Bull Environ Contam Toxicol (2010) 85:497–501
DOI 10.1007/s00128-010-0125-7

Mercury Accumulation in the Clam, *Galatea paradoxa* (Born 1778) at the Volta Estuary, Ghana

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Received: 31 May 2010 / Accepted: 11 October 2010 / Published online: 23 October 2010

Abstract The concentration of mercury in the tissues of the clam, *Galatea paradoxa* at in the Volta estuary, Ghana, were analysed over an 18-month period, from March 2008 to August 2009. The concentrations were well below the International Human Consumption Advisory Limit of THg (0.5 μg/g wet weight). The concentrations in the tissues of the different clam size classes were between 6 and 18 times lower than the WHO Safety Reference Standard. Variation in the mean mercury concentration in the different clam size classes was not significant ($p > 0.05$) for clams from Aveglo but were highly significant ($p < 0.0001$) for clams from Ada, indicating a possible effect of size on accumulation. *G. paradoxa* is therefore suitable for human consumption based on the WHO Safety Reference Standards.

Keywords Mercury · Consumption · *Galatea paradoxa* · Volta estuary

Mercury is a non-essential element for aquatic organisms and is among the most toxic elements to man and other higher animals (Steinnes 1995; Landner and Lindestrom 1998). Its role as an environmental hazard has been recognised for decades, after thousands of residents were poisoned in Minamata (Japan) by the release of methylmercury (MeHg) from a chemical factory into a local bay in 1956 (Harada 1995). The poisonings were a result of the consumption of MeHg-contaminated seafood which led to the onset of the serious neurological disease, termed Minamata disease. Victims of the disease were diagnosed as having a degeneration of their nervous systems numbness in their limbs and lips, slurred speech (Zahir et al. 2005), and concentric constriction of visual fields (Järup 2003). Victims had serious brain damage, while others lapsed into unconsciousness or suffered from involuntary movements. The effect of mercury on the environment is similarly catastrophic. Entire fisheries have been either restricted or significantly curtailed because of mercury contamination (Moore 1991). The general human population is primarily exposed to mercury via food, where fish is the major source of methylmercury exposure (Järup 2003).

The clam, *Galatea paradoxa* (Born 1778) is a commercially-important bivalve species exploited mainly for its flesh and is consumed boiled or fried. It is a filter-feeding organism with a wide distribution extending from the Gulf of Guinea to the Congo (Moses 1990). Limited information about the prevalence and commercial exploitation of this clam is available from only a few countries, including Ghana, Nigeria and Cameroon, despite its extensive distribution in the wider West African region. In Ghana, the Volta estuary represents the main fishing grounds of *G. paradoxa* and clam fishing represents a viable source of income and livelihood for the local people. Furthermore, it constitutes an important and affordable protein source to the riparian communities in the Volta basin and beyond (Amador 1997). There is evidence that the Volta basin receives a considerable range of polluting effluents, particularly heavy metals from metal fabrication,

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refuse dump sites and agricultural industries along the basin (Obirikorang et al. 2009).

This study was conducted to examine the levels of mercury in whole tissues of the *G. paradoxa* in Ghana to ascertain whether mercury concentrations in the clams were within acceptable standard safety limits for human consumption. The research also examined variations in mercury concentrations in the tissue of *G. paradoxa* in relation to body size to elucidate whether or not mercury uptake, storage and sequestration varies with clam sizes.

Materials and Methods

The study was carried out at Ada and Aveglo, both located in the Volta estuary, Ghana, over an 18-month period, from March 2008 to August 2009. Ada (Latitude 05°49′ 18.6″ N and 000°38.46′ 1″ E) and Aveglo (05°53 28.2″ N and 000° 38′ 24.7″ E) represent the southern and northern limits of the most active clam fishing grounds at the Volta estuary (Fig. 1).

Clam samples were obtained from the two sampling locations on a monthly basis from fishermen's catch for 18 months and transported to the laboratory, submerged in river water, in insulated chests within 12 h for processing and storage for heavy metal analyses.

