



# Human health risk assessment from heavy metals in three dominant fish species of the Ankobra river, Ghana

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## ABSTRACT

This study assessed heavy metal contamination of fish and its associated health risk to communities around the Ankobra River in the Western Region of Ghana. Species of fish randomly collected from different sections of the river were analyzed for Cd, Ni, Zn, Pb, Mn, Hg, As, Co and Cr using Atomic Absorption Spectrophotometry. Three commonly consumed fish species, *Clarias gariepinus*, *Sarotherodon melanothron* and *Pseudotolithus senegalensis*, were analyzed. The health risks were assessed based on the potential non-carcinogenic effect associated with the daily consumption of fish by communities around the river. Concentrations of all the metals were higher in gills than the muscles of all three species. On average, levels of Mn ( $6.65 \pm 7.30 \text{ mg.kg}^{-1}$ ), Zn ( $2.24 \pm 1.99 \text{ mg.kg}^{-1}$ ) and Hg ( $3.06 \pm 1.53 \text{ mg.kg}^{-1}$ ) in all three species were above the permissible limits recommended by the World Health Organization. The health risk estimated for all the heavy metals was  $< 1$ , significantly below the  $\geq 1$  index associated with the incidence of cancer. This suggests that fish species examined in this study pose no significant non-carcinogenic risk and are safe for human consumption.

## 1. Introduction

Now, it is common knowledge that aquatic ecosystems and their services are under pressure due to global climate change, and restructuring caused by pollution, overfishing and other human activities [1,2]. In particular, urbanization, agriculture and disposal of untreated effluent by petrochemical industries and others are introducing an excessive amount of heavy metals such as cadmium, lead, mercury, arsenic and chromium into the aquatic environment [3]. These heavy metals are adsorbed by microbes and other primary producers [4]. Unlike other contaminants, the metals are non-degradable and hence may persist in the environments, become bioaccumulated and biomagnified up the food chain [5]. Eventually, they are transferred to humans through the food chain with potential harmful effect on the health of seafood consumers [6,7]. Even at lower concentrations, heavy metal pollutant is extremely dangerous to seafood consumers [8].

The health risks posed by heavy metals are especially high in developing countries where a significant number ( $\approx 70\%$ ) of the most polluting industries are located around aquatic ecosystems [7]. In

Ghana, for example, heavy metal pollution is a major public health concern [9,10]. The mining of minerals especially by small-scale, artisanal industries is widespread around major rivers and lakes of the country [7]. These mining industries are notorious for releasing untreated effluent, laden with heavy metals into their surrounding water systems [7]. In addition, research shows that the majority of the industries located within Ghana's coastal communities are sources of heavy metals to estuaries and other coastal ecosystems of the country [11]. Hence as an obvious consequence, the heavy metal load of some species of fish inhabiting key aquatic systems in Ghana is high, well above the permissible limit recommended for fishery products meant for human consumption [10,11,5].

One aquatic ecosystem that serves as a major source of fish in Ghana is the Ankobra River basin in the Western Region of the country. The river and its associated estuarine ecosystem serve as primary sources of fish food and livelihood opportunities for many communities [12]. It runs through mineral mining communities and receives inflows from a network of streams and rivers running through major agricultural lands and areas of small- and large-scale mining activities [13]. Awuah (2016)

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recorded high levels ( $1.40 \pm 1.78 \text{ mgkg}^{-1}$ ) of lead in sediment from the Ankobra river. Asare-Donkor & Adimado (2016) has also recorded high levels of mercury in fish species from the river. These pollutants accumulate in the aquatic food chain (Anim et al., 2011) and are associated with cancer and other detrimental health impacts (e.g. typhoid, coronary heart disease, hematologic disorders) on humans [14]; Tchounwou et al., 2003). Past research carried out in the river have focused on a few heavy metals and do not assess the human health risk associated with the metals [15,16]. As a result, the potential effect of heavy metal pollution of the Ankobra River particularly on the communities dependent on the river for food is not fully known although the river is an important source of fish food for many communities. Furthermore, research suggests that the accumulation of contaminant within individual fish species may not be uniform. Some findings suggest that heavy metals accumulate more in the gills and other organs [17,18]. These findings have implications for the preparation of fish for consumption as consumers can discard contaminated part if this is known. However, to the best of our knowledge, there is no published information on heavy metal accumulation within different organs of fish inhabiting freshwater systems in Ghana to help guide the selection of fish and fish body parts for consumption. Such information is needed given that the country relies on fish for  $\approx 60\%$  of its animal protein requirement; it has a higher per capita fish consumption (25 kg per annum) than the average of 18.9 kg per annum estimated for the whole world (FAO, 2016).

