METAL ACCUMULATION BY RIVERINE AND LACUSTRINE POPULATIONS OF *ANGULYAGRA OXYTROPIS* (BENSON) (GASTROPODA : VIVIPARIDAE)

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Abstract. Cadmium, chromium, iron, manganese, nickel, lead and zinc concentrations were determined in sediment and body tissues, viz. digestive gland, mantle and shell, of the freshwater snail, *Angulyagra oxytropis* (Benson) (Gastropoda : Viviparidae), from River Barak and one of its floodplain lakes in Cachar district, Assam State, Northeastern India. The concentrations of all the metals except iron are significantly higher in the lake sediment. When compared to their riverine counterparts, the lacustrine snails contain higher concentrations of cadmium, chromium and iron in their mantle; nickel and zinc in digestive gland; manganese in both digestive gland and mantle; and lead in all the three tissues examined. The accumulation patterns of most of the metals varied considerably between the two sites. The implications of these findings in storage, sequestration and detoxification of metals by this animal are discussed. The study also indicates that *A. oxytropis* may be a potential biological indicator of metal contamination in freshwater ecosystems.

Key words: lacustrine, metal accumulation, riverine, sediment, snail, tissue

1. Introduction

River-floodplain systems are highly interactive ecosystems of considerable ecological interest. While it is known that the concentrations of macronutrients like nitrites, nitrates, ammonium, phosphates and silicates, as well as major cations such as sodium, potassium, calcium and magnesium increase considerably in the water of Amazonian floodplain lakes during low water (Furch *et al*., 1983; Furch, 1984; Junk *et al*., 1989; Furch and Junk, 1993), little is known about the relative concentrations of other cations in tropical and subtropical rivers and their floodplain lakes, as well as their relative accumulation by the biota inhabiting these systems. The present study constitutes a preliminary investigation on the concentrations of cadmium, chromium, iron, manganese, nickel, lead and zinc in the sediments of River Barak and one of its floodplain lakes in Assam State, India, and in the body tissues of the snail, *Angulyagra oxytropis* (Benson) (Gastropoda : Viviparidae), inhabiting these systems.

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2. Materials and Methods

2.1. Study area

Collections were made during December 1993, from River Barak and one of its floodplain lakes near Silchar town (24 °50′ N; 92 °40′ E) in Cachar district, Assam State, India. The floodplain lakes in this area, locally called 'bils' or 'haors', are connected with the river in the wet season (May/June – September/October), while in the dry season (November – April) they usually retain water in saucer-shaped depressions cut off from the river. This area receives an annual rainfall of around 2000 mm. The floodplain is extensively cultivated, with rice in the wet season, and with a winter crop (rice, legumes or vegetables) as well in certain areas.

2.2. Sample collection and analysis

Sediment samples were collected from the shallow, marginal areas of the river and the lake (depth 5–10 cm) with a PVC corer and stored in clean, acid-washed PVC containers. Specimens of *A. oxytropis* were collected by shovelling the bottom mud with a PVC trowel and subsequently hand-picking the animals. The snails were dissected immediately and digestive glands, mantles, and portions of shell from 4–5 specimens of uniform size (4–5 mm long) were pooled together and dried at 70 °C to constant weight. Sediment samples were similarly dried and passed through a 2 mm mesh sieve. Water samples were not analyzed, as it was not possible to store and transport them at 4 °C, because of the non-availability of laboratory facilities in the study area.

Six replicate samples of snail tissues and sediment were weighed and digested in 10 ml concentrated HNO_3 and $HClO_4$ (3 : 1 v.v.) to dryness, and redissolved in 20 ml 10% HNO_3. Analyses for Cd, Cr, Fe, Mn, Ni, Pb and Zn were carried out in a Perkin-Elmer 2380 flame atomic absorption spectrophotometer. The readings were checked with those of standard solutions, and contamination errors minimized by using blanks, acid-washed glasswares, analytical grade reagents and double distilled deionized water. The detection limits for Cd, Cr, Fe, Mn, Ni, Pb and Zn were 0.5, 4.0, 3.0, 1.0, 2.0, 10.0 and 0.8 μg l^{-1}, respectively. Statistical analysis of the data comprised t-tests, one-way ANOVA and Duncan's New Multiple-Range tests. Data were log-tranformed where necessary.

