Trace Metal Concentrations in Commercially Important Fishes from some Coastal and Inland Waters in Ghana

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Abstract

An assessment was conducted on the concentrations of zinc, copper, manganese, iron, lead and cadmium in 10 different fish species caught from some coastal and inland waters in Ghana, as part of a project on monitoring of pollution in water bodies in Ghana. Shellfish species (*Egeria paradoxa galanata* and *Atya gabonensis*) caught from inland waters had higher elemental concentrations than those caught from coastal waters. Mean concentrations of Fe and Mn were higher in *E. paradoxa galanata, A. gabonensis* and *Trachiurus trachiurus*, while *Panulirus regius* and *Sardinella eba* had higher mean concentrations of Cu. *T. trachiurus*, *Dentex congoensis* and *T. ovatus* had higher mean concentrations of Pb, while *T. trachiurus* and *S. eba* had higher mean concentrations of Zn. Mean Cd concentrations in the fish species were relatively low, with mean concentrations of *Cynoglossus cadenati*, *D. congoensis* and *T. ovatus* below detection limits. The mean concentrations of Zn, Cu, Pb and Cd for shell fishes were comparable to those obtained from previous studies in Ghana. However, they were lower than those reported in other areas of the sub-region. The mean concentrations of Zn, Cu, Pb and Cd in fin fishes were higher than those obtained from previous studies in Ghana. However, these values were comparable to those obtained from other areas in the sub-region. Compared to WHO limits, the levels of Zn, Pb, Cu and Cd in the fish species were lower, and, therefore, safe for human consumption. The study also showed that all the fish species except *S. eba*, *Solar crumophthalmus* and *P. regius* are safe for human consumption with respect to Zn, Cu and Fe.

Introduction

Some trace metals such as zinc and copper are important in small quantities for biological processes in plants and animals, and occur naturally in soil, water and the atmosphere. However, when they are discharged in large quantities from sewage, industrial or agricultural run-off, they ultimately find their way into water bodies including the ocean and constitute an increasing hazard to humans through the food chain. Alongside increasing urbanization and industrialization in the West and Central African Region, there is increasing awareness of the need to control waste discharges into the environment. In order to properly formulate pollution control policies, it is undoubtedly necessary to ascertain the actual state and trend of pollution.

In connection with the Action Plan for the Protection and Development of the Marine Environment and the Coastal Areas of the West and Central Region, a Joint FAO/IOC/WHO/IAEA/UNEP project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2) was established, with the view to generating data to provide the basis for assessing the state of the marine environment and for developing legislation against marine pollution. Within this framework, studies were initiated to assess the levels of trace metals in marine and freshwater organisms (Biney, 1985; Kwakye & Khwaja, 1986; Biney *et al*., 1987; Biney & Ameyibor, 1989; Biney & Beeko, 1991). However, these studies did not cover all commercially available fish species in the Ghanaian market and also trace metals which, when discharged in large quantities into marine environments, could constitute health hazard to man.

It is against this background that the paper seeks to asses the current trend of trace metal pollution in some selected fin and shell fishes that are commercially available in the Ghanaian market by determining the levels of zinc, copper, manganese, iron, lead and cadmium in these fish species from the coastal waters of Accra, Tema and the Volta river at Sogakope. The objective is to assess the state and trend of contamination in comparison to previous studies in Ghana and other countries in Africa where data is available.

Materials and methods

Study areas

The Greater Accra Region of Ghana lies within 5^0 30^I- 5^0 42^I N and 0^0 00^I-0^0 20^I W, which include sampling sites in James Town, Salaha and Tema Fishing Harbour. The Accra-Tema metropolis covers less than 1% of the total area of the country but houses almost 60% of all industries in Ghana (Biney, 1987). The Region lies within the coastal savanna plains of Ghana, where the topography varies from flat to gently rolling with elevation of about 75 m above sea level. Temperatures within the Accra-Tema metropolis are generally high, between 22 and 32 ^{o}C with little variation throughout the year and a relative humidity of 65-95%. The mean annual rainfall is 846 mm and the dominant soils are ochrosols, sodium soils and groundwater laterites, which are underlain by Accraian formations, largely consisting sandstones and clay shales (Ahn, 1970).

About a dozen lagoons occur along the coast of Greater Accra (Fig. 1) and most of these are open to the sea, at least during the rainy season, or are connected to the sea by man-made structures (Biney, 1986). The most prominent include, the Korle and Sakumo I lagoons fed by the Odaw and Densu rivers, respectively.

The Volta Region of Ghana lies within 5^o 47^I N – 8^o 45^I N and 1^o 14^I E – 0^o 22^I W which include the sampling site in Sogakope, the capital of the South Tongu District, and lies about 30 km upstream of the mouth of the Volta river. The region covers an area of 20,570 km^2 representing 8.6% of Ghana.

