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Research article

Assessment of toxic elements in selected fish species in the marine water at Jamestown, Ghana

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A R T I C L E I N F O

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A B S T R A C T

Fish is an excellent source of low-fat protein. Fish contains a lot of omega-3 fatty acids, as well as vitamins D and B_2 (riboflavin). The daily consumption of contaminated food, especially fish, is among the primary cause of heavy metals pollution to human health. The aim of the research was to determine the concentration of heavy metals in selected species of fish from the Gulf of Guinea at James Town in Ghana. In tandem with the study's objective, samples of different forms of fish, Cassava fish, Flatfish, Redfish, Kingfish, and Silverfish, and sediment were obtained and analyzed for the presence of heavy metals using atomic absorption spectrometer (PerkinElmer®, PinAAcle 900T). The analysis indicated a high concentration of Pb, Cd, and Cr concentrations in fish gills, muscles, and sediment. High lead concentration in Silverfish gills (5.9 mg/kg) and Flatfish gills (2.29 mg/kg) above WHO levels. Cadmium was found in all fish species and sediment except Kingfish. Chromium concentrations were high n Cassava fish (3.10 mg/kg) and Silverfish (4.01 mg/kg) and copper concentrations were absent in the fish species. Arsenic and mercury were also not detected in all fish species and sediment. Manganese concentrations were found in fish and sediment. High cadmium target hazard quotient (0.17–11.60 for adults and 0.24 to 16.24 for children) and cancer risk (0.00–0.04) values in fish samples indicated potential health concerns. The Hazard Index (HI) for the analyzed samples ranged from 0.00 to 12.48 for adults and 0.00 to 17.47 for children. The study suggests that eliminating pollution and other sources of waterbody pollution is crucial to protecting the marine environment and the health of seafood consumers.

1. Introduction

Heavy metals are inherent components of the Earth's crust. They cannot be degraded or eliminated. To a lesser degree, they enter our bodies through food, drinking water, and air. Several heavy metals, such as zinc, selenium, and copper, are required to sustain the metabolism of the human body [1]. However, in larger amounts, they may cause toxicity. Heavy metal toxicity negatively affects the growth, reproduction, and physiology of fish, which is threatening the sustainable development of the aquaculture sector [2].

Numerous man-made activities release large amounts of contaminants into the sea. Due to their toxicity and storage by sea creatures, heavy metals are considered the most significant source of pollution in aquatic habitats [3]. Aquatic habitats, particularly freshwater ecosystems, seem more exposed to pollution than other environments because of the amount of water used in industrial

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processes and the discharge of waste substances from these industries and urban development. Heavy metals are a major biological concern since they are not removed from water by self-purification but rather accumulate over time and enter the food chain [4]. Increasing metal concentration in the bottom sediment is a major signal of growing metal levels. Many marine species have been found to have the capacity to store harmful toxins in their bodies in minuscule quantities in the sea without damaging them, yet the toxicity affects humans who consume them [5]. According to Ref. [6] indicated that various levels of heavy metals exist in the fish species sampled, but those concentrations are within the maximum residual levels recommended by the European Union and FAO/WHO.

Heavy metals may infiltrate aquatic environments through air deposition and agricultural, industrial, and human activities. Consequently, aquatic bodies have been recognized as significant recipients of heavy metals either wholly or partly [7]. James Town in the Greater Accra region of Ghana serves as one of the most popular communities that provides fish to other parts of the country. Sewerage plant, industry, animal farming, markets, and some part of the residential community in James Town is located closer to the seashore. Liquid waste generated from the sewerage plant, industries, farming activities, markets, and people living close to the seashore are channeled into the sea. The solid waste generated from the community, market, and from farmers also finds its way into the sea as a result of improper regulations by the regulatory bodies whose role is to prevent sea contamination. This indiscriminate waste disposal provides a route for polluting the water body thus the sea with poisonous heavy metals. These heavy metals, if ingested, might be detrimental to human life [8]. Heavy metals will always be rampant in the ecosystem because they are elemental and not biodegradable. Heavy metals can build up, notably in lakes, rivers, or marine sediments, and can be carried from one biological system to another. According to Ref. [9] reported high concentrations of cadmium in fish in riverine systems in India. Several fish and crustacean species, most notably shark, swordfish, and tuna, have been shown to contain significant amounts of mercury, according to Ref. [10]. The size of the fish, however, is a significant factor in accumulation. There is a relationship between fish size and Hg accumulation rate, with larger fish having higher accumulation levels [11]. In contaminated aquatic habitats, heavy metals cannot be metabolized; instead, they amass in tissues and organs, including the gills, gallbladder, stomach, liver, and shells of shellfish and fish [12]. Furthermore, the consumption of contaminated fish regularly might have negative health consequences. Potential health risk may exist for high exposure consumers considering the possible contamination of As and Hg [13]. As a result, it is necessary to carry out this study to identify whether fish from various seaside communities have certain amounts of heavy metals. Hence, this project seeks to assess the heavy metal concentration in some selected fish from the Gulf of Guinea at James Town in Ghana. This research will inform stakeholders of the dangers associated with indulging in practices that contaminate the sea with heavy metals, curbing its effects, and what needs to be done to reduce or prevent this situation.

