TRACE METAL CONCENTRATIONS IN THE PINK SHRIMP *PENAEUS NOTIALIS* FROM THE COAST OF GHANA

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Abstract. Studies were conducted on the concentrations of Cu, Pb, Zn, Hg, Cd, and Fe in 48 samples of the pink shrimp *Penaeus notialis* caught off the mouth of the Korle Lagoon, the most polluted coastal lagoon in Ghana. The pattern of occurence in order of decreasing concentration was Zn > Fe > Cu > Pb > Hg > Cd. A positive correlation was found between Hg and body weight suggesting its accumulation by shrimp. Comparatively, the concentrations obtained in the present study were similar to corresponding values for shrimp caught off the coast of West and Central Africa. However, they, except Hg, were higher than values for fin fishes from the Ghanaian coast. Results indicate that the shrimp are safe for human consumption.

1. Introduction

In spite of the relatively low level of industrial activity in the West and Central African region, there is increasing awareness of the need to control waste discharges into the environment. There has also been a lot of concern about the mode of discharge of domestic wastes from densely populated industrial centers. These discharges, whether gaseous, liquid or solid, ultimately reach our water bodies including the ocean and constitute an increasing hazard to man through the food chain.

In order to properly formulate pollution control policies it is necessary to ascertain the actual state of pollution. It was with this objective that the Joint FAO/IOC/WHO/IAEA/UNEP Project on monitoring of pollution in the marine environment of the West and Central African region was begun. Within this framework studies have been initiated on the determination of the levels of trace metals in marine organisms. Hitherto reports from Ghana had focused mainly on marine fin fish (Biney, 1985). This paper however reports on continuing work involving the levels of Cu, Pb, Zn, Hg, Cd and Fe in the popular local pink shrimp (*Penaeus notialis*). Penaeid shrimp normally inhabit muddy or sandy bottoms near river mouths and lagoon outlets. This littoral distribution exposes them to important environmental factors originating from land. Shrimp may therefore be useful as indicators of pollution arising from man's activities.

2. Study area

Shrimp were caught off the mouth of the Korle Lagoon, 5°32′N 0°14′E, located in Accra (Figure 1). This area forms a part of the Greater Accra Region, which

