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Bioaccumulation of Heavy Metals in Water, Sediments and Tissues of Some Selected Fishes from the Red Volta, Nangodi in the Upper East Region of Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. Author FA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript and managed literature searches. Authors EA, GA and AKQ performed the analyses of the study and literature searches. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: To investigate the concentrations of Manganese (Mn), Cadmium (Cd) and Mercury (Hg) in water, sediment and organs of *Sarotherodon galilaeus*, *Labeo senegalensis* and *Brycinus nurse*.
Study Design: One-way ANOVA (no Blocking)
Place and Duration of Study: Nangodi, in the Upper East Region of Ghana, West Africa. Between November, 2012 and March, 2013
Methodology: 3 samples of water, sediment and 36 fish samples were collected from the Red Volta River in Ghana. All samples collected were labelled and placed in clean polyethylene bags with ice to maintain the freshness and immediately taken to laboratory where samples were deep frozen at -20°C until prepared for analysis.
Results: There was significant difference between heavy metals found in the river water, however there was no significant difference between heavy metals found in sediment (*P*=

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.05). Mn content was the highest and that of Cd was the lowest in water whiles in sediment Mn content was the highest and that of Hg was the lowest.
Also concentration of heavy metals found in the gills and muscles of *Sarotherodon galilaeus*, *Labeo senegalensis* and *Brycinus nurse* were statistically significant(*P*= .05).
The gills of *Sarotherodon galilaeus* accumulated the highest concentration of Mn whiles that of *Brycinus nurse* accumulated the lowest concentration, also the gills of *Brycinus nurse* accumulated the highest concentration of Cd whiles that of *Sarotherodon galilaeus*accumulated the lowest concentration and *Labeo senegalensis* accumulated the highest concentration of Hg whiles that of *Sarotherodon galilaeus*accumulated the lowest concentration.
In muscles of the fish species studied, *Sarotherodon galilaeus* accumulated the highest concentration of Mn and Hg whiles *Brycinus nurse* accumulated the lowest concentration in the gills, *Brycinus nurse* accumulated the highest concentration of Cd whiles *Labeo senegalensis* accumulated the lowest concentration in the muscles.
Conclusion: The research revealed that the water and fishes from Red Volta is polluted with Mn, Cd and Hg. Consumption of fish from the river could lead to health hazards induced by heavy metals.

Keywords: Heavy metals; bioaccumulation; red volta river; Sarotherodon galilaeus; Brycinus nurse; Labeo senegalensis.

1. INTRODUCTION

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 [1,2,3,4,5,6] all over the world and this is due to the fact that they are very harmful to living organisms even at lower concentrations. There have been instances where mass deaths resulted from heavy metal toxicity [7].

These 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 bioaccumulate over a period of time. The main natural source of heavy metals in water is weathering of minerals [8]. Beside their natural occurrence, heavy metals may enter the ecological system through human activities, such as, mining, sewage sludge disposal, application of pesticides and inorganic fertilizers as well as atmospheric deposition.

The rate of bioaccumulation of heavy metals in aquatic organisms depends on the ability of the organisms to metabolize the metals and the concentration of such metal in the river. Also it has to do with the concentration of the heavy metal in the surrounding sediments as well as the feeding habits of the organism. Aquatic animals (including fish) bioaccumulate trace metals in considerable amounts and store it over a long period of time in the bone, liver or gills as a result of their different physiological roles [9]. Fishes have been recognized as a good accumulator of organic and inorganic pollutants. Age of fish, lipid content in the tissue and mode of feeding are significant factors that affect the accumulation of heavy metals in fishes[10]. Fishes often accumulate large amounts of certain metals and assimilate them 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 which becomes toxic at high levels and exert harmful effects on fish. Such metals are finally transferred to other animals including humans through the food chain [11].

Sarotherodon galilaeus, *Labeo senegalensis* and *Brycinus nurse* are consumed by a number of Ghanaians and they constitutes some of the main fishes caught in the river, they also serves as one of the main sources of protein diet for the community. This study was carried outto address the deficiency in the data on heavy metal levels in the region because there has never been study in the region.

1.1 Objectives

Releasing of heavy metals into the Red Volta by mining activities may cause serious water pollution problems, because the metals cannot be degraded (destroyed), they are deposited, assimilated or incorporated into water, sediments and aquatic animals. Heavy metals and pesticides have the potential to bioaccumulate and biomagnify through the food chain and finally assimilated by the final consumer [12].

Due to the adverse effects of heavy metals, it is of great significance to identify the sources and measure the concentration of these metals in our water bodies and aquatic organisms like fish.

