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Heavy metals concentration and human health risk assessment in seven commercial fish species from Asafo Market, Ghana

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Abstract Health risk assessment and heavy metal accumulation were evaluated in the muscles of widely consumed *Trachurus trachurus*, *Lutjanus fulgens*, *Lutjanus goreensis*, *Acanthocybium solandri*, *Pagellus bellottii*, *Scomber colias* and *Dentex congoensis* fish species in Asafo, Ghana. The fish samples were prepared using a wet digestion method and the heavy metals analysis was performed with the flame atomic absorption spectrophotometer (UNICAM 969). The results revealed that Mn, Cu, Zn, Cd, and Pb concentrations were below the permissible values set by several health institutions. The health risk assessment based on non-carcinogenic and cancer factors effect indicates no adverse health effect of fish intake. The results of heavy metal concentrations showed that different varieties of fish could be safe for human intake and the results are anticipated to create alertness among the local people.

Keywords Fish · Bioaccumulation · Health risks assessment · Heavy metals · Ghana

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Introduction

In the past decades, fast economic development and population growth have aroused a global worry about heavy metals contamination owing to their persistent, non-biodegradable and stability (Miri et al., 2017). Heavy metals including Zn and Cu play vital contribution in biological systems, however, they are toxic at elevated levels, while Hg, Ni, Cr, Pb, and Cd are noxious even at low levels (Gu et al., 2015a). Thus, Hg, Ni, Cr, Pb, and Cd may be categorized as potentially harmful heavy metals (Makedonski et al., 2017). The dietary ingestion of contaminated food (Ghasemi et al., 2017), particularly seafood is among the main source of heavy metals contamination to human well-being (Zhao et al., 2014). Heavy metals may enter aquatic ecosystems via atmospheric deposition, agricultural, industrial and domestic activities (Zazouli et al., 2013). Hence, water bodies have been identified as key receivers of heavy metals either directly or indirectly (Miri et al., 2017).

Fish is a central constituent of well-balanced diet, offering low cholesterol level, high-quality proteins, omega-3 fatty acids, healthy source of energy, vitamins and other important nutrients (Parida et al., 2017). The regular intake of fish may reduce the risk of several illnesses, such as preterm delivery, stroke, and asthma (Oyewole and Amosu, 2012). Due to the high potential of heavy metals entering food chains, their accumulation in aquatic ecosystems has attracted global interest (Jarić et al., 2011). Fish are normally at the top of marine food chains and their metabolisms can accrue heavy metals from sediment, water, and food (Yılmaz et al., 2007). Heavy metals are accumulated in fish by absorption from aquatic ecosystems via their gills or skin, as well as consumption of contaminated particles and food (Miri et al., 2017). The environmental condition may cause accumulations of heavy metals in muscles of marine species (Elkady et al., 2015). Heavy metals have divergent accumulations behavior in different organs of fish and several factors including feeding behavior, swimming pattern, reproductive cycle, as well as sex, size, and age of fish species can affect their intake (Canli and Atli, 2003).

The accretion of heavy metals in tissues of fish may cause actual adverse health effects via fish intake (Hao et al., 2013). Therefore, various types of fishes are normally used as biomarkers to study heavy metals accumulation in aquatic environments, in addition to assessing risks caused by anthropogenic activities (Muiruri et al., 2013). As a result, several studies have been performed to evaluate health risks caused by fish intake (Gu et al., 2017; Rahman et al., 2012; Taweel et al., 2013). In Ghana, farmers employ chemical fertilizers, weedicides, and several types of pesticides during cultivation of rice and vegetables (Anim-Gyampo et al., 2013). These chemicals often contain some heavy metals including Cd and Mn (in trace amounts), and hence when they are applied to crops and soils, they have high affinity to be percolated into groundwater system and also taken up by surface run-offs into streams, which eventually may find their way into rivers, lake and dam reservoir (Anim-Gyampo et al., 2013). The accretion of heavy metals in fish have long-term effects on biogeochemical cycling (Gu et al., 2015a), where a large number of heavy metals are accumulated with increasing tropical levels. The accumulation of heavy metals in different fish species have been extensively investigated in Ghana (Akoto et al., 2014; Anim et al., 2011; Asante et al., 2014; Laar et al., 2011). However, accretion of heavy metals in muscles of commercially significant fish species in the Asafo Market, Kumasi is yet to be reported. Therefore, in Kumasi Metropolis, the general people and authorities are not mindful of the health implication of heavy metals accumulation in fish. Henceforth, this study aimed to examine the concentration and health risk assessment of heavy metal accumulation in muscle tissues of *Trachurus trachurus*, *Lutjanus fulgens*, *Lutjanus goreensis*, *Acanthocybium solandri*, *Pagellus bellottii*, *Scomber colias* and *Dentex congoensis* species from the Asafo Market.