In the laboratory, clam samples were cleansed to remove the mud and any debris and washed with double distilled water. The clams were categorized into three groups each with 10 individuals for each sampling station based on shell length as follows: small (25–40 mm), medium (41–55 mm), and large (above 55 mm). The groupings were done based on the three dominant size groups in the natural populations to give a broad and fairly representative range of metal concentration in the clams and determine if there were significant differences. The various clam size classes were purged of ingested organic and inorganic particles before being analyzed for heavy metal accumulation by keeping each size class in distilled water for a 24 h depuration. After the depuration process, a sterile stainless steel knife was used to dislodge and remove the soft tissue of each clam from the shell (Chiu et al. 2000). The flesh of each subsample was weighed on a Sartorius BP 210 S micro balance to the nearest 0.0001. Individuals of each size class were homogenised thoroughly in a food blender with stainless steel cutters. Samples were then digested without delay for Mercury analysis.

About 0.5 g of the homogenized clam subsamples were weighed into a 50 mL digestion tube and 1 mL of distilled water, 2.0 mL perchloric acid (HNO_3–$HClO_4$) (1:1 vv) and 5.0 mL sulphuric acid (H_2SO_4) were added. Each mixture was refluxed at 200°C for 30 min in a clean fume chamber. The completely digested subsamples were allowed to cool at room temperature, and the undigested portions were filtered off through a Whatmann Glass Microfibre filter paper (GF/C) to obtain a clear solution and diluted to 50 mL in volumetric flasks with double distilled water (Jin et al. 1999; Otchere 2003).

The Atomic Mercury Analyzer (Model HG 5000) equipped with a mercury lamp at a wavelength 253.7 nm was used for the determination of total mercury in the clam soft tissue samples. Responses were recorded on strip chart

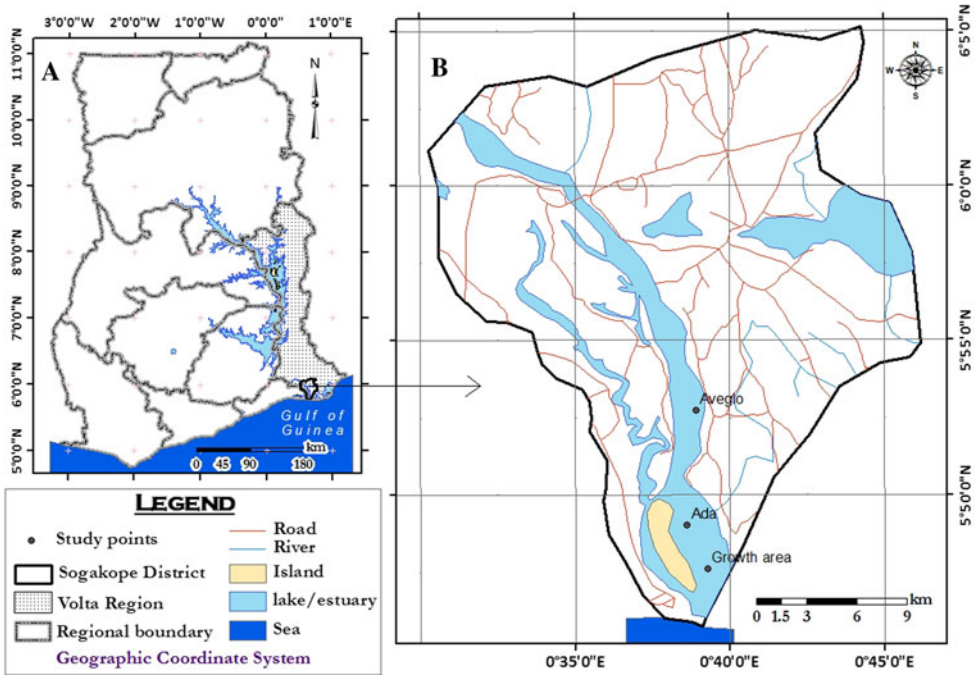

Fig. 1 Map showing the clam sampling locations at Ada and Aveglo in the Volta estuary, Ghana

recorders as sharp peaks. The peak heights were used for computation of the total mercury concentrations in the clam and expressed as microgram per gram wet weight (μg/g wet wt). Total mercury concentrations were validated according to standard procedures described for Mercury Analyzer Model HG 5000 to check for precision and accuracy.

Monthly measurement of temperature, salinity, pH, pressure, total dissolved solids (TDS), conductivity and dissolved oxygen (DO) of the Volta River were taken at both sites for the period using a Hanna (HI 9028) multi-parameter probe.

Results of the Mercury analyses were subjected to a one-way Analysis of variance (ANOVA) to test for significant differences ($p < 0.05$) in the concentrations of Mercury in the tissues of the different class sizes of the clams. The whole tissue Mercury concentrations were further subjected to a post-test; the Bonferroni's Multiple Comparison Test to compare all the possible pairs of columns; i.e. Small vs. Medium, Small vs. Large and Medium vs. Large for significant differences between the compared classes.

