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Metals in Crayfish from Neutralized Acidic and Non-Acidic Lakes

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Large amounts of acid forming SO_2, as well as Cu, Ni and other metals are being continuously released into the environment by mining and smelting activities at Sudbury, Ontario, Canada (Gorham and Gordon 1960; Niebor et al. 1972; Hutchinson and Whitby 1977; Semkin and Kramer 1976; Conroy et al. 1978). Consequently, a number of lakes in this region has become both acid and metal stressed.

The addition of basic calcium compounds to acidic ponds and lakes has long been recognized as beneficial, as it contributes to increased fish production and water quality (Neess 1948; Yan and Dillon 1982). In addition to increases in pH and alkalinity, such additions may reduce water-dissolved metal concentrations, change water transparency and bring about alterations in species diversity. Neutralization experiments performed in 1975 on a number of acidic lakes in the Sudbury area (Yan and Dillon 1982) have known to increase water pH and reduce metal concentrations. Zitco et al. (1973), Andrew (1976), Spear and Pierce (1979), and Miller and Mackay (1980) have shown that an increase in water alkalinity and DOC may reduce the acute toxicity of Cu to fish. However, the influence of water quality on metal availability and accumulation has received scant attention (Bradley and Morris 1986).

Earlier work by Bagatto and Alikhan (1987 a,b) showed that tissue metal concentrations in crayfish were related to the distance from the emission site. The purpose of the present study is to compare concentrations of six metals in freshwater crayfish from a neutralized acidic lake and a closely situated non-acidic lake. Various tissue concentrations in crayfish are also examined to determine specific tissue sites for these accumulations.

MATERIALS AND METHODS

During July 1984, intermoult adult Cambarus bartoni were obtained from Joe Lake (46° 44' N 81° 01' E) and Nelson Lake (46° 44' N 81° 05' E) in Chelmsford, Ontario. Both lakes are situated

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approximately 30 km from the Sudbury smelting works. In 1975, Nelson Lake was neutralized with a mixture of $Ca(OH)_2$ and $CaCO_3$ as part of an experimental neutralization program of lakes near Sudbury, Ontario (Yan and Dillon 1982). Consequently, the pH of this lake was raised from 5.7 to 6.5. Joe Lake did not receive such treatment and has a pH of 6.3.

Ten animals (5 females and 5 males, average wet weight = 5.4±0.2g; average carapace length = 45±5mm) collected from each site were separated by sex, quick frozen, and stored at -15°C. The hepatopancreas, exoskeleton, abdominal muscles, digestive gut (alimentary canal) and remaining viscera (including gills, reproductive organs, etc.), were oven dried for 48 h at 80°C, and their dry weights were determined. Samples for analysis by Perkin-Elmer atomic absorption spectrophotometer were digested in boiling concentrated aqua regia (3 mL concentrated nitric acid: 1 mL concentrated hydrochloric acid, British Drug House standards), diluted to 20 mL with 1 M nitric acid and analyzed for Cu, Cd, Ni, Mn, Mg and Zn by the flame method (Perkin-Elmer manual, 1971). Procedural blanks, acid washed glassware, analytical grade reagents and double distilled deionized water were used in the tissue analysis to minimize contamination error. The sensitivity (µg/mL) for each metal was Cu (.077), Cd (.025), Ni (.15), Mn (.055), Mg (.007) and Zn (.018).

Statistical analysis of the data was computed with the aid of a DEC-VAX/VMS computer, using $SPSS^X$ software (SPSS, Chicago, Ill., U.S.A.). An initial three-way ANOVA evaluated the effects on metal levels by site, sex and tissue of the crayfish. Within site and tissue, comparisons were made using one-way ANOVA with Duncan's Multiple Range Test. All data were checked for normality (Kolgomorov-Smirnoff test) and homogeneity of variance (Bartlett-Box F test), and they were log transformed where necessary.

RESULTS AND DISCUSSION

Table 1 summarizes the data on concentrations of trace metals in various tissues in the crayfish from the two sampling sites. Since differences in metal concentrations between males and females within each site were statistically insignificant ($p > 0.05$), the data for the two sexes were pooled.

The general relationship between the crayfish tissue metal concentrations at the two sites was Cu >Mg >Mn >Zn >Cd >Ni. This observed relationship, however, is somewhat different from the metal concentration relationship (Mg >Mn >Cu >Ni >Zn >Cd) reported by Yan and Dillon (1982) in Nelson Lake. The discrepancy between the environmental and the crayfish tissue concentrations at a given site appears to be related to the physiological mechanisms involved in the accumulation, regulation and excretion of these metals in the crayfish (for details, see Bagatto and Alikhan 1987 a,b).

