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Heavy Metals in Clams from a Subtropical Coastal Lagoon Associated with an Agricultural Drainage Basin

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Bivalves molluscs have been used to assess the levels of contamination in coastal ecosystems, and certain genera and species, notably mussels and oysters, have been extensively studied in temperate waters (Goldberg et al. 1983; Gault et al. 1983; Olafsson 1986). In the particular case of the Altata-Ensenada del Pabellón lagoon system, an extensive (360 Km^2) coastal lagoon located in the northwest coast of Mexico, it is characterized by the presence of an important zone of intensive agriculture. Various bivalve species occur in this lagoon complex, principally the oysters Crassostrea corteziensis and Crassostrea palmula, the mussel Mytella strigata and the clams Chione subrugosa, Chione californiensis and Tellina sp. However, no single species is present throughout the lagoon in sufficient abundance to be used as a cosmopolitan bioindicator.

The present study was carried out to obtain data on the concentrations of Cd, Cr, Cu, Fe, Mn, Ni, and Zn in clams from a subtropical coastal lagoon associated with an agricultural drainage basin, at different times during the year.

MATERIALS AND METHODS

Five stations were sampled in the Altata-Ensenada del Pabellón lagoon system. Samples were collected during spring ("dry season"), summer ("rainy season") and late autumn prior to the sugar-making season. C. californiensis was collected at the Altata portion where marine conditions prevail (stations 1 and 2); C. subrugosa was sampled at station 5, which is subject to regular riverine influence, and station 9 which is affected by intermittent discharges of agricultural and sugar cane industry wastes; Tellina sp. was collected only at station 8, which is apparently less regularly influenced by river and agricultural discharges. Collection data for these samples are included in

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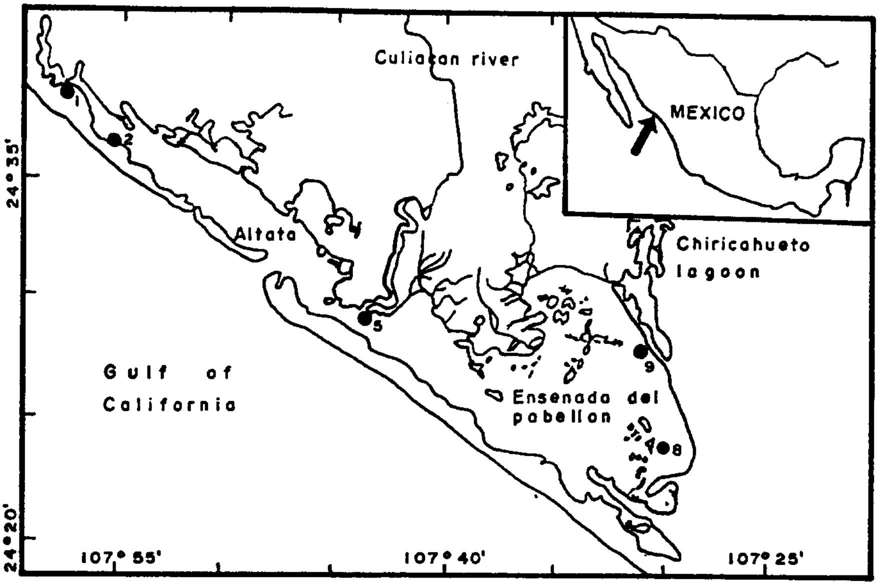

Figure 1. Sampling sites in the Altata-Ensenada del Pabellon lagoon system of Northwest Mexico (●).

Table 1. Most of the clams were sampled in the low intertidal zone; C. subrugosa (2.8-3.2 cm) and Tellina sp.(3.7-4.3 cm) were found associated with fine sediments and C. californiensis (3.8-4.8 cm) with mud-sand substrates. The samples were immediately rinsed with sea water and transported in pre-cleaned polyethylene containers (Moody and Lindstrom 1977) within 24 hr of collection. While choosing clams for the preparation of composite samples, emphasis was placed on organisms of nearly equal length, in this way we hoped to limit as far as possible differences attributable to size and age (NAS 1980). Twenty-five individuals of each species were removed from their shells. Each composite sample (25 individuals) of soft tissue was dried by heating (90-110^0 C) for 48 hr. Pulverization and homogenization were achieved by grinding in a teflon mortar. Samples and blanks for analysis were prepared by digesting triplicate samples of dry material with concentrated and distilled nitric acid using the multiple standard addition method. The metal concentrations were measured by flame atomic absorption spectrophotometry. A total of eighteen composite samples were analyzed, eight of C. californiensis, six of C. subrugosa and four of Tellina sp. The concentrations of the seven metals have been expressed in μg metal per gram dry weight. The accuracy and precision of the method employed was established by means of a reference material mussel homogenate MA-M-2/TM (IAEA 1985) as indicated previously in Paez-Osuna et al. (1991).

