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Heavy Metals in Shrimp Culture Areas from the Gulf of Fonseca, Central America. II. Cultured Shrimps

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Concerns on the exposure of reared aquatic organisms to metals derive both from toxicity, i.e., the potential of deleterious effects on the reared population (Carbonell and Tarazona 1993), and from bioaccumulation, with possible health hazards for the human consumer (Vos and Hovens 1986). Crustaceans have a high sensitivity to metals, demonstrated for several taxonomic groups including those with a high commercial value such as shrimps, prawns, lobster, or crabs (Barnbang et al. 1995). Toxicity is related to the concentration of the bioavailable form of the metal in the surrounding environment. For decapod crustaceans the free (hydrated) metal ion is commonly considered the available (toxic) form for uptake from solution (Rainbow 1995). The available form is in equilibrium with the non-available form bound to complexing ligands. Bioavailability can result for the bioaccumulation of the metal. Any increase in total dissolved metal concentration would correspondingly increase the free metal ion concentration, and thereby lead to an increase in metal uptake rate (Rainbow 1995). If the rate of excretion does not follow a parallel increase, a net accumulation of metal occurs within the body. The accumulation of metals in aquatic invertebrates is generally greater than in fish as result of the differences in the evolutionary strategies adopted by the various phyla (Phillips and Rainbow 1993).

Crustaceans are used as bioindicators of marine metal contamination, and are potentially toxic when used as food. Concentration of metal within crustacean body will depend on (a) the level of contamination, (b) speciation of metal in sea water, and (c) the capacity of the organism to keep body concentration constant (Rainbow 1995). Crustaceans, under some circumstances, are a potential source of toxic metals and several countries have developed maximum acceptable concentrations for commercialization and consumption of these organisms. Present study concerns metal concentrations in shrimps collected from the Gulf of Fonseca.

MATERIAL AND METHODS

Seven intensive culture areas in the Gulf of Fonseca, four in Nicaragua and three in Honduras, were selected. Carbonell et al. in this issue details the location of

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sampling sites. Up to twenty individuals of commercial size were collected in each sampled pond.
Shrimps were frozen at -20°C and sent to the laboratory. Each animal was washed with water and peeled. The edible portion, soft tissue, was digested with HNO_3, diluted up to 25 ml with milli-Q water and analyzed by atomic absorption spectrophotometry. Accuracy of analysis was checked using certified tuna fish homogenate (IAEA - 350, nl 377) provided by the International Atomic Energy Agency (Monaco). The recovery was 90-100% for most of the analyzed metals, 85% 105% for Zn and Cd respectively.

Student "t" test was employed to check differences between sampling sites. Pearson correlation coefficients were used to determine significant metal interrelationships. Scattered plots, linear and nonlinear regression analyses were used to look for relationships between concentration of each metal in shrimps and in sediments collected in the same pond, using aid of the sediment data presented in the previous paper. Statistical analyses were performed with Statgraphics and SPSS softwares. Statistically significant differences were expresed as $p < 0.05$.

RESULTS AND DISCUSSION

Mean metal concentrations in shrimps (Nicaragua and Honduras) samples are presented in Table 1. Individual concentrations (µg/g wet wt), ranged between <0.001 and 0.095 for Cd, 2 and 15 for Cu, 2 and 99 for Fe, 18 and 33 for Zn, 0.01 and 0.08 for Cr, 0.04 and 1 for Pb, and 0.5 and 35 for Mn. Li was always below the detection level. The most abundant elements were Fe and Zn, followed by Cu.

Table 1. Metal concentrations (expresed as µg/g wet-weight) in shrimps from the Gulf of Fonseca .

Nicaragua

Metal (µg/g)	Sampling 2	Sampling 3	Sampling 4	Sampling 5
Cd	0.02 ± 0.015	0.002 ± 0.003	0.011 ± 0.003	0.030 ± 0.009
Cu	6.6 ± 4.6	3.3 ± 0.68	2.1 ± 0.39	4.4 ± 1.4
Fe	64.1 ± 30.8	17.7 ± 8.5	35.3 ± 33.5	45.1 ± 19
Zn	25.6 ± 5.5	19.1 ± 1.5	19 ± 1.2	20.9 ± 1.6
Cr	0.04 ± 0.03	0.009 ± 0.005	0.011 ± 0.010	0.03 ± 0.005
Pb	0.5 ± 0.4	0.035 ± 0.033	0.071 ± 0.021	0.055 ± 0.038
Mn	19.3 ± 10.6	1.5 ± 0.43	6.4 ± 6.2	8.8 ± 2.1

Table 1 (cont.) Metal concentrations (expresed as µg/g wet-weight) in shrimps from the Gulf of Fonseca .