Sample collection

Three shell fish species were purchased, two (*Egeria paradoxa galanata* and *Atya gabonensis*) from Sogakope while the third species (*Parapenaeopsis atlantica*) was purchased from the Tema Fishing Harbour (Fig. 1). Seven fin fish species were also purchased from James Town, Salaha and Tema Fishing Harbour (Fig. 1). The samples were collected between November 2003 and October 2004. Samples were placed in polyethylene bags and transported in a polystyrene ice-chest to the laboratory, where they were washed with distilled water and stored in polyethylene bags at -19 ^{o}C. The total lengths (cm) and weights (g) of the fish species were measured and, thereafter, samples were prepared for trace metal analysis (UNEP, 1984a).

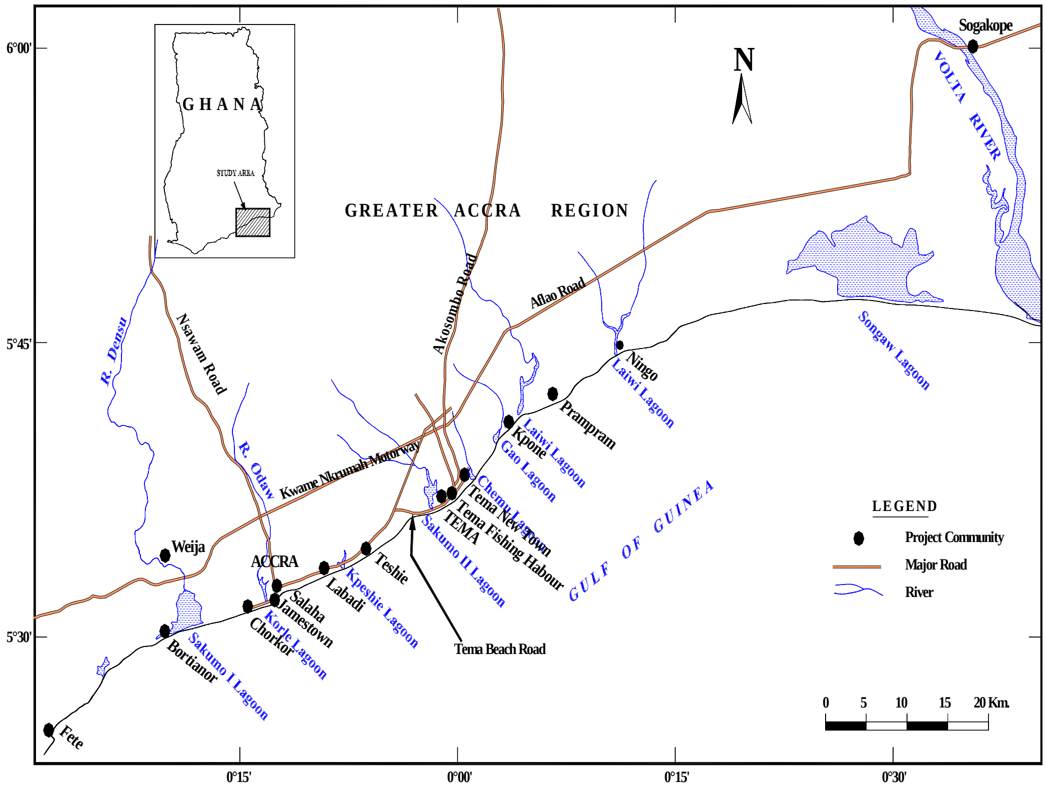


Fig. 1. Map of the Accra- Tema Coastline and the Volta River showing sampling sites.

Sample decomposition and analysis

A sub sample of 1 g of fish muscle tissue was weighed into a 60-ml Teflon vessel and digested under pressure with 2 ml concen-trated nitric acid (HNO_3) by slow heating to 110 °C for 1 h followed by rapid heating to 150 °C for 7 h. The samples were then allowed to cool to room temperature. Digested samples were transferred to graduated polypropylene tubes and made up to 25 ml with double distilled water for analysis [Canadian National Laboratory for Environmental Testing (CNLET), 1994]. Fe, Mn, Cu, Pb, Zn and Cd were determined by flame atomization (UNEP, 1984b) using a Unican 969 Atomic Absorption Spectro-photometer. To ascertain the accuracy of the results, blanks were included in every batch of nine samples analyzed. Analytical quality control measures adopted by the International Atomic Energy Agency (IAEA-350) – the intercomparison run which uses tuna fish homogenate as a certified reference material – was used. The detection limits for the different elements were Zn (0.05), Cu (0.05), Mn (0.02), Fe (0.02), Pb (0.005) and Cd (0.05) µg/g fresh weight (FW).