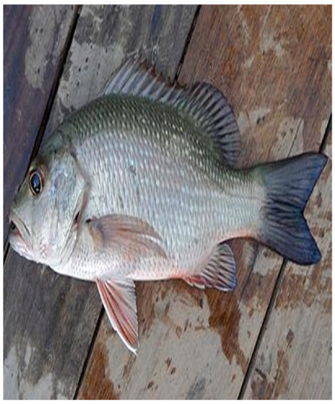
2. Materials and methods

2.1. Sampling of fish samples and sediment

The study took place at Jamestown (in Ghana), a town with a latitude of 5.53334, and the longitude is −0.21357 with the GPS coordinates of 05° 32′ 00.45″ N: and 00° 12’ 48.85” W. Various fish species; *Pseudotolithus senegalensi (*Cassava fish), Pleuronectiformes (Flatfish), *Lutjanus agennes* (Redfish), *Scomberomorus tritor* (Kingfish), and *Dorosoma petenense* (Silverfish) which five each were randomly selected and bought directly from fishermen. The sampling was done during the dry season.

Cassava fish

Flatfish



Redfish

Cassava fish

Silverfish

The live fish was put in a bucket with some seawater that had been sampled, and more aeration was provided to the bucket to ensure that the fish arrived at the laboratory for testing, not under oxygen-stressed conditions. Fish was transported as soon as possible to the laboratory. The grab method was used for sampling of the sediment. The grab was cautiously lowered through the water column after being adjusted in accordance with the manufacturer's recommendations. After that, the sampler was tripped, elevated gradually through the water column, and put in the proper container. To enable deeper penetration into the sediment, extra weight was (if appropriate) added to the sampler in the event that an inadequate or incorrect sample was taken.

2.2. Heavy metal content analysis

A stock solution of mercury, lead, chromium, cadmium, and arsenic was prepared by dissolving various elements in a minimum dilute HNO_3 with 5 % nitric acid solution. Calibration standards were prepared for each metal by diluting it with deionized water.

A stock solution of Cd (1000 ppm) was prepared by dissolving 2.7440 g of Cd $(NO_3)_2{\cdot}4H_2O$ in 200 ml deionized water. With the help of a stirring rod, the solution was stirred for complete dissolution, transferred into a 1000 ml volumetric flask and topped up to the mark with 2 % v/v HNO_3. A working standard solution of concentration 100 ppm was prepared from the stock solution. Calibration standards that fall within the linear range were then prepared from the working standard solution by dilution with 2 % v/v HNO_3. A stock solution of Pb (1000 ppm) was prepared by dissolving 1.5985 g of Pb $(NO_3)_2$ anhydrous in 200 ml deionized water. With the help of a stirring rod, the solution was stirred for complete dissolution, transferred into a1000 ml volumetric flask and topped up to the mark with 2 % v/v HNO_3. A working standard solution of concentration 100 ppm was prepared from the stock solution. Calibration standards that fall within the linear range were then prepared from the working standard solution by dilution with 2 % v/v HNO_3. Commercially available 1000 ppm stock solution of As and Hg were used to prepare a working standard solution of 100 ppm. A stock solution of Cr (1000 ppm) was prepared by dissolving 7.696 g Cr $(NO_3)_3{\cdot}9H_2O$ in about 200 ml deionized water. With the help of a stirring rod, the solution was stirred for complete dissolution, transferred into a clean 1000 ml volumetric flask and topped up to the mark with 2 % v/v HNO_3. A working standard solution of concentration 100 ppm was prepared from the stock solution. Calibration standards that fall within the linear range were then prepared from the working standard solution by dilution with 2 % v/v HNO_3.

The heavy metals were analyzed using atomic absorption spectrometer (PerkinElmer®, PinAAcle 900T). Levels of Cr, Pb and Cd in acid digestates were determined by Flame Atomic Absorption Spectrometer (FAAS). Acetylene gas (C_2H_2) was used as fuel and nitrous oxide (N_2O) as oxidant. Levels of Arsenic was determined by Flow Injection Analysis - Atomic Absorption Spectrophotometer (FIA-AAS) (Hydride Generation System) using Argon gas as fuel. Levels of Mercury was determined by Flow Injection Analysis - Atomic Absorption Spectrophotometer (FIA-AAS) (Cold Vapor Technique) using Argon gas as fuel. Acid digestates of samples were introduced into the spectrometer by suction into the AAS and metal concentrations (Cr, Pb, Cd, Hg and As) was read and recorded. Analysis was done in triplicates and the mean concentrations expressed in units of mg/kg.

2.3. Determining the contamination factor

The contamination factor was calculated using the expression as shown in equation (1):

$$CF_1 = \frac{C_1}{B_1} \qquad \text{Eq. 1}$$

where Ci and Bi are the measured concentration and the background value of metal i, respectively.

2.4. Determining the health risk assessment

Adult and pediatric consumers' non-carcinogenic and carcinogenic health risks were evaluated in relation to the amount of heavy metals present in fish samples.