The objective of the present study was to assess the human health risk associated with the consumption of fish from the river Ankobra. To achieve this objective, we measured the concentrations of Manganese (Mn), Arsenic (As), Cadmium (Cd), Chromium (Cr), Nickel (Ni), Cobalt (Co), Mercury (Hg), Lead (Pb) and Zinc (Zn). The International Agency

for Research on Cancer classifies As, Cd, Cr, Zn and Ni as carcinogenic metals (Group 1); it describes Co, Hg and Pb as possible carcinogens (Group 2B) [19]. For the assessment of health risks, one of the most useful approaches is the determination of non-cancer and cancer risks [20]. This approach allows one to evaluate the relationship between the environment and human health using a Target Hazard Quotient (THQ) defined as the ratio between the level of exposure and the highest non-harmful dose of each metal. It has been used in previous studies to quantify the level of risk associated with the pollution of the environment [20–22]. The present study uses the quotient to estimate human health risk associated with the consumption of contaminated fish. The amount of selected heavy metals in dominant fish species inhabiting the River basin and the exposure of communities around the river to the contaminant were determined using a field-based study. We have compared our findings to international standards (WHO/USEPA) on permissible levels of pollutants in fish food and used the results to establish the human health implication for consuming fish from the Ankobra River.

## 2. Materials and methods

### 2.1. Study area

The present study was conducted in the Ankobra River in the Western Region of Ghana (Fig. 1). The River has a surface area of about  $8460 \text{ km}^2$ . It takes its source from the hills of Basin Dare (near Bibiani) in the western north of the country and flows for about 260 km to enter the Gulf of Guinea in an estuary located in a coastal community called Asanta, near Axim in the southern part of the country. The basin is