3. Results and Discussion

3.1. Metals in sediments

The concentrations of Cd, Cr, Fe, Mn, Ni, Pb and Zn (μg g^{-1} dry weight) in the sediments of R. Barak and the floodplain lake are given in Table I. The concentrations of all the metals except Fe are significantly elevated in the lake sediment as

Table I

Concentrations of Cd, Cr, Fe, Mn, Ni, Pb and Zn (mean ± S.D) in sediment and body tissues of *A. oxytropis* from river Barak and a floodplain lake during December 1993. Statistical comparisons among samples by t-tests, one-way ANOVA and Duncan's New Multiple-Range tests

	Metal concentration (μg g^{-1} dry weight)							
	Sediment (n=6)		*A. Oxytropis* tissue (n=6)					
Metal	River	Wetland	DG1	DG2	M1	M2	S1	S2
Cd	0.21	1.2[b]	5.1	7	1.33	4.94[a]	0.6	1.61
	±0.12	±0.51	±2.5	±3.4	±0.61	±1.1	±0.44	±1.31
Cr	5.45	14[b]	17.7	21.3	5.8	51.9[b]	7.4	1.4
	±4.59	±3.2	±6.9	±6.5	±1.8	±22.3	±2.1	±0.9
Fe	6010.2	11927.5	2246.2	3880.4	691.7	3923.8[a]	392.1	200.3
	±3480.9	±6878.1	±1375.7	±2320.8	±305.9	±3357.9	±35.9	±154.6
Mn	105.7	233.9[b]	368.7	5289.9[b]	167.9	2450.5[a]	204.7	453.95
	±41.4	±40.2	±146.5	±3021.5	±62.9	±1593.9	±32.8	±487.1
Ni	21.2	70.8[b]	181.8	456.5[b]	93.6	65.9	126.3	108.2
	±3.3	±17	±51.1	±174	±52	±54.5	±51.4	±89
Pb	10.1	39[a]	21.6	53.9[a]	22.9	54.8[a]	44.3	77[a]
	±6.9	±18.7	±8.6	±17.3	±9.6	±23.7	±13.3	±24.4
Zn	45.8	102.4[b]	476.7	906.5[b]	177.9	360.3	45.1	103.4
	±2.3	±25.4	±67.7	±380.2	±29.4	±252.9	±15.1	±80.1

DG1, DG2, M1, M2, S1, S2 : Digestive gland, mantle and shell from river Barak (1) and floodplain lake (2), respectively.
[a] $P< 0.05$
[b] $P< 0.01$.

revealed by t-tests. Thus there is considerable metal enrichment of the lake sediments, at least during the low water period when the present study was conducted. The concentrations of major cations, viz. Na, K, Mg and Ca were found to increase substantially in the water of an Amazonian floodplain lake at low water (Furch *et al*., 1983; Furch, 1984). In their floodpulse concept, Junk *et al*. (1989) put forward the view that in river-floodplain systems, free floating aquatic macrophytes store dissolved elements during the flooded period and release them when decomposing at low water on the exposed sediments. This probably explains the observed increase in the concentrations of most metals in the lake sediment during low water. Furthermore, the floodplain lakes and other lentic water bodies in the study area have a dense growth of the floating aquatic weed, *Eichhornia crassipes*, which is known to readily accumulate various heavy metals (reviewed by Trivedy and Gudekar, 1985). The detritus accumulated beneath *E. crassipes* mats in a pond and a wetalnd of the study area were found to contain high levels of various metals such as Ca, Fe, Mg and Zn (Paul and Gupta, 1985), as well as Cd, Ni, and Pb (Gupta and Paul, in preparation). Therefore, decomposing stands of *E. crassipes* could be especially instrumental in raising the metal concentrations in the lake sediments.

