	Sediment	C. *tulipa* (uncooked)	4.167	0.000
		C. *tulipa* (cooked)	1.678	0.000
		water	4.8833	0.000
Hg	C. *tulipa* (uncooked)	C. *tulipa* (cooked)	-0.012	0.000
		water	0.342	0.000
		Sediment	0.088	0.000
	C. *tulipa* (cooked)	C. *tulipa* (uncooked)	0.012	0.000
		water	0.354	0.000
		Sediment	0.100	0.000
	water	C. *tulipa* (uncooked)	-0.342	0.000
		C. *tulipa* (cooked)	-0.354	0.000
		Sediment	-0.254	0.000
	Sediment	C. *tulipa* (uncooked)	-0.088	0.000
		C. *tulipa* (cooked)	-0.100	0.000
		water	0.254	0.000

Table 4. Multiple comparisons of Cd and Pb levels in samples from Benya lagoon

Metal	(I) Sample_type	(J) Sample_type	Mean Difference (I-J)	Sig.
Cd	water	Sediment	-0.714662333	0.000
		Cooked (*S. melanotheron*)	-0.234152667	0.000
		Uncooked (*S. melanotheron)*	-0.75116	0.000
		Depurated C. *tulipa*	-11.905	0.000
		Non Depurated C. *tulipa*	-14.636	0.000
	Sediment	water	0.714662333	0.000
		Cooked *(S. melanotheron)*	0.480509667	0.000
		Uncooked *(S. melanotheron)*	-0.036497667	0.000
		Depurated *C. tulipa*	-11.19033767	0.000
		Non Depurated C. *tulipa*	-13.92133767	0.000
	Cooked *(S. melanotheron)*	water	0.234152667	0.000
		Sediment	-0.480509667	0.000
		Uncooked *(S. melanotheron)*	-0.517007333	0.000
		Depurated *C. tulipa*	-11.67084733	0.000
		Non Depurated *C. tulipa*	-14.40184733	0.000
	Uncooked (S. *melanotheron*)	water	0.75116	0.000
		Sediment	0.036497667	0.000
		Cooked *(S. melanotheron)*	0.517007333	0.000
		Depurated C. *tulipa*	-11.15384	0.000
		Non Depurated C. *tulipa*	-13.88484	0.000
	Depurated C. *tulipa*	water	11.905	0.000
		Sediment	11.19033767	0.000
		Cooked *(S. melanotheron)*	11.67084733	0.000
		Uncooked *(S. melanotheron)*	11.15384	0.000
		Non Depurated *C. tulipa*	-2.731	0.000
	Non Depurated C. *tulipa*	water	14.636	0.000
		Sediment	13.92133767	0.000
		Cooked *(S. melanotheron*)	14.40184733	0.000
		Uncooked (*S. melanotheron)*	13.88484	0.000
		Depurated C. *tulipa*	2.731	0.000
Pb	water	Sediment	-0.715	0.000
		Cooked (*S. melanotheron*)	-12.384	0.000
		Uncooked *(S. melanotheron)*	-0.751	0.000
		Depurated C. *tulipa*	-0.208	0.000
		Non Depurated C. *tulipa*	-0.187	0.000
	Sediment	water	0.715	0.000
		Cooked *(S. melanotheron)*	-11.669	0.000
		Uncooked *(S. melanotheron)*	-0.036	0.000
		Depurated *C. tulipa*	0.507	0.000
		Non Depurated C. *tulipa*	0.528	0.000
	Cooked (S)	water	12.384	0.000
		Sediment	11.669	0.000
		Uncooked *(S. melanotheron)*	11.633	0.000
		Depurated *C. tulipa*	12.176	0.000
		Non Depurated *C. tulipa*	12.197	0.000
	Uncooked (S)	water	0.751	0.000
		Sediment	0.036	0.000
		Cooked *(S. melanotheron)*	-11.633	0.000
		Depurated C. *tulipa*	0.543	0.000
		Non Depurated C. *tulipa*	0.564	0.000
	Depurated C. tulipa	water	0.208	0.000
		Sediment	-0.507	0.000
		Cooked *(S. melanotheron)*	-12.176	0.000
		Uncooked *(S. melanotheron)*	-0.543	0.000
		Non Depurated *C. tulipa*	0.021	0.000
	Non Depurated C. tulipa	water	0.187	0.000
		Sediment	-0.528	0.000
		Cooked *(S. melanotheron*)	-12.197	0.000
		Uncooked (*S. melanotheron)*	-0.564	0.000
		Depurated C. *tulipa*	-0.021	0.000

*. The mean difference is significant at the 0.05 level.