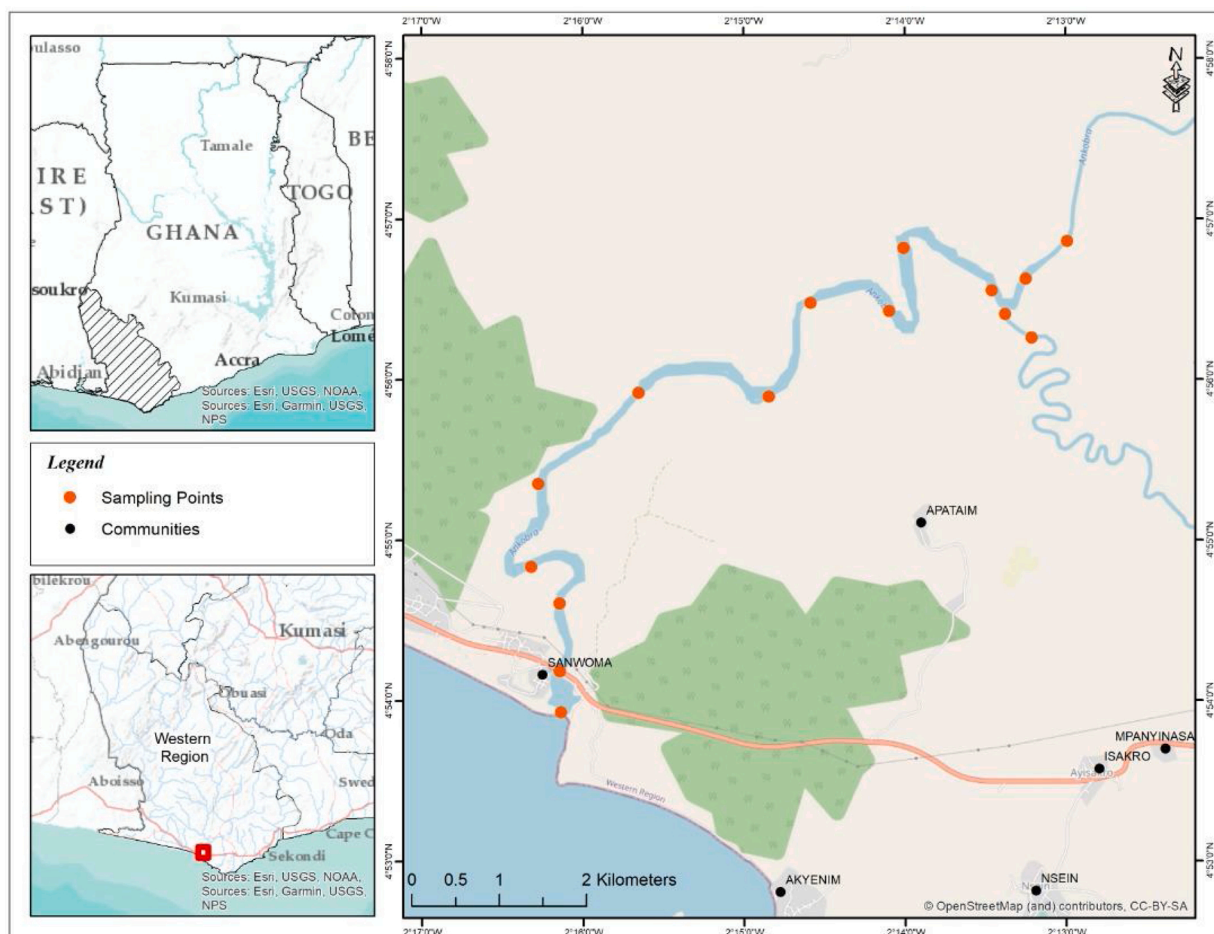


Fig. 1. Sampling sites and fishing communities located around The Ankobra River in the Western Region of Ghana.

characterized by flat land in the southern half and round hills which are occasionally steep-sided in the northern sections. The hilly part is prominent around Wassa Akropong, chain of hillocks forming the north-eastern part of the basin, south of Dunkwa and north of Awaso in the upstream north-western corner of the basin. The hilly terrain reaches an altitude of close to 500 m above sea level (Water Resource Commission, 2009).

## 2.2. Collection of fish samples

Fish analyzed in this study were harvested quarterly, from September 2017 to August 2018, using a seine net. Samples were taken from sites randomly selected along the river. On each sampling occasion, 30 specimens of species were randomly collected from the catch and transported to the laboratory on ice. In the laboratory, the specimens of fish were identified to the species level fish identification manual on fishes in Ghanaian waters by the Fisheries Commission of Ghana. They were dissected for their gills and muscles which were later analyzed for heavy metal content. These organs were considered because; muscles are the main edible part and the gills are the exposure route in fish for the accumulation of pollutants [18,23]. The amount of nine different types of heavy metals – mercury (Hg), manganese (Mn), cadmium (Cd), lead (Pb), cobalt (Co), chromium (Cr), arsenic (As), nickel (Ni) and zinc (Zn) – accumulated in these organs were determined in this study to improve upon the available set of information on the contaminants in the study area.

## 2.3. Determination of heavy metal content in fish

The heavy metal content of gills and muscles extracted from each fish was determined using the acid digestion method. The organs were cut into pieces, placed in a conical flask and dried at 45 °C for 8 h on a hot plate in a furnace. For the analysis, 2 g of the dried samples were used. The digestion of the samples was done using nitric acid (concentration: 70 %; volume taken: 20 mL) and hydrogen peroxide (concentration: 35 %; volume taken: 2 mL). The digestion was done in high borosilicate glass vessel on a hot plate at a temperature of 45 °C for 3 h. The digested samples were allowed to cool at room temperature. After digestion, the samples were diluted to 30 mL with distilled water before the levels of heavy metals were measured with an acetylene air flame atomic absorption spectroscopy (spectrometer used: Varian AA 240FS).

The digested samples were filtrated into test tubes and kept for element analysis. The filtered samples were assayed for the presence of metals on the AAS under the recommended instruments parameters such as the detection limits (Tables 1 and 2). To ascertain reproducibly and quality assurance, blanks and standard reference reagents were used in the Nuclear Chemistry and Environmental Research Centre Laboratory, Ghana Atomic Energy Commission (GAEC).

### 2.3.1. Reagents

The reagents used were of analytical grade, supplied by British Drug House (BDH) and Sigma. Distilled water used was produced by the

Nuclear Chemistry and Environmental Research Centre, Ghana Atomic Energy Commission (GAEC). Other reagents used were Trioxonitrate (V) acid (HNO<sub>3</sub>) and Hydrochloric acid (HCL). The heavy metal content, M<sub>C</sub>, in mg per kilogram of each fish was calculated using Eq. 1

$$M_c = \frac{\text{Digested Conc (mg/mL)} \times \text{Nominal volume (mL)}}{\text{Dry weight of fish (kg)}} \quad (1)$$

The nominal volume in the equation represents the total volume of the samples measured.

