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Comparative Study of Cadmium and Lead Accumulations in *Cambarus bartoni* (Fab.) (Decapoda, Crustacea) from an Acidic and a Neutral Lake

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Cadmium and lead are important environmental contaminants of current interest, primarily because of their high toxicity, common occurrence in industrial discharges, and presence as pollutants in freshwater reservoirs. According to Freedman and Hutchinson (1980), the long - established Inco (International Nickel Company of Canada) Copper - Nickel smelters at Copper Cliff, Ontario, and Falconbridge Nickel Smelting Works at Garson, Ontario, are two of the major emission sources of class B and borderline elements, including cadmium and nickel, in Northeastern Ontario. As a consequence, the superficial sediments (upper 5 to 10 cm) and water of most of the freshwater reservoirs in this region are contaminated with these two toxicants. The toxic potential of cadmium to both aquatic organisms and man is well documented, as is its ability to accumulate in various body tissues (Friberg *et al.* 1971; Bagatto and Alikhan 1987a). Lead is a cumulative toxicant and there is no evidence that it is essential or beneficial to living organisms (Holcombe *et al.* 1976). Nevertheless, this metal is accumulated in the tissues of a wide variety of freshwater organisms (Simkiss and Mason 1983).

In earlier studies, Bagatto and Alikhan (1987a, 1987b) and Alikhan *et al.* (1990) showed that *Orconectes virilis* trapped from Ramsey (46°28'N 80°57'E) Lake in Sudbury, Ontario, and *Cambarus bartoni* (Astacidae, Decapoda) caught from Nepahwin (46°28'N 80°57'E) Lake in Sudbury, Ontario, and Joe (46°44'N 81°01'E) and Nelson (46°44'N 81°05'E) Lakes in Chelmsford, Ontario, were tolerant to copper, cadmium, iron, magnesium, manganese, nickel and zinc, and that concentrations of these metals in the crayfish hepatopancreas and exoskeleton were related to their levels in the lake sediments, as well as to the distance of the habitat from the emission site.

The purpose of the study reported in this paper was to compare concentrations of lead and cadmium in the sediment and water, as well as in the crayfish, *Cambarus bartoni* (Fab.) (Decapoda - Crustacea) trapped from an acidic and a neutral lake in the Sudbury district of Northeastern Ontario. Hepatopancreatic, alimentary canal, tail muscles and exoskeletal concentrations in the crayfish are also examined to determine specific tissue sites for these accumulations.

MATERIALS AND METHODS

During October 1989, intermoult adult *Cambarus bartoni* were trapped, with the aid of modified minnow traps, from the rocky areas in Nepahwin Lake (46°28'N

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80°57'E) in Sudbury, Ontario, and Wavy Lake (46°18'S 81°06'W) in Eden, Ontario, situated approximately 22 km south-southwest of Inco (International Nickel Company of Canada Ltd.) smelters at Copper Cliff, Ontario, is an acidic lake (mean pH = 4.6 ± 03, Table 1), while Nepahwin Lake, a neutral freshwater reservoir (mean pH = 6.5 ± 0.4, Table 1), borders the southwest corner of the Laurentian University campus, and is approximately 12 km downwind from the emission source.

The hepatopancreas, alimentary canal, tail muscles and exoskeleton from forty crayfish (twenty males and twenty females, average wet weight = 5.4 g, average carapace length = 45 mm), collected from each site, were digested in 5 mL of boiling concentrated nitric acid to dryness. The resulting pastes were dissolved in 20 mL of 10% hydrochloric acid and were analysed in a Perkin - Elmer atomic absorption spectrophotometer for cadmium and lead by the flame method. Lake sediment samples (top 5 to 15 cm), obtained with the aid of a gravity corer and 4.7 cm i.d. polycarbonate plastic tubes (for details, see Alikhan *et al.* 1990) from the two sites, were dried in an oven for three days at 70°C, cooled in a desiccator to room temperature, and were analysed for lead by the x-ray photometer and for cadmium, after necessary extraction in a 1:1 boiling mixture of analytical grade (British Drug House standards) HNO_3 and $HClO_4$, by the flame method. Data on the water pH, conductivity (µmho cm^{-1}), alkalinity (as $CaCo_3$), dissolved oxygen (mg L^{-1}) and lead and cadmium concentrations in both water and sediments from the two sites were also collected.