The Objectives of this Study are a) to investigate the concentrations of manganese (Mn), mercury (Hg) and cadmium (Cd) in water, sediment and organs of *Sarotherodon galilaeus*, *Labeo senegalensis* and *Brycinus nurse* and to find out which fish tissue and species will accumulate the highest concentration of Mn, Cd and Hg b) to determine the bioaccumulation factor.

2. MATERIALS AND METHODS

2.1 Sampling Site

Nangodi and its catchment area have been characterized with mining activities by illegal miners called “galamsey” since 1930’s. It is situated in the Upper East Region of Ghana(Fig 1). Its geographical coordinates are 10° 51' 28" North, 0° 40' 16" West. The town falls within the Birrimain, Tarkwaian and Voltaria rocks of Ghana and has gold deposit.

2.2 Sample Collection

A total of 3 liters of water samples was collected from the sampling site during sampling using 500mL polythene bottles with screw caps.Bottles were treated with nitric acid and rinsed with distilled water previously before use [13].The samples collected were acidified with 5mL nitric acid [14].

Three sediment samples were collected using grab sampler at a depth of 6-7cm. Sediment samples were placed in wide mouthed; disposable plastic containers treated with nitric acid and packed separately in pre cleaned polyethylene bags.

A total of 36 matured fish samples; that is twelve fishes for each species of *Sarotherodon galilaeus*, *Labeo senegalensis* and *Brycinus nurse* were obtained from the sampling station by fishermen at the river bank.The total length and weights of fishes collected are shown in

(Table 1).All samples collected were labelled and placed in clean polyethylene bags with ice to maintain the freshness and immediately, taken to laboratory where samples were deep frozen at -20°C until prepared for analysis [15].All the samples were collected withinNovember 2012 and March, 2013.

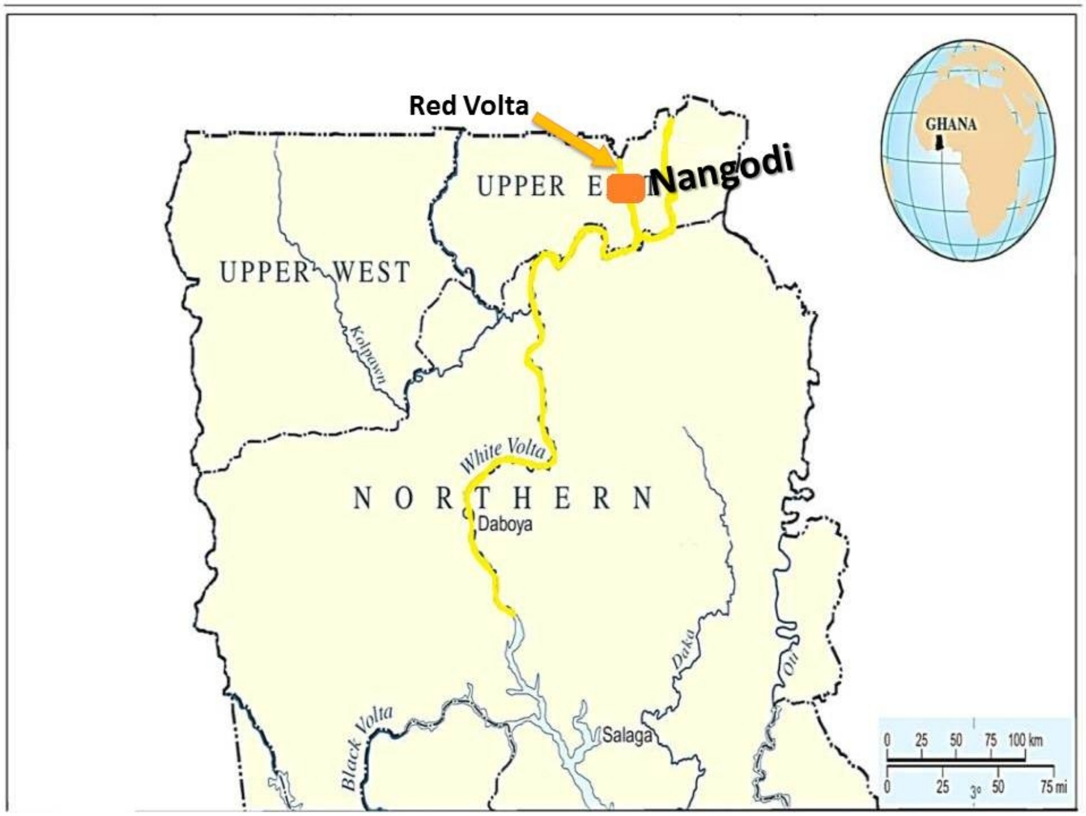

Fig. 1. Map for Ghana showing the Red Volta (arrow) and sampling site (Orange spot)