Honduras

Metal (µg/g)	Sampling 7	Sampling 9	Sampling 11
Cd	0.013 ± 0.008	0.003 ± 0.002	0.007 ± 0.008
Cu	6.9 ± 2.9	6.5 ± 3.4	4.3 ± 1.8
Fe	34.5 ± 30.7	23.3 ± 18.9	29.6 ± 29.8
Zn	25.4 ± 4.8	30 ± 1.6	21.4 ± 3.1
Cr	0.033 ± 0.019	0.015 ± 0.022	0.026 ± 0.016
Pb	0.4 ± 0.3	0.041 ± 0.022	0.23 ± 0.35
Mn	2.4 ± 1.3	4.6 ± 3.1	5.3 ± 5.5

Concentration of metals detected in shrimps from the Gulf of Fonseca are presented in Table 2, and compared to those reported for different shellfish species of commercial value. The distribution of metals in the tissues (including muscle and exoskeleton) of *Penaeus californiensis* given by Paez-Osuna and Tron-Mayen (1995) has been used for comparison of data with those for muscle or non-peeled animals. In general, concentrations of metals in the study area were lower than those reported for natural or reared populations of marine crustaceans and molluscs collected in other areas of the world. As observed in other studies (Pastor et al. 1994), the concentrations of Cd and Pb in shrimps were lower than those reported for molluscs. For the essential metals Cu, Fe, Zn the concentrations detected in shrimps from the Gulf of Fonseca were similar to those detected for shrimps and other crustaceans in other areas, while the levels of Mn were relatively high as sampling site 2, but with large individual variations. Average concentrations in shellfish were within the metal levels considered safe for daily intake of fishery products (Vos and Hovens 1986). As such, no problem is likely to occur with the consumption of shrimps reared in the Gulf of Fonseca.

A good correlation between a group of metals has been suggested as indicative of particular biochemical pathways (Mason and Simkiss 1983). In Table 3, positive correlations were observed for: Cu:Cr, Fe:Cr, Fe:Cu, Cu:Mn, Fe:Mn, Cr:Mn, Zn:Pb and Cd:Mn. Correlation coefficients between metal pairs in decapod crustaceans show species and location dependent differences. The only interspecific consistency was a significant positive correlation between Fe and Cu in the muscle tissue (Darmono and Denton 1990). Muscle contains the highest load of both metals (Páez-Osuna and Tron-Mayer 1995); thus, the correlation in muscle should also be observed in peeled shrimps. Fe: Cu Pearson correlation coefficient observed in our study, $r=0.89$ ($p < 0.001$) is in perfect agreement with this suggestion.

Table 2. Ranges of metals detected in the edible portion shellfish reported for shellfish in other areas of the world (expressed as $\mu g/g$ wet-weight).

Shellfish	Cd	Cu	Fe	Zn	Cr	Pb	Mn	Reference
Shrimps Gulf of Fonseca	0.002-0.03	2.1-6.9	17-64.1	19-30	0.009-0.04	0.035-0.5	1.5-19.3	Present study
Shrimps Mexico	0.01-0,3*	3.7-8.8*	7.5-94*	2-17*	<0.05-1.4*		0.4-3.1*	Paez-Osuna and Ruiz-Fernandez 1995
Shrimps Spain	0.03-0.05					0.05-0.79		Pastor et al. 1994
Prawns(muscle) Australia	<0.05	7.2-9.1	0.61-2.1	12.2-16.1			0.49-1.1	Darmono and Denton 1990.
Prawns India		5-10.2*		5-15*			3-5*	Zingde et al. 1976
Shrimps (non-peeled) Holland	0.003-0.12	7.2-23		19-48	0.1-0.71	0.05-0.34		Vos and Hovens 1986
Shrimps (mean value) Belgium	0.024	10.5		19-48		0.07		De Clerck et al. 1984
Crab(muscle) USA	0.007-0.06	6.8-15.9	1.8-11.8	30.7-50.6			0.53-2.85	Caldwell and Buhler 1983
Crustaceans Spain	0.02-0.18					0.05-0.79		Pastor et al. 1994
Mussels Spain	<0.05-0.29	2.14-3.59	5.7-39	6.7-25.6		<0.5-2.39		Tarazona et al. 1991
Mussels Spain	0.01-1.0					0.05-2.8		Pastor et al .1994
Sea scallop USA	0.75-8.9	0.3-3		9.3-109	0.2-2.4	0.4-2.2		Palmer and Rand 1977
Clams USA	0.001-0.07	1.6-4.2	241-1835	6.4-20.9			5.2-34.7	Caldwell and Buhler 1983

*Transformed to wet from the original publication assuming a wet:dry weight ratio of 4.5 (Damono and Denton 1990)

All comparisons, linear and nonlinear correlations including graphic representations, between the concentration of metals in the shrimps and the level of the same metal in the sediments in the rearing pond showed the absence of correlations. Thus, for all studied metals, levels in the shrimps must be considered independent of the metal level in the sediments.