Materials and methods

Sample collection and preparation

The *Trachurus trachurus*, *Lutjanus fulgens*, *Lutjanus goreensis*, *Acanthocybium solandri*, *Pagellus bellottii*, *Scomber colias* and *Dentex congoensis* species were obtained from major markets in and around Asafo in Kumasi, Ashanti region of Ghana from June 12, 2017, to August 12, 2017. The fish species were caught from Barekese reservoir. A total of forty-two (42) fish samples of varying sizes were collected. The species used in this study were based on their popularity among local consumers and their accessibility at the time of sampling. The fish species collected were also based on their consumption rate during the study period. The samples were placed in clean plastic bags (each species in a separate bag), stored on an ice chest to avoid deterioration and transported to the Department of Fisheries, Faculty of Renewable and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi for identification. The body weight and length of each fish sample was measured and recorded after which they were washed with distilled water and kept in a refrigerator prior to digestion and chemical analysis. Biological information and trophic level characteristics of the seven studied species are shown in Table 1.

Sample digestion and metal extraction

A part of the comestible muscle tissue between the dorsal fin and lateral line of each fish sample was removed using a stainless-steel knife, homogenized with mortar and pestle (Kaya and Turkoglu, 2017). Each sample was then kept in a clean-capped glass vial and stored in a refrigerator until digestion. About 1.00 g of homogenized fish muscle tissues were weighed into the digestion tube. Using wet digestion method, an 8.00 mL comprising of 1:1:2 (v/v) of HNO_3:-$HClO_4$: H_2SO_4, respectively were added to each weighed samples and the resulting mixture was subjected to heat on a hot plate for 30 min at 200 ± 5 °C until the evolution of brown fumes ceased. The solution was permitted to cool to room temperature and subsequently filtered into a 100 mL volumetric flask. The filtrate was topped up the 100 mL mark using deionized water and then transferred into a well cleaned brown bottle and sealed with a plastic cork.

Instrumental analysis

The digested fish samples were investigated for Mn, Cu, Zn, Cd, and Pb, using flame atomic absorption spectrophotometer (AAS) UNICAM 969 (Geleen, Netherlands) with deuterium background corrector. The heavy metal concentrations were measured by calibration based on internal standards. The AAS was calibrated to assess the analytical procedure with reference to known quantities of heavy metal standards. Multi-element standard solutions were employed during the calibration curve preparation. These were prepared by diluting a stock solution of each element. The calibration curve was plotted from six points and an $R^2 > 0.999$ was accepted. All the experiments were assessed by an internal quality method and authenticated to

Table 1 The biological background information and trophic level characteristics of the studied fish species

Scientific name	Range of length	Range of weight	English name	Main foods	Habitat	Trophic level	References
Trachurus trachurus	28.10–30.90	222.31–299.02	Atlantic horse mackerel	Fishes, crustaceans, and cephalopods	Coastal areas	3.7	Smith-Vaniz et al. (2015)
Lutjanus fulgens	23.10–31.40	179.44–412.80	Golden African Snapper	Fishes, and crustacean	Rocky bottoms	4.0	de Morais et al. (2015b)
Lutjanus goreensis	29.70–36.50	406.72–682.12	Gorean Snapper	Fishes and bottom-dwelling invertebrates	Rocky reefs	4.0	de Morais et al. (2015a)
Acanthocybium solandri	33.60–37.10	337.55–463.83	Kingfish	*Cypselurus cyanopterus*, *Oxyporhamphus micropterus*, *Dactylopterus*, *volitans*, squids, cephalopods,	Ocean	4.3	Collette et al. (2011a)
Pagellus bellottii	16.10–18.60	68.46–100.33	Red Pandora	Crustaceans, cephalopods, amphioxus, small fish, and worms	Sandy bottoms	3.6	Russell and Carpenter, (2014)
Scomber colias	32.60–39.50	447.78–764.22	Atlantic Chub Mackerel	Copepods, pelagic invertebrates, silversides crustaceans, sardinella, anchovy, pilchard, sprat, fishes, and squids	Coastal area	3.9	Collette et al. (2011b)
Dentex congoensis	24.10–29.60	203.58–469.88	Congo Dentex	Fishes, tunicates, and mollusks	Continental shelf and upper slop	3.71	Edwards et al. (2010)

verify whether they satisfied internal quality control. For each batch of analysis, reagent blanks were used simultaneously to validate and offer baseline correction for the analytical results. The value obtained from running blank experiment was subtracted from the analyte value. The analytical accuracy and precision were evaluated using the DORM-2 certified standard reference material (dogfish muscle) provided by the National Research Council, Canada, Division of Chemistry. The DORM-2 reference material was used in the calibration procedure, as well the development of procedure for the analysis of heavy metal in other marine species. This reference material was prepared from homogenate fish protein. The heavy metal concentrations were recorded as mg/kg wet weight.