Results and Discussion

The physicochemical parameters of the estuary over the 18-month sampling period were fairly similar at the two sampling locations. The summary of the results are shown in Table 1.

The concentrations of mercury in the tissue of the clams from the Ada and Aveglo sampling stations over the 18-month sampling period were all well below the International Human Consumption Advisory Limit of THg (0.5 μg/g wet weight) set by WHO (2000). The recorded concentrations in the tissues of the different clam size classes from the two sampling stations were between 6 and 18 times lower than the WHO Safety Reference Standard.

Total Mercury (THg) concentrations for the small-sized clams ranged between 0.028 μg/g in April 2008 and 0.042 μg/g in August 2008. The medium-sized clams recorded a highest THg value of 0.049 μg/g in March and September 2008 and a low value of 0.035 μg/g in April 2008. THg concentrations ranged between a low of 0.044 μg/g and high of 0.059 μg/g in July 2008 and September 2008 in the large-sized clams.

Total mercury concentrations in the tissues of the small-sized clams at the Aveglo sampling station ranged between 0.037 μg/g and 0.055 μg/g in May and March 2008 respectively. Sampled medium-sized clams recorded values ranging from 0.042 in July 2008 to 0.056 μg/g in August 2008. The large-sized clams had a lowest THg concentration of 0.037 μg/g in March 2008 and a highest concentration of 0.074 μg/g in June 2008 Table 2.

One of the objectives of this work was to study the variations in mercury concentrations in the tissue of *G. paradoxa* in relation to body size and investigate

Table 1 Physicochemical parameters of the Volta Estuary at Ada and Aveglo

Sampling Station	Parameter	Range	Mean ± SD
Ada	pH	6.18–8.50	6.94 ± 0.52
	Temperature (°C)	27.28–29.59	28.60 ± 0.80
	Salinity	0.02–0.03	0.027 ± 0.005
	DO (mg/L)	1.52–8.76	4.19 ± 1.93
	TDS (mg/L)	27–35	30.06 ± 2.65
	Conductivity (μS/cm)	52–70	60 ± 5.16
Aveglo	pH	6.23–7.28	6.85 ± 0.27
	Temperature (°C)	27.19–29.62	28.68 ± 0.69
	Salinity	0.02–0.04	0.028 ± 0.005
	DO (mg/L)	1.58–6.79	3.89 ± 1.80
	TDS (mg/L)	27–42	31 ± 3.48
	Conductivity (μS/cm)	54–84	62.83 ± 7.62

Table 2 Mercury Concentration (μg/g wet wt) in the tissue of different size classes of *G. paradoxa*

Month	Hg (μg/g)					
	S	M	L	S	M	L
Ada				Aveglo		
Mar, 08	0.029	0.049	0.049	0.055	0.04	0.037
Apr, 08	0.028	0.035	0.051	0.042	0.045	0.047
May, 08	0.043	0.040	0.049	0.037	0.054	0.040
Jun, 08	0.049	0.045	0.048	0.046	0.047	0.074
Jul, 08	0.039	0.042	0.044	0.045	0.042	0.042
Aug, 08	0.042	0.041	0.049	0.053	0.056	0.064
Sept, 08	0.040	0.049	0.059	0.047	0.051	0.045
Oct, 08	0.044	0.044	0.055	0.049	0.045	0.040
Nov, 08	0.039	0.039	0.045	0.041	0.047	0.039
Dec, 08	0.033	0.037	0.055	0.038	0.055	0.043
Jan, 09	0.026	0.033	0.048	0.026	0.033	0.048
Feb, 09	0.038	0.037	0.039	0.039	0.049	0.039
Mar, 09	0.034	0.036	0.045	0.049	0.049	0.041
Apr, 09	0.041	0.044	0.043	0.044	0.047	0.040
May, 09	0.039	0.045	0.049	0.043	0.050	0.047
Jun, 09	0.049	0.041	0.051	0.041	0.048	0.049
Jul, 09	0.047	0.047	0.050	0.050	0.044	0.048
Aug, 09	0.044	0.050	0.048	0.048	0.048	0.045
WHO STANDARD (WHO 2000) 0.5						

S Small-sized clams (n = 10); *M* Medium-sized clams (n = 10) ; *L* Large-sized clams (n = 10)