The Target Hazard Quotient (THQ), which was computed using the given formula shown in equation (2), was used to assess the non-carcinogenic risk of heavy metals:

$$THQ = \frac{CDI}{RfD} \qquad \text{Eq. 2}$$

RfD denotes the heavy metals' oral reference dose (expressed in mg/kg/day) through the oral exposure route, and Chronic Daily Intake (CDI) denotes the estimated intake of heavy metals per kilogram of body weight. The [14] provided the corresponding RfD values for the heavy metals.

The CDI was calculated as shown in equation (3) below:

$$CDI = \frac{C\ X\ IR_i\ X\ EF_i\ X\ ED_i}{BW_i\ X\ AT} \qquad \text{Eq. 3}$$

Where C is the amount of heavy metal present in the samples (milligrams per linear liter), IRi is the rate at which adult and child consumers consume the metal, EFi is the frequency of exposure (350 days per year for both age groups), EDi is the duration of exposure (70 years for adults and 6 years for children), BWi is the body weight (20 years for adults and 70 years for children), and AT is the average time lifespan (EF × ED) for adults and children (25,550 and 2190 days, respectively) [15]. Potentially harmful effects are probable if the computed THQ is higher than 1; unfavorable effects are unlikely if THQ is less than or equal to 1 [16].

The carcinogenic risk, R, was calculated using equation (4) [17] seen below;

$$\text{CR} = \text{CDI x CSF x ADAF} \qquad \text{Eq. 4}$$

where ADAF is the age-dependent adjustment factor (for both adults and children), and CSF is the cancer slope factor (measured in kg/day/mg) [15]. Next, the computed CR value was contrasted with the upper limit of allowable risk.

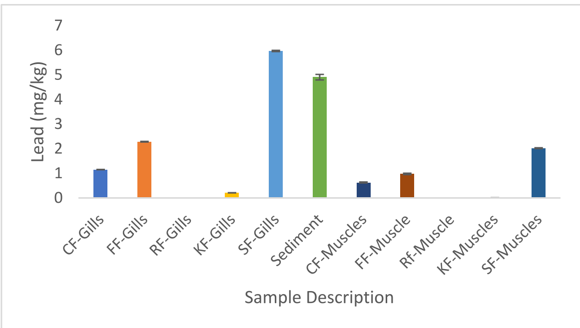


Fig. 1. Average lead concentration in different types of fish and sediment
CF – Cassava Fish, FF – Flat Fish, RF – Redfish, KF – King Fish, SF – Silver Fish.

2.5. Data analysis

The collected data were examined using SPSS and Microsoft Excel to find the mean and variance. The analyses carried out included descriptive statistics, as well as, an Analysis of Variance (ANOVA) test. The pollution index was also used to determine the level of contamination heavy metals.

3. Results

Lead concentrations varied among fishes and sediment. Silverfish had high concentrations in their gills and muscles, while Flatfish had similar levels. The sediment had an average Pb concentration of 4.91 mg/kg. The gills and muscles of various fishes had high Pb concentrations, with gills having higher Pb concentrations than muscles (Fig. 1).

The fish samples had different cadmium concentrations in their gills and muscles, with Silverfish having the highest concentrations of 0.21 mg/kg and 14.12 mg/kg gills. The presence of cadmium was not detected in sediment. The average cadmium concentrations in the gills and muscles of various fishes were higher than in the muscles but not in the Kingfish (Fig. 2).

The results indicated that chromium concentrations varied among different fish species, with the highest concentration in silver fish's gills at 4.012 mg/kg and the lowest in Kingfish at 0.01 mg/kg. The sediment also showed an average concentration of 2.18 mg/kg. The gills had higher chromium concentrations than the muscles, indicating a difference in chromium levels among different fish species (Fig. 3).

There were high variations in the concentration of manganese in fish and sediment. Silverfish had the highest concentrations in gills and muscles, while flatfish and kingfish had low concentrations of manganese in gills and muscles respectively. Sediment also had an average manganese concentration of 26.61 mg/kg. The gills and muscles of various fishes had different manganese concentrations, with gills having higher concentrations than muscles (Fig. 4).

3.1. Heavy metals not detected in the samples

No copper, arsenic, and mercury concentrations were found or detected in the various fish (Table 1). An average copper concentration of 0.81 mg/kg was, however, found in the sediment (Table 1). Furthermore, no concentration of arsenic and mercury was found in the sediment (Table 1).

3.2. Statistical tests conducted to determine pertinent relationships

The p-value was calculated based on an assumed null hypothesis (there is no significant difference or correlation between the heavy metal concentration in the gills of various fishes). Hence an Analysis of Variance test was conducted). A confidence interval of 95 % was assumed. The p-value <0.05 for all the fish gills showed a significant difference in heavy metal concentration between the fish.

The p-value for heavy metal concentrations in the fish was calculated based on an assumed null hypothesis (there is no significant difference or correlation between the heavy metal concentration in the muscles of various fishes). A confidence interval of 95 % was assumed. The p-value <0.05 for all the fish muscles showed a significant difference in heavy metal concentration between the fish.