Intake rate limits

Estimated weekly and daily intakes

The estimated daily intake (EDI) was evaluated using Eq. (1) (Miri et al., 2017):

$$EDI = \frac{E_F \times E_D \times F_{IR} \times C_F \times C}{W_{AB} \times T_A} \times 10^{-3} \quad (1)$$

where E_D, E_F, C_F, W_{AB}, F_{IR}, C and T_A are the exposure duration (60 years), exposure frequency (365 days/year), conversion factor (0.208) to convert dry weight of fish to wet weight, average body weight for adult (70 kg), ingestion rate (25.2 g/day); heavy metal concentrations in muscle tissues of fish and average exposure time, respectively (Miri et al., 2017).

The estimated weekly intake (EWI) was evaluated using Eq. (2) developed by USEPA (2000)

$$EWI = \frac{C_m \times C_R}{W_{AB}} \quad (2)$$

where C_R represent the fish consumption rates (ca. 0.160 kg of fish per week) (FAO, 2016). This value is the recommended level of fish consumption (FAO, 2016).

The percentage of provisional tolerable weekly intake (%PTWI)

The %PTWI was evaluated for each heavy metal using Eq. (3) (Miri et al., 2017):

$$\%PTWI = \frac{EWI}{PTWI} \times 100 \quad (3)$$

The PTWI (mg/kg bw/week) is a reference dose set by joint World Health Organization (WHO)/Food and Agricultural Organization (FAO) Expert Committee on Food Additive and it epitomizes an innocuous weekly ingestion of contaminants (JECFA, 2003). The PTWI guidelines of 7.0, 3.5, 0.007, 0.025, and 0.98 mg/kg for Zn, Cu, Cd, Pb, and Mn, respectively were used in this study (JECFA, 2003).

Daily intake limit

For carcinogenic effects of contaminants, the daily consumption rate limit (CR_{lim}) of fish species was evaluated using Eq. (4) (Miri et al., 2017):

$$\mathrm{CR_{lim}} = \frac{\mathrm{ARL} \times W_{\mathrm{AB}}}{CSF \times C_{\mathrm{m}}} \tag{4}$$

where *ARL* and *CSF* are the maximum acceptable lifetime risk level (10^{-5}) and cancer slope factor, respectively (Yu et al., 2014). The cancer slope factor value of Pb is 0.0085 mg/kg day^{-1} according to the Integrated Risk Information System (USEPA, 2010).

The maximum acceptable daily intake of fish was also calculated for non-carcinogenic risk of heavy metals contaminant (Miri et al., 2017):

$$CR_{lim} = \frac{RfD \times W_{\mathrm{AB}}}{C} \tag{5}$$

where *RfD* is the oral reference dose (Alipour et al., 2015). The *RfD* values for Cd, Pb, Zn, Mn and Cu are 0.001, 0.0035, 0.3, 0.14 and 0.04 in mg/kg-day respectively (USEPA, 2011).

The maximum allowable intake rate of fish contaminated with heavy was obtained using Eq. (6) (Shakeri et al., 2015):

$$CR_{mm} = \frac{CR_{lim} \times T_{\mathrm{ap}}}{MS} \tag{6}$$

where *MS*, T_{ap}, and CR_{mm} are the meal size (0.227 kg fish/meals), average time period (30.44 day/month), and maximum allowable intake rate, respectively (Shakeri et al., 2015).

Metal pollution index (MPI)

The MPI was employed to calculate the accumulation of total heavy metals, as shown in Eq. (7) (Usero et al., 1997)

$$MPI = (C_1 \times C_2 \times C_3 \ldots C_n)^{1/n}. \tag{7}$$

Health risks assessments

Target hazard quotient (THQ)

The non-carcinogenic risks were examined based on THQ calculation, as shown in Eq. (8) (Miri et al., 2017)

$$THQ = \frac{E_F \times E_D \times F_{IR} \times C_F \times C_m}{W_{AB} \times T_A \times RfD} \times 10^{-3} \tag{8}$$

The hazard index (HI) was evaluated by adding all the target hazard quotient values (Giri and Singh, 2015).

$$HI = \sum THQ \tag{9}$$

If the THQ or HI is below one, it implies no threat to health, while THQ or HI above 1, indicate a higher risk associated with fish intake (USEPA, 2011).

