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Heavy Metals in Various Molluscs from the Mauritanian Coast

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Due to coastal upwelling, Mauritanian coastal waters are among some of the most productive in the world, supporting abundant invertebrate and fish populations, many of which are harvested as food for human consumption. In the future, this area will presumably be even further exploited as its potential productivity becomes apparent to this developing country. The chemical quality of the marine organisms, namely their contents in heavy metals, will become of major importance to resource managers and public health officials.

The purpose of the present study was to evaluate heavy metal concentrations in four species of bivalve molluscs; the oyster *Crassostrea gigas,* the African mussel *Perna perna*, the clam *Venus verrucosa* and the wedge shell *Donax rugosus*. These species are commonly found along the West African coast.

MATERIALS AND METHODS

Molluscs were collected at different periods and from various stations along the coast of Mauritania (Fig. 1). The species, sampling sites and sampling periods are shown in Table 1. Levrier Bay is a large bay which includes Cansado Cove in its western part (Fig. 2). In order to determine heavy metal concentrations, soft tissues (ca 0.5 g dry weight) of animals were digested with nitric acid 65% (Merck Suprapur) in a microwave oven. The digestion procedure (described in Sidoumou et al. 1997) followed four steps: microwaving at 240 w for 4 min; cooling for 10 mn; microwaving again at 180 W for 4 min; and finally at 220 W for 5 min. Analyses were carried out on the resulting solutions by means of flame (copper and zinc) and flameless (cadmium) atomic absorption spectrometry (GBC 904 AA equipped with GF 3000). Deuterium background correction was used. Mercury was determined using the cold-vapor technique according to Hatch and Ott (1968) using a Coleman Mercury Analyser MASB 50, Perkin Elmer; the detection limit was 0.02 μg Hg/g dry wt. Blanks were done in the same conditions as samples. The analytical procedure was calibrated against a standard reference material, namely lobster hepato-pancreas (TORT-2 provided by the National Research Council of Canada). Results of these analyses are given in Table 2. The results are in agreement with the certified values.

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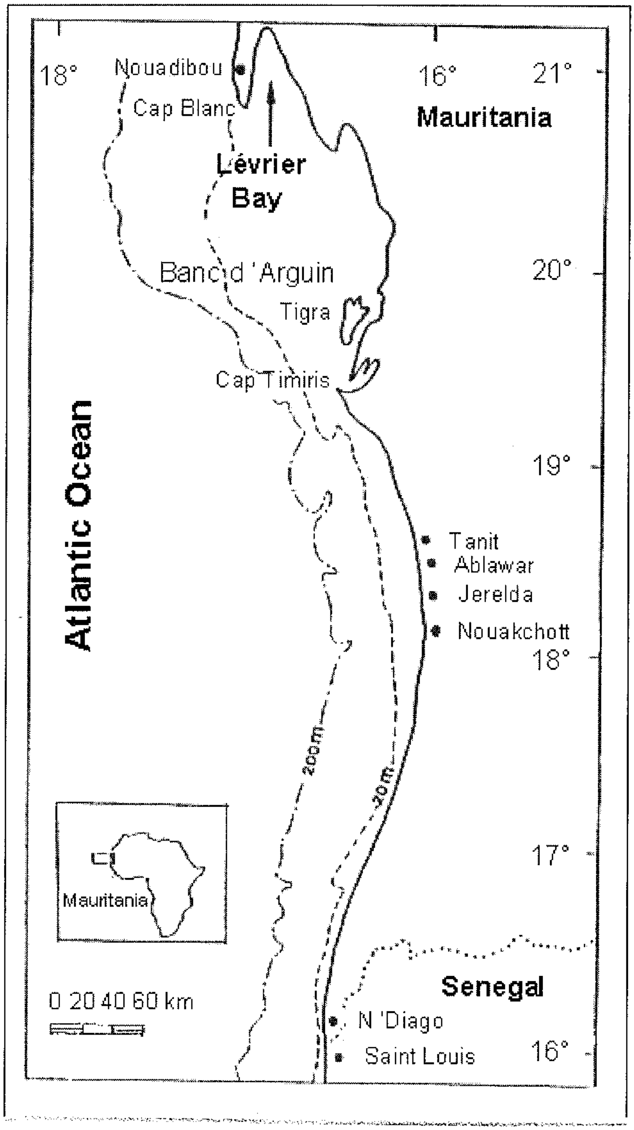

Figure 1. Sampling locations for mollusc collections along the Mauritanian Coast

Table 1. Mollusc species, sampling locations and sampling periods along the Mauritanian coast.