3.3. Contamination factor of the fish

Samples were tested for contaminants to ensure they meet safety or quality standards and protect human health, the environment, or valuable resources. The contamination factor was utilized in this study to determine the health risk of the fish (Table 2).

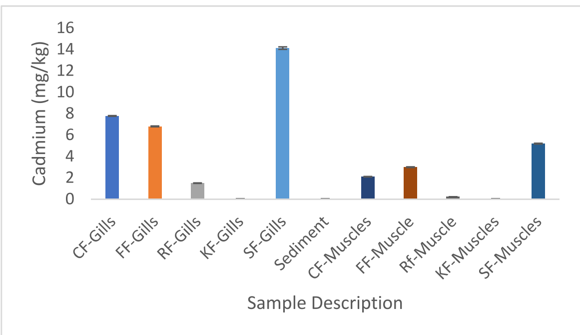


Fig. 2. Average cadmium concentration in different types of fish and sediment
CF – Cassava Fish, FF – Flat Fish, RF – Redfish, KF – King Fish, SF – Silver Fish.

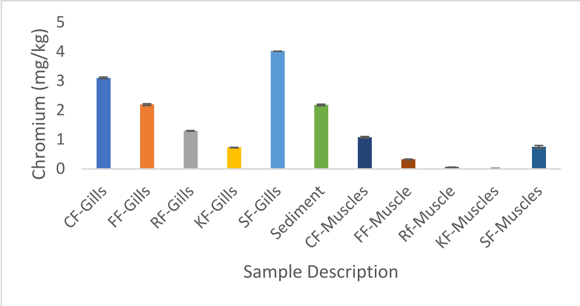


Fig. 3. Average chromium concentration in different types of fish and sediment
CF – Cassava Fish, FF – Flat Fish, RF – Redfish, KF – King Fish, SF – Silver Fish.

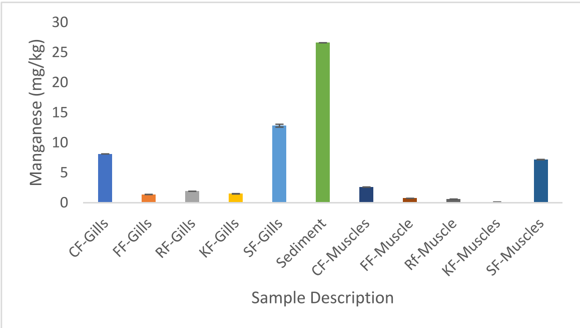


Fig. 4. Average manganese concentration in different types of fish and sediment
CF – Cassava Fish, FF – Flat Fish, RF – Redfish, KF – King Fish, SF – Silver Fish.

Table 1
Average concentration of heavy metals in the various samples of fish and sediment.

Sample Description	Pb (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	As (mg/kg)	Hg (mg/kg)	Mn (mg/kg)
	Avg ± Std	Avg ± Std	Avg ± Std	Avg ± Std	Avg ± Std	Avg ± Std	Avg.±Std
Cassava Fish (Gills)	1.15 ± 0.00	7.77 ± 0.03	3.10 ± 0.03	ND	ND	ND	8.13 ± 0.01
Flat Fish (Gills)	2.29 ± 0.01	6.80 ± 0.04	2.19 ± 0.03	ND	ND	ND	1.39 ± 0.02
Red Fish (Gills)	ND	1.50 ± 0.02	1.29 ± 0.01	ND	ND	ND	1.92 ± 0.01
King Fish (Gills)	0.21 ± 0.00	ND	0.72 ± 0.01	ND	ND	ND	1.50 ± 0.03
Silver Fish (Gills)	5.97 ± 0.03	14.11 ± 0.12	4.01 ± 0.01	ND	ND	ND	12.82 ± 0.24
Sediment	4.91 ± 0.11	ND	2.18 ± 0.03	0.81 ± 0.00	ND	ND	26.61 ± 0.01
Cassava Fish (Muscles)	0.63 ± 0.02	2.10 ± 0.02	1.07 ± 0.03	ND	ND	ND	2.61 ± 0.02
Flat Fish (Muscles)	0.97 ± 0.03	2.98 ± 0.03	0.32 ± 0.01	ND	ND	ND	0.75 ± 0.01
Red Fish (Muscles)	ND	0.21 ± 0.00	0.05 ± 0.01	ND	ND	ND	0.62 ± 0.01
King Fish (Muscles)	0.01 ± 0.00	ND	0.01 ± 0.00	ND	ND	ND	0.13 ± 0.01
Silver Fish (Muscles)	2.02 ± 0.02	5.18 ± 0.04	0.75 ± 0.05	ND	ND	ND	7.18 ± 0.03
Standards (WHO*/USEPA**)	2.0 mg/kg*	0.05 mg/kg*	2.5 mg/kg*	–	0.1 mg/kg**	0.3 mg/kg**	–

ND: Not Detected; Avg: Average; Std: Standard Deviation.