Cancer risks (CR)

The *CR* over a lifetime of Pb exposure was calculated following Eq. (10) (Miri et al., 2017):

$$CR = EDI \times CSF. \tag{10}$$

Condition factor (*K*)

The condition factor of fish is useful in assessing the status of aquatic ecosystem (Anene, 2005), as well as monitoring physiological factors, parasitic infections and feeding conditions of fish (Le Cren, 1951). The condition factor is also used to reflects physiological and health conditions of marine species (Sauliutė and Svecevičius, 2015). Hence, a study on condition factor is significant since they offer consumers with information about explicit condition beneath which fish are emerging (Araneda et al., 2008). The condition factor of fish species was evaluated following Eq. (11) (Froese, 2006):

$$K = \frac{W}{L^3} \times 100 \tag{11}$$

here *W* and *L* are the fresh weight (g), and length of fish (cm), respectively. To bring the coefficient of condition close to unity, a factor of 100 was used. Generally, higher *K* value indicates fatter or thicker species.

Statistical analysis

The statistical analysis was performed using IBM Statistical Package for Social Sciences (SPSS) v. 20 software. To evaluate whether the data of each fish samples were normally distributed, a normality test was carried out. Several statistical tests, such as Shapiro–Wilk and Kolmogorov–Smirnov have been used to perform the normality of probability distributions. In this study, the normality was examined by Shapiro–Wilk test since even after Lilliefors correction, it offers a better performance compared to Kolmogorov–Smirnov test (Steinskog et al., 2007). The association between fish size (length and weight) and heavy metal concentrations among the fish species was assessed using Pearson's correlation analysis. The cluster and principal component analyses were used to attain a further understanding of heavy metal distributions by evaluating the similarities or dissimilarities in the different fish samples. The principal component analysis was carried out by Ward's Method and Varimax normalized rotation was used to extract components with an eigenvalue greater than one.

Results and discussion

Heavy metal concentrations

The levels of targeted heavy metals recorded in the muscle tissues of *Trachurus trachurus*, *Lutjanus fulgens*, *Lutjanus goreensis*, *Acanthocybium solandri*, *Pagellus bellottii*, *Scomber colias* and *Dentex congoensis* are summarized in Table 2.

The concentration of heavy metals recorded in the studied fish species follow the order of Cu > Pb > Mn > Zn > Cd except for *Trachurus trachurus* and *Scomber colias*. The Shapiro–Wilk normality revealed that the concentration of Mn, Zn, Pb, Cu, and Cd were normally distributed ($p > 0.05$) in the analyzed fish species. Also, Leven test showed homogeneous variance among the groups. The one-sample t-test results showed that the selected heavy metals varied significantly among the studied fish species ($p < 0.05$) at 95% confidence limit ($t = 5.27$–20.48). The coefficient of variation (CV) was employed to study the degree of variability of heavy metal concentrations in the muscle tissue of *Trachurus trachurus*, *Lutjanus fulgens*, *Lutjanus goreensis*, *Acanthocybium solandri*, *Pagellus bellottii*, *Scomber colias* and *Dentex congoensis*, species. The coefficient of variation are classified as low (CV $\leq$ 20%), moderate (21% < CV $\leq$ 50%), and high variability (50% < CV $\leq$ 100%) (Nezhad et al., 2015). A low CV of $\leq$ 20% was found in Zn and Pb, which revealed that their concentrations did not vary significantly in the studied fish species. The CV of Mn, Cu, and Cd signified moderate variability, which revealed non-homogeneous levels. The skewness value of the studied heavy metals was almost equal to or less than one, and this revealed that these concentrations were not positively skewed in the direction of low concentration. However, the negative kurtosis value of Mn, Cd, and Pb indicate that their distributions in the fish species were less steep (Chen et al., 2012). The condition factor values recorded in this study were 1.13 ± 0.08, 1.45 ± 0.11, 1.45 ± 0.09, 1.04 ± 0.01, 1.61 ± 0.04, 1.33 ± 0.11 and 1.54 ± 0.24 in *Trachurus trachurus*, *Lutjanus fulgens*, *Lutjanus goreensis*, *Acanthocybium solandri*, *Pagellus bellottii*, *Scomber colias* and *Dentex congoensis*, respectively. The condition factor showed a variable health effect with regard to heavy metal contamination. The K value > 1 revealed that all the studied fish samples were healthy (Datta et al., 2013) and this was in agreement with earlier K value in the range of 1.05–1.89 recorded by Chandra and Jhan (2010). The mean concentration of Mn ranging from 0.015 ± 0.002 mg/kg in *Scomber colias* to 0.028 ± 0.019 mg/kg in *Pagellus bellottis* was below the level proposed by FAO/WHO (1.0 mg/kg) (Javed and Usmani, 2014). The levels of Cu ranging between 0.020 ± 0.012 mg/kg wet wt. in *Scomber colias* and 0.156 ± 0.046 mg/kg wet wt. in *Lutjanus fulgens* was below the FAO permissible value of 30 mg/kg (FAO, 2016). The mean concentration of Cu was comparatively higher compared with the other heavy metals. This could be ascribed to the source of Cu and its mode of availability to the studied fish species. The concentration of Zn ranging between 0.015 ± 0.003 mg/kg wet wt. in *Pagellus bellottii* and 0.022 ± 0.005 mg/kg wet wt. in *Scomber colias* was below FAO/WHO permitted value of