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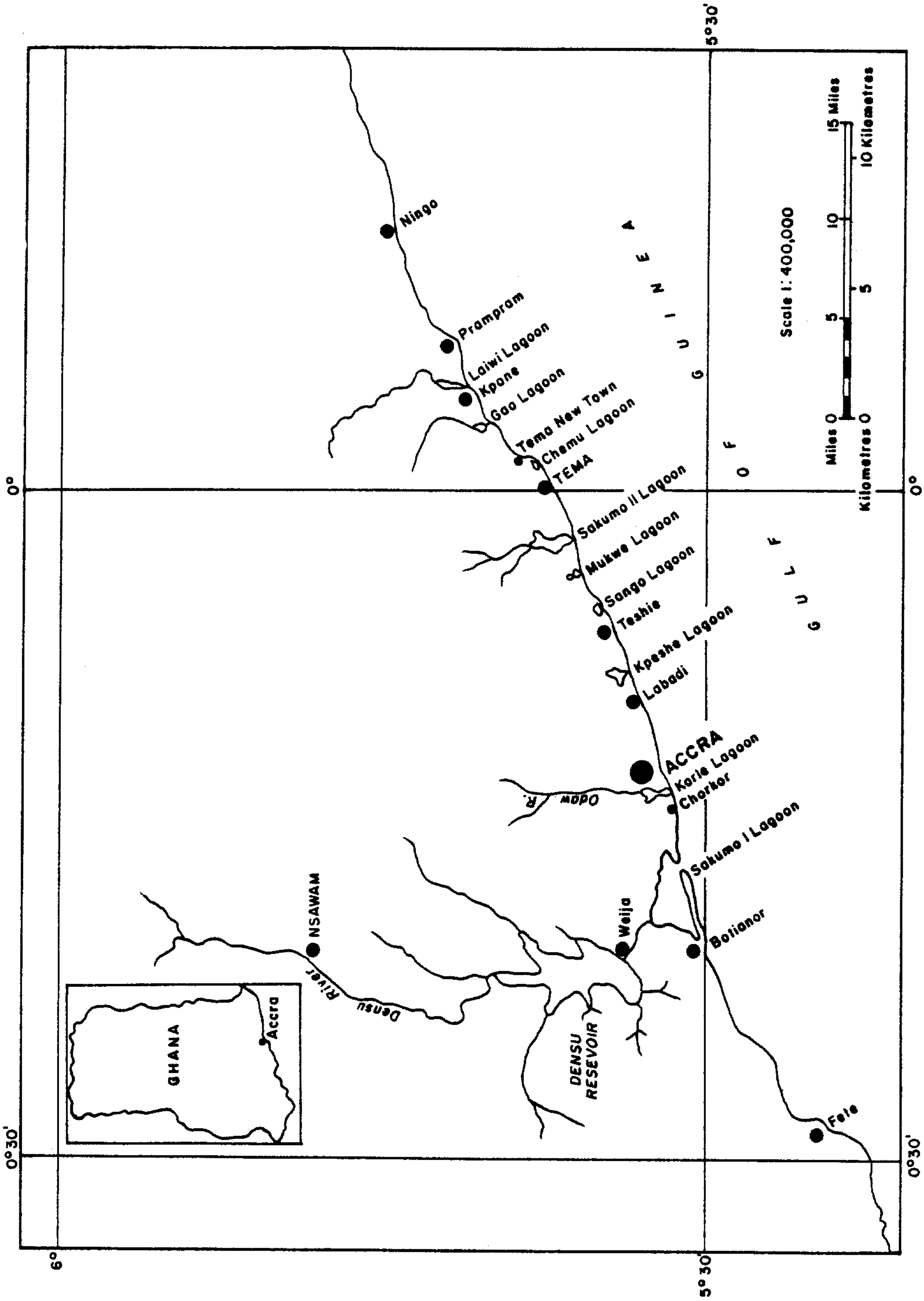

Fig. 1. Map of coastline of Greater Accra Region, Ghana.

is the most densely populated in Ghana. Although the Accra-Tema metropolis covers less than 1% of the total area of the country, more than 30% of all industries are located here.

The study area lies within the coastal savannah plains of Ghana, where the topography varies from flat to gently rolling with a general elevation of about 75 m about sea level. Here, temperatures are high between 22 and 32 °C with little variation throughout the year. The mean annual rainfall is 846 mm and the dominant soils are ochrosols, sodium soils and groundwater laterites (Ahn, 1970). These soils are underlain by Accraian formations, which are made up of mainly sandstones and clay shales.

About a dozen lagoons occur along the coast of Greater Accra (Figure 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 culverts (Biney, 1986). The most prominent include the Korle and Sakumo I Lagoons fed by the Odaw and Densu rivers, respectively. The 2.7 km^2 Korle Lagoon, into which the greater proportion of the floodwaters of Accra flows before entering the sea, has been classified as grossly polluted (Biney, 1982).

3. Methods

Shrimp were obtained by beach seining off the mouth of the Korle Lagoon between January 1987 and June 1988. Samples were put in polyethylene bags and conveyed in a polystrene box to the laboratory, where they were washed with distilled water and stored in polyethylene bags at −19 °C.

The individual length and weight of the shrimp were measured before the samples were prepared for the trace metal analysis (UNEP, 1984a). A subsample of 1 g of shrimp tail muscle was accurately weighed into a digestion crucible and digested under pressure with 2.5 mL HNO_3 by slow heating to 80 °C followed by rapid heating to 160 °C. The temperature was maintained at 160 °C for 7 to 8 hrs. Digested samples were made up to 10 mL with double distilled water for analysis.