3.4. Health risk assessment

The health risk assessment for the contamination of heavy metals in the analyzed samples was carried out by calculating the Target Hazard Quotient (THQ), Hazard Index (HI), and Target Cancer Risk (TCR) (Fathabad et al., 2018). The THQ and HI values of the heavy metal concentrations of samples for both adult and child consumers (Tables 3 and 4). For the majority of the samples, the THQ values for heavy metals concentrations (Lead, Chromium, and Manganese) were less than the safe threshold of 1 [14], except for cadmium concentrations that were found in the samples ranging from 0.17 to 11.60 for adults and 0.24 to 16.24 for children. The HI, which considers the combined effects of consuming many potentially dangerous substances, likewise exceeded 1 in some of the products analyzed (Tables 3 and 4). In general, the THQ in children was higher than in adults. THQ values were present in copper, arsenic, and mercury, as these metals were not detected in the fish samples. Considering the heavy metals, the Hazard Index (HI) for the analyzed samples ranged from 0.00 to 12.48 for adults and 0.00 to 17.47 for children. The high hazard index was recorded due to the high target

Table 2
Contamination factor of heavy metals in the samples.

	Pb (mg/kg)		Cd (mg/kg)		Cr (mg/kg)		Cu (mg/kg)		As (mg/kg)		Hg (mg/kg)		Mn (mg/kg)	
	Average	CF	Average	CF	Average	CF	Average	CF	Average	CF	Average	CF	Average	**CF**
Sediment	4.91		ND		2.18		0.81		ND		ND		26.61	
CF-Gills	1.15	0.23	7.77	–	3.10	1.43	ND	–	ND	–	ND	–	8.13	**0.31**
FF-Gills	2.29	0.47	6.80	–	2.19	1.01	ND	–	ND	–	ND	–	1.39	**0.05**
RF-Gills	ND	–	1.49	–	1.29	0.59	ND	–	ND	–	ND	–	1.92	**0.07**
KF-Gills	0.21	0.04	ND	–	0.72	0.33	ND	–	ND	–	ND	–	1.50	**0.06**
SF-Gills	5.97	1.22	14.11	–	4.01	1.84	ND	–	ND	–	ND	–	12.82	**0.48**
CF-Muscles	0.63	0.13	2.10	–	1.07	0.49	ND	–	ND	–	ND	–	2.61	**0.10**
FF-Muscle	0.97	0.20	2.98	–	0.32	0.15	ND	–	ND	–	ND	–	0.75	**0.03**
Rf-Muscle	ND	–	0.21	–	0.05	0.02	ND	–	ND	–	ND	–	0.62	**0.02**
KF-Muscles	0.01	0.00	ND	–	0.01	0.01	ND	–	ND	–	ND	–	0.13	**0.00**
SF-Muscles	2.02	0.41	5.18	–	0.75	0.34	ND	–	ND	–	ND	–	7.18	**0.27**

Contamination Factor (CF) = Metal concentration in fish tissue/Reference metal concentration in sediment (Waichman et al., 2024).

Table 3
THQ and HI of heavy metals contamination in fish samples (Adults).

	Pb	Cd	Cr	Cu	As	Hg	Mn	HI
CF-Gills	0.06	6.39	0.43	–	–	–	0.02	6.89
FF-Gills	0.11	5.59	0.30	–	–	–	0.00	6.00
RF-Gills	–	1.22	0.18	–	–	–	0.01	1.41
KF-Gills	0.01	–	0.10	–	–	–	0.00	0.11
SF-Gills	0.29	11.60	0.55	–	–	–	0.04	12.48
CF-Muscles	0.03	1.72	0.15	–	–	–	0.01	1.91
FF-Muscle	0.05	2.45	0.04	–	–	–	0.00	2.55
Rf-Muscle	–	0.17	0.01	–	–	–	0.00	0.18
KF-Muscles	0.00	–	0.00	–	–	–	0.00	0.00
SF-Muscles	0.10	4.26	0.10	–	–	–	0.02	4.48

CF – Cassava Fish, FF – Flat Fish, RF – Red fish, KF – King Fish, SF – Silver Fish, -: not available.

Table 4
THQ and HI of heavy metals contamination in fish samples (Children).

	Pb	Cd	Cr	Cu	As	Hg	Mn	HI
CF-Gills	0.08	8.94	0.60	–	–	–	0.03	9.65
FF-Gills	0.15	7.82	0.42	–	–	–	0.01	8.40
RF-Gills	–	1.71	0.25	–	–	–	0.01	1.97
KF-Gills	0.01	–	0.14	–	–	–	0.01	0.16
SF-Gills	0.40	16.24	0.77	–	–	–	0.05	17.47
CF-Muscles	0.04	2.41	0.21	–	–	–	0.01	2.67
FF-Muscle	0.07	3.43	0.06	–	–	–	0.00	3.56
Rf-Muscle	–	0.24	0.01	–	–	–	0.00	0.26
KF-Muscles	0.00	–	0.00	–	–	–	0.00	0.00
SF-Muscles	0.14	5.96	0.14	–	–	–	0.03	6.27

CF – Cassava Fish, FF – Flat Fish, RF – Red fish, KF – King Fish, SF – Silver Fish, -: not available.

hazard quotient of cadmium in the fish samples.