3.2. Metals in *A. oxytropis*

The concentrations of the different metals in the digestive gland, mantle, and shell of *A. oxytropis* from river Barak and the floodplain lake are presented in Table I as well. The concentrations of Cd, Cr, and Fe are significantly elevated in the mantle, those of Ni and Zn in the digestive gland, those of Mn in both digestive gland and mantle and those of Pb in all the three tissues of the snails from the floodplain lake than in those from the river. Thus the relatively higher metal levels in the lake sediment are reflected in at least one body tissue of *A. oxytropis* inhabiting the same system. However, the concentration of Fe was higher in the mantle of the lake population, despite no significant difference having been recorded between the levels of this metal in the river and lake sediments. Information available on the relationship between the metal concentrations in the habitat and those in the different body tissues of invertebrates appear somewhat contradictory. Alikhan *et al*. (1990) found the crayfish *Cambarus bartoni* to be a fairly reliable indicator of several metals in three neutral lakes. However, when *C. bartoni* from an acidic and a neutral lake were analyzed for their Cd and Pb contents, no discernible relationship could be established between Cd and Pb levels in the crayfish tissues and in the sediments (Keenan and Alikhan, 1991). Nevertheless, positive relationships between mean tissue concentrations of several metals and their levels in the habitat have been shown for many aquatic and terrestrial invertebrates (Anderson and Brower, 1978; Hopkin *et al*., 1985; Alikhan, 1993, 1995; Gupta, 1996). It however, seems likely that several factors such as pH, temperature, hardness, and salinity of the medium, the proportion of bio-available metal species/fractions, the interactions of different metals that could be either synergistic or antagonistic, and the types of ligands available, may considerably influence the rate of absorption of metals by organisms.

The riverine and lacustrine snails exhibit distinct differences in the accumulation patterns of all the metals except Pb and Zn in their body tissues (Table II). It appears that exposure to higher metal levels in the lacustrine environment does not result in an equitable distribution of the excess metal load among all the tissues. Furthermore, some metals appear to be preferentially accumulated in certain tissues, such as the excess Cd, Cr and Fe largely in the mantle, and Mn and Ni in the digestive gland. Nevertheless, the digestive gland remains a major site for accumulation of most metals. According to Simkiss (1977), both essential and non-essential elements in excess of physiological needs must either be rapidly excreted out, or stored in an insoluble form to prevent their diffusion to issues where they can interfere with biochemical reactions. Hence, appreciable amounts of most metals in the digestive gland would imply that adequate reserves of essential elements are maintained, while the excess amount, probably stored in the phosphate granules found therein (Mason and Nott, 1981), can eventually be excreted. At the same time, the mantle is also found to play an important role in the storage, recycling, and probably detoxification, of excess metals, especially Cd, Cr, Fe and Mn, as has also been

Table II

Comparisons among metal concentrations (by one-way ANOVA and Duncan's New Multiple-Range tests) in the body tissues of *A. oxytropis* from river Barak and a floodplain lake during December 1993

Metal	Site	
	River	Floodplain lake
Cd	DG > M, S	DG, M > S
Cr	DG $\simeq$ M $\simeq$ S	M > DG > S
Fe	DG $\simeq$ M $\simeq$ S	M, DG > S
Mn	DG $\simeq$ M $\simeq$ S	DG > M > S
Ni	DG $\simeq$ M $\simeq$ S	DG > M, S
Pb	S > DG, M	S > DG, M
Zn	DG > M, S	DG > M, S

DG, M, S : Digestive gland, mantle and shell respectively

pointed out by Mason and Nott (1981), who suggested that metals are bound to the calcium carbonate granules found extensively in the mantle.

Of all the tissues, shell was found to contain the highest concentration of Pb, both in riverine and lacustrine snails. This probably reflects the tendency of Pb to compete with Ca for binding sites (Smith, 1976). The concentrations of the other metals in the shell are relatively low. However, it should be borne in mind that the total weight and volume of the shell far exceed those of the other tissues. Hence, the total metal content of the shell is likely to be fairly high, although the concentration per unit weight is low. Again, as the shell is secreted by the shell glands and the general epithelial lining of the mantle, metals accumulated in the mantle may eventually be mobilized and sequestered in the shell.

