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Arsenic Levels in Chilean Marine Species

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Arsenic is toxic, and also a known carcinogen (IARC 1979) listed by the U.S. E.P.A. as a priority pollutant. Its toxicity to marine organisms is well documented and results in reduced growth or increased mortality of the species (PASSINO & NOVAK 1984; OLADIMEJI et al. 1984b; WEIR & HINE, 1970).

Arsenic in the environment has both natural and anthropogenic origin. In nature (LA TOUCHE & MIX, 1982), it occurs in minerals and ores from which it may be released to the aquatic environment by dissolution and erosion. In turn, anthropogenic sources of arsenic include industrial and agricultural activities, from where it finds its way to the marine ecosystem.

Although many data have been reported on the distribution and heavy metal uptake by marine organisms, arsenic is rarely included in those studies, probably because the methods for its determination require more complex procedures than the ones used in direct atomic absorption spectrophotometry.

The purpose of this investigation was to provide information about the arsenic levels in marine species of wide consumption by the Chilean population. These data represent the first so far reported about the arsenic contents in marine species from the South Eastern Pacific coastal waters.

MATERIALS AND METHODS

All glassware utilized here was soaked in detergent, rinsed with water, soaked in 10% nitric acid, rinsed with distilled water, and kept in the oven at 110 C until needed.

The reagents used were analytical grade or equivalent, and pretested for possible contamination by heavy metals.

The marine species investigated here were randomly collected by professional local fishermen along the Chilean coast in the period April 1985 to November 1985. Only species of commercial interest

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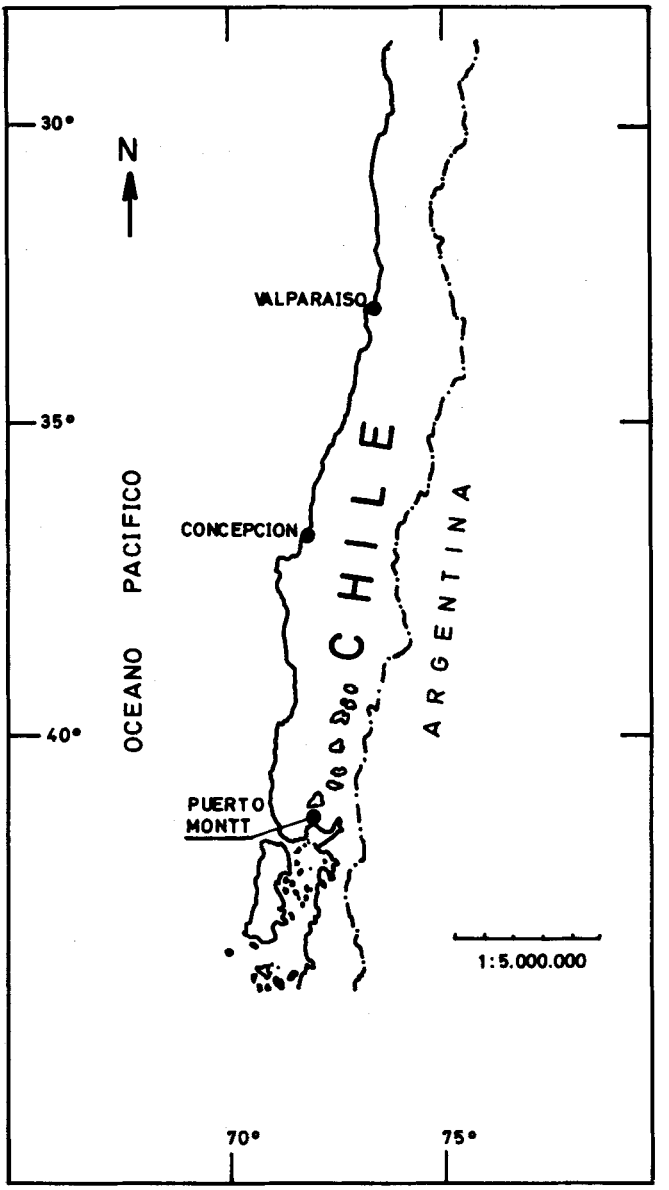

Figure 1. Location of the sampling areas along the Chilean coast.

were analyzed. All the fish species were captured in the bay of Valparaíso, while the shellfish species were collected in the bays of Valparaíso, Concepción and Puerto Montt. The sampling sites are shown in Figure 1.