3.5. Cancer risk assessment

The cancer risk for lead, cadmium, chromium, and manganese in adults ranged from 0.01 to 8.96, 0.32 to 21.17, 0.02 to 6.02, and 0.19 to 19.23, respectively (Table 5). The cancer risk for Lead, Cadmium, Chromium, and Manganese in consumers ranged from 0.00 to 0.02, 0.00 to 0.04, 0.00 to 0.01, and 0.00 to 0.03 respectively (Table 6). Generally, high cancer risk values were recorded for cadmium in the fish samples for adults and children. In general, the cancer risk values in adults were higher than in children.

4. Discussion

Lead is toxic to all living organisms, including fish [18,19]. It has no known biological function and can accumulate in fish tissues, including the gills and muscles [20]. The recorded variations in Pb concentrations among the fish species and sediment highlight the heterogeneous nature of heavy metal contamination in the Gulf of Guinea Jamestown area. Among the fish species, notably high concentrations of Pb were found in the gills and muscles of the Silverfish and Flatfish. These findings suggest that specific fish species may have a higher bioaccumulation capacity for Pb, potentially due to their habitat preferences, dietary choices, or physiological traits

Table 5
Cancer risk associated with heavy metals concentration in fish samples (Adult).

	Pb	Cd	Cr	Cu	As	Hg	Mn
CF-Gills	1.73	11.66	4.66	–	–	–	12.19
FF-Gills	3.43	10.20	3.28	–	–	–	2.08
RF-Gills		2.23	1.94	–	–	–	2.88
KF-Gills	0.31	–	1.08	–	–	–	2.25
SF-Gills	8.96	21.17	6.02	–	–	–	19.23
CF-Muscles	0.94	3.15	1.61	–	–	–	3.92
FF-Muscle	1.46	4.48	0.48	–	–	–	1.12
Rf-Muscle	–	0.32	0.08	–	–	–	0.93
KF-Muscles	0.01	–	0.02	–	–	–	0.19
SF-Muscles	3.03	7.77	1.12	–	–	–	10.77

Table 6
Cancer risk associated with heavy metals concentration in fish samples (Child).

	Pb	Cd	Cr	Cu	As	Hg	Mn
CF-Gills	0.00	0.02	0.01	–	–	–	0.02
FF-Gills	0.01	0.02	0.01	–	–	–	0.00
RF-Gills	–	0.00	0.00	–	–	–	0.00
KF-Gills	0.00	–	0.00	–	–	–	0.00
SF-Gills	0.02	0.04	0.01	–	–	–	0.03
CF-Muscles	0.00	0.01	0.00	–	–	–	0.01
FF-Muscle	0.00	0.01	0.00	–	–	–	0.00
Rf-Muscle	–	0.00	0.00	–	–	–	0.00
KF-Muscles	0.00	–	0.00	–	–	–	0.00
SF-Muscles	0.01	0.01	0.00	–	–	–	0.02

CF – Cassava Fish, FF – Flat Fish, RF – Red fish, KF – King Fish, SF – Silver Fish, -: not available.

[21]. Lead can damage the nervous system of silver fish, leading to problems such as coordination loss and paralysis [1,22]. Lead can accumulate in flatfish, causing them to become brittle and more susceptible to fractures [23]. According to this investigation, Pb in flatfish and silverfish samples were higher than the WHO/FEPA permitted limit of 2.0 mg/kg [24]. The amounts of Pb in samples of redfish, cassava fish, and kingfish were however below the limit. Notably, the gills consistently exhibited higher lead concentrations than the muscle tissues, suggesting that the gills play a significant role in Pb accumulation. The elevated lead concentrations in the gills may be attributed to the direct exposure of these tissues to waterborne contaminants [25,26]. Gills are the primary site of metal uptake in fish because the gills are constantly exposed to water, which can contain Pb and other metals [26,27].

The detection of an average Pb concentration of 4.91 mg/kg in the sediment indicates the presence of Pb in the water body. The sediment can serve as a significant reservoir of Pb, which may be accessible to benthic organisms and contribute to the overall cycling of the heavy metal within the ecosystem. High levels of Pb consumed by individuals can cause damage to the kidneys, liver, lungs, and spleen, as well as lead to neuropathology and blood pressure [28].

Cadmium was present in the gills and muscles of most fish samples, with a notable exception of the Kingfish. This outlier may be attributed to unique feeding habits, habitat preferences, or physiological traits that limit cadmium uptake or enhance its elimination in King fish [29,30]. Cadmium concentrations displayed considerable variability in the amount in the various fishes studied. The levels of cadmium were, however, higher (in all the fishes except the Kingfish) than the WHO/FEPA permissible limit of 0.05 mg/kg for Cd in food [31]. The study, therefore, implies that the fishes (Cassava fish, Flatfish, Redfish, and Silverfish) containing high levels of cadmium, when consumed by individuals, may cause some damage to the consumers, such as kidney damage and cancer [32,33].