Species	Location	Sampling Date
Venus verrucosa	Cansado Bay ; n = 39	Feb. 1987 ; April 1988
		June 1988 ; Sept.1988
	Levrier Bay ; n = 20	Mars 1988 ; April 1988
Donax rugosus	From N'Diago to Tanit ; n 116	June 1989
Perna perna	Nouakchott ; n = 33	December 1994
	Nouakchott ; n = 3	July 1998
	Nouadhibou ; n = 20	July 1996
	Nouadhibou ; n = 3	July 1998
Crassostrea gigas	Nouadhibou ; n = 18	October 1996

Table 2. Analysis of the reference material Lobster Hepatopancreas *TORT-2.* (National Research Council Canada). Mean values ± 1 standard deviation.

Metal	Certified values (µg/g dry wt)	*N*	Recorded values
Cd	26.7 ± 0.6	5	27.0 ± 0.7
Cu	106 ± 10	5	101 ± 1
Zn	180 ± 6	5	177 ± 2
Hg	0.27 ± 0.06	5	0.24 ± 0.01

RESULTS AND DISCUSSION

The results of heavy metal concentrations in the clam *Venus verrucosa* and the wedge shell *Donax rugosus* are shown in Table 3. Metal concentrations in the clams from Levrier Bay (n = 20) are significantly higher (t-test significant at $p < 0.001$ for Cd and at $p < 0.05$ for Cu and Zn) than those from Cansado Bay (n = 39). Cansado Bay (Fig. 2) directly receives the wastes from two harbors (fishing and commercial harbors), fishing factories as well as from the town of Nouadhibou and the village of Cansado. Cansado is located near an oil refinery and an ore ship harbor. A strong current follows the shoreline closely and carries the waters into the Bay of Cansado, whereas in the Levrier Bay the waters are relatively calm. Hence, the renewal of waters in this last bay is slow. In addition, evaporation levels are very high (Reyssac and Roux 1975). This could explain the higher values found in the clams from Levrier Bay compared to those of Cansado Bay. *Donax rugosus* samples were collected from an area spanning from the Senegal river estuary to 100 kms North of Nouakchott. Comparison of heavy metal concentrations in the small *D. rugosus* (mean shell length 1.75 cm) and the large *V. verrucosa* (mean shell length 4.5 cm) revealed lower contents in *V. verrucosa* with the exception of cadmium levels. The two species were collected at different places and do not have the same life styles. The greater metabolic rate of small organisms (Blueweiss et al. 1978, Williamson 1980) may partially account for the higher concentrations of the essential elements Cu and Zn in *D. rugosus*. Contrary to copper and zinc, cadmium is non-essential to life. Some large molluscs may have high cadmium concentrations. Boyden (1977) reported for the scallop *Pecten maximus* that cadmium concentrations were constant up to 2 g of dry weight but larger, older individuals contained considerably more cadmium.