Table 1. Total lengths (cm) and weights (g) of fish species collected

Fish Species	Range (min. max.)	Mean length ± SD	Range (min. max.)	Mean weight ± SD
Sarotherodon galilaeus	10.6 - 15.3	12.92 ± 1.58	90 - 155	123.01 ± 21.52
Brycinus nurse	14.2 - 20.2	17.64 ± 1.98	179 - 287	219.58 ± 31.63
Labeo senegalensis	11.2 - 26.3	16.43 ± 4.68	100 - 395	176.83 ± 86.36

2.3 Sample Treatment

All the fish samples previously stored in deep freezer were allowed to thaw at room temperature (about 27ºC). The fish samples were dissected to remove gills and muscle and place in a glass Petri dish. The muscles and gills were oven dried in a hot air oven for 24 hours at a temperature of 110 – 115 ˚C. After drying, the fish samples were grounded separately into tiny pieces using a pre-cleaned proceline mortar and pestle and placed in separate labeled petri-dish and stored in desiccator until digestion [16].

Sediment sample were air-dried in the laboratory at room temperature for 24 hours. After air-drying sample were grounded into fine powder using pestle and mortar and passed through 2mm mesh sieve to remove coarse materials. The samples were packed in polyethylene bags for digestion.

Fine powdered samples of sediment, fish muscle and fish gills were taken separately and digested by a procedure similar to that described by [17]. After complete digestion samples were stored in pre-cleaned polyethylene bottles until analysis using atomic absorption spectrophotometer. At each step of the digestion processes of the samples, acid blanks (laboratory blank) were prepared using an identical procedure to ensure that the samples and chemicals used were not contaminated. They contain the same digestion reagents as the real samples with the same acid ratios but without fish and sediment samples. After digestion, acid blanks were treated as samples and diluted with the same factor. They were analysed by atomic absorption spectrophotometry before real samples and their values were subtracted to check the equipment to read only the exact values of heavy metals in real samples. Each set of digested samples had its own acid blank and was corrected by using its blank sample.

Water samples were not subjected to further treatment. After filtration through Whatman filter papers, 1mL of nitric acid was added and then aspirated directly into the Atomic Absorption Spectrophotometer (Shimadzu, AAS6800) with flame and graphite furnacefor heavy metal determination (14).

2.4 Bioaccumulation Factor (BF)

The Bioaccumulation factor was calculated according to formula used by [18];

$$\mathbf{BF} = \frac{\text{Concentration of metals in fish tissues}}{\text{Concentration of metals in abiotic media}}$$

Where the abiotic media represents the water and sediment

2.5 Statistical Analysis

One-way ANOVA was done using a computer program GenStat version 9.2.Microsoft Excel 2010 editionwas used to calculate mean and standard deviation.Tables were used to represent results.

3. RESULTS AND DISCUSSION

3.1 RESULTS

3.1.1 Heavy metals in water and sediment

In the water samples, the mean concentration of Mn, Cd and Hg were 0.239mg/L, 0.005 mg/L and 0.036 mg/L respectively and the mean concentrations in sediment were 8.871 mg/L, 0.045 mg/L and 0.019 mg/L respectively. MN content was the highest and that of Cd was the lowest in water whiles in sediment Mn content was the highest and that of Hg was the lowest(Table 2).

3.1.2 Heavy metals in fish

The mean concentrations of heavy metals in the gills and muscles of *Sarotherodon galilaeus, Brycinus nurse and Labeo senegalensis* are presented in Table 3 and 4. The gills of the three fish species accumulated the highest concentration of metals while their muscles accumulated the lowest.

Table 2. Mean concentrations ± SD of heavy metal in water and sediment (mg/L)

Samples	Mn	Cd	Hg
Water	0.239 ± 0.095	0.005 ± 0.004	0.036 ± 0.060
Sediment	8.871 ± 10.06	0.045 ± 0.032	0.019 ± 0.001
WHO	0.4 mg/L	0.003 mg/L	0.006 mg/L
GRWCG	0.5 mg/L	0.2 mg/L	0.001 mg/L

SD = Standard deviation

Table 3. Mean concentrations ± SD of heavy metal in Gills (mg/L) of fish species

Fish Species	Mn	Cd	Hg
Sarotherodon galilaeus	1.522 ± 0.631	0.029 ± 0.020	0.019 ± 0.003
Brycinus nurse	0.868 ± 0.480	0.052 ± 0.046	0.020 ± 0.012
Labeosenegalensis	0.998 ± 0.283	0.037 ± 0.034	0.026 ± 0.019
WHO	0.4 mg/L	0.003 mg/L	0.006 mg/L
GRWCG	0.5 mg/L	0.2 mg/L	0.001 mg/L

Table 4. Mean concentrations ± SD of heavy metal in Muscles (mg/L) of fish species

Fish Species	Mn	Cd	Hg
Sarotherodon galilaeus	0.394 ± 0.194	0.026 ± 0.016	0.017 ± 0.017
Brycinus nurse	0.206 ± 0.044	0.031± 0.018	0.009 ± 0.011
Labeo senegalensis	0.379 ± 0.164	0.024± 0.017	0.013 ± 0.006
WHO	0.4 mg/L	0.003 mg/L	0.006 mg/L
GRWCG	0.5 mg/L	0.2 mg/L	0.001 mg/L

3.1.3 Bioaccumulation factor (BF)

The bioaccumulation factor of heavy metals from water and sediments in gills and muscles of *Sarotherodon galilaeus, Labeo senegalensis and Brycinus nurse* are shown in Tables 5, 6 and 7.