According to Ref. [31] some fish species had cadmium concentrations higher than the acceptable limit, which is consistent with current findings. They asserted that the results were caused by applying several agricultural insecticides and pesticides in the neighboring agricultural fields of the research area. One striking observation from the study was the absence of detectable cadmium in the sediment despite the presence of cadmium in fish tissues. This finding suggests that the source of cadmium contamination in the fish may not be primarily linked to the sediments in the study area. Instead, it may be attributed to other sources, such as waterborne or atmospheric deposition. Cadmium may have been introduced into aquatic environments through industrial discharges, urban runoff, and agricultural activities [34,35]. It may also come from factories, wastewater treatment plants, and agricultural runoff containing cadmium-based fertilizers or pesticides [34,35]. Notably, it was observed that the gills of the sampled fishes had higher cadmium concentrations compared to their muscles, which could be since gills are a major site for heavy metal uptake in fish through direct exposure to the aquatic environment [36,37].

The results also reveal substantial variability in chromium concentrations among the studied fish species. The presence of chromium in the gills and muscles of fish, including Cassava fish, Flat fish, Redfish, King fish, and Silver fish, can be attributed to various environmental sources and pathways of contamination [38]. Chromium for instance can be introduced into aquatic environments through industrial discharges, such as from metal-processing industries and tanneries [39,40]. According to Ref. [41], industrial activities, especially plastics, chemical industries, and metals melting are the major sources of heavy metals like chromium in water. In this study, the presence of chromium in the various fishes may be due to the presence of the aforementioned industries in the James Town Sea location. The mean concentration detected from cassava fish, flatfish, and silver fish exceeded the WHO permissible standard of value 2.5 mg/kg, thereby making it unsafe for consumption. Redfish and kingfish had traces below the WHO limit and hence considered safe [41]. There was also variation in chromium concentrations between the gills and muscles of the fish. Notably, the gills consistently exhibited higher chromium concentrations compared to the muscle tissues. This phenomenon could be attributed to the fact that gills play a crucial role in ion regulation and respiration, making them susceptible to accumulating certain heavy metals [36,42]. Additionally, the average chromium concentration in the sediment, measuring 2.18 mg/kg, indicates the presence of chromium in the marine environment. This suggests that the sediment may serve as a potential source of chromium exposure for the aquatic organisms, including fish [43]. Sediment contamination can be a significant source of exposure for bottom-dwelling fish like Flatfish [44]. The bioaccumulation of Cr depends on size and organs; hence, shown from the results that more fish samples recorded alarming amounts of chromium. With subsequent size and dimension, chromium concentration in soft tissues and shells is reduced substantially [45]. Cr accumulation occurs differently in various sorts of tissues. Its concentration is high in the gills, kidneys, and liver of fish, with there is hardly any tendency for chromium accumulation in muscular tissues, which may have accounted for the high levels of Cr accumulation in cassava and silverfish [45].

Copper was not detected in the various fish species, while a significant but relatively low average concentration of 0.81 mg/kg was detected in the sediment. It is a heavy metal that can accumulate in fish tissues and pose potential risks to aquatic organisms and human consumers [46–48]. The absence of detectable copper in the sampled fish suggests that it may not have been a significant concern for seafood safety along the coast of Ghana. The absence of copper in the fish samples, while present in the sediment, may suggest that the fish species studied had relatively low bioaccumulation capacities for copper or that they primarily obtain their nutrition from sources with lower copper content [28,49]. Copper can enter aquatic systems through various pathways, such as industrial discharges, urban runoff, and agricultural practices, and may therefore find its way into the sediment [28,49–51].

Arsenic was not detected in both the analyzed fish species and the sediment. It is a well-known toxic heavy metal that can harm aquatic life and human health when present in high concentrations [52,53]. The absence of detectable arsenic in the sampled fish suggests that the fishes from the coast of Ghana, particularly Jamestown, may not pose significant risks related to arsenic exposure for consumers. Similarly, the absence of arsenic in the sediment indicates that the sediment may not be a significant source of arsenic contamination in the studied region.

Mercury is a well-known toxic heavy metal that can harm aquatic life and human health when present in high concentrations [52,53]. The absence of detectable mercury in the sampled fish and sediment portends that the fishes from the coast of Ghana, particularly Jamestown, may not pose significant risks related to mercury exposure for consumers.

Manganese is a naturally occurring element, but its presence in fish tissues can result from several sources and processes [54]. It plays a role in many important biological processes, such as energy metabolism, bone formation, and immune function [55,56]. However, too much manganese can be toxic to fish [57]. A wide range of manganese concentrations were recorded in the fish species and sediment in the marine ecosystem. Among the fish species, notably high concentrations of manganese were found in the gills and muscles of the Silver fish and Cassava fish. These findings indicate that specific fish species may have a higher bioaccumulation capacity for manganese, potentially due to their habitat preferences, dietary choices, or physiological traits [58,59]. The gills consistently exhibited higher manganese concentrations compared to the muscle tissues of the various fishes, possibly due to the role of gills in ion regulation and heavy metal uptake [36,42]. The detection of an average manganese concentration of 26.61 mg/kg in the sediment highlights the presence of manganese in the marine environment. The sediment can serve as a significant reservoir of manganese, which may be accessible to benthic organisms and contribute to the overall cycling of this heavy metal within the ecosystem. Manganese can be naturally present in the sediments and rocks within aquatic ecosystems [60,61]. Water passing through these geological formations can become enriched with manganese, making it accessible to aquatic organisms, including fish [62,63].