Finally, although more long-term studies in a larger number of ecosystems on metal accumulation by *A. oxytropis* would have to be conducted to fully assess its suitability as a biological indicator of metal pollution, the present investigation is suggestive of such a possibility.

References

Alikhan, M. A.: 1993, 'Differentiation in copper and nickel accumulation in adult female and juvenile *Porcellio spinicornis* from contaminated and uncontaminated sites in Northeastern Ontario', *Bull. Environ. Contam. Toxicol.* **50**: 922–928.

Alikhan, M. A.: 1995, 'Comparative study of metal bioaccumulation, and oxygen and nitrogen metabolism in three terrestrial isopod species from contaminated and uncontaminated sites in Northeastern Ontario', in: M. A. Alikhan (ed.). *Terrestrial Isopod Biology*, A. A. Balkema, Rotterdam, Brookfield, pp. 1–13.

Alikhan, M. A., Bagatto, G. and Zia, S.: 1990, 'The crayfish as a "biological indicator" of aquatic contamination by heavy metals', *Wat. Res.* **24**: 1069–1076.

Anderson, R. V. and Brower, J. E.: 1978, ‘Patterns of trace metal accumulation in crayfish populations’, *Bull. Emviron. Contam. Toxicol.* **20**: 120–127.

Furch, K.: 1984, ‘Seasonal variation of major cation content of the Varzea-lake Lago Cameleao, middle Amazon, Brazil in 1981 and 1982’, *Verh. Internat. Verein. Limnol.* **22**: 1288–1293.

Furch, K., Junk, W. J., Dietrich, J. and Kochert, N.: 1983, ‘Seasonal variations in the major cation (Na, K, Mg and Ca) content of the water of Lago Cameleao, an Amazonian floodplain-lake near Manaus, Brazil’, *Amazoniana* **8**: 75–89.

Furch, K. and Junk, W. J.: 1993, ‘Seasonal nutrient dynamics in an Amazonian floodplain lake’, *Arch. Hydrobiol.* **128**: 277–295.

Gupta, A.: 1996, ‘Heavy metals in water, periphytonic algae, detritus, and insects form two streams in Shillong, Northeastern India’, *Environ. Monit. Assess.* **40**: 215–223.

Hopkin, S. P., Martin, M. H. and Moss, S. J.: 1985, ‘Heavy metals in isopods from the supralittoral zone on the south shore of the Severn Estuary, U. K’, *Environ. Pollut.*, Serie **B9**, 239–254.

Junk, W. J., Bayley, P. B. and Sparks, R. E.: 1989, ‘The flood pulse concept in river-floodplain systems’, in: D. P. Dodge (ed.), Proceedings of the International Large River Symposium (Lars), *Can. Spec. Publ. Fish. Aquat. Sci.* **106**: 110–127.

Keenan, S. and Alikhan, M. A.: 1991, ‘Comparative study of cadmium and lead accumulations in *Cambarus bartoni* (Fab.) (Decapoda, Crustacea) from an acidic and a neutral lake’, *Bull. Environ. Contam. Toxicol.* **47**: 91–96.

Mason, A. Z. and Nott, J. A.: 1981, ‘The role of intracellular biomineralized granules in the regulation and detoxification of metals in gastropods with special reference to the marine prosobranch *Littorina littorea’*, *Aquat. Toxicol.* **1**: 239–251.

Paul, S. B. and Gupta, A.: 1995, ‘Trace element concentrations in two species of shrimps from Hailakandi, Assam, India’, *Curr. Sci.* **68**: 967–968.

Simkiss, K.: 1977, ‘Biomineralization and detoxification’, *Calcif. Tiss. Res.* **24**: 199–200.

Smith, J. L.: 1976, ‘Metabolism and toxicity of lead’, in: A. S. Prasad (ed.), *Trace elements in Human Health and Disease, Vol. II – Essential and Toxic Elements*, Academic Press, New York, pp. 443–452.

Trivedy, R. K. and Gudekar, V. R.: 1985, ‘Water hyacinth for waste water treatment: a review of the progress’, in: R. K. Trivedy and P. K. Goel (eds.), *Current Pollution Researches in India*, Environmental Publications, Karad, India, pp. 109–145.