Results and discussion

Table 1 presents the types and numbers of fin and shell fishes analysed, Table 2 presents the total lengths and weights and the corresponding ranges of the different fish species, and Table 3 presents the mean trace metal concentrations (µg/g fresh weight) of fin and shell fishes.

TABLE 1

Types and numbers of fin and shell fishes analysed

Scientific name	*Common/English name*	*Number analysed*
Shell fishes		
Parapenaeopsis atlantica	Guinea shrimp	34
Atya gabonensis	Prawn	45
Egeria paradoxa galanata	Bivalve (Clamps)	44
Fin fishes		
Cynoglossus cadenati	Ghanaian tonguesole	28
Dentex congoensis	Congo dentex	39
Trachinotus ovatus	Pompano	26
Trachiurus trachiurus	Atlantic horse mackerel	33
Sardinella eba	Flat sardine	49
Solar crumophthalmus	Big-eye scad	35
Panulirus regius	Royal spiny lobster	40

TABLE 2

Total lengths (cm) and weights (g) of fish species

Species	*Range (min. max.)*	*Mean length (±SD)*	*Range (min. max.)*	*Mean weight (±SD)*
Shell fishes				
Parapenaeopsis atlantica	8.50 - 17.82	12.04 ± 0.87	ND	ND
Egeria paradoxa galanata	2.60 - 7.32	5.70 ± 0.11	21-28	25.16 ± 1.20
Atya gabonensis	9.60 - 14.30	11.01 ± 0.69	15.23 - 19.32	16.09 ± 0.43
Fin fishes				
Cynoglossus cadenati	10.20 - 27.50	18.90 ± 2.14	24.4 - 50	31.18 ± 4.71
Dentex congoensis	17.20 - 30.01	23.38 ± 1.24	100 - 200	140.00 ± 6.83
Trachinotus ovatus	13.00 - 25.03	17.83 ± 0.85	26 - 37	31.50 ± 4.20
Trachiurus trachiurus	25.40 - 48.12	35.28 ± 1.28	150 - 200	171.25 ± 7.75
Sardinella eba	20.70 - 36.51	29.14 ± 1.96	70 - 180	131.25 ± 3.23
Solar crumophthalmus	15.50 - 31.21	23.06 ± 2.12	70 - 105	93.0 ± 11.96
Panulirus regius	13.20 - 26.20	17.98 ± 1.32	120 - 160	145.00 ± 17.32

ND – Not determined, SD = Standard deviation

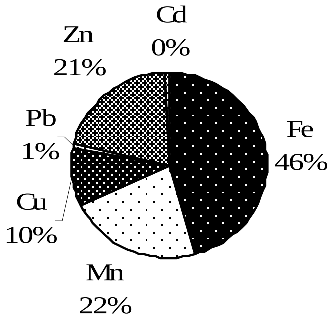
TABLE 3

Mean trace metal concentrations (µg/g wet weight) of fin and shell fishes

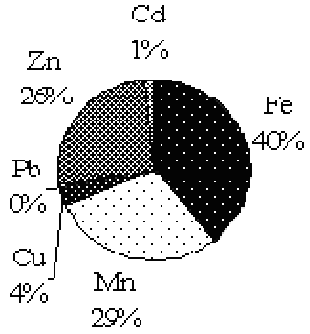
Species	*Fe*	*Mn*	*Cu*	*Pb*	*Zn*	*Cd*
Shell fishes						
Parapenaeopsis atlantica	9.68 ± 1.72	7.27± 1.27	0.87± 0.01	0.08 ± 0.001	6.55 ± 0.28	0.34 ± 0.01
Egeria paradoxa galanata	35.04 ± 2.54	16.74 ± 1.29	7.73 ± 0.47	0.42 ± 0.01	16.09± 0.17	0.33 ± 0.16
Atya gabonensis	23.28 ± 1.21	22.16 ± 0.08	3.30 ± 0.02	0.44 ± 0.02	13.68 ± 0.98	0.17 ± 0.01

Fin fishes						
Cynoglossus cadenati	10.25± 1.47	0.49± 0.22	0.10 ± 0.01	0.76 ± 0.16	6.63± 0.15	ND
Dentex congoensis	18.57± 2.88	0.61±0.01	1.22 ± 0.15	0.90± 0.11	6.20± 0.31	ND
Trachinotus ovatus	0.75 ± 0.15	0.03 ± 0.001	0.35 ± 0.01	0.90± 0.03	1.05 ± 0.50	< 0.002
Trachiurus trachiurus	23.18± 0.91	19.37± 2.81	7.68 ± 1.61	1.09 ± 0.58	19.19 ± 0.17	ND
Sardinella eba	15.06 ± 0.01	1.70 ± 0.56	13.23 ± 0.23	0.74 ± 0.01	18.08 ± 1.20	ND
Solar crumophthalmus	7.62 ± 0.46	1.51± 0.80	11.91 ± 0.50	ND	16.73 ± 1.06	0.14 ± 0.09
Panulirus regius	9.24 ± 0.11	1.06 ± 0.23	14.18 ± 0.59	0.13 ± 0.15	14.58 ± 1.05	0.08 ± 0.01