A Contamination Factor (CF) value above 1 indicates potential enrichment and possible contamination, while values below 1 suggest lower or no contamination. Higher CF values typically signify greater potential risks associated with consuming those fish [64]. The CF of the various fish samples was below 1, indicating that there would be less harm when consumed. However, when consumed over time, there could be a tendency of health implications due to bioaccumulation. So, if possible, consumers can avoid eating the gills of these fishes as they serve as a major site of accumulation of heavy metals compared to the muscles.

The study findings raised concern about heavy metals, particularly cadmium in the analyzed fish samples. While most individual Target Hazard Quotients (THQs) for Lead, Chromium, and Manganese remained below the safe threshold of 1, the combined Hazard Index (HI) surpassed 1 in some samples, thereby indicating potential health risks for consumers due to the high cadmium THQ values. Several factors could contribute to this, including industrial activities, mining operations, and agricultural runoff, which are common sources of heavy metal contamination in water bodies. Cadmium, for instance, finds its way into aquatic ecosystems through wastewater discharge and erosion of contaminated soil. This persistent metal accumulates in fish tissue, reaching higher levels in older individuals due to bioconcentration [15]. Children generally consume smaller portions of food than adults, but their higher metabolic rates and body weight ratios lead to proportionately higher contaminant intake per kilogram of body weight. Thus, the high THQs recorded for children potentially put them at greater risk [65]. Consequently, the elevated HI values suggest potential non-carcinogenic health risks associated with consuming these fish, particularly for children.

The permissible limits for cancer risk linked with carcinogenic metals, according to standards established by Ref. [14] are within the range of 1×10^{-4} to 1×10^{-6}. The cancer risk values for Pb, Cd, Cr, and Mn recorded in the study were, however, high and thus posed a risk to individuals (adults and children). While individual Target Cancer Risks (TCRs) for Pb, Cr, and Mn were relatively low, Cd recorded high values ranging from 0.32 to 21.17 for adults and 0.24 to 16.24 for children. A similar study in the Persian Gulf reported Cadmium TCRs in fish ranging from 0.18 to 3.52 for adults, demonstrating comparable levels of risk [14]. Another research in China found that elevated Cd concentrations in fish corresponded to an increased risk of lung cancer in local populations [49]. The elevated Cd TCRs have potential health implications for consumers, particularly high-risk groups like children more susceptible to environmental toxins. While the absolute risk remains relatively low, consistent consumption of fish with high Cd levels could contribute to an increased risk of developing cancer over time.

5. Conclusion

The study found high concentrations of lead, cadmium, and chromium in fish gills (4.49 mg/kg, 6.03 mg/kg, 2.24 mg/kg) muscles 1.00 mg/kg, 2.09 mg/kg, 0.44 mg/kg) and sediment 4.91 mg/kg, ND, 2.18 mg/kg). Lead was found in Silverfish gills and muscles, while Cadmium concentrations were above WHO/USEPA permissible levels. Chromium concentrations were also high in some fish species, including Cassava fish and Silverfish. Copper concentrations were absent in selected fish species, while arsenic and mercury were not detected in all fish species and sediment. Manganese concentrations were found in fishes and sediment, but the high concentrations suggest species-specific bioaccumulation patterns (Gills-5.15 mg/kg, muscles-1.74 mg/kg and sediment-26.62 mg/kg). Consumption of silverfish gills may lead to potential lead intake, while copper, arsenic, and mercury intake is considered low. High

Cadmium TCRs indicate potential health concerns for consumers. To ensure the sustainability of the marine environment and seafood consumption in Ghana, pollution sources must be eliminated.

Ethics approval and consent to participate

The experiment was conducted according to established ethical guidelines, and consent was obtained for animal subject. The Humanities and Social Sciences (HuSSREC) of Kwame Nkrumah University of Science and Technology approved of this research. The study complies with all regulations relating to research, including experimentation on animal subjects ethics.

Consent to publish

Since this study is not attempting to re-publish/publish any third party or author's previously published material, this section does not apply.

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Data availability statement

Data is available upon request.

Ethical approval

This research didn't involve any human or animal subjects hence ethical approval was not needed.

Consent to participate

All the authors have agreed to participate in the publication of the manuscript.

CRediT authorship contribution statement

Lyndon N.A. Sackey: Writing – review & editing, Supervision, Conceptualization. **Nicholas Twum:** Writing – original draft, Formal analysis, Data curation, Conceptualization. **Anthony Boakye Antwi:** Formal analysis, Data curation, Conceptualization. **Bernard Fei-Baffoe:** Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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