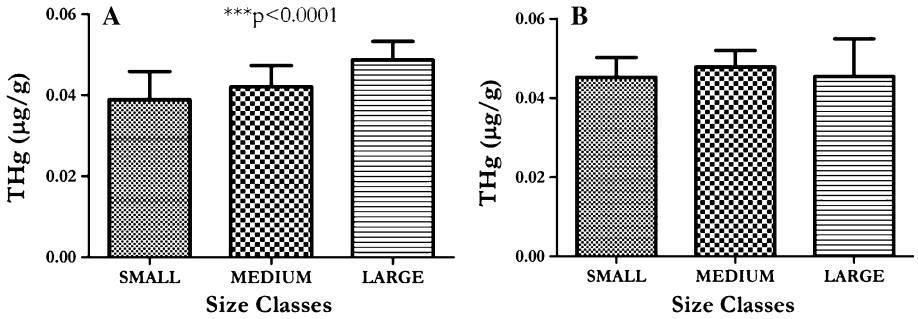

Fig. 2 Means ± SD of Mercury concentrations in the clam size classes from Ada (**a**) and Aveglo (**b**). Significant variations: *** $p < 0.0001$

whether mercury uptake, storage and sequestration varied with clam sizes.

Variations in the mean mercury concentrations in the different clam size classes were highly significant ($p < 0.0001$) for the clams from the Ada sampling station over the sampling period indicating a possible effect of size on accumulation. Mercury concentrations increased with increasing size for the clams from the Ada sampling station over the sampling period. The Bonferroni's Multiple Comparison Test revealed that the specific variations were found between the following classes; Small vs. Large ($p < 0.0001$) and Medium vs. Large ($p < 0.001$). Variations in mercury concentrations with respect to the different size classes were however not significant ($p > 0.05$) for the clams from the Aveglo sampling station (Fig. 2).

The study did not observe any known point source of pollution at the two sampling stations in the Volta estuary, similar to the phenomenon observed by Otchere (2003) in his study on heavy metal concentrations in the tissues of some bivalves from three lagoons in Ghana. This, in conformity to Otchere (2003), provide evidence that even clams from areas with no known point sources of contamination may have measurable body burdens of heavy metals. This may probably be due to natural processes rather than anthropogenic input.

The concentrations of mercury in the tissues of the clams were generally low. However, the incorporation into the clam tissues over a certain period even in very low concentrations, may also lead to biomagnification at higher trophic levels, especially in the human consumers. This can have serious detrimental effects on the health of the consumers over time even though the clams appear wholesome for consumption as far as the WHO International Human Consumption Advisory Limit for total Mercury (THg) is concerned.

Despite the very low mercury concentration, inorganic mercury, following its introduction into aquatic environments, is readily methylated by microorganisms to the more toxic form, Methyl-mercury (MeHg), which can bioaccumulate in the estuarine biota and consequently biomagnifies through food webs (Ikingura and Akagi 1999; Bustamante et al. 2006; Kinghorn et al. 2007; Yamaguchi et al. 2007). Mercury methylation generally increases its toxicity as a result of its enhanced penetration through the lipid membranes living organisms (Bustamante et al. 2006).

In organisms near the top of the food chain, like humans, almost all mercury accumulated is in the methylated form, primarily as a result of the consumption of food containing methyl-mercury (MeHg); methylation also occurs at the organism level by way of mucous, intestinal bacteria, and enzymatic processes, but these pathways are not as important as diet (Huckabee et al. 1979; Boudou and Ribeyre 1983). This implies that even the low mercury concentrations in the tissues of the clams can be lethal to heavy clam consumers.

Analysis of mercury risk levels associated with the consumption of clams by humans revealed that they were safe to eat as far as the International Human Consumption Advisory Limit of THg (0.5 µg/g wet weight) set by WHO (2000) was concerned. Low concentrations of mercury however have been reported to adversely affect the reproduction, growth, behaviour, metabolism, blood chemistry, osmoregulation, and oxygen exchange of marine and freshwater organisms. It is therefore imperative that frequent and wider scale mercury studies of the estuarine biota are undertaken to monitor mercury levels.

It is also important that allochthonous inputs from the catchment area are devoid of heavy metals especially mercury and regulatory mechanism being enforced to ensure that current trends are not exacerbated.

Acknowledgment The authors are grateful to the International Foundation for Science (IFS) for providing financial support (A/4421-1) to conduct this research work and the Department of Fisheries and Watershed Management of the Kwame Nkrumah University of Science and Technology, Kumasi for logistical support.

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