[OP 2.5]

Effects of Zinc on the Phosphorus Availability to Periphyton Communities in the River Göta Älv

Maria Paulsson, Vivianne Månsson and Hans Blanck

Department of Plant Physiology, Göteborg University, Box 461, 405 30 Göteborg, Sweden
Tel. +46-31-773 2609, Fax. +46-31-773 2626, E-mail. maria.paulsson@fysbot.gu.se

Zinc is a widely used heavy metal and concentrations of total zinc in European rivers range from nmoles per litre to near hundred µmoles per litre in the most polluted ones (Whitton et al. 1982). Zinc is considered to be the least toxic of the heavy metals (Weatherley et al. 1980) and long-term effects of zinc on microbenthic communities have generally been reported at concentrations ranging from 0.05 $mg \cdot l^{-1}$ (0.8 µM) to 2.5·mg l^{-1} (38 µM) (Williams & Mount 1965, Genter et al. 1987, Colwell 1989, Dean-Ross 1990, Niederlehner & Cairns 1992, Niederlehner & Cairns 1993, Loez et al. 1995) implying that long-term effects only can be expected in the more polluted rivers. However, long-term effects on biomass production have also been reported to occur at much lower concentrations (Pratt et al. 1987, Paulsson et al. 2000). In the latter study two ranges of long-term effects were found. Zinc exposure induced community tolerance, measured as an increase in EC_{50} for photosynthesis, and had marked effects on structure at much higher concentrations (>9.7 µM) than it had on biomass and biomass-dependent parameters (0.12-0.42 µM). It was hypothesised that two different toxic actions by zinc were measured, one direct and one indirect on nutrient availability, possibly caused by an interaction between zinc and phosphorus leading to a decreased biomass production. The aim of this study was to test this hypothesis. The results will show that the lower effect levels of zinc on biomass production in periphyton communities seen by Paulsson et al. (2000) is concomitant with indicators of phosphorus deficiency.

Periphyton communities from the phosphorus-limited (12-15 µg/l) River Göta Älv in Sweden were exposed to zinc during four weeks in a flow-through aquaria microcosm system. After the four-week exposure, indicators of phosphorus deficiency such as alkaline phosphatase activity (APA) and phosphorus status of the periphyton communities were measured. An increase in APA is generally a sign of phosphorus deficiency (Cembella et al. 1984). If phosphate is added to the medium, the activities normally decrease (Cembella et al. 1984) while derepression of the enzyme often is associated with low phosphorus levels in the cells (Jansson et al. 1988).

Periphyton biomass in terms of dry weight decreased at zinc concentrations higher than 0.1 µM, concomitantly as the APA increased (Fig. 1) and luxury stored phosphorus decreased. This is similar to the threshold concentration observed in the previous study (Paulsson et al. 2000), therefore supports the hypothesis of an indirect toxic action by zinc on phosphorus availability. The effects on periphyton dry weight also coincided with an increase in the concentration of voltammetrically labile zinc, indicating a low complexing capacity of the system.

Even though the results point to an interaction between zinc and phosphorus further studies are needed to discriminate between two possible mechanismsan external or internal interaction. Rai and Kumar (1980) and Hughes and Poole (1991) suggest that zinc interacts with phosphate leading to a precipitation of zinc phosphate, while Kuwabara (1985) on the other hand found an intracellular interaction affecting the utilisation of phosphate. It has been shown that addition of phosphate decreases zinc toxicity (Rana & Kumar 1974, Rai & Kumar 1980, Kuwabara 1985) making it less available. This implies that it also might occur the other way around, making phosphate less available.

We can conclude that zinc interacts with phosphorus in some way leading to phosphorus deficiency in Göta Älv periphyton communities at concentrations >0.1-0.2 µM of total zinc and consequently to a decrease in biomass production. This does, however, not exclude interactions with other enzymes important for uptake of other nutrients. In systems rich in phosphorus, zinc exposure might not be a problem, but in systems with low phosphorus it might pose a risk.

References

Cembella, A.D., Antia, N.J., Harrison, P.J. 1984. The utilization of inorganic and organic phosphorous compounds as nutrients by eukaryotic microalgae: a multidisciplinary perspective: part 1. CRC Crit. Rev. Microbiol. 10, 317-391.

Colwell, F.S., Hornor, S.G., Cherry, D.S., 1989. Evidence of structural and functional adaptation in epilithon exposed to zinc. Hydrobiologia 171, 79-90.

Dean-Ross, D., 1990. Response of attached bacteria to zinc in artificial streams. Can. J. Microbiol. 36, 561-566.

Hughes, M.N., Poole, R.K. 1991. Metal speciation and microbial growth-the hard (and soft) facts. J. Gen. Microbiol. 137, 725-34.

Genter, R.B., Cherry, D.S., Smith, E.P., Cairns, J.Jr., 1987. Algal-periphyton population and community changes from zinc stress in stream mesocosms. Hydrobiologia 153, 261-275.

Jansson, M., Olsson, H., Pettersson, K. 1988. Phosphatases; origin, characteristics and function in lakes. Hydrobiol. 170, 157-75.

Kuwabara, J.S. 1985. Phosphorus-zinc interactive effects on growth by *Selenastrum capricornutum* (*Chlorophyta*). Environ. Sci. Technol. 19, 417-21.
Loez, C.R., Topalian, M.L., Salibian, A., 1995. Effects of zinc on the structure and growth dynamics of a natural freshwater phytoplankton assemblage reared in the laboratory. Environ. Pollut. 88, 275-281.
Niederlehner, B.R., Cairns, J.Jr., 1992. Community response to cumulative toxic impact: effects of acclimation on zinc tolerance of aufwuchs. Can. J. Fish. Aquat. Sci. 49, 2155-2163.
Niederlehner, B.R., Cairns, J.Jr., 1993. Effects of previous zinc exposure on pH tolerance of periphyton communities. Environ. Toxicol. Chem. 12, 743-753.
Paulsson, M., Nyström, B., Blanck, H. 2000. Long-term toxicity of zinc to bacteria and algae in periphyton communities fom the river Göta Älv, based on a microcosm study. Aquat. Toxicol. 47, 243-57.
Pratt, J.R., Niederlehner, B.R., Bowers, N.J., Cairns, J.Jr., 1987. Effects of zinc on microbial communities. In: Lindberg, S.E., Hutchinson, T.C. International conference on heavy metals in the environment. CEP Consultants Ltd. , Edinburgh, pp. 324-329.
Rana, B.C., Kumar, H.D. 1974. The toxicity of zinc to *Chlorella vulgaris* and *Plectonema botyanum* and its protection by phosphate. Phykos. 13, 60-6.
Rai, L.C., Kumar, A. 1980. Effect of certain environmental factors on the toxicity of zinc to *Chlorella vulgaris*. Microbios. Lett. 13, 79-84.
Weatherley, A.H. Lake, P.S. Rogers, S.C., 1980. Zinc pollution and the ecology of the freshwater environment. In: Nriagu, J.O. Zinc in the environment. Part I: Ecological cycling John Wiley & Sons, New York, pp. 337-418.
Whitton, B.A., Say, P.J., Jupp, B.P., 1982. Accumulation of zinc, cadmium and lead by the aquatic liverwort *Scapania*. Environ. Pollut. 3, 299-316.
Williams, L.G., Mount, D.I., 1965. Influence of zinc on periphytic communities. Amer. J. Bot. 52(1), 26-34.