Copper, Pb, Zn, Cd, and Fe were determined by flame atomization (UNEP, 1984b) using a Varian 1275 AAS. Mercury was determined by cold vapor atomic absorption spectroscopy (UNEP, 1984c). The total number of samples analyzed was 48. Of this 21 were composite samples, each prepared with 6 different specimens. In order to check the accuracy of the results, a homogenized shrimp sample of known certified metal values was included in all batches of samples analyzed. The detection limits for the different elements were Hg 0.01, Cu 0.2, Pb 0.2, Fe 0.5, and Zn 0.2 $\mu g\ g^{-1}$ fw.

4. Results and Discussion

Body size

Samples of shrimp analyzed had lengths ranging from 6.1 to 11.8 cm, with a mean

TABLE I

Range and mean values of body size

Variable (unit)	Range	Mean	SD
Length (cm)	6.10 - 11.8	8.92	1.56
Total Weight (g)	1.05 - 9.50	3.74	2.10
Dry Weight (%)	14.63 - 25.0	20.59	2.12

of 8.92 cm (Table I), which makes them of moderate size. In the East Central Atlantic penaeid shrimp vary in size from a few cm to 20 cm (FAO, 1981). The mean total weight per specimen was 3.74 g (Table I). Sample dry weight ranged from 14.63 to 25.0%, with a mean of 20.59%.

Mercury, cadmium and lead

Table II summarizes the range and mean values of trace metals analyzed. In order of decreasing concentrations, the pattern of trace metal occurrence in the tail muscle of the pink shrimp was Zn> Fe> Cu> Hg> Cd. Cadmium was not detected in any of the 48 samples analyzed. For Hg, 23% (11) of the samples had concentrations below the detection limit of 0.01 $\mu g\ g^{-1}$. Also, the highest level did not exceed the widely accepted maximum permissible limit of 0.5 $\mu g\ g^{-1}$ (Nauen, 1983). Although Pb was detected in all the samples, the levels were generally low. Thus, the mean concentration of 0.29 $\mu g\ g^{-1}$ was only slightly higher than the detection limit of 0.2 $\mu g\ g^{-1}$. It is therefore reasonable to conclude that the pink shrimp *P. notialis* from the coastal waters of Ghana are safe for human consumption with respect to Hg, Cd and Pb.

It is significant to note that Hg, Cd, and Pb, the most toxic of the six elements analyzed occurred in relatively low concentrations. This is attributed to the limited discharges into water bodies of contaminants, containing these metals. Anthropogenic activities which may introduce Hg into the environment include fossil fuel burning and industrial operations such as those of chloralkali plants and mining.

TABLE II

Ranges and means of trace metal concentrations ($\mu g\ g^{-1}$ fw)

Elements	Ranges	Means	SD	WHO Limit
Hg	<0.01 - 0.063	0.027	0.004	0.5
Cd	ND	ND		2.0
Pb	0.2 - 0.42	0.29	0.15	2.0
Cu	2.62 - 7.49	4.81	1.09	10
Zn	11.8 - 25.1	15.7	2.81	1000
Fe	2.39 - 14.9	4.99	2.46	-

* ND - Not detected.

TABLE III

Relationship between elemental concentrations and shrimp body weight

Element	*n*	*r*	p (%)
Hg	45	0.288	95
Cu	48	−0.030	<95
Pb	48	−0.047	<95
Zn	48	−0.175	<95
Cd	48	−0.266	<95
Fe	48	−0.101	<95

Ghana has no chloralkali plant and mining operations occur mostly inland where any Hg contamination would be localized. Cadmium is used in electroplating and plastic manufacture and a major source of Pb derives from the Pb alkyls used as petrol additives. Both Cd and Pb are constituents of some pigments and significant quantities are also released during smelting operations. At the present low level of industrial technology, discharges of contaminants from such activities are low.