RESULTS AND DISCUSSION

The concentrations of the seven metals studied in the three species of clams from all stations are given in Table 1. To demonstrate any possible differences from one station to another, average values and the coefficients of variation (CV %) of each metal at each station for the sampling time were calculated. Factors, including the reproductive state, season of sampling, age, sex, and physical factors such as temperature, can affect metal concentrations in the bivalves (NAS 1980). It is as yet not exactly clear how these factors affect the metal accumulation in such organisms. However, their integral effect is evident from the large variations of metal concentrations. The quoted coefficients of variation are within the ranges of 6.3-176.6% for C. californiensis, 2.3-102.5% for C. subrugosa, and 48.3-132.5% for Tellina sp. (Table 1). The Tellina sp. (station 8) samples appeared to have higher values of copper, zinc, iron, chromium and cadmium than either from C. californiensis (stations 1 and 2) or C. subrugosa (station 5 and 9), but these averages are not significantly (Student's t-test adapted to pairs of variables) different. Comparisons of the average metal concentrations among the three species of clams revealed significant differences only for copper between C. californiensis (stations 1 and 2) and C. subrugosa (stations 5 and 9), and for nickel between C. subrugosa (stations 5 and 9) and Tellina sp. (station 8). Although, such differences among the concentrations of these elements in the soft tissue of clams can result from both species and geographic differences.

It was initially hoped that collecting samples from the mouth of the Culiacán River (station 5), suburban and agricultural areas would demonstrate differences in metal levels in bivalves and, thus, clams could be used for pollution monitoring. Specifically, it was thought that the various activities in the surrounding areas of the river would be reflected by metal levels in the clam samples. Data do not clearly demonstrate this. Nickel concentrations were slightly more elevated at station 5 (Fig. 2). The remaining metals were comparable to levels at the other stations. Although, the situation is complicated by the fact that (with exception of stations 1 and 2) the distinct samples and stations involve different species. The bioaccumulation of iron in Tellina sp. is apparently higher than in C. californiensis and C. subrugosa. Higher values in some lamellibranchs have been related to the presence of the iron-linked respiratory protein, hemoglobin, rather than the copper-containing hemocyanin present in other molluscs (Simkiss and Mason 1983).

The behavior of zinc is interesting. This element was extremely high in only four of five stations sampled in April 1990. Iron showed a similar tendency, but the maximum values sometimes corresponded to November 1989. The unusually high values of the two metals in April 1990 samples was similar to results obtained in oysters in the study area (Páez-Osuna et al. in press). These results were probably influenced by irregular rains prior to sampling time.

Table 1. Heavy metal concentration in clams from five stations in Altata-Ensenada del Pabellón lagoon. Concentrations are expressed in ($\mu g/g$) dry weight

Date	Cu	Cd	Cr	Mn	Fe	Ni	Zn
			<u>C. californiensis</u> (Station 1)				
April/89	11.1	2.7	0.4	32	108	8.7	55
July/89	11.3	2.7	1.5	46	229	13.0	28
Nov/89	11.8	2.2	0.4	69	497	8.1	37
April/90	8.4	3.6	1.1	54	573	5.6	1247
Mean	10.4	2.8	1.1	50	352	8.9	342
CV	12.5%	21.4%	25.6%	30.8%	62.4%	34.8%	176.6%
			<u>C. californiensis</u> (Station 2)				
July/89	8.3	3.0	1.0	22	298	9.1	25
Nov/89	9.9	0.7	0.9	31	468	9.9	46
April/90	10.4	3.8	1.0	53	395	7.2	1230
April/91	8.4	1.3	0.9	13	113	3.3	348
Mean	9.3	2.2	0.9	30	319	7.4	412
CV	11.8%	63.6%	6.3%	57.6%	48.3%	39.8%	137.0%
			<u>C. subrugosa</u> (Station 5)				
April/89	33.0	3.5	1.2	30	394	9.9	64
July/89	41.2	3.2	3.0	16	491	11.1	78
Nov/89	82.9	1.7	2.6	80	2231	10.7	1075
April/90	57.7	3.3	2.1	18	1129	9.2	1218
Mean	53.7	2.9	2.2	36	1061	10.2	609
CV	41.0%	27.6%	35.3%	83.3%	79.6%	8.3%	102.5%
			<u>C. subrugosa</u> (Station 9)				
April/89	35.1	3.2	1.0	66	350	8.9	71
April/90	51.8	2.4	2.9	26	686	9.2	99
Mean	43.4	2.8	1.9	46	518	9.0	85
CV	27.2%	23.6%	68.7%	60.9%	45.9%	2.3%	23.5%
			<u>Tellina</u> sp. (Station 8)				
April/89	29.4	8.4	1.2	22	895	2.1	66
July/89	37.0	2.9	1.5	35	1212	6.5	64
Nov/89	54.7	4.2	3.3	43	933	5.3	1151
Abril/89	355.1	8.7	5.0	10	2311	1.2	1944
Mean	119.0	6.0	2.7	27	1338	3.8	806
CV	132.5%	48.3%	64.0%	52.7%	49.6%	65.8%	113.5%