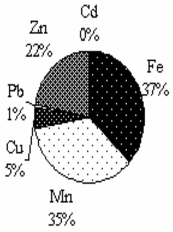
ND - Not determined, SD = Standard deviation



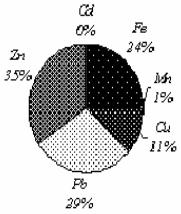
Egeria paradoxa galanata



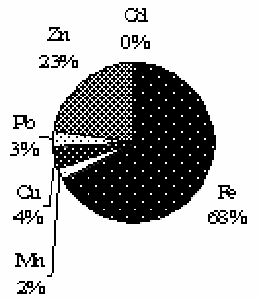
Parapenaeopsis atlantica



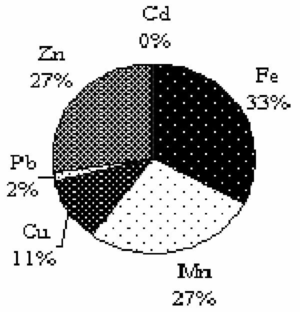
Atya gabonensis



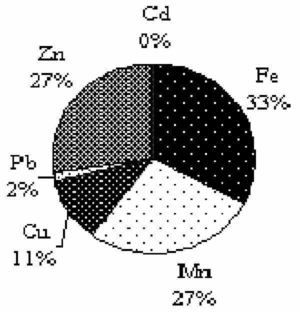
Trachinotus ovatus



Dentex congoensis



Trachiurus trachiurus



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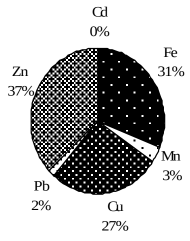
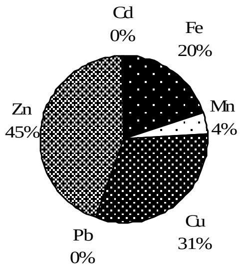
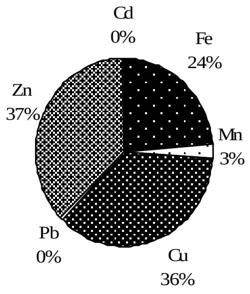


Sardinella eba



Solar crumophthalmus



Panulirus regius

Trace metal in fin and shell fish

The patterns of mean trace metal occurrence (Table 3) in order of decreasing concentrations in the muscle of shell and fin fish species were as follows:

Iron. Shell fish: *Egeria paradoxa galanata* > *Atya gabonensis* > *Parape-naeopsis atlantica*
Fin fish: *Trachiurus trachiurus* > *Dentex congoensis* > *Sardinella eba* > *Cynog-lossus cadenati* > *Panulirus regius* > *Solar crumophthalmus* > *Trachinotus ovatus.*

Manganese. Shellfish: *Atya gabonensis* > *Egeria paradoxa galanata* > *Parapena-eopsis atlantica*
Fin fish: *Trachiurus trachiurus* > *Sardinella eba* > *Solar crumophthalmus* > *Panulirus regius* > *Dentex congoensis* > *Cynoglossus cadenati* > *Trachinotus ovatus.*

Copper. Shellfish: *Egeria paradoxa galanata* > *Atya gabonensis* > *Parape-naeopsis atlantica*
Fin fish: *Panulirus regius* > *Sardinella eba* > *Solar crumophthalmus* > *Trachiurus trachiurus* > *Dentex congoensis* > *Trac-hinotus ovatus* >*Cynoglossus cadenati.*

Lead. Shell fish*: Atya gabonensis* > *Egeria paradoxa galanata* > *Parape-naeopsis atlantica*
Fin fish: *Trachiurus trachiurus* > *Dentex congoensis* = *Trachinotus ovatus* > *Cynoglossus cadenati* > *Sardinella eba* > *Panulirus regius.*

Zinc. Shell fish: *Egeria paradoxa galanata* > *Atya gabonensis* > *Parape-naeopsis atlantica*
Fin fish: *Trachiurus trachiurus* > *Sardinella eba* > *Solar crumophthalmus* > *Panulirus regius* > *Cynoglossus cadenati* > *Dentex congoensis* > *Trachinotus ovatus.*

Cadmium. Shell fish: *Parapenaeopsis atlantica* > *Egeria paradoxa galanata* >*Atya gabonensis*
Fin fish: *Solar crumophthalmus* > *Panulirus regius*.