Table 5. Multiple comparisons of As and Hg levels in samples from Benya lagoon

Metal	(I) Sample_type	(J) Sample_type	Mean Difference (I-J)	Sig.
As	water	Sediment	-9.030	0.000
		Cooked (*S. melanotheron*	-0.964	0.268
		Uncooked (*S. melanother*	-1.201	0.173
		Depurated C. *tulipa*	-0.281	0.742
		Non Depurated C. *tulipa*	-0.260	0.761
	Sediment	water	9.030	0.000
		Cooked *(S. melanotheron)*	8.065	0.000
		Uncooked *(S. melanothero*	7.828	0.000
		Depurated *C. tulipa*	8.749	0.000
		Non Depurated C. *tulipa*	8.770	0.000
	Cooked (S)	water	0.964	0.268
		Sediment	-8.065	0.000
		Uncooked *(S. melanothero*	-0.237	0.781
		Depurated *C. tulipa*	0.684	0.427
		Non Depurated *C. tulipa*	0.705	0.414
	Uncooked (S)	water	1.201	0.173
		Sediment	-7.828	0.000
		Cooked *(S. melanotheron)*	0.237	0.781
		Depurated C. *tulipa*	0.921	0.289
		Non Depurated C. *tulipa*	0.942	0.279
	Depurated C. tulipa	water	0.281	0.742
		Sediment	-8.749	0.000
		Cooked *(S. melanotheron)*	-0.684	0.427
		Uncooked *(S. melanothero*	-0.921	0.289
		Non Depurated *C. tulipa*	0.021	0.980
	Non Depurated C. tulipa	water	0.260	0.761
		Sediment	-8.770	0.000
		Cooked *(S. melanotheron*)	-0.705	0.414
		Uncooked (*S. melanothero*	-0.942	0.279
		Depurated C. *tulipa*	-0.021	0.980
Hg	water	Sediment	-0.371	0.001
		Cooked (*S. melanotheron*	-0.332	0.003
		Uncooked (*S. melanother*	-0.477	0.000
		Depurated C. *tulipa*	-4.831	0.000
		Non Depurated C. *tulipa*	-1.216	0.000
	Sediment	water	0.371	0.001
		Cooked *(S. melanotheron)*	0.038	0.668
		Uncooked *(S. melanothero*	-0.106	0.248
		Depurated *C. tulipa*	-4.460	0.000
		Non Depurated C. *tulipa*	-0.845	0.000
	Cooked (S)	water	0.332	0.003
		Sediment	-0.038	0.668
		Uncooked *(S. melanothero*	-0.145	0.124
		Depurated *C. tulipa*	-4.499	0.000
		Non Depurated *C. tulipa*	-0.884	0.000
	Uncooked (S)	water	0.477	0.000
		Sediment	0.106	0.248
		Cooked *(S. melanotheron)*	0.145	0.124
		Depurated C. *tulipa*	-4.354	0.000
		Non Depurated C. *tulipa*	-0.739	0.000
	Depurated C. tulipa	water	4.831	0.000
		Sediment	4.460	0.000
		Cooked *(S. melanotheron)*	4.499	0.000
		Uncooked *(S. melanothero*	4.354	0.000
		Non Depurated *C. tulipa*	3.615	0.000
	Non Depurated C. tulipa	water	1.216	0.000
		Sediment	0.845	0.000
		Cooked *(S. melanotheron*)	0.884	0.000
		Uncooked (*S. melanothero*	0.739	0.000
		Depurated C. *tulipa*	-3.615	0.000

*. The mean difference is significant at the 0.05 level.

There were significant differences in the average concentrations of Cd and As in the depurated C. *tulipa* and non- depurated C. *tulipa* (P-value<0.05). This implies that depuration significantly reduced the Cd and As levels in the C. *tulipa* samples from Benya lagoon. However the reverse was the case for the average concentrations of Pb and Hg in the depurated and non- depurated *C. tulipa* samples from Benya lagoon.