## 2.4. Comparison of fish-based heavy metal content

The contamination of the fish was based on the amount of individual heavy metals measured in the fish species. The level of individual heavy metals within the gills and muscles of fish species were compared using a one-way Analysis of Variance (ANOVA). The critical p-value for all the ANOVA was taken to be 0.05. Whenever differences were found between any set of data, the Tukey's HSD ( $\alpha = 0.05$ ) procedure was used as a post hoc test to determine which pairs of means were significantly different. Statistical analysis was done using a computerized statistical programme (Minitab 17 version). Heavy metals content in fish were compared with permissible limits for human consumption proposed by WHO [24] to ascertain the consumability of the fish in the study area.

## 2.5. Health risk estimation

### 2.5.1. Target hazard quotient (THQ)

The THQ proposed by the United States Environmental Protection Agency, USEPA in 2011 was used as the yardstick for evaluating the non-carcinogenic risk associated with the amount of individual heavy metals measured in each fish. The THQs were estimated using Eq. 2 modified from the USEPA Region III risk-based concentration criteria assuming the duration of heavy metal exposure of fish consumers is 30 years [25].

$$\text{THQ} = \frac{M_C \times IR \times EF \times CF}{RfD \times BW} \times 10^{-3} \quad (2)$$

M<sub>C</sub> was the concentration of heavy metal in fish (mg. kg<sup>-1</sup> determined as described by Eq. 1), IR was the fish intake rate of consumers (calculated as heavy metals measured per fish x Fish consumption rate assumed to be 0.02 kg person<sup>-1</sup>.day<sup>-1</sup> for adults according to [26]), EF represents the exposure frequency (365 days. year<sup>-1</sup>), CF is the conversion factor = 4 (for converting the fresh weight fish to dry weight), RfD was the healthy, acceptable reference dose of individual metals recommended for each weight of fish by World Health Organization [24]. For the metals in the present study, the acceptable doses are provided as follows: Mn = 1.0 mg. kg<sup>-1</sup>, Cd = 0.05 mg. kg<sup>-1</sup>, Cr = 2.0 mg. kg<sup>-1</sup>, Co = 0.5 mg. kg<sup>-1</sup>, Zn = 0.5 mg. kg<sup>-1</sup>, Pb = 0.02 mg. kg<sup>-1</sup>, Ni = 0.5 mg. kg<sup>-1</sup>, As = 0.12 mgkg<sup>-1</sup> and Hg = 0.5 mg. kg<sup>-1</sup>. BW was the average body weight of fish consumers; this was taken to be 70 kg as recommended by USEPA [25].

**Table 1**  
Operational Working Conditions (AA 240 FS; Unit: ppm).

Element	Wavelength (nm)	Lamp current (ma)	Slit width (nm)	Fuel	Support	LoD	LoQ
Mn	279.5	5	0.2	Acetylene	Air	0.0020	1.00
Zn	213.9	5	1.0	Acetylene	Air	0.0010	0.25
Pb	217.0	5	1.0	Acetylene	Air	0.0010	2.0
Cd	228.8	4	0.5	Acetylene	Air	0.0020	0.50
Cr	357.9	7	0.2	Acetylene	Air		
Ni	232.0	20	0.2	Acetylene	Air	0.0010	2.00
Co	240.7	7	0.2	Acetylene	Air	0.0050	2.00
As	193.7	10	0.5	Acetylene	Nitrous oxide	0.0060	0.020
Hg	253.7	4	0.5	Argon	Air	0.0010	0.020

Ref: VARIAN, Publication No.85–100009-00 Revised March 1989.

**Table 2**  
Estimated Target Hazard Quotient (THQ) and Hazard Index (HI) of metals in fish species.

Fresh fish species	Sample	Mn	Cd	Cr	Co	Zn	Pb	Ni	As	Hg	HI
<i>Clarias gariepinus</i>	Gill	2.8E-03	6E-04	2.6E-05	1.2E-04	1.6E-03	6E-04	1.5E-04	6E-06	1.5E-04	6E-03
	Muscle	2.6E-03	6E-04	3E-05	1.2E-04	1.4E-03	6E-04	1.2E-04	2.9E-06	1.3E-04	5.9E-03
<i>Pseudotolithus senegalensis</i>	Gill	3.7E-03	6E-04	3.2E-03	1.3E-03	2.4E-02	1E-03	2.5E-04	1.2E-02	2.7E-02	7.6E-02
	Muscle	3.6E-03	5E-04	3E-03	1.3E-03	2E-02	1E-03	5E-05	1.2E-02	3E-03	7.8E-02
<i>Sarotherodon melanotheron</i>	Gill	1.5E-02	3E-04	1.9E-03	7E-04	1.1E-02	6E-04	1.4E-03	2E-03	1.8E-02	5.1E-02
	Muscle	1.2E-02	3E-04	1E-03	7E-04	1E-02	6E-04	1.2E-03	3.3E-03	1.7E-03	3.2E-02