Table 5. Bioaccumulation factors of heavy metals in different tissues of *Sarotherodon galilaeus*

Parameter	Mn	Cd	Hg
Gills/Water	6.37	5.80	0.53
Gills/Sediment	0.17	0.64	1.00
Muscles/Water	1.65	5.20	0.47
Muscles/Sediment	0.04	0.58	0.89

Table 6. Bioaccumulation factors of heavy metals in different tissues of *Brycinus nurse*

Parameter	Mn	Cd	Hg
Gills/Water	3.63	10.4	0.56
Gills/Sediment	0.10	1.16	1.05
Muscles/Water	0.86	3.40	0.25
Muscles/Sediment	0.02	0.38	0.47

Table 7. Bioaccumulation factors of heavy metals in different tissues of *Labeo senegalensis*

Parameter	Mn	Cd	Hg
Gills/Water	4.18	7.4	0.72
Gills/Sediment	0.11	0.82	1.37
Muscles/Water	1.59	3.2	0.36
Muscles/Sediment	0.04	0.36	0.68

4. DISCUSSION

The occurrence of metal contaminants especially the heavy metals in excess of natural loads has become a problem of increasing concern. The situation is as a result of the rapid population growth, increased urbanization and expansion of industrial activities, exploration and exploitation of natural resources, extension of irrigation and other modern agricultural practices as well as the lack of environmental regulations [19]. Ghana is rich in mineral resources such as gold (Au), Manganese (Mg), Bauxite/Aluminum (Al), Zinc (Zn), and as such mining is one of the key industries in Ghana. As a result, heavy metal pollution is a big environmental issue, with serious implications for the health of humans and animals [20].

The mean concentration of Mn recorded in water in this investigation was generally below limits acceptable by [21,22] whiles the mean concentration of Cd were above limits acceptable by [21] but below limits acceptable by [22]. However the mean concentration of Hg in water was above accepted levels. The higher concentration of Cd and Hg could be linked to weathering and processing of minerals which occurs through mining activities in the area.

The results of the present study showed that, the mean concentrations of Mn and Hg in Gills of the three (3) fishes where above limits acceptable by [21,22] whiles the mean concentration of Cd were above limits acceptable by [21] but below limits acceptable by [22]. [23,24] Found that, the concentrations of metals in fish gills studied were higher than the other tissues. The higher concentration of metals in gills could be linked to their direct contact with ambient medium and also they are the main site of water movement.The mean concentration of Mn in the muscles of fishes in this study were below the allowable concentration suggested by [21,22], also the mean concentrations of Hg in the Muscles were above acceptable limits however the mean concentration of Cd in muscles were above the allowable concentration suggested by [21] but below limits acceptable by [22]. This result was in agreement with many authors who reported that Muscles is not an active organ in accumulation of most heavy metals [25,26].

The differences in accumulation metal concentrations in the gills and muscles of the three fish species could be attributed to differences in their physiological roles. It has been reported that different organisms have different metabolic rates and different food requirements and amounts. Organisms with high food intake tend to accumulate more metals [15]. The results showed that the Bioaccumulation factor of Mn and Cd in fishes from water were greater than that from sediment and this implies that the fishes bioaccumulated these metals from the water [18]. Also the accumulation of Hg in fishes from water were lower than that from sediment and this implies that the fishes bioaccumulated these heavy metals from the sediment. This result may be due to the feeding behaviours of *Sarotherodon galilaeus*, *Labeo senegalensis*and *Brycinus nurse* and the result was concordant with the findings of [27].

The general increase in mean concentration of heavy metals in the entire samples could be attributed to more bioaccumulation due to metal concentration arising from reduced water volume during the dry season.

5. CONCLUSION

The study clearly indicated significant accumulation of heavy metals in the water, sediment and organs of *Sarotherodon galilaeus*, *Labeo senegalensis*and*Brycinus nurse* from Red Volta River. The finding of this study is consistent with the results obtained for other fish species from Ogba River in Benin City, Nigeria [28,29]. The implication of this finding is that the consumption of fish from the Red Volta could lead to various health hazards induced by heavy metals.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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