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Environmental Contamination and Toxicology

High Cadmium Residues Observed during a Pilot Study in Shorebirds and Their Prey Downstream from the El Salvador Copper Mine, Chile

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Untreated mining wastes, at the rate of 39,000 tons per day, are discharged through a semi-artificial canal directly to the marine shore from the El Salvador copper mine in northern Chile (Castilla and Nealler 1978). The tailings were deposited on a sandy beach near Chanaral between 1938 and 1974 and since 1975 at Caleta Palito, 8 km north of Chanaral (Fig. 1). Total biological loss of the sandy beach macrofauna occurred at the latter site as a result of smothering by tailing sediments (Castilla 1983). Massive fish and mollusc mortality was observed by local inhabitants at the new discharge site a few days after its establishment in 1975 (Castilla and Nealler 1978).

Since no chemical analyses of marine organisms have been conducted along the 20 km beach area contaminated with tailings, a pilot study was initiated in the last weeks of November 1981 and March 1982 to determine cadmium and copper residues in discharged mine tailings on the beach deposits, algae, marine invertebrates, shorebirds and prey from their stomachs. The results of the analyses are presented here.

MATERIALS AND METHODS

Beach deposit samples were collected at beach sites north of Chanaral, and were located at 1) the tailings discharge site, 2) the northern edge of the visible contaminated area, 3) a bay, 4 km north of station 2, 4) Puerto Pan de Azucar, another bay 8 km north of station 2, and 5) an accessible beach locality about 60 km south of Chanaral (Fig. 1). Algae (Enteromorpha sp.) were sampled at stations 1, 2, and 4. Limpets (Collisella spp.) grazing on Enteromorpha and snails (Littorina peruviana), sand crabs (Emerita analoga) and locos (Concholepas concholepas) were also sampled. Enteromorpha and L. peruviana are upper and mid rocky intertidal organisms, C. concholepas is found in the lower rocky intertidal and adjacent subtidal zone, and the sand crab (E. analoga) is mainly a lower intertidal sandy beach organism.

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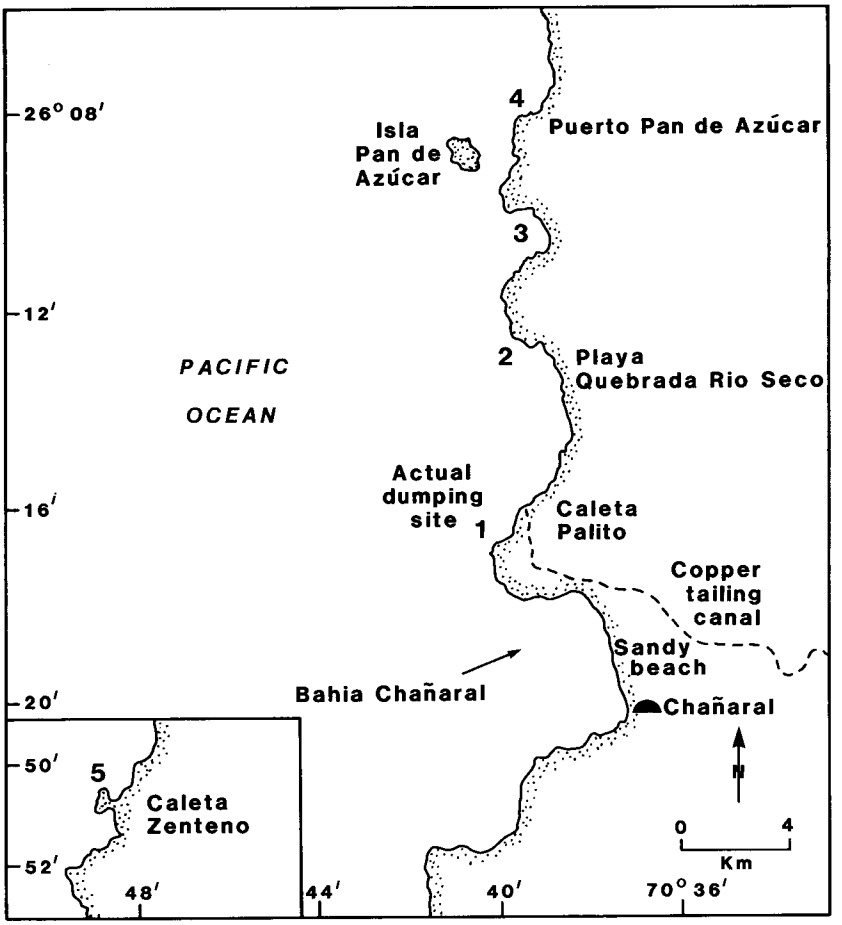

Figure 1. Shoreline between Puerto Pan de Azucar and Caleta Zenteno showing the sampling stations (numbers 1 to 5 and sandy beach near Chanaral).