As shown in Fig. 2 (a-j), the percentage mean Fe, Zn, Mn and Cu contamination in all the fish species were high relative to Pb and Cd, with *Dentex congoensis* (68%), *Solar crumophthalmus* (20%); *Solar crumophthalmus* (45%), *Egeria paradoxa galanata* (21%); *Atya gabonensis* (35%), *Trachinotus ovatus* (1%); *Panulirus regius* (36%), *Cynoglossus cadenati* (1%); *Trachinotus ovatus* (29%), *Parape-naeopsis atlantica* (0%) recording the highest and lowest percentage mean Fe, Zn, Mn, Cu and Pb, respectively. Percentage mean Cd contamination in all the fish species were zero, except *Parapenaeopsis atlantica* (1%).

Mean trace metal concentrations (Table 3) were, generally, higher in *Egeria paradoxa galanata* with respect to shell fishes. This could be due partly to differences in body fat as a result of the relative retention ability of the outer sheath of *Egeria paradoxa galanata*. It could also be due to the likelihood of *Egeria paradoxa galanata* having both dietary and contact exposure with metal-laden sediments, since sediments have been described as ready sinks or reservoirs for pollutants including trace metals, where they concentrate according to the level of pollution (Becker *et al*., 2001; Onyari *et al*., 2003). In the case of fin fishes, metal concentrations in *Trachiurus trachiurus* and *Sardinella eba* were, generally, higher relative to *Cynoglossus cadenati, Dentex con-goensis*, *Trachinotus ovatus*, *Solar crumophthalmus* and *Panulirus regius*. This may be due in part to the relatively large sizes of *Trachiurus* and *Sardinella eba sp*ecies resulting in their abilities to store more fat in their muscle tissues (Biney, 1991).

Generally, shell fishes had relatively higher metal concentrations than fin fishes, which could be partly attributed to differences in body fat content. The current result supports what has been reported in several studies in the sub-region (Kakulu & Osibanjo, 1986; Kakulu *et al*., 1987b; Institute of Aquatic Biology, 1990). Studies have shown that the levels of metals in the environment have increased tremendously in the past decades as a result of human inputs and activities (Merian, 1991). Two of the three shell fishes analysed in this study were caught from inland waters which stretches over long distances, along which several farming communities can be found. High metal content in these shell fishes, therefore, could be due to human inputs and activities.

Manganese, lead and cadmium

Manganese occurs in surface waters that are low in oxygen and often does so with iron. When oxidised in aerobic waters, the oxide builds up in distribution to cause severe discolouration at concentrations above 0.05 mg/l (WHO, 2004). Mean Mn concen-trations ranged from 0.03 ± 0.001 µg/g FW in *Trachinotus ovatus* to 22.16 ± 0.08 µg/g FW in *Atya gabonensis* (Table 3). Comparative analysis for shell fishes showed that, mean Mn concentration was higher in *Atya gabonensis* than in *Egeria paradoxa galanata (16.74* ± 1.29 µg/g FW) or *Parapenaeopsis atlantica (7.27* ± 1.27 µg/g FW). This may be partly due to differences in physiological requirements. Similar analysis showed that *Trachiurus trachiurus* (19.37 ± 2.81 µg/g FW) had the highest mean Mn concentration relative to all the other fin fishes (Table

3). This may be due to the relatively large fat content of *Trachiurus trachiurus*, resulting in higher accumulation of Mn.

Generally, there were significant variations in trace metal levels between fin and shell fishes. This may be due to the differences in physiology and feeding habits. The United States Environmental Protection Agency has classified Pb as being potentially hazardous and toxic to most forms of life (USEPA, 1986a). This metal has been found to be responsible for quite a number of ailments such as chronic neurological disorders especially in foetuses and children. Mean Pb concentrations ranged from 0.08 ± 0.001 µg/g FW in *Parapenaeopsis atlantica* to 1.09 ± 0.58 µg/g FW in *Trachiurus trachiurus* (Table 3). In the case of shell fishes, the mean Pb concentration was significantly higher in *Atya gabonensis* (0.44 ± 0.02 µg/g FW) than in *Parapenaeopsis atlantica* (0.08±0.001 µg/g FW) but almost comparable to the level in *Egeria paradoxa galanata* (0.42 ± 0.01 µg/g FW). Comparative analysis for fin fishes showed that *Trachiurus trachiurus* (7.68 ± 1.61 µg/g FW) had relatively higher mean Pb concentration than all the other fin fishes.