### 2.5.2. Hazard Index (HI)

This was calculated as the sum of all the estimated THQ of all metals [25]

$$HI = \sum_i^n THQ_i \quad (3)$$

Where  $THQ_i$  is the hazard quotient value estimated for each metal  $i$ , as described by Eq. 2;  $n$  represents the total number of heavy metals in this study. In following the critical of USEPA, THQ and HI values less than 1 were taken to indicate no significant carcinogenic health risk for the exposed population [25].

## 3. Results and discussion

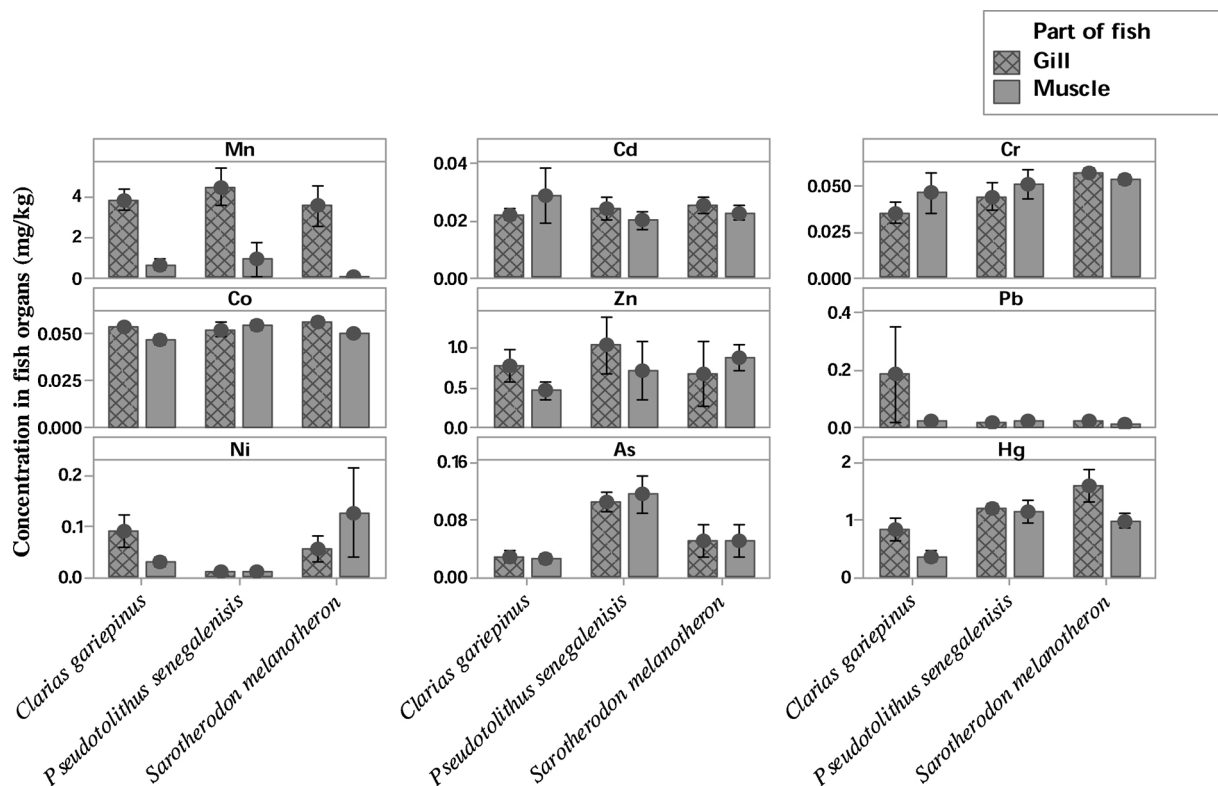
Seven different species of fish naturally associated with both marine and freshwater systems were encountered during this study. These species were the black-chinned tilapia (*Sarotherodon melanotheron*), African sharp-tooth catfish (*Clarias gariepinus*), flathead Grey mullet (*Mugil cephalus*), Cassava croaker (*Pseudotolithus senegalensis*), and Gorean snapper (*Lutjanus goreensis*), Angolan dentex (*Dentex angolensis*) and Senegalese tongue sole (*Cynoglossus senegalensis*). This report focuses on health risk associated with three fish species, i.e. *S. melanotheron*, *P. senegalensis* and *C. gariepinus*, that are commonly consumed and are of important economic value to communities in the study area.