Shorebirds were collected with a shotgun (under permit) at the above mentioned stations, as well as at Chanaral beach. Birds collected for analysis were the Dominion or Kelp Gull (Larus dominicanus), the most abundant resident gull in the area, the Grey Gull (Larus modestus), which nests in the Chilean desert but feeds on the coast, the Franklin's Gull (Larus pipixcan), a migrant from the North American prairies, the Whimbrel (Numenius hudsonicus) and the Sanderling (Calidris alba), two shorebird species from arctic North America, and a resident oystercatcher (Haematopus ostralegus). All birds were collected in November except Whimbrels and Sanderlings which were sampled both in November and March for comparative purposes.

Bird livers and stomachs were removed immediately after collection, and these tissues were examined to ensure that no shot fragments remained in the samples for analyses. Bird livers and stomachs, invertebrates and fishes were frozen within two hours after collection. In the laboratory, bird livers, beach deposit, Enteromorpha, whole marine invertebrates, and

identifiable food items of the birds were analyzed for cadmium and copper by Barringer Magenta Ltd. of Rexdale, Ontario. These metals were determined by flameless atomic absorption and are shown in parts per million (mg kg^{-1}) wet weight. The accuracy of the analytical procedures was checked against the following National Bureau of Standard (NBS) samples: bovine livers (2 replicates), oysters (5 replicates), tuna, spinach leaves, and syenite rock standard SY-2. All values were within the certified limits. Coefficients of variation for cadmium and copper in bovine livers was 0% and 5%, and in oysters 3% and 1%, respectively. The precision of the analytical procedures was also checked using 4 blind replicate fish samples, which showed coefficients of variation of 21% for cadmium and 5% for copper.

RESULTS AND DISCUSSION

Copper shows a decreasing residue gradient in beach deposit from the discharge site (1) to sampling station 3, but that metal became somewhat elevated again at Puerto Pan de Azucar (4) (Fig. 2). Cadmium residues decreased from the tailings discharge site to sampling station 2, but they became elevated again at stations 3 and 4, and even more so at station 5, 60 km south of Chanaral. The elevated copper and cadmium concentrations at Puerto Pan de Azucar can perhaps be attributed to an ore processing plant which ceased operation about 50 years ago. Elevated cadmium residues in beach deposits at site 5 are not understood, unless cadmium residues were naturally high or currents concentrated them at that beach.

Enteromorpha, shows a decrease in copper residues, from the discharge to the reference sites (Fig 2). Enteromorpha was the only visible aquatic organism inhabiting the discharge site suggesting tolerance to high copper concentrations and smothering. High cadmium residues in Collisella and Littorina peruviana at site 5 are in agreement with elevated residues of that element in beach deposits at that location.

Fish obtained from the stomachs of Larus dominicanus indicated relatively low cadmium, and copper residues compared to those in crabs and snails obtained from Larus modestus, Haematopus ostralegus and Numenius hudsonicus (Table 1). Emerita analoga from birds at Puerto Pan de Azucar had the highest cadmium residues which are in agreement with those observed in crabs collected directly from the beach (Fig. 2).

The most outstanding residue differences in bird livers concern cadmium (Table 2). Cadmium residues were particularly elevated in Larus modestus (22.8 mg/kg^{-1}), Numenius hudsonicus from Puerto Pan de Azucar (49.3 mg/kg^{-1} in November, 89.7 mg/kg^{-1}in March) and Whimbrels collected between the discharge site and Puerto Pan de Azucar (32.2 mg kg^{-1}) and reference site 5 (38 mg kg^{-1}). The high cadmium residues encountered in livers of those birds may relate to their diet consisting of Emerita analoga which in turn had elevated cadmium residues compared to