Zinc, copper and iron

Unlike Hg, Cd, and Pb, the elements Zn, Cu, and Fe are essential for metabolic processes, although they may be toxic beyond their required concentrations. The most abundant trace metals in the tail muscle of the pink shrimp was Zn, which had a mean concentration of 15.7 $\mu g\ g^{-1}$ (Table II). The next abundant element was Fe, with a range of 2.39 to 14.9 $\mu g\ g^{-1}$ and a mean of 4.99 $\mu g\ g^{-1}$. Mean Cu levels were slightly lower at 4.81 $\mu g\ g^{-1}$.

Like Hg, Cd and Pb, the highest concentrations of Zn and Cu were also below the WHO maximum permissible limits (Kakulu *et al.*, 1987), a further indication of the low level of trace metal contamination of Ghana's marine environment.

Elemental concentrations and body weight

The results of regression analysis done to establish the relationship between trace metal concentrations and shrimp body weight are presented in Table III. The investigation revealed a 95% correlation for only Hg. This is in agreement with the results of other studies on marine organisms such as those of Leonzio *et al.*, (1981) and Biney (1985). Also, it supports the assumption that Hg accumulates through the food chain (UNEP, 1988).

Comparison with shrimps from other areas

A few studies have been conducted on the levels of the trace metals in penaeid shrimp from the marine environments of the West and Central African region. In recent times, the only reported studies are those of Ba (1988), Mbome (1988) and Metongo (1988), who analyzed shrimps from the coast of Senegal, Cameroon and Cote d'Ivoire, respectively. A comparison of their results with those of the

TABLE IV

Trace metals in Penaeid shrimp from Ghana and other areas of West and Central Africa μg g^{-1} fw

Location	Hg	Cd	Pb	Cu	Zn	References
Ghana	0.027 <0.01 – 0.063	ND	<0.29 0.2 – 0.42	4.81 2.62 – 7.49	15.7 11.8 – 25.1	This Study
Senegal	0.15 0.04 – 0.36	<0.1	<0.5	4.68 0.40 – 5.60	13.9 0.80 –19.6	Ba (1988)
Cote d'Ivoire	0.042 ± 0.006	<0.25	–	6.02 ± 0.61	17.94 ± 2.52	Metongo (1988)
Cameroon	0.099 ± 0.006	0.27 ± 0.06	–	4.85 ± 0.42	24.5 ± 0.25	Mbome (1988)

present study is summarized in Table IV.

While there was little variation between Cu levels, Hg and Zn concentrations from the present study fell within the range for the region. It is therefore apparent that penaeid shrimp from the West and Central African region have comparable levels of tissue trace metals. In general, the countries of the region have the same level of industrial technology, mainly agro-based, and it is expected that discharges into the marine environment would be similar. It may also be inferred from the comparability of the data that there are no major trace metal sources of natural origin in the region.

Comparison with fish

Comparison of the levels of trace metals in shrimp with those of Ghanaian marine fishes (Table V) showed that while Cd was undetected in both groups, shrimp had higher concentrations of all elements except Hg. These differences may be explained by the fact that unlike most finfishes, shrimp are normally bottom dwellers off estuary and lagoon outlets. Estuaries, lagoons and near-shore waters determine the amounts of land-originating trace metals entering the coastal environment by acting as zones of deposition (Salomons and Forstner, 1984). These zones are efficient in trapping dissolved and particulate metals, most of which would therefore be available to bottom dwellers.

Higher levels of Hg in fish may be due to the shrimp being younger since Hg levels in marine organisms increase with age (UNEP, 1988). Also studies by Luoma

TABLE V

Mean body weights (g) and trace metal concentrations in shrimp and marine fish from Ghana (μg g^{-1} fw)

Species	Wt	Hg	Cd	Pb	Cu	Zn	References
Shrimp	3.74	0.027	ND	0.29	4.81	15.7	This study
Fish	268	0.092	ND	<0.2	0.45	4.07	Biney (1985)

(1977a, b) indicated that Hg levels in the deposit feeding shrimp, *Palasaman debilis*, were related to availability from the water rather than from the sediment under field conditions.

Acknowledgments

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