Generally, the mean Pb concentrations in fin fishes were relatively higher than those in shell fishes (Table 3). This could be due to the source of lead and its mode of availability to the organisms; while most trace metals originate from land-based particulate sources, Pb is mainly of atmospheric origin as a result of emissions from automobile exhaust fumes. Such sources of Pb could be more available to fin fishes (caught from coastal waters, at the bank of which, there are vast trunks of roads stretching several km, i.e. Accra and Tema-beach roads, on which there are heavy vehicular traffics) than to shell fishes (caught from inland freshwaters, where there are absence of roads), to which only sedimentary sources are available. The relatively higher Pb content of fin fishes could also be due to the presence of small bones embedded within the muscle tissue of fin fishes; these bones may serve as repositories for Pb (Nord *et al*., 2004).

Mean Pb concentration for fin fishes (Table 4) in this study (0.66 µg/g FW) was relatively higher than those reported from previous studies in Ghana in 1990 (0.36 µg/g FW), Senegal in 1998 (0.5 µg/g FW) or Egypt in 1987 (0.07 µg/g FW); but lower than those of Nigeria in 1991a (2.28 µg/g FW) or Cameroon in 1988 (1.83 µg/g FW). In the case of shell fishes, those reported from previous studies in Ghana in 1990 (0.82 µg/g FW) or Nigeria in 1991a (5.10 µg/g FW) were relatively higher than that reported in the current study (0.43 µg/g FW). However, Senegal in 1988 (< 0.5 µg/g FW) or South Africa in 1982b (0.08 µg/g FW) reported levels lower than this study. Comparative analyses of Pb levels in fin and shell fishes reported in this study and those reported in Ghana in 1991 showed that Pb levels of fin fishes in this study were relatively higher while the levels in shell fishes were on the contrary. This could be due to the sources of Pb to the aquatic environment. Of the total 373 specimens of fin and shell fishes collected over the entire 1-year period, 149 (40%) had Pb concentrations above the WHO guideline of 2.0 µg/g FW (Kakulu *et al.,* 1987b).

Cadmium (Cd) is one of the most toxic elements with reported carcinogenic effects in humans (Goering *et al.*, 1994). High concentrations of Cd have been found to lead to chronic kidney dysfunction. Cd may bio-accumulate at all levels of aquatic and terrestrial food chains. Intestinal absorption of Cd is low and bio-magnification through the food chain may not be significant (Sprague, 1986). The mean Cd concen-trations for the fish species ranged from < 0.002 µg/g FW in *Trachinotus ovatus* to 0.34 ± 0.01 µg/g FW in *Parapenaeopsis atlantica* (Table 3). For shell fishes, the mean Cd concentration was significantly higher in *Parapenaeopsis atlantica* (0.34 ± 0.01 µg/g FW) as compared to the concentration in *Atya gabonensis* (0.17 ± 0.01 µg/g FW). In the case of fin fishes, *Solar crumophthalmus* (0.14 ± 0.09 µg/g FW) had relatively higher mean Cd concentration than *Panulirus regius* (0.08 ± 0.01 µg/g FW) or *Trachinotus ovatus* (< 0.002 µg/g FW), with the Cd levels in the other fin fishes below detection limits. Comparative analysis showed that mean Cd concentrations in shell fishes were relatively higher than those in fin fishes (Table 3). This could be due to the bottom-dwelling and bottom-feeding habits of the shell fishes which are likely to ingest and contact considerable Cd-laden sediment. However, none of the fish species analysed had Cd content higher than the WHO guideline value of 2 µg/g (Kakulu *et al.,* 1987b). Marine biota from Ghana is, therefore, safe for human consumption with respect to Cd.

Mean Cd concentration for fin fishes (Table 4) in this study (0.19 µg/g FW) was relatively higher than those reported from previous studies in Egypt in 1987 (0.004 µg/g FW), Cameroon in 1988, Ghana in 1990, Nigeria in 1991a, or Senegal in1998, – all of which reported < 0.10 µg/g FW – but lower than those of Cote d'Ivoire in 1988 (0.25 µg/g FW), or Cameroon in 1988 (0.26 µg/g FW). In the case of shell fishes, those reported from previous studies in Senegal in 1988 (< 0.10 µg/g FW), Cote d'Ivoire in 1988 (< 0.25 µg/g FW), Cameroon in 1988 (0.21 µg/g FW), Ghana in 1990 (< 0.10 µg/g FW), or Nigeria in 1991a (0.18 µg/g FW) were relatively lower than that reported in this study (0.25 µg/g FW). However, South Africa in 1982b (1.62 µg/g FW) reported a level relatively higher than the level detected in the current study.