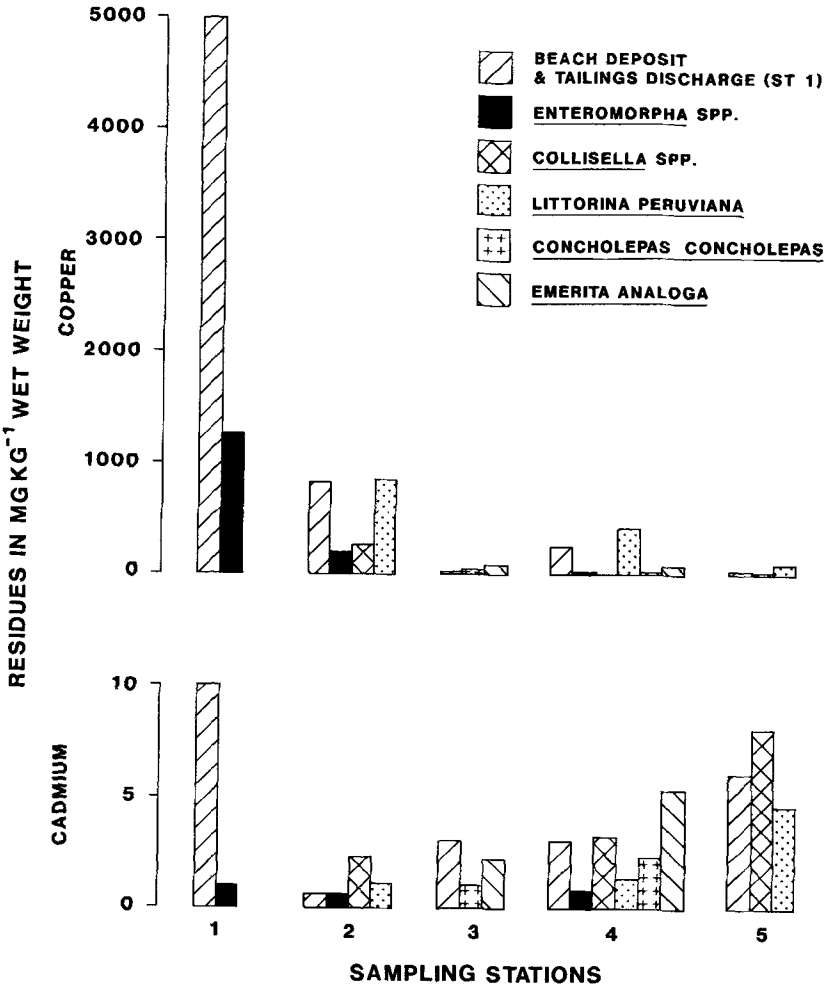

Figure 2. Comparison of cadmium and copper residues in beach deposit, Enteromorpha, limpets, snails, crabs and "locos" along the coastline downstream of El Salvador copper mine, Chile.

other marine organisms (Table 1). Since the highest cadmium residues in birds and marine organisms occurred at Puerto Pan de Azucar and reference site 5, most cadmium contamination does not appear to be related to the present tailings discharge from the El Salvador copper mine, but may relate to former handling of ore at those locations or to naturally occurring high background levels of cadmium. High cadmium residues mostly occur in birds feeding on intertidal marine organisms, rather than in fish.

Table 1. Comparison of cadmium and copper residues in fish, crabs, and snails from stomachs of shorebirds collected downstream from the El Salvador copper mine, Chile. Samples are from November 1981 except where indicated from March 1982.

Food and sampling stations		Bird species	Metal residues in mg/kg^{-1} wet weight Cd	Cu
FISH				
Clupea benticki	4	Larus dominicanus	0.9	2.1
Scombersox saurus stolatus	4	"	1.3	3.4
"	4	"	1.3	3.4
"	5	"	1.2	1.8
Isacia conceptionensis	4	"	0.8	0.8
SAND CRABS				
Emerita analoga	4	Larus modestus	5.3	46.7
"	4	"	5.7	30.0
"	4	Haematopus ostralegus	5.7	24.4
"	4	"	4.8	27.2
SNAILS				
Littorina peruviana (March)	3	Numenius hudsonicus	2.6	86.4
Eatonina atacamae (March)	3	"	4.8	6.1

No gross ill effects were observed in birds during our investigation in the Chanaral region, except for the Whimbrel with the highest observed cadmium residues in its liver ($89.7\ mg/kg^{-1}$), which was much emaciated and showed necrosis of the liver. Whether the necrosis resulted from the high cadmium residues and/or the poor condition of the bird is unknown. The relatively low copper residues in birds in or near the tailing area, compared to high copper residues in beach deposit and Enteromorpha, suggest low dietary uptake of this metal. Low copper residues in birds from the Chanaral area may be explained by the observation that most of the intertidal macrofauna died off during the establishment of the new discharge site in 1975 (Castilla and Nealler 1979), and left therefore little contaminated prey for the birds to feed upon.