The low metal levels and the absence of significant correlations between sediment and shrimp metal concentration suggest that the degree of contamination by heavy metals in the shrimp culture area of the Gulf of Fonseca is very low, representing normal background for metal concentrations, and in no case exceed the recommended limits for human consumption. These results agree with those presented for sediments in the previous paper, which demonstrated that heavy metals do not represent, nowadays, a contamination problem in this area.

Table 3. Pearson correlation coefficient for metal interrelationships in shrimps from Nicaragua and Honduras.

Metal	Cd	Cu	Fe	Zn	Cr	Pb
Cu	-.0585 p=.671					
Fe	.1071 p=.437	**.888** **p=.000**				
Zn	.1384 p=.314	-.3988 p=.003	-.7119 p=.000			
Cr	.1962 p=.151	**.9267** **p=.000**	**.9135** **p=.000**	.3971 p=.003		
Pb	-.1365 p=.320	-.3841 p=.004	-.5448 p=.000	**.3815** **p=.004**	-.6401 p=.000	
Mn	**.2811** **p=.038**	**.6744** **p=.000**	**.6638** **p=.000**	-.3343 p=.013	**.5542** **p=.000**	.2099 p=.12

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REFERENCES

Bambang Y, Thuet P, Charmantier-Daures M, Trilles JP, Charmantier G (1995) Effect of copper on survival and osmoregulation of various developmental stages of the shrimp *Penaeus japonicus* Bate (Crustaea, Decapoda). Aquatic Toxicol 33 125-139

Caldwell RS, Buhler DR (1983) Heavy metals in estuarine shellfish from Oregon. Arch Environ Contam Toxicol 12: 15-23

Carbonell G, Tarazona JV (1993) A proposed method to diagnose acute copper poisoning in cultured rainbow trout, (Oncorhynchus mykiss). Sci. Total Environ. Sup. 1993: 1329-1334

Darmono D, Denton GRW (1990) Heavy metal concentration in banana prawn, *Penaeus merguiensis,* and leader prawn, *P. monodon*, in the Townsville region of Australia. Bull Environ Contam Toxicol 44:479-486.

De Clerk R, Guns M, Vynckee W , Hoeyweghem V (1984) Content of heavy metal in cod, flounder and shrimp from Belgiam costal waters. Landwbouwtijchrift 37: 1065

Mason AZ, Simkis K (1983) Interaction between metals and their distribution in tissues of *Littorina littoria* (L) collected from clean and polluted sites. J Mar Biol Ass UK 63:661-672

Paez-Osuna F, Ruiz-Fernandez C (1995) Trace metals in the Mexican shrimp Penaeus vannamei from estuarine and marine environments. Environ Poll 86:83-88

Paez-Osuna F, Tron-Mayen (1995) Distribution of heavy metals in tissues of the shrimp Penaeus californiensis from the Northwest coast of Mexico. Bull Environ Contam Toxicol 55:209-215

Palmer JB, Rand GM (1977) Trace metal concentrations in two shellfish species of commercial importance. Bull Environ Contam Toxicol 18:512-520

Pastor A, Hemandez F, Peris MA, Beltrán, J, Sancho JV, Castillo MT (1994) Levels of heavy metals in some marine organisms from the Western Mediterranea Area (Spain) Mar Pollut Bull 28:50-53

Phillips DJH, Rainbow PS (1993) Biomonitoring of trace aquatic contaminants. Elsevier Science Publications, Barking UK

Rainbow PS (1995) Physiology, physicochemistry and metal uptake- A crustacean perspective. Mar Pollut Bull 31:55-59

Tarazona JV, Muñoz MJ, Carbonell G, Carballo M, Ortiz JA, Castaño A (1991) A toxicological assessment of water pollution and its relationship to aquaculture development in Algeciras Bay, Cadiz, Spain. Arch Environ Contam Toxicol 20:480-487

Vos G, Hovens JPC (1986) Chromium, nickel, copper, zinc, arsenic, selenium, cadmium, mercury and lead in Dutch fishery products 1977-1984. Sci Total Environ 52:25-40

Zingde MD,Singbol SYS, Moraes CF, Reddy CVG (1976) Arsenic copper zinc and mangenese in the marine flora and faune of coastal