Table 1. Mean concentrations of Cu, Cd, Ni, Zn, Mn and Mg (μg/g dry wt) in various tissues of crayfish collected from Nelson and Joe Lakes. N = 10 at each lake.

Tissues:	Hepatopancreas	Exoskeleton	Abdominal Muscles	Digestive Gut	Viscera
Copper					
Nelson	1510[a,1] (1032, 2210)*	68[b,c,1] (57, 81)	147[c,d,1] (105, 205)	230[b,1] (123, 431)	60[d,1] (18, 192)
Joe	996[a,1] (641, 1546)	96[b,2] (74, 124)	114[b,2] (81, 161)	182[b,1] (127, 260)	118[c,1] (99, 141)
Cadmium					
Nelson	30.2[a,1] (21.7, 42.2)	7.5[b,1] (5.9, 9.5)	4.4[b,1] (2.5, 7.8)	15.8[c,1] (8.3, 30.2)	5.6[b,1] (4.8, 6.5)
Joe	32.5[a,1] (21.4, 49.2)	4.9[b,2] (4.1, 5.9)	4.4[b,1] (2.5, 7.6)	15.5[c,1] (8.5, 28.2)	4.9[b,1] (4.5, 5.4)
Nickel					
Nelson	7.5[a,1] (0.3, 176)	49.5[a,1] (4.5, 543)	5.09[a,1] (0, 334)	7.0[a,1] (0, 792)	2.7[a,1] (0.1, 44)
Joe	0.8[a,1] (0, 55.6)	54[b,1] (2.3, 1243)	0[a,1] (0, 1.2)	0.3[a,1] (0, 21.2)	82[b,2] (13.7, 493)
Zinc					
Nelson	149[a,1] (73, 302)	17[b,1] (15, 21)	96[c,1] (87, 106)	82[c,1] (70, 95)	95[c,1] (92, 98)
Joe	166[a,1] (105, 263)	32[b,2] (28, 37)	97[c,1] (88, 106)	100[c,1] (77, 130)	76[c,1] (38, 151)
Manganese					
Nelson	241[a,1] (148, 392)	220[a,1] (162, 300)	32[b,1] (22, 45)	914[c,1] (745, 1121)	207[a,1] (170, 253)
Joe	337[a,1] (183, 622)	293[a,1] (174, 493)	45[b,1] (30, 68)	1148[c,1] (847, 1555)	230[a,1] (146, 362)
Magnesium					
Nelson	812[a,1] (658, 1002)	2422[b,1] (1864, 3146)	1363[c,1] (1269, 1464)	2247[b,c,1] (1924, 2624)	3957[d,1] (1964, 7974)
Joe	775[a,1] (580, 1036)	2306[b,1] (1629, 3265)	1449[c,1] (1348, 1558)	2302[b,1] (1976, 2682)	2924[b,1] (2358, 3625)

* 95 per cent confidence limits.

Means within each row followed by the same letter, and within each column followed by the same number are not significantly different at the 5% level.

Although tissue metal concentrations, in general, were not significantly different between crayfish from the two lakes, exoskeletal concentrations of Cu, Cd and Zn in the two decapod populations were significantly different. It is, however, not known if these differences were due to bioaccumulation of various metals or surface contamination of the exoskeleton. The moderate amount of variation in the tissue metal concentrations among the two crayfish populations appears, however, to support the latter contention.

Ni concentrations in various tissues among the members of the two crayfish populations were highly variable. In the majority of the crayfish samples from the Nelson Lake, highest concentrations were detected in the exoskeleton, and the lowest in the viscera. In the Joe Lake population, highest concentrations were observed in the viscera and the exoskeleton, while the hepatopancreas, abdominal muscles and the digestive gut were relatively free.

According to Mierle (1981), Ni concentration in cells is not a true intracellular uptake, but probably represents amounts bound at the cell surface. According to Hall (1978), Ni absorption into carapace is a result of flux - equilibrium condition established by a balance between uptake and loss. It is possible that in the present studies, some of the crayfish forming the sample had recently undergone moulting, and thus they had lost Ni through exuviae. However, more experimental work will be required to confirm this contention.

The decrease in metal concentrations following liming, and the residual neutralizing capacity of the liming agent have significantly improved the water quality of Nelson Lake. However, Yan and Dillon (1982) suggest that Nelson Lake would experience a slow, longterm reacidification. Since metal levels in a lake decrease because of reduced metal solubility at higher pH, the reverse is also probable as the lake reacidifies. It is our contention that tissue metal accumulation in crayfish from this, and other such lakes, would provide useful data on the effect of reacidification on their fauna. As such, crayfish would prove to be a useful monitor of the deterioration and improvement of water quality in lakes which have been neutralized.

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