Table 2 The descriptive analysis of the targeted heavy metals

Fish species	Mn	Cu	Zn	Cd	Pb
Trachurus trachurus	0.016 ± 0.002	0.058 ± 0.052	0.017 ± 0.006	0.008 ± 0.001	0.085 ± 0.010
Lutjanus fulgens	0.025 ± 0.004	0.156 ± 0.046	0.017 ± 0.005	0.015 ± 0.009	0.060 ± 0.007
Lutjanus goreensis	0.020 ± 0.005	0.093 ± 0.051	0.018 ± 0.006	0.012 ± 0.002	0.077 ± 0.014
Acanthocybium solandri	0.024 ± 0.003	0.118 ± 0.043	0.019 ± 0.001	0.007 ± 0.001	0.054 ± 0.042
Pagellus bellottii	0.028 ± 0.019	0.076 ± 0.032	0.015 ± 0.003	0.015 ± 0.010	0.074 ± 0.019
Scomber colias	0.015 ± 0.002	0.020 ± 0.012	0.022 ± 0.005	0.010 ± 0.003	0.069 ± 0.029
Dentex congoensis	0.024 ± 0.007	0.083 ± 0.020	0.016 ± 0.003	0.019 ± 0.008	0.071 ± 0.017
Shapiro–Wilk Test	0.451	0.99	0.567	0.755	0.949
Skewness	− 0.38	0.162	1.072	0.304	− 0.273
Kurtosis	− 1.335	0.549	1.463	− 0.954	− 0.246
Coefficient of variation (%)	22.40	50.12	12.94	35.04	14.84

30.0 mg/kg (FAO, 2016). The concentration of Cd ranging from 0.007 ± 0.001 mg/kg wet wt. in *Acanthocybium solandri* to 0.019 ± 0.008 mg/kg wet wt. (*Lutjanus fulgens*) was below the permitted limits of 0.05, 0.50, and 0.05 mg/kg recommended by the FAO, WHO, and European Commission Regulation (EC), respectively (Commission Regulation, 2006; FAO, 2016). The concentration of Pb ranging from 0.054 ± 0.042 mg/kg (*Acanthocybium solandri*) to 0.085 ± 0.010 mg/kg (*Trachurus trachurus*) was below WHO, FAO, and EC permissible limit of 2.00, 0.50, and 0.20 mg/kg in fish, respectively (Akoto et al., 2014; Commission Regulation, 2006; FAO, 2016). This low levels of Pb could be due to the ban on the use of leaded fuels, as well as proper disposal of waste substances containing lead or less use of leaded materials (Nyarkoa et al., 2013).

Comparative study

The heavy metal concentrations measured in the studied fish species were compared with earlier studies (Table 3).

The concentration of Pd, Zn, Cd, and Cu recorded in this study were lower compared with those in the Yangtze River, Hypermarkets, Pearl River, Iskenderun Bay, Qinzhou Bay and Fosu Lagoon. The concentration of Zn, Pb, and Cu in fish sampled from Taihu Lake, Pearl River Delta, and Yangtze River were higher than Pb, Zn and Cu levels recorded in this study; however, Cd concentrations were comparable in above areas and São Paulo. The range of Zn and Cu levels in this study were comparable with those recorded in Tono Irrigation Reservoir and higher than the range recorded in Kerguelen Islands and Daya Bay's Fishery Resource Reserve. Bustamante et al. (2003), Gu et al. (2016), Ahmed et al. (2009), Anim-Gyampo et al. (2013) and Asante et al. (2014) found that different fish species contained Cd levels higher than the present study. Moreover, earlier studies (Ahmed et al., 2009; Anim-Gyampo et al., 2013; Idris et al., 2015; Morgano et al., 2011), recorded higher levels of Pb than this study. The concentration of Mn in fish from Hypermarkets, Iskenderun Bay, Pearl River Delta, Southern Red Sea, Fosu Lagoon, Tono Irrigation Reservoir and Red Volta were higher than this study. This comparative study reveals that heavy metals contaminant in fish from Asafo Market were not serious compared to those that have been recorded in literature.