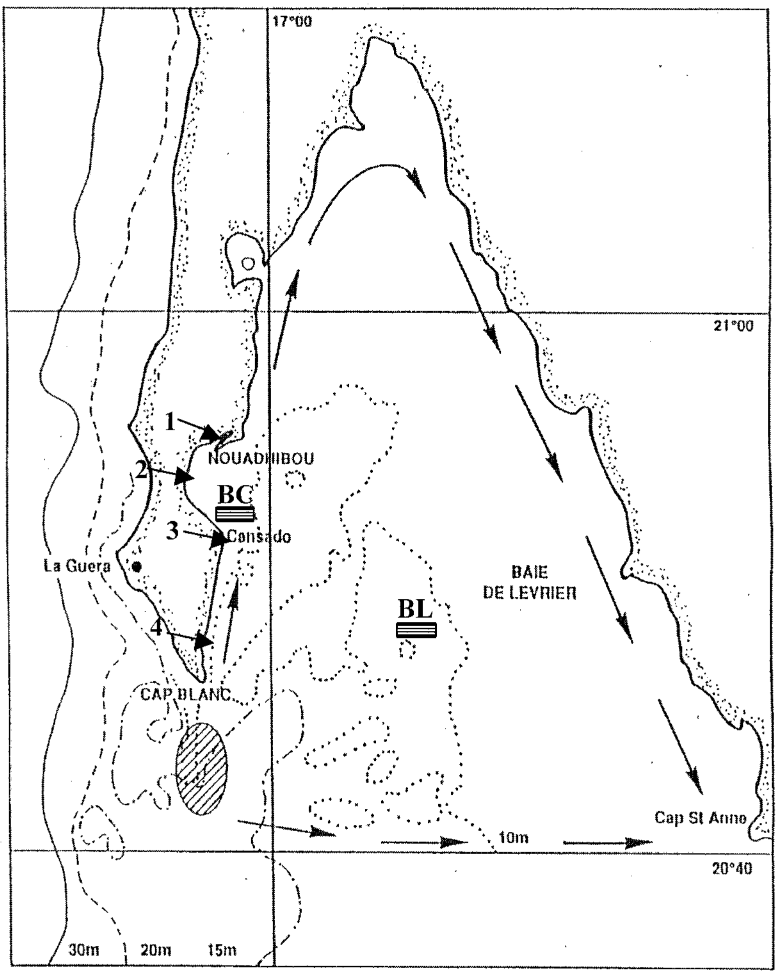

Figure 2. Levrier Bay and Cansado Bay. The collection sites of *Venus verrucosa* are shown ▤ BC (Bay of Cansado) and ▤ BL (Bay of Levrier). Arrows indicate the direction of currents and small arrows show 1: waste water from Nouadhibou, 2: harbor of Nouadhibou, 3: waste water from Cansado, 4: influence of ore ship harbor. Hachures show the permanent upwelling south of Cap Blanc.

Table 3. Heavy metal concentrations (µg/g d.w.) in the clam *Venus verrucosa* near Nouadhibou and in the wedge shell *Donax rugosus* along the Mauritanian coast (n.d.= not determined). Mean values ± 1 standard deviation.

Species	Cd	Cu	Hg	Zn
Venus verrucosa				
Cansado Bay (n = 39)	3.93 ± 2.84	5.5 ± 2.5	n.d.	48 ± 20
Levrier Bay (n = 20)	11.86 ± 4.82	7.1 ± 3.0	n.d.	64 ± 18
Donax rugosus (n = 116)	1.05 ± 0.63	20.6 ± 10.0	n.d.	120 ± 39

The results concerning the African mussel *Perna perna* are shown in Table 4.

Table 4. Heavy metal concentrations (µg/g d.w.) in the African mussel *Perna perna*, collected along the Mauritanian coast (n.d.= not determined). Mean values ± 1 standard deviation.

Perna perna	Cd	Cu	Hg	Zn
Nouakchott				
December 1994, n = 33	5.54 ± 2.12	6.2 ± 3.2	n.d.	34 ± 5
Females, n = 24	6.05 ± 2.15	6.8 ± 2.7	n.d.	36 ± 5
Males, n = 9	4.09 ± 1.25	5.1 ± 4.2	n.d.	29 ± 5
July 1998, n = 3	3.26 ± 0.71	4.2 ± 0.8	n.d.	64 ± 2
Nouadhibou				
July 1996, n = 20	0.33 ± 0.12	3.1 ± 0.9	0.05 ± 0.01	48 ± 10
July 1998, n = 3	0.67 ± 0.12	4.9 ± 0.1	n.d.	66 ± 10

Sex could be determined in the specimens of *Perna perna* collected at the Nouakchott sites in December 1994 (Table 4). Significantly lower cadmium and zinc concentrations were found in males (n=9) (t-test significant at $p < 0.01$ for Cd and $p < 0.001$ for Zn) as compared to females (n=24). Copper concentrations did not show any significant differences according to the sex. Metal concentrations in the three samples collected in July 1998 at Nouakchott were in the same range as the former samples. The specimens of *P. perna* collected at Nouadhibou (n=20) in July 1996 and July 1998 showed much lower cadmium contents and similar levels of copper and zinc than those from Nouakchott. Mercury levels were low in these samples (Table 4).

The results of metal concentrations in *Crassostrea gigas* collected from Nouadhibou in October 1996 are shown in Table 5. A significant relationship was found between copper and zinc concentrations in the whole soft body of *Crassostrea gigas* ($r = 0.832$; $n = 18$, $p < 0.001$). Comparison between the mussel and oyster species, collected at Nouadhibou demonstrates that *Crassostrea gigas* has higher cadmium, copper and zinc concentrations than *Perna perna*. The same phenomenon was found by Amiard-Triquet et al. (1998), comparing oysters *Crassostrea gigas* and mussels *Mytilus edulis* from the Bay of Bourgneuf (a clean coastal area of Atlantic Ocean, south of French Brittany). Mercury levels are low in both species.

Table 5. Concentrations (µg/g d.w.) in the oyster *Crassostrea gigas*, collected from Nouadhibou. Mean values ± 1 standard deviation.