Table 1. Water quality and cadmium and lead concentrations in sediments of Lake Nepahwin in Sudbury, Ontario, and Wavy Lake in Eden, Ontario, during October 1989.

	Water		Sediment	
	Nepahwin Lake	Wavy Lake	Nepahwin Lake	Wavy Lake
pH	6.5 ± 0.4	4.6 ± 0.3		
Conductivity	38.0 ± 1.46	42.2 ± 2.7		
Alkalinity	9.93± 0.38	1.08± 0.05		
Dissolved Oxygen	8.55± 0.43	9.52± 0.44		
Cd (ppb)	tracestraces	4.78± 0.33	21.53± 6.24	
Pb (ppb)	0.24± 0.04	0.32± 0.04	196.11 ± 1.88	110.11 ± 1.04

Average of six samples in each case.

Statistical analysis of the data was computed with the help of a DEC-VAX/VAM mainframe computer, using SPSS^x software (SPSS, Chicago, Ill., U.S.A.). The data were checked for both normality (Kolgomorov-Smirnoff test) and homogeneity of variances (Bartlett-Box F test). As the data lacked homogeneity, non-parametric Krustil-Walis one-way analysis of variances were performed to determine significance of differences in metal concentrations between males and females, crayfish tissue and the sampling sites.

RESULTS AND DISCUSSION

There were significant differences ($P < 0.05$) in cadmium and lead concentration between the superficial sediments (upper 5-15 cm) collected from the two sites (Table 1). Cadmium levels were approximately 4 times higher in sediments procured from wavy lake than in those collected from Nepahwin Lake. Lead levels in the sediments from Nepahwin Lake, on the other hand, were approximately twice the amount found in samples from Wavy Lake (Table 1). In spite of these significant differences in the cadmium and lead concentrations in the sediments from these two sampling sites, the crayfish trapped from these two lakes did not show any significant difference ($P > 0.05$) between their cadmium concentrations (Table 2, Figs. 1 and 2). Lead concentrations, on the other hand, ranged from 72.5 to 74.9 $\mu g\ g^{-1}$ wet weight in the decapods trapped from Nepahwin Lake and 94.8 to 106.6 $\mu g\ g^{-1}$ wet weight in those obtained from Wavy Lake (Table 2, Figs. 1 and 2). The general relationship in cadmium and lead concentrations between the four tissues of the crayfish from the two sites is hepatopancreas < alimentary canal > exoskeleton > tail muscles (Figs. 1 and 2). However, differences in metal concentrations between males and females at each site are not significant at the 5% level (Table 2).

According to Wright (1977), cadmium in crustacean species is absorbed through gills, and is accumulated in highest concentrations in the gills, hepatopancreas, exoskeleton and particularly the green glands of *Uca pugilator*. In the euphasiid *Megaanyctiphanes norvegica* (Sars) food has been found to be an important source of cadmium with metal retention heavily dependent upon dietary dosage and faecal pellets accounting for 84% total cadmium flux (Benayoun *et al.* 1974). In both cases, cadmium uptake is considerably enhanced at lower salinities (Wright 1977). Lead adsorbed to the plasma membrane, according to Roldan and Shivers (1987), is endocytosed at the basal and lateral plasmalemmas (surface) of R - cells (and possibly F-cells) of the hepatopancreas and then transported towards the apical region of the cell where it ultimately coalesces with larger electron-dense vacoules. Lewis and McIntosh (1986) have shown that lead uptake by *Asellus communis* is greater at the lower pH than at higher salinities. Similar pH differences, in the present studies, may have attributed to the relatively higher uptake and accumulation of lead in the tissues of the crayfish trapped from Wavy Lake.

Cadmium and lead concentrations detected in the alimentary canal, according to Alikhan and Storch (1990), should be regarded as a part of the ambient environment, as they have not been absorbed by the tissue, while those detected in the tail muscles may be the function of the haemolymph.