Multivariate analyses

Cluster analysis

Cluster analysis classifies variables into homogeneous clusters in the form of dendrogram with variables show similarities in the same group and dissimilarities between

Table 3 Assessment of the levels of heavy metals recorded in this study with levels from previous studies

Sampling site	Cd	Cu	Pd	Zn	Mn	References
Asafo Market	0.007–0.019	0.020–0.156	0.054–0.085	0.016–0.022	0.015–0.028	This study
Dhaleshwari River[b]	0.61–0.71	5.17–7.48	4.25–8.17	–	–	Ahmed et al. (2009)
Daya Bay's Fishery Resource Reserve[a]	0.002–0.919	0.07–4.10	0.014–0.070	4.57–15.94	–	Gu et al. (2016)
Fosu Lagoon[b]	0.17–0.32	0.10–0.35	4.32–10.85	18.25–23.15	20.95–32.30	Akoto et al. (2014)
Hypermarkets[b]	1.17–4.25	2.3–12.05	3.24–9.17	16.79–49.43	7.72–13.99	Alturiqi and Albedair (2012)
Iskenderun Bay[b]	0.01–4.16	0.04–5.43	0.09–6.95	0.60–11.57	0.05–4.64	Türkmen et al. (2005)
Kerguelen Islands[a]	0.010–0.086	0.5–2.5	–	9.2–33.2	–	Bustamante et al. (2003)
Pearl River[b]	ND-33.2	1.17–6.72	0.05–1.94	2.62–20.2	–	Xie et al. (2010)
Pearl River[b]	0.005–0.079	0.009–2.025	ND-1.049	ND-5.507	–	Wei et al. (2002)
Pearl River Delta[a]	0.02–0.06	0.79–2.26	0.03–8.62	15.7–29.5	0.82–6.91	Leung et al. (2014)
Qinzhou Bay[a]	0.001–0.154	0.01–3.8	0.042–0.299	5.73–11.42	–	Gu et al. (2015b)
Red Volta[b]	0.024–0.031	–	–	–	0.206–0.394	Asante et al. (2014)
São Paulo[a]	0.005–0.047	–	0.026–0.481	–	–	Morgano et al. (2011)
Southern Red Sea[a]	–	–	0.150–0.386	–	0.073–0.128	Idris et al. (2015)
Taihu Lake[a]	0.003–0.021	0.228–1.89	0.177–0.287	16–130	–	Chi et al. (2007)
Tono Irrigation Reservoir[b]	0.035	0.045	0.375	0.004	0.693	Anim-Gyampo et al. (2013)
Yangtze River[a]	ND-2	0.361–18.76	0.009–10.1	0.793–50.8	–	Yi et al. (2011)

[a]Values signify the mean or ranges expressed as mg kg^{-1} wet wt

[b]Values signify the mean or ranges expressed as mg kg^{-1} dry wt

different groups (Boateng et al., 2015; Muhammad et al., 2011). The cluster analysis was used to group heavy metals and fish size (weight and length) into two clusters, as given in Fig. 1(A).

Cluster 2 showed a high correlation of fish size (weight and length) and Zn. This cluster results showed that Zn exhibited an association with all studied fish species, which signify that Zn in the aquatic ecosystem was biologically accessible for uptake by the studied fish species. However, Cd, Mn, Cu, and Pb in cluster 1 signifying their dissimilarity sources of contamination.

Sources of heavy metals pollution

The relationship between fish size and heavy concentration was checked by Pearson's correlation analysis for each fish species. Cu and Mn levels were significantly correlated (r = 0.655) with each at $p < 0.05$. This might be ascribed to their similar dissemination behavior, natural, and anthropogenic activities. Nonetheless, no significant association was observed for the other heavy metals. Only Zn showed a strong significant association with fish size for all the studied species. This might be attributed to differences in the feeding behavior of each fish species. The positive correlation of Zn between weight and length agree well with earlier findings (Miri et al., 2017).