Twenty-four different marine species, including 12 fish species and 12 shellfish species, were chemically analyzed for their arsenic contents.In order to get representative samples, 4 to 6

specimens of the bigger fish species, 12 to 20 of the smaller ones, and 18 to 30 molluscs, crustacean and shellfish specimens were taken for analysis. The specimens were brought fresh to the laboratory and analyzed almost upon arrival.

Table 1. Arsenic levels in the edible parts of Chilean marine fishes (ppm in dry weight).

	% Water	As	s.d.
Trachurus murphyi	76	1.90	0.27
Merluccius gayi	79	1.50	0.36
Ophictus pacifici	63	1.00	0.20
Paralabrax humeralis	75	2.00	0.02
Prolatilus jugularis	78	5.95	0.90
Cilus montii	77	0.60	0.12
Genypterus chilensis	82	1.00	0.19
Paralichtys microps	81	1.18	0.18
Engraulis rigens	81	1.19	0.22
Clupea betinchi	80	0.56	0.04
Sycyaces sanguineus	78	0.72	0.19
Odonthestes regia	80	1.24	0.33

s.d.: standard deviation

The fish species investigated included: **Trachurus murphyi** (horse mackerel), **Merluccius gayi** (hake), **Ophictus pacifici** (snake eel), **Protolatilus jugularis** (tilefish), **Genypterus chilensis** (crusk eel), **Paralichtys microps** (plaice), **Engraulis rigens** (silverside), **Clupea bentichi** (silverside), **Odonthestes regia** (silverside), **Paralabrax humeralis** (no simil in the U.S.), **Cilus montii** (no simil), and **Syaciases sanguineus** (no simil). In return,the molluscs, crustacean and shellfish species included: **Concholepas concholepas** (abalone), **Thais chocolata** (sea snail), **Chlamys purpuratus** (scallops), **Mytilus chilensis** (blue mussel), **Aulacomya ater** (ribbed mussel), **Armaghinomya antiqua** (clam), **Mesodesma donacium** (no simil), **Cancer edwardsii** (common crab), **Heterocarpus reedi** (baby rock lobster), **Pleuroncodes monodon** (pink shrimp), **Pyura chilensis** (edible sea squirt) and **Loxechinus albus** (sea urchin).

The wet samples were homogenized and dried at 135 C for 2 hours or until constant weight was attained.Tissue moisture was determined from here.For digestion, 35 g of the dried tissue were treated with conc. nitric acid (10 ml) and conc. sulfuric acid (15 ml) at 150 C. After cooling down to room temperature, 3% hydrogen peroxide (3 ml) was added and the process repeated until a colorless solution was obtained. Finally, the digest volume was made up to 100 ml with deionized water.

Arsenic was determined by hydride generatiom using a Perkin-Elmer MHS-10 hydride system interfaced to a Perkin-Elmer Model 5000 atomic absorption spectrophotometer. Instrumental conditions were as follows: wavelength, 193.7 nm; range, UV; EDL lamp, 8 watts; air flow, 17.5 l/min; acetylene flow, 3.0 l/min.For arsenic

determination, 0.5 ml of the digest solution or an appropiate dilution was placed in a polypropylene flask and reduced for 10 min with 1M KI in 10% sodium ascorbate (0.1 ml) . Then, the sample was reacted with a 3% sodium borohydride-1% sodium hydroxide solution for 5 sec. Hydrogen arsenide generated was flushed with nitrogen (1.0 l/min) into a quartz cell heated with an air-acetylene flame. The method of additions was used to correct for matrix interferences.

Table 2. Arsenic levels in the edible parts of Chilean marine molluscs, crustacea and other shellfish species (ppm in dry weight).

	% Water	As	s.d.
Mytilus chilensis	85	7.8	0.64
Aulacomya ater	82	7.0	0.92
Chlamys purpuratus	81	8.2	0.72
Concholepas concholepas	82	10.2	0.85
Armaghinomya antiqua	76	12.6	0.42
Thais chocolata	62	16.9	0.72
Loxechinus albus	73	1.3	0.14
Cancer edwardsii	69	11.7	1.77
Heterocarpus reedi	84	10.8	1.06
Mesodesma donacium	75	12.3	0.42
Pyura chilensis	79	1.7	0.07
Pleuroncodes monodon	70	21.9	0.99

s.d.: standard deviation

RESULTS AND DISCUSSION

All the 24 marine species included in this study are of commercial significance and widely consumed by the Chilean population. The 12 fish species and most of the shellfish species were caught in the bay of Valparaíso (Figure 1). **M. chilensis** and **A. ater** were from the bay of Concepción located more towards the South, while **P. chilensis** and **L. albus** were from Puerto Montt.