Cd contamination in inland and coastal environments could be attributed to discharge of contaminants containing Cd. Activities which may introduce Cd into these environments include electroplating and plastic manufacture. Cd is a constituent of some pigments and significant quantities are released during the smelting of raw sulphide ores. Atmospheric deposition from non-ferrous metal mines and refineries, coal combustion and refuse incineration are other probable sources of Cd. The levels of Cd contamination in fin and shell fishes in this study have both been observed to be relatively higher than those reported in 1990, suggesting increased industrial and domestic activities. Of the total 373 specimens of fin and shell fishes collected over the entire 1-year period, 138 (37%) showed no detection for Cd.

Zinc, copper and iron

Studies have shown that, Zn could be toxic to some aquatic organisms such as fish (Alabaster & Lloyd, 1980). Although Zn has been found to have low toxicity to man, prolonged consumption of large doses can result in some health complications such as fatigue, dizziness and neutropenia (Hess & Schmidt, 2002).

Mean Zn concentrations in the current study ranged from 1.05 ± 0.50 µg/g FW in *Trachinotus ovatus* to 19.19 ± 0.17 µg/g FW in *Trachiurus trachiurus* (Table 3). For shell fishes, the mean Zn concentration was relatively higher in *Egeria paradoxa galanata* (16.09 ± 0.17 µg/g FW) than in *Atya gabonensis* (13.68 ± 0.9 µg/g FW) or *Parapenaeopsis atlantica* (6.55 ± 0.28 µg/g FW). Of all the fin fishes analysed, *Trachiurus trachiurus* showed the highest mean Zn concentration. Generally, there was not much variation of Zn concentrations between fin and shell fishes. Zn concen-trations of all the fish species analysed in the current study were lower than the WHO guideline value of 1000 µg/g FW (Kakulu *et al.*, 1987b). Marine biota from Ghana is, therefore, safe for human consumption with respect to Zn.

Mean Zn concentration for fin fishes (Table 4) in this study (11.0 µg/g FW) was higher than those reported from previous studies in the sub-region, Egypt in 1987 (4.23 µg/g FW); Senegal in 1988 (4.55 µg/g FW); Cote d'Ivoire in 1988 (4.86 µg/g FW); Ghana in 1990 (4.63 µg/g FW); Cameroon in 1988 (5.55 µg/g FW), but lower than that reported in Nigeria in 1991 (27.5 µg/g FW). In the case of shell fishes, this study reported the same mean Zn concentration as from previous studies in Ghana in 1990 (14.9 µg/g FW), which was higher than that reported in Senegal in 1988 (13.9 µg/g FW) but relatively lower than the levels reported from other studies in the sub-region, with Nigeria reporting the highest in 1991a (240 µg/g FW). The relatively higher Mean Zn level in fin fish reported in this study, as compared to that reported in Ghana in 1999, could be due to increased human activity.

Copper is one of the metals classified as essential to life due to its involvement in certain physiological processes and metabolic activities in organisms. However, elevated levels of Cu have been found to be toxic (Spear, 1981). Mean Cu concentrations in the current study ranged from 0.10 ± 0.01 µg/g FW in *Cynoglossus cadenati* to 14.18 ± 0.59 µg/g FW in *Panulirus regius* (Table 3). For shell fishes, the mean Cu concentration was relatively higher in *Egeria paradoxa galanata* (7.73 ± 0.47µg/g FW) compared to *Atya gabonensis* (3.30 ± 0.02 µg/g FW) or *Parapenaeopsis atlantica* (0.87 ± 0.01 µg/g FW). Comparative analysis of mean Cu concentrations showed that the highest mean concentration of Cu occurred in fin fishes, with those of *Solar crumophthalmus* (11.91 µg/g FW), *Sardinella eba* (13.23 µg/g FW) and *Panulirus regius* (14.18 µg/g FW) exceeding the WHO guideline value of 10.0 µg/g FW (Kakulu *et* *al.*,1987b). This could be partly due to the likelihood of fin fishes having both dietary and contact exposure with Cu-laden sediments as a result of their bottom-feeding habits (Nord *et al*., 2004). However, mean Cu concentrations of the shell fishes were below the WHO guideline value of 10.0 µg/g FW (Kakulu *et al.*,1987b).

Mean Cu concentration for fin fishes (Table 4) in this study (6.19 µg/g FW) was higher than those reported from previous studies in Egypt in 1987 (1.65 µg/g FW); Cote d'Ivoire in 1988 (< 0.80 µg/g FW); Cameroon in 1988 (0.75 µg/g FW); Senegal in 1988 (0.73 µg/g FW) or Ghana in 1990 (0.46 µg/g FW) but lower than that reported from Nigeria in 1991a (11.3 µg/g FW). In relation to shell fishes, mean Cu concentration detected from this study (5.52 µg/g FW) was lower than those reported from previous studies from Cameroon in 1988 (9.5 µg/g FW); Ghana in 1990 (6.16 µg/g FW); Nigeria in 1991a (23.6 µg/g FW) or Cote d'Ivoire in 1998 (6.02 µg/g FW) but higher than those reported from South Africa in 1982b (2.35 µg/g FW) or Senegal in 1988 (4.68 µg/ FW). The relatively higher and lower mean Cu levels of fin and shell fishes, respectively, reported in this study as compared to that reported in Ghana in 1990 could be due to the differences in the input of organic matter deposited in the aquatic environment. This is because Das & Nolting (1993) reported that Cu is intimately related to the aerobic degradation of organic matter, and since fin and shell fishes have different physiology and feeding habits, there could be differences in the availability of Cu to fin and shell fishes.