Principal component analysis

Since there were various factors influencing accretion of heavy metals in fish muscles, PCA was introduced to explore the effects of fish species on bioaccumulation using the analyzed heavy metal concentrations matrix. The PCA is a great tool for pattern recognition, which elucidates the change of large dataset of inter-associated variables. PCA extracts eigenvalues and eigenvectors from the covariance matrix of the original associated variables. The principal component (PC) is an orthogonal variable, which was attained by multiplying the eigenvector with the original associated variables. The contribution of the original variable in the PC was obtained by the loading with the individual score. The PCA results are presented in Fig. 1(B). In this study, two component was extracted, which accounted for 81.5% of the overall variance, with PC1 and PC2 accounting for 53.47 and 28.02%, respectively. The proximity of Zn, weight and length variables indicates the strength of their common relationship. Thus, Zn with positive loading in both weight and length tended to be accumulated in the fish species. Mn with relative negative loading in PC1 indicated that the fish species had a tendency to accumulate less Mn than Cu, Cd, and Pb. Moreover, negative correlations observed between Mn and fish sizes might possible indicated that the younger fish species accumulated more Mn than the older ones (Konz et al., 1989). PC2 comprising Mn and Cu was mainly affected by anthropogenic inputs and natural sources.

Consumption rate limits

The accretion of heavy metals in fish is of great concern because fish is a vital food source in human diet. To evaluate the health risk induced by the intake of fish, the concentration of heavy metals recorded in the muscle tissues were used. The daily consumption of heavy metals was evaluated based on their levels in the muscle tissues of the analyzed fish species. The consumption rate limits values are given in Table 4.

In this study, an RfD value of 0.14 mg/kg bw/day suggested by USEPA (2011) for Mn was used since the PTDI value was unavailable for Mn. From Table 4, the maximum daily intake was in the order of Zn < Mn < Pb < Cu < Cd. However, the EWI was in the order of Cd < Zn < Mn < Pb < Cu, while the %PTWI follow the order of Zn < Mn < Cu < Pb < Cd. The lower estimated EDI values compared with the PTDI values for all the studied heavy metals indicated that the intake of the studied fish species poses no effect on consumers. The estimated EDI values were comparable with earlier studies for several fish species sampled from Chilika lagoon (Parida et al., 2017) and Subarnarekha River (Giri and Singh, 2015).

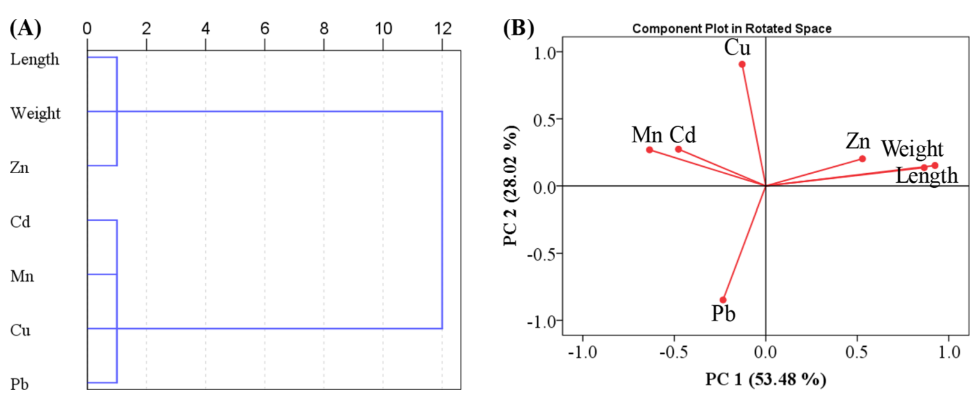

Fig. 1 (**A**) Dendrogram of clustering and (**B**) Score plot of PCA of heavy metals in fish species

Table 4 The PTDI, EDI, and EWI values recorded for the different heavy metals detected in the fish species

Metals	PTDI[a]	EDI (mg/kg bw/day)	EWI (mg/kg bw/week)	%PTWI
Mn	0.14[b]	1.63×10^{-6}	7.07×10^{-5}	0.007
Cu	500	6.46×10^{-6}	28.10×10^{-5}	0.008
Zn	1000	1.32×10^{-6}	5.72×10^{-5}	0.001
Cd	1	91.99×10^{-6}	4.00×10^{-5}	0.572
Pb	3.57	5.31×10^{-6}	23.08×10^{-5}	0.923

[a]PTDI values in μg kg body wt^{-1} day^{-1} of Cu, Zn, Cd, and Pb

[b]The PTDI value of Mn was based on the RfD of Mn proposed by USEPA

Metal pollution index

The MPI was considered using heavy metal concentrations in the fish species. The distribution pattern of total concentrations of heavy metal accumulations in the studied fish species follow the order: *Lutjanus fulgens* (0.036) > *Dentex congoensis* (0.034) > *Pagellus bellottii* (0.032) > *Lutjanus goreensis* (0.031) > *Acanthocybium solandri* (0.029) > *Trachurus trachurus* (0.025) > *Scomber colias* (0.021). The results indicated that *Lutjanus fulgens* fish species accumulated higher heavy metals than the other fish species and this agreed well with the pattern of heavy metal concentrations. We observed that fish species with larger weights recorded a lower MPIs value and this agreed with earlier studies (Caçador et al., 2012). Thus, weight was among the factors affecting the MPI results of fish and relied on their feeding habit (Hao et al., 2013). The MPIs value of Pikeperch (0.91) (Hao et al., 2013) was higher compared with the MPIs values of this study.