### 3.1. Mean heavy metal concentration in the fish gills and muscle ( $mg\ kg^{-1}$ )

Mean concentration and standard deviation of three fish species (*Pseudotolithus senegalensis*, *Sarotherodon melanotheron* and *Clarias gariepinus*) from the Ankobra River are presented in Fig. 2. The levels of heavy metals in the different species varied considerably and this could be due to their different feeding habits as well as their bioaccumulation factor [18].

#### 3.1.1. Cadmium

The mean cadmium levels recorded in the gills and muscle of the different fish species were ( $0.02 \pm 0.01\ mg\ kg^{-1}$ ) and ( $0.02 \pm 0.01\ mg\ kg^{-1}$ ) for *Pseudotolithus senegalensis*, ( $0.02 \pm 0.01\ mg\ kg^{-1}$ ) and ( $0.03 \pm 0.03\ mg\ kg^{-1}$ ) for *Clarias gariepinus* and ( $0.02 \pm 0.01\ mg\ kg^{-1}$ ) and ( $0.02 \pm 0.01\ mg\ kg^{-1}$ ) for *Sarotherodon melanotheron* (Fig. 2). On average, cadmium levels recorded in the gills of *Pseudotolithus senegalensis*, *Clarias gariepinus* and *Sarotherodon melanotheron* were not significantly different. Similarly, levels of Cd in the muscles of the fish species were not different. In contrast, the amount of the metal found in muscles of *C. gariepinus* was approximately 33 % higher than the concentration recorded in the gills of the species (Tukey post hoc;  $p > 0.05$ ). For human consumption, the acceptable level of Cd recommended by WHO is 0.05 mg per each kg of fish [24]. Kortei et al. [27] also recorded lower levels of Cadmium in *Clarias sp.* and *Tilapia sp.* in



**Fig. 2.** Heavy metal levels (Mean  $\pm$  SD) in the gills and muscle of fish species from the Ankobra River.

the Ankobra River.

### 3.1.2. Lead

Lead levels recorded in the gills and muscle of the different species of fish were  $(0.02 \pm 0.01 \text{ mg kg}^{-1})$  and  $(0.02 \pm 0.01 \text{ mg kg}^{-1})$  for *Pseudolithus senegalensis*,  $(0.18 \pm 0.64 \text{ mg kg}^{-1})$  and  $(0.02 \pm 0.03 \text{ mg kg}^{-1})$  for *Clarias gariepinus* and  $(0.02 \pm 0.01 \text{ mg kg}^{-1})$  and  $(0.01 \pm 0.00 \text{ mg kg}^{-1})$  for *Sarotherodon melanotheron* (Fig. 2). Levels in the gills and muscles of *Pseudolithus senegalensis* and *Sarotherodon melanotheron* were similar. However, the levels in the gills of *Clarias gariepinus* were higher than the muscles. Statistically, there was a significant difference ( $P > 0.05$ ) between the gills and muscles of *C. gariepinus*. Mean concentrations of lead observed in the three species were lower than the permissible limit of  $0.2 \text{ mg kg}^{-1}$  for human consumption [24]. The three fish species examined are bottom dwellers and in contact with sediment mostly, therefore the possible source of lead contamination could be from the sediments. Awuah (2016) recorded high levels ( $1.40 \pm 1.78 \text{ mg kg}^{-1}$ ) of lead in sediment from the Ankobra River. Higher levels of lead in sediments have also been recorded in the Pra River [28]. Other study conducted in the river recorded low levels of Pb in similar fish species [27].

### 3.1.3. Chromium

The mean Chromium levels recorded in the gills and muscles of the different fish species were *Pseudolithus senegalensis*  $(0.044 \pm 0.02 \text{ mg kg}^{-1})$  and  $(0.05 \pm 0.02 \text{ mg kg}^{-1})$ , *Clarias gariepinus*  $(0.04 \pm 0.02 \text{ mg kg}^{-1})$  and  $(0.05 \pm 0.04 \text{ mg kg}^{-1})$  and *Sarotherodon melanotheron*  $(0.05 \pm 0.01 \text{ mg kg}^{-1})$  and  $(0.05 \pm 0.01 \text{ mg kg}^{-1})$ . In this study, Cr levels recorded in the gills and muscles were similar (Fig. 2) and the one-way ANOVA indicated no significant difference ( $P > 0.05$ ) between the organs of all fish species. Cr levels observed in this study were below the permissible limit value of  $2.0 \text{ mg/kg}$  set by WHO [24].