Table 1 summarizes the arsenic contents of the fishes, and Table 2 the arsenic levels of the molluscan, crustacean and other marine species. Samples were analyzed in triplicate and the results are expressed as mean values on the basis of dry weight. Water percentages are included to enable the results to be compared with published results that might be expressed on a wet basis.

As shown in Tables 1 and 2, the arsenic contents in the fishes are lower than the ones in the other marine species. In the bay of Valparaíso, the arsenic concentration in the fishes ranged from 0.56 to 5.95 ppm, while the arsenic content in the molluscan and crustacean species ranged from 8.2 to 21.9 ppm. Arsenic concentrations for the species from Concepción were lower, ranging from 7.0 to 7.8 ppm , while those from Puerto Montt were even smaller and ranged from 1.3 to 1.7 ppm.

The above results show a higher arsenic content for the species from Valparaíso as compared to those from Concepción and Puerto Montt, most probably due to the copper refinery operating on the coast of Valparaíso. Huge piles of coarse to finely ground residues from this industry may well be the cause of the Valparaíso coastal water contamination.

As there is a lack of comparative data for the arsenic levels in Chilean marine species, it is possible to suggest that the arsenic concentrations quoted in Tables 1 and 2 are high, only by refering to results obtained by other authors (LA TOUCHE 1982a; LYTLE & LYTLE 1982; CARDEILHAC et al. 1981). The current State Food Regulations in Chile (MINISTERIO DE SALUD, 1982) do not specify allowable maxima for the quantities of arsenic which marine products may contain.

On the basis of the results presented here, Chilean fishes and other marine species are rich in arsenic, and although the Chilean population ingest large amounts of these products, there has been no report of any impairment of health with the arsenic contents of these foods. Probably, the rapid excretion of arsenic compounds and its low retentions in the humans obviates health concerns (TAM et al. 1982; YAMAUCHI & YAMAMURA 1984).

Arsenic was not detected by direct analysis of the sea water from the areas from where the fishes were caught. However, because it has been shown that the levels of arsenic accumulation in marine tissues is directly related to the levels of arsenic to which the species have been exposed (OLADIMEJI et al. 1984a), our results support the deduction that the marine organisms in the Valparaíso area are contaminated. This is specially true when comparing the arsenic levels in the species from Valparaíso with the ones from a non-industrialized region like Puerto Montt.

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REFERENCES

Cardeilhac PT, Simpson CF, White FH, Thompson NP, Carr WE (1981) Evidence for metal poisoning in acute deaths of large red drum (Sciaenops ocellata). Bull Environ Contam Toxicol 27: 639-644

International Agency for Research on Cancer (1979) Chemicals and industrial processes associated with cancer in humans. IARC Monogr Suppl 1.Lyon.

La Touche YD, Mix MC (1982) Seasonal variation of arsenic in bay mussels (Mytilus edulis). Bull Environ Contam Toxicol 29: 665-670

Lytle TF, Lytle JS (1982) Heavy metals in oysters and clams of St. Louis Bay, Mississippi. Bull Environ Contam Toxicol 29: 50-57

Passino DM, Novak AJ (1984) Toxicity of arsenate and DDT to the cladoceran Basmina longirostris. Bull Environ Contam Toxicol 33: 325-329

Ministerio de Salud (1982) Proyecto de Reglamento Sanitario.Ministerio de Salud, Santiago de Chile.
Oladimeji AA, Qadri SU, De Freitas ASW (1984a) Measuring the elimination of arsenic by the gills of rainbow trout (Salmo gairdneri) by using a two compartment respirometer. Bull Environ Contam Toxicol 32: 661-668
Oladimeji AA, Qadri SU, De Freitas ASW (1984b) Long term effects of arsenic accumulation in rainbow trout, Salmo gairdneri. Bull Environ Contam Toxicol 32: 732-741
Tam GKH, Charbonneau BM, Bryce F, Sandi E (1982) Excretion of a single oral dose of fish-arsenic in man. Bull Environ Contam Toxicol 28:669-673
Weir PA, Hine CH (1970) Effects of various metals on the behaviour of conditioned goldfish. Arch Environ Health 20: 45-51
Yamauchi H, Yamamura Y (1984) Metabolism and excretion of orally ingested trimethylarsenic in man. Bull Environ Contam Toxicol 32: 682-687
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