Health risks assessment

Fish constitute a major part of the diet of Ghanaian people. Herein, we anticipated that the local population consumes fish and, since muscle is an edible part of fish for human consumption, it intakes risks must be taken into account. The risk assessment results are summarized in Table 5.

From Table 5, the non-carcinogenic daily intake rate effects for a contaminated fish range between 1.98 and 11.95 kg/day, while carcinogenic daily consumption rate limit of Pb in contaminated fish was 1.15 kg/day. This was expected not to cause any adverse effects on human health. The meal size of fish intake/month for both non-carcinogenic and carcinogenic adverse effects was calculated, as shown in Table 5. The meal size for non-carcinogenic effect of contaminated fish ranged between 265 and 1603 meals/month, while the meal of carcinogenic effect of Pb was 154 meals/month. The highest THQ was Pb, followed by Cd, Cu, Mn, and Zn. As given in Table 4, the values of THQ were less than 1. The combined THQ of the studied heavy metals was 2.61×10^{-3} and this was below 1. Hence, the detected heavy metals in the different fish species from Asafo Market has no carcinogenic risks to consumers. Hwang et al. (2017) showed that THQ values of wild fishes in the Southern Sea of Korea follow the order of Cd > Cr > Zn. The combined THQ value of 26.94×10^{-3}, which was below 1 has been reported in Sistan region, Iran (Miri et al., 2017). The carcinogenic risk factor of Pb for fish consumption in Asafo, Ghana was calculated. The carcinogenic risk via contaminated fish intake was 6.75×10^{-5}. Generally, CR above 10^{-4} are regarded as unacceptable, CR below 10^{-6} are regarded as negligible, and CR ranging from 10^{-4} to 10^{-6} are regarded as an acceptable carcinogenic risk (USEPA, 2010). To this effect, the CR value of Pb was in an acceptable range. A carcinogenic risk value of Pb in the range from 0.001 to 0.009 was calculated for frequently consumed fish species in Bogra District of Bangladesh (Islam et al., 2016). The

Table 5 Estimated CR_{lim} (non-carcinogenic and carcinogenic), CR_{mm}, THQ, CR and RR

Metals	Carcinogenic		Non-carcinogenic		THQ	CR (mg/kg/day)	RR (%)
	CR_{lim} (kg/day)	CR_{mm} (meals/month)	CR_{lim} (kg/day)	CR_{mm} (meals/month)			
Mn	–	–	4.51	605	1.16×10^{-5}	–	0.16
Cu	–	–	3.25	435	1.62×10^{-4}	–	2.16
Zn	–	–	11.95	1603	4.39×10^{-6}	–	0.06
Cd	–	–	5.70	764	9.19×10^{-4}	–	12.29
Pb	1.15	154	1.98	265	1.52×10^{-3}	6.75×10^{-5}	20.24

carcinogenic risk value for Pb (1.57×10^{-7}) via fish intake in Sistan region, Iran was also below the tolerable carcinogenic risk factor (Miri et al., 2017).

In conclusion, this study was designed to offer baseline insights on the concentration and health risk of some toxic heavy metals in commercial fish species consumed in Asafo, Ghana. The results disclosed that the levels of Pb, Cu, Cd, Mn and Zn in the muscle tissue of the studied fish species were lower compared with the permitted limits suggested by WHO, FAO and EC. The PCA extracted two components, which accounted for 81.5% of the overall variance. The PCA results further showed that the clustering of Zn with fish size (weight and length) in the loading plot, indicated their important reciprocal positive association. The EWI of the studied heavy metals via fish consumption was below the PTWI values. The results of this study revealed that the risk of non-carcinogenic adverse effects of fish consumption is not high for consumers. In this study, the highest risks to human and aquatic health were contributed by Pb followed by Cd. The carcinogenic risk of Pb in the fish species was below 10^{-6}, which was acceptable. In conclusion, the heavy metal concentration and health risk analysis showed that the studied fish species could be considered safe to local people and that there may be no potential risks relating to fish intake in Asafo.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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