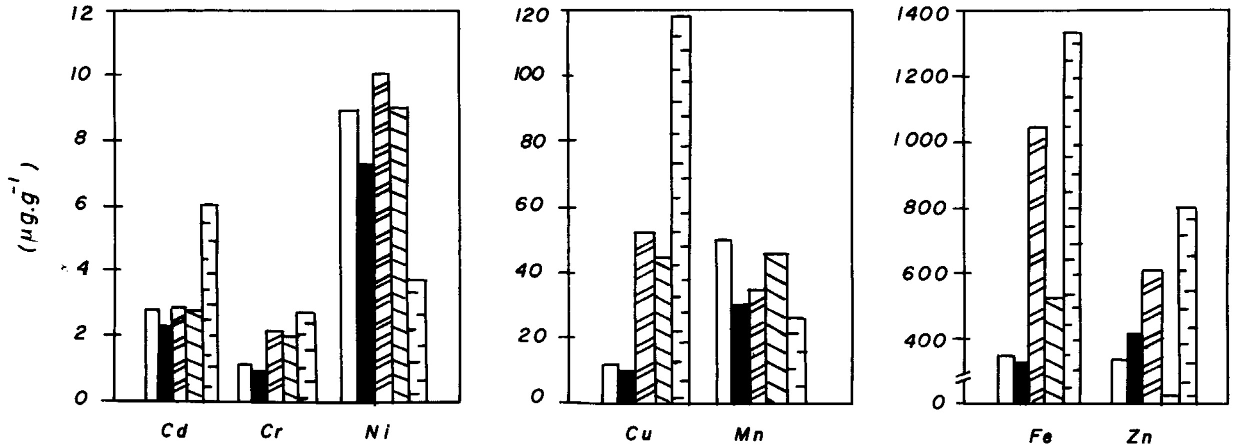

Figure 2. Average metal concentrations in clams from Altata-Ensenada del Pabellón lagoon complex. C. californiensis (station 1) ▭ , C. californiensis (station 2) ■ , C. subrugosa (station 5) ▨ , C. subrugosa (station 9) ▧ , Tellina sp. (station 8) ⊟ .

There is evidence of problems with the intercomparison of trace metal data, but the ranges of concentrations found in this study were comparable to the clam Macoma balthica from United Kingdom estuaries (Bryan et al. 1980; Langston 1986) some of which are moderately contaminated. The levels of copper, iron, manganese, nickel and probably zinc in C. subrugosa from Altata-Ensenada del Pabellón lagoon were higher than in the clam Anadara antiquata from the Fiji Islands (Dougherty 1988) or Chione sp. from Navachiste (México) (Páez-Osuna et al. 1991). Zinc is notorious, due that is various times more elevated with respect to Macoma balthica, Macoma nasuta and Tapes japonica from San Francisco Bay (Bradford and Luoma 1980; Luoma et al. 1985). These comparisons suggest that the clams from Altata-Ensenada del Pabellón lagoon are moderately contaminated with the majority of metals analyzed, as might be expected in a coastal lagoon draining a region inhabited by some 1.3 million people and supporting a vast and intensive agriculture area. It is well known (UNPH 1988) that very large quantities of pesticides and fertilizers are often used in the region. A recent compilation of data (IAEA 1990) in the zone showed that the major agrochemicals used during the agricultural year 1987-1988 were organophosphorous pesticides, carbamates and some metallic fungicides (Maneb, Zineb, Cupravit, copper sulphate, etc). These fungicides are enriched in heavy metals; Maneb (C_4 H_6 Mn N_2 S_4)n, Zineb (C_4 H_6 Zn N_2 S_4)n, Cupravit (Cl Cu_2 H_3 O_3) (RSC 1987) which explain partially the results.

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