It is well known that bird livers and kidneys retain the highest residue levels of cadmium in tissues (e.g. White and Finley 1978, and Jacobs et al. 1978). Cadmium residues in other tissues are relatively low compared to those in kidneys and livers (White and Finley 1978). Cadmium residues in kidneys of

Table 2. Comparison of cadmium and copper residues in livers of shorebirds feeding along the coastline downstream of the El Salvador copper mine, Chile. Residue range in parentheses. Samples are from November 1981 except where indicated from March 1982. Livers are analyzed individually, except where indicated that they were pooled.

Bird species	Sampling locations	No. birds sampled	Average metal residues in mg/kg^{-1} wet weight			
			Cd		Cu	
Larus dominicanus	2	2	2.8	(2.8-2.9)	4.1	(3.8-4.3)
"	4	5	4.8	(2.6-7.9)	5.4	(3.8-6.3)
"	5	5	9.1	(5.4-13.7)	5.1	(4.2-5.9)
Larus modestus	4	4	22.8	(12-41)	6.2	(4-7.4)
Larus pipixcan	Chanaral beach	2	1.5	(1-2)	4.8	(4.7-4.8)
"	5	1	3.6		5.5	
Numenius hudsonicus	2	1	1.0		7.8	
"	4	3	49.3	(24.6-65.7)	5.0	(3.9-5.7)
" (March)	1	1	7.9		7.5	
" (March)	3	2	32.2	(7.3-57.1)	10.3	(7.1-13.5)
" (March)	4	1	89.7		9.4	
" (March)	5	2	38.0	(20.7-55.3)	13.2	(8.7-17.8)
Calidris alba	2	2	4.2	(1-7.4)	10.0	(7.8-12.2)
"	5	1	0.8		9.2	
" (March)	3	4(pooled)	7.9		11.1	
" (March)	3	4(pooled)	7.6		11.5	
" (March)	3	4(pooled)	6.5		9.2	
Haematopus ostralegus	Chanaral beach	3	13.7	(8.4-19.9)	8.0	(6.8-8.6)

shorebirds appear to be about 3 times that found in their livers (Blomqvist et al. 1987). Blomqvist et al. (1987) found that cadmium concentrations in the kidney versus the liver tissues of Dunlins (Calidris alpina) and Curlew Sandpipers (C. ferruginea) were strongly linearly related. Applying the 1:3 ratio for cadmium residue levels in livers and kidneys of shorebirds observed by Blomqvist et al. (1987), the highest observed cadmium residue of 89.7 mg/kg^{-1} in the liver of a Whimbrel in our study might relate to a 270 mg/kg^{-1} level in the kidney of that bird. The accumulation of cadmium in the shorebird food chain in northern Chile needs investigation. It also should be determined if the birds acquired cadmium from background levels from beach deposits, mining ore, phosphate deposits or from particles deposited by upwelling, a well known phenomenon occurring along the coasts of northern Chile and Peru. Cadmium concentrations in marine sediments from the Atlantic and Pacific Oceans range from 0.1 to 1.0 mg/kg^{-1} with some marine phosphate deposits having cadmium levels ranging from 50 to 170 ppm (Caro 1964). The Chanaral coastal region may be ideal

for investigation of the cadmium pathway in the shorebird food chain, since shore feeding birds with high cadmium levels are accessible for observation. From other studies it appears that mostly pelagic seabirds, which are generally less accessible than shoreline foragers, accumulate high cadmium residues (Ottaway and Campbell 1976; Bull et al. 1977). Emerita analoga, a common food item of avian intertidal foragers, is widely distributed along the Pacific coast of North and South America and could be used as an indicator of dietary cadmium utilized by birds.

A study of cadmium in Whimbrels may have some urgency from the public health point as these birds are used for human consumption. Whimbrels are commonly hunted in northern Chile and extensive consumption could lead to nephrotoxicity in humans. When cadmium reaches a critical value of 100-200 μg cadmium per gram of wet tissue in humans, necrosis of the kidneys will occur (Goyer et al. 1984).

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