Fe is found in natural fresh waters and has no health-based guideline value, although high concentrations in water give rise to consumer complaints (WHO, 2004). Mean Fe concentrations detected from the current study ranged from 0.75 ± 0.15 µg/g FW in *Trachinotus ovatus* to 35.04 ± 2.54 µg/g FW in *Egeria paradoxa galanata* (Table 3). For shell fishes, the mean Fe concentration was higher in *Egeria paradoxa galanatan* (35.04±2.54 µg/g FW) than in *Atya gabonensis* (23.28 ± 1.21 µg/g FW) or *Parapenaeopsis atlantica* (9.68 ± 1.72 µg/g FW). This could be due to differences in dietary habits with *Egeria paradoxa galanata* being exposed to more Fe from sedimentary sources. In the case of fin fishes, the highest mean Fe concentrations occurred in *Trachiurus trachiurus*. Comparatively, shell fishes had relatively higher mean Fe concentrations than fin fishes, suggestive of differences due to physiology and feeding habits.

TABLE 4

Comparison of mean trace metal concentrations in fin and shell fishes from Ghana and other areas of Africa (µg/g FW)

Location	*Fe*	*Mn*	*Cu*	*Pb*	*Zn*	*Cd*	*Reference*
Shell fish							
Senegal			4.68	< 0.5	13.9	< 0.10	Ba, 1988
Cote d'Ivoire			6.02		17.9	< 0.25	Metongo, 1988
Ghana			6.16	0.82	14.9	< 0.10	Institute of Aquatic Biology, 1990
Ghana	29.16	19.45	5.52	0.43	14.9	0.25	This study
Nigeria			23.6	5.10	240	0.18	Okoye, 1991a
Cameroon			9.5	–	40.4	0.21	Mbome, 1988
South Africa			2.35	0.08	213	1.62	Watling and Watling, 1982b
WHO Limits	–	–	10.0	2.0	1000	2.0	Kakulu *et al*., 1987b
Fin fish							
Senegal			0.73	0.5	4.55	< 0.10	Ba, 1988
Cote d'Ivoire			< 0.80	–	4.86	< 0.25	Metongo, 1988
Ghana			0.46	0.36	4.63	< 0.10	Institute of Aquatic Biology, 1990
Ghana	11.74	4.0	6.19	0.66	11.1	0.19	This study
Nigeria			11.3	2.28	27.5	< 0.10	Okoye, 1991a
Cameroon			–	–	–	0.26	Mbome *et al*.,1985
Cameroon			0.75	1.83	5.55	< 0.10	Mbome, 1988
Egypt			1.65	0.07	4.23	0.004	El Nabawi *et al*., 1987

Conclusion

Fish species (*Egeria paradoxa galanata* and *Atya gabonensis*), caught from inland waters, had higher elemental concentrations than those caught from coastal waters. Mean concentrations of Fe and Mn were higher in *Egeria paradoxa galanata*, *Atya gabonensis* and *Trachiurus trachiurus*, while *Panulirus regius* and *Sardinella eba* had higher mean Cu concentrations. *Trachiurus trachiurus*, *Dentex con-goensis* and *Trachinotus ovatus* had higher mean concentrations of Pb. *Trachiurus trachiurus* and *Sardinella eba* had higher mean Zn concentrations. Mean Cd concen-trations of the fish species were relatively low, with mean concentrations of *Cynoglossus cadenati*, *Dentex con-goensis* and *Trachinotus ovatus* below detection limits.

The study showed that, mean concen-trations of Zn, Cu, Pb and Cd for shell fishes were comparable to those obtained from previous studies in Ghana. However, they were lower than those for other areas in the sub-region. The mean concentrations of Zn, Cu, Pb and Cd in fin fishes were higher than those obtained from previous studies in Ghana. However, these values were comparable to those obtained from other areas in the sub-region. Compared to World Health Organization limits, the levels of Zn, Pb, Cu, and Cd in the fish species were within acceptable limits for human consumption. The study also showed that all the fish species, except *Sardinella eba, Solar crumophthalmus* and *Panulirus regius* are safe for human consumption with respect to Zn, Cu and Fe.

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