The measured concentrations of all the studied metals in sediment samples were higher than the recorded concentrations in the water columns. This phenomenon agrees with what was reported by Boamponsem *et al*. [12].

DISCUSSION

The current work looked at the effect of heating or depuration (oysters) on heavy metal concentration in *S. melanotheron* and oysters as well as the sediment and the water of the Benya and Nakwa lagoons. The reduction concentration of heavy metals in the fish sample could be attributed to vaporization of these metals by heat. The concentration of lead was highest in the fish samples which indicated high toxicity of lead pollution in the lagoon. Lead is highly toxic to fish [13].The biological effects of high concentrations of lead include delayed embryonic development, suppressed reproduction and inhibition of growth. It also causes increased mucus formation, neurological problems. It may also cause enzyme inhibition and kidney malfunction [13, 14]. This lead pollution may chiefly be caused by erosion of natural metal deposits, corrosion of metals used in building canoes and small ferries. Another source may be the town's domestic effluence channeled into the lagoon.

The concentration of lead in the lagoons was higher than the recommended value of 0.015 mg/kg which is the maximum contaminant level (MCL) for EPA (Environmental Protection Agency). The concentration of lead in fish was 12.51 mg/kg which was higher than the EPA standard for concentration of lead (0.0015 mg/kg). This means lead pollution in the fish is extremely high and not good for human consumption.

The effect of high levels of cadmium is mainly kidney damage [15].The corrosion of galvanized pipes on the canoes and other deposits, erosion of natural deposits, runoffs from waste batteries and paints from the town and nearby surroundings are the main sources of cadmium contamination. The 0.36 mg/kg concentration level of cadmium for fish samples was relatively higher than the EPA standard for cadmium concentration (0.05mg/kg). The high concentration of cadmium in fish from the Benya lagoon (0.13 mg/kg) is a possible indication of cadmium pollution in the lagoon.

The concentration of As in the fish samples from the Benya lagoon was 1.02 mg/kg. This concentration was higher than the 0.01 mg/kg standard by the EPA. This may pose health threats to consumers. Arsenic contamination in the tissue of living things may result in blood circulation problems, acute cancer and skin damage [16]. The sources of pollution in the lagoon may be from runoffs, electronic and glass waste that get deposited in the lagoon. Lastly, the concentration of mercury (0.33 mg/kg) for cooked fish sample was also relatively higher than the EPA standards for mercury (0.001 mg/kg) contamination. High levels of mercury concentration results in kidney damage [17].

The concentrations of As, Cd, Hg, Pb in the cooked fish samples were above the EPA standards for their concentrations which would be regarded as toxic since they may have significant effects on the consumer. Comparing to the EPA standards, the results indicate that Benya lagoon is least polluted with mercury but highly polluted with lead. This may pose future problems for fish in terms of growth and reproduction since these heavy metals are non-biodegradable and continue to accumulate in the lagoon. The high concentrations of all heavy metals than the EPA standards make fishes caught from the lagoon not safe for consumption. There was higher concentration of metals in the sediment than in the water which may be attributed to the fact that suspended heavy metals in the water column settle in the sediments and accumulate over time. Considering the fish samples too, concentrations of heavy metals were higher than in water. This could also be attributed to the bioaccumulation of heavy metals in the tissues of the fish. The overall differences in the concentration of heavy metals in all three samples were significant ($P<0.05$).

Considering the many environmental factors usually claimed by diverse researchers to influence the bioaccumulation of heavy metals in *S. melanotheron* to any specific physico-chemical factors, in a more rational way, it would be prudent to attribute these elemental tissue accumulation to the influence of their feeding habits as well as the contamination gradient of the lagoons [1.]

CONCLUSION

The concentration of heavy metals in the fish samples exceeded the acceptable levels proposed for human consumption. However, the levels of concentration of heavy metals in the water body itself exceeded the acceptable levels as proposed with the exception of mercury. It could be concluded that the water in the Benya and Nakwa lagoons was polluted with Pb, As, Cd and Hg.

Recommendation

It is recommended that further research should be done on the levels of other heavy metals in the lagoons in order to monitor and prevent them from reaching high levels that make them toxic to living organisms. Health screening should be undertaken on the inhabitants to check for symptoms of some of these heavy metals.

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