Species	Cd	Cu	Hg	Zn
Crassostrea gigas ; n = 18	10.06 ± 4.61	68.0 ± 12.5	0.03 ± 0.01	300 ± 46

Metal storage may differ according to the species. In oysters, blood amoebocytes have been reported to present membrane-limited/membrane-bound vesicles which can trap copper and zinc (George et al. 1984, Thomson et al. 1985). For *C. gigas* from Mauritania, the correlation found between copper and zinc concentrations suggests a storage in the amoebocytes. Nevertheless, copper and zinc values are low compared with literature data concerning this species (Amiard and Berthet 1996) and may be due to low concentrations of these metals in the seawater. Cadmium concentrations in *C. gigas* and *V. verrucosa* are as high as those reported for oysters *C. gigas* from the moderately contaminated French Bay of Marennes Oléron (mean value of 9 µg Cd/g, Boutier et al. 1989). Cadmium could be trapped as metallothioneins in the digestive gland of these bivalves. Martoja and Martin (1985) demonstrated an experimental induction of MTs binding cadmium in various tissues of *C. gigas* (gills, labial palps, digestive tract). The form of cadmium storage has not been studied in *V. verrucosa* and induction of MTs has not been reported in this species. In another economically important Veneridae species *Ruditapes decussatus*, metallothionein induction has been detected in the whole soft tissues, gills and digestive gland as well as in the remaining tissues (Bebianno et al. 1993, Roméo and Gnassia-Barelli 1995).

The smallest species studied here, namely *Donax rugosus*, generally presents relatively low cadmium concentrations. Moreover, in a previous paper (Roméo et al. 1993), a decreasing gradient in cadmium concentrations in this species was demonstrated from N'Diago to Tanit. Cadmium concentrations in *Perna perna* from Nouakchott and in *Venus verrucosa* from Nouadhibou are in a relatively high range of the values reported in the literature for mussels and Veneridae whereas for *Crassostrea gigas* the values are in the mean range (Boutier et al. 1989). Differences in cadmium concentrations, found locally (between Cansado Bay and Lévrier Bay) in *V. verrucosa*, were attributable to the presence of currents. For *P. perna*, higher cadmium concentrations were found in samples from Nouakchott than in those from Nouadhibou, this differences may be explained by the concentrations of this heavy metal in the respective water masses. Mart and Nürnberg (1986) reported that cadmium concentrations in the Atlantic Ocean, measured in surface waters along a transect from Recife (Brazil) to Lisbon (Portugal), reach a mean value of 2 ng Cd/L, except in the upwelling along the Senegal coast where these concentrations reach 16 ng Cd/L. Waters from Mauritania may present the same characteristics. Nevertheless, biogeographic differences between upwelling areas have been observed by Margalef (1975) in Mauritanian waters. The Nouadhibou region is under the influence of Canarian waters with nearly constant upwellings, whereas southwards (and especially the area of Nouakchott) warm tropical waters but less saline Senegalese waters are present (Margalef, 1975). Another hypothesis could be that the high environmental phosphate concentrations facilitates the uptake of cadmium by organisms, and phosphate ores are present in the waters of both Senegal and southern Mauritania (Nouakchott). Martin et al. (1976) underlined that cadmium concentrations were correlated with those of phosphates in seawater. This last hypothesis could explain high cadmium concentrations in the mussels *P. perna* from Nouakchott. In a recent study Roméo et al. (1999) analyzed heavy metals in different species of fish collected off Nouakchott, concentrations in all the fishes analyzed (40 specimens) were low compared with data on the same species collected in the North Atlantic ocean, except concentrations found for cadmium in the livers of the benthic fishes. According to the authors, hepatic cadmium in these benthic fishes could originate from water, sediment and food.

Contrary to cadmium, zinc concentrations in the studied species are in the lower range of values reported in the literature. Zinc is an essential metal. Conversely, cadmium, which has chemical and physical properties similar to those of zinc, is known to have toxic effects. Antagonism between zinc and cadmium has been reported on many organisms. Bebianno and Langston (1991) observed a decrease in zinc in cadmium-exposed mussels and hypothesized a displacement of zinc from metallothionein by the influx of cadmium. Amiard and Berthet (1996) examined the effect of age on zinc concentrations in the oyster *Crassostrea gigas* (whole soft body). These authors reported that zinc concentrations initially decreased with increasing size followed by an increase as a function of age from 1171 µg Zn/g (dry weight) for 18 month old oysters to 2247 µg Zn/g for 42 month old oysters. These zinc values are much more elevated than those presented in the present study.

Among the four studied species, the African mussel *Perna perna* and the clam *Venus verrucosa* seem sensitive to cadmium since significant differences were found for cadmium concentrations as a function of sampling location. This study provides insight into the heavy metal concentrations of locally consumed and exported molluscs which are common along the West coast of Africa. Moreover, molluscs are important links in the food web. The metal body burden in molluscs may reflect the concentrations of metals in sea water and may thus be an indication of water quality along the Mauritanian coast. In this respect, relatively high cadmium concentrations were found in some of the species examined here.

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