### 3.1.4. Arsenic

Mean Arsenic concentrations recorded in the organs of fish species were  $(0.11 \pm 0.03 \text{ mg kg}^{-1})$  and  $(0.12 \pm 0.06 \text{ mg kg}^{-1})$  for *Pseudolithus senegalensis*,  $(0.03 \pm 0.03 \text{ mg kg}^{-1})$  and  $(0.03 \pm 0.03 \text{ mg kg}^{-1})$  for *Clarias gariepinus*,  $(0.02 \pm 0.01 \text{ mg kg}^{-1})$  and  $(0.01 \pm 0.00 \text{ mg kg}^{-1})$  for *Sarotherodon melanotheron* (Fig. 2). Arsenic concentrations in the gills and muscles in all three species recorded were in the order *Pseudolithus senegalensis* > *Clarias gariepinus* > *Sarotherodon melanotheron*. Statistically, there was no significant difference ( $p > 0.05$ ) between the gills and muscles of the fish species. Awuah (2016) has reported high levels ( $0.47 \pm 0.29 \text{ mg kg}^{-1}$ ) of Arsenic in sediments from the Ankobra River. Kyereme et al. (2015) also reported higher levels ( $0.71 \pm 0.46 \text{ mg kg}^{-1}$ ) of As in the Ankobra River. The levels of As recorded in this study were below the permissible limit of  $0.12 \text{ mg kg}^{-1}$  by WHO [24]. Similar levels of As has been recorded in fish in coastal waters of Ghana [29]. Kortei et al. [27] has also reported high levels of As ( $0-0.04 \text{ mg kg}^{-1}$ ) in the river.

### 3.1.5. Cobalt

Cobalt (Co) concentrations recorded in the gills and muscles of the different fish species were  $(0.05 \pm 0.00 \text{ mg kg}^{-1})$  and  $(0.05 \pm 0.05 \text{ mg kg}^{-1})$  for *Pseudolithus senegalensis*,  $(0.05 \pm 0.01 \text{ mg kg}^{-1})$  and  $(0.05 \pm 0.01 \text{ mg kg}^{-1})$  for *Clarias gariepinus* and  $(0.05 \pm 0.01 \text{ mg/kg})$  and  $(0.05 \pm 0.01 \text{ mg kg}^{-1})$  for *Sarotherodon melanotheron* (Fig. 2). The levels recorded in the gills and muscles of the different fish species were similar and statistically, showed no significant difference ( $p > 0.05$ ) between the organs. Mean Co concentration in the species did not exceed the recommended limit of  $0.5 \text{ mg/kg}$  set by the WHO.

### 3.1.6. Nickel

In this study, Ni levels in the gills of the three species were in the order *Clarias gariepinus* > *Sarotherodon melanotheron* > *Pseudolithus*

*senegalensis*. Ni levels in the different fish species were  $0.01 \pm 0.00 \text{ mg kg}^{-1}$  and  $0.01 \pm 0.00 \text{ mg kg}^{-1}$  for *Pseudolithus senegalensis*,  $0.09 \pm 0.13 \text{ mg kg}^{-1}$  and  $0.03 \pm 0.04 \text{ mg kg}^{-1}$  for *Clarias gariepinus* and  $0.56 \pm 0.64 \text{ mg kg}^{-1}$  and  $0.45 \pm 0.89 \text{ mg kg}^{-1}$  for *Sarotherodon melanotheron*. In the muscles, the levels were higher in *Clarias gariepinus* and *Sarotherodon melanotheron* than *Pseudolithus senegalensis*. Nickel content recorded in the fish species did not exceed the permissible limit of  $0.5 \text{ mg kg}^{-1}$  set by WHO [24].

### 3.1.7. Zinc

Zinc levels in examined fish were in the order *P. senegalensis* > *S. melanotheron* > *C. gariepinus*. Mean concentrations recorded in the gills and muscles were  $1.03 \pm 0.08 \text{ mg kg}^{-1}$  and  $0.71 \pm 0.81 \text{ mg kg}^{-1}$  for *Pseudolithus senegalensis*,  $0.76 \pm 0.77 \text{ mg kg}^{-1}$  and  $0.46 \pm 0.45 \text{ mg kg}^{-1}$  for *Clarias gariepinus*,  $(1.69 \pm 0.71 \text{ mg kg}^{-1})$  and  $(0.67 \pm 0.39 \text{ mg kg}^{-1})$  for *Sarotherodon melanotheron* respectively (Fig. 2). The levels in the gills were slightly high compared with the muscles. The levels recorded in the organs of fish species were above the WHO permissible limit value of  $0.05 \text{ mg kg}^{-1}$ . Zn concentrations observed in this study are consistent with studies from the Densu River in Ghana where high levels of Zn was recorded in *C. gariepinus* (Anim et al. 2013).