Cadmium and lead are biologically non-essential, but toxic elements. According to Hopkin and Martin (1985), non - essential metals enter the animal by following the same biochemical pathways as essential elements with which they are chemically similar. Cadmium has been shown to be assimilated by the same route as copper, and it has been found to be stored in the protein metallothionein (Reichert et al. 1974; Simkiss 1983). Lead in copper tolerant isopods competes with copper for sites in the hepatopanceas and both of these metals are stored in the "cuprosomes" (Brown 1978). However, "lead is more readily bound than copper, which is released into the lumen of the hepatopancreas, probably as a result of apocrine secretion in which the apical end of the cell is lost togather with the granules, in response to an incoming dose of lead" (Brown 1978). Similar preferential bindingof lead over copper has also been observed

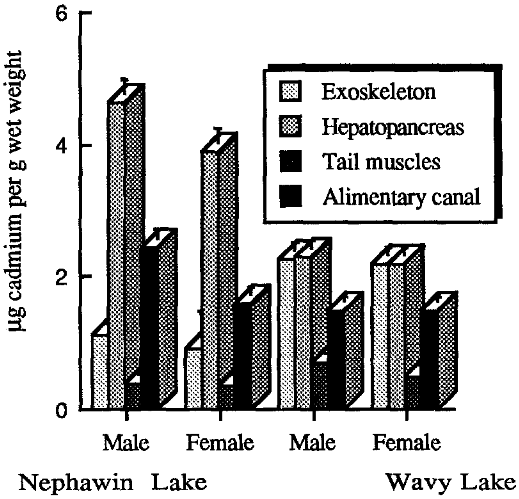

Figure 1. Cadmium concentrations (µg g^{-1} wet weight) in the various tissues of *Cambarus bartoni* from Nepahwin and Wavy lakes. Each column represents the mean of 40 animals. Vertical bars represent the standard error of the mean.

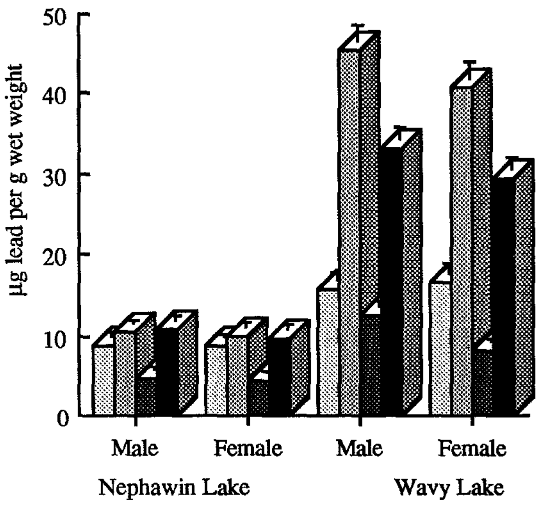

Figure 2. Lead concentrations (µg g^{-1} wet weight) in various tissues of *Cambarus bartoni* from Nepahwin and Wavy lakes. Each column represents the mean of 40 animals. Vertical bars represent the standard error of the mean.

Table 2. Mean cadmium and lead concentrations (µg g^{-1} wet weight ± S.E. of the mean) in whole *Cambarus bartoni* trapped from Nepahwin lake in Sudbury, Ontario and Wavy Lake in Eden, Ontario.

Lake	Cadmium	Lead
Nepahwin	(1) 8.6 ± 1.9^a	74.9 ± 5.6^b
	(2) 6.7 ± 0.8^a	72.5 ± 6.2^b
Wavy	(1) 6.6 ± 0.6^a	106.6 ± 12.4^c
	(2) 6.3 ± 0.7^a	94.8 ± 13.2^c

Average of 20 samples in each case.
(1) males; (2) females.
Means within each column followed by the same letter are not significantly different at the 5% level.

in earthworm chloragosomes (Brown 1978). In isopods from uncontaminated areas, according to Brown (1978), uptake of both copper and lead into the hepatopancreas is actively resisted.

In lead - exposed crayfish, lead accumulating vesicles appear to originate at the basal plasmalemma and many are transported to and stored in homogeneous cytoplasmic bodies called ordense bodies (Roldan and Shivers 1987). As these organelles are normally expelled from the cell as cytoplasmic extrusions into the lumen of the antennal gland tubules (Peterson and Loizzi 1974), this may serve as a device for the clearance of ingested lead. Both fish and mammalian systems are known to possess no specific low molecular weight protein like metallothionein in the cytosolic fraction of kidneys, liver, and gills involved with lead detoxification (Reichert *et al.* 1979).

The presence of substantial concentrations of both cadmium and lead in the exoskeleton of *Cambarus bartoni*, detected in the present studies, may indicate, as shown by Alikhan (1989) for magnesium and manganese accumulations in *Porcellio spinicornis*, that this tissue is involved in the excretion of these metals.

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