### 3.1.8. Manganese

Mean Mn levels recorded in the gills and muscles of fish species were *Pseudolithus senegalensis*  $(4.47 \pm 2.13 \text{ mg kg}^{-1})$  and  $(0.8 \pm 1.87 \text{ mg kg}^{-1})$ , *Clarias gariepinus*  $(3.83 \pm 2.02 \text{ mg kg}^{-1})$  and  $(0.60 \pm 1.18 \text{ mg kg}^{-1})$ , *Sarotherodon melanotheron*  $(3.54 \pm 2.02 \text{ mg kg}^{-1})$  and  $(0.02 \pm 0.00 \text{ mg kg}^{-1})$ . The levels of Mn in the gills were higher than in the muscles. Statistically, there were significant differences ( $p > 0.05$ ) in the levels of Mn between gills and muscles. Manganese concentrations in the fish species were above the recommended level of  $1.0 \text{ mg kg}^{-1}$  set by WHO. Mn levels recorded in this study were higher than mean Mn concentrations recorded in *C. gariepinus* from the Densu River, Ghana [30].

### 3.1.9. Mercury

Mercury concentrations in the gills and muscles of species recorded were  $(1.20 \pm 0.20 \text{ mg kg}^{-1})$  and  $(1.15 \pm 0.45 \text{ mg kg}^{-1})$  for *Pseudolithus senegalensis*,  $(0.83 \pm 0.80 \text{ mg kg}^{-1})$  and  $(0.35 \pm 0.39 \text{ mg kg}^{-1})$  for *Clarias gariepinus*,  $(0.73 \pm 0.66 \text{ mg kg}^{-1})$  and  $(0.55 \pm 0.47 \text{ mg kg}^{-1})$  for *Sarotherodon melanotheron*. The levels observed in the different fish species were above the WHO [24] limit value of  $0.5 \text{ mg kg}^{-1}$ . The levels of mercury in *P. senegalensis* could be possible due to its ingestion of sediments which may contain high levels of mercury through feeding since is a demersal fish species (Johnson & Battram, 1993). The levels of mercury in fish species in the present study recorded higher concentrations compared with other studies done in the Ankobra River by Asare-Donkor & Adimado (2016), an indication that the levels of mercury in the river is increasing and this could be attributed to the small scale gold mining activities along the river [31]. Gbogbo et al. [29] also recorded high levels of Hg in fish species from the Densu Delta, Ghana. A study by Kortei et al. [27] has recorded high levels of Hg ( $0.04-0.06 \text{ mg kg}^{-1}$ ) in the River

## 3.2. Health risk estimation of metals

The THQ for Mn, As, Zn, Pb, Cr, Co, Cd, Ni, Co, As and Hg via the consumption of the examined fish species are shown in Tables 1 and 2. The health risk assessment for the metals was done based on assumption that the river system in the present study is the major source of fish to the communities surrounding the river [12]. The acceptable value for the THQ is 1 according to the [32].

In this study, the THQ and HI for all metals were less than 1 indicating that all examined fish species are safe for consumption, and possible health risk related with non-carcinogenic effect is relatively low for long term consumption (about 30 years)

#### 4. Conclusion

The present study showed that fish species collected from the Ankobra River accumulate Mn, Zn and Hg levels higher than the maximum acceptable limits for human consumption. However, the concentrations of Cd, Ni, Cr, As and Co in fish species were lower than the permissible limits by WHO [24]. All metals examined in this study were found not to be potential health hazard for consumers.

#### Author contributions

**Elizabeth Effah:** Conceptualization, Methodology, Investigation, Writing - Original Draft. **Denis Worlanyo Ahetu:** Supervision, Writing-Reviewing and Editing. **Emmanuel Acheampong:** Supervision, Writing-Reviewing and Editing. **Samuel Kofi Tulashie:** Writing- Reviewing and Editing. **Joshua Adotey:** Writing- Reviewing and Editing.

#### Declaration of Competing Interest

The authors declare that there are no conflicts of interest.

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