

The significance of water ionic strength on aluminium toxicity in brown trout (*Salmo trutta* L.)

Nina E.W. Alstad^a, Birgitte M. Kjelsberg^a, L. Asbjørn Vøllestad^a,
Espen Lydersen^b, Antonio B.S. Poléo^{a,*}

^aDepartment of Biology, University of Oslo, P.O. Box 1066 Blindern, N-0316 Oslo, Norway

^bNorwegian Institute for Water Research, P.O. Box 173 Kjelsås, N-0411 Oslo, Norway

Received 10 November 2003; accepted 31 May 2004

Ionic strength has a slight ameliorating effect on Al toxicity in brown trout.

Abstract

The toxicity of aluminium to fish is related to interactions between aluminium and the gill surface. We investigated the possible effect of water ionic strength on this interaction. The mortality of brown trout (*Salmo trutta* L.) exposed to three different degrees of Al polymerisation was compared in water with increased ionic strength (mean 7.31×10^{-4} M) after additions of the base cations Ca^{2+} , Mg^{2+} , Na^{+} or K^{+} , and in water with no such addition (mean ionic strength 5.58×10^{-4} M). Only a very slight ameliorating effect of increased ionic strength was observed, while the degree of Al polymerisation was of major importance in fish mortality. In addition, it was observed that smaller fish survived the Al exposures for a longer time than larger fish. We hypothesise that this is because larger fish are more susceptible to hypoxia than smaller fish.

© 2004 Elsevier Ltd. All rights reserved.

Keywords: Ionic strength; Aluminium toxicity; Al polymerisation; Base cations; Brown trout; *Salmo trutta*

1. Introduction

An important consequence of the acidification of soil water systems is the mobilisation of both aluminium and base cations (Ca^{2+} , Mg^{2+} , Na^{+} , and K^{+}) from the edaphic to the aquatic environment (Cronan and Schofield, 1979; Seip et al., 1989; Lawrence et al., 1999; Stoddard et al., 1999). Weathering rates and release of ions depend on climate and the composition of bedrock. In most areas of silicate rock the loss of elements to stream water relative to their concentration in bedrock follows the order $\text{Ca} > \text{Na} > \text{Mg} > \text{K} > \text{Si} > \text{Fe} > \text{Al}$

(Schlesinger, 1991). Slowly weatherable soils and rocks with poor anion exchange capacity are especially vulnerable to losses of cations due to the elevated inputs of SO_4^{2-} in acid rain. Accordingly, it is repeatedly observed that the negative impacts of acid precipitation on freshwater fish are most severe in the low conductivity waters of such catchments (Bua and Snekvik, 1972; Leivestad et al., 1976; Grande and Andersen, 1979; Brown, 1981; Muniz, 1984; Hutchinson et al., 1989; Bulger et al., 1993). Such waters may have a scattered distribution reflecting local geology, or they extend over large areas such as the Canadian Shield (Lonergan and Rasmussen, 1996) and major parts of Scandinavia (Skjelkvåle et al., 1997).

Increased concentrations of aqueous aluminium arising from freshwater acidification are considered a major

* Corresponding author. Tel.: +47 22855785; fax: +47 22854664.
E-mail address: toni.poleo@bio.uio.no (A.B.S. Poléo).

environmental problem due to the relationship between aluminium toxicity and fish (Driscoll et al., 1980; Sparling and Lowe, 1996). Moreover, aqueous aluminium is recognised by many authors as the principal toxicant killing fish in acidified waters (Howells et al., 1994; Gensemer and Playle, 1999). The main effects of Al exposure in fish are respiratory and ion regulatory disturbances (Neville, 1985; Gensemer and Playle, 1999). Respiratory dysfunction seems to dominate at pH above 5.5 (Neville, 1985), where positively charged Al species bind to negatively charged sites at the gill surface (Poléo, 1995). Subsequent Al polymerisation and mucus secretion cause clogging of the interlamellar spaces leading to hypoxia (Poléo, 1995; Poléo et al., 1995). Ion regulatory disturbances, however, predominate at pH below 4.5 and involve a decrease in plasma Na^+ and Cl^- (Neville, 1985; Gensemer and Playle, 1999).

It is repeatedly observed that high concentrations of water Ca^{2+} can decrease Al toxicity in fish (Brown, 1981; Brown, 1983; Wood and McDonald, 1987; Playle et al., 1989), possibly by stabilising biological membranes controlling ion and water permeability (Steen and Stray-Pedersen, 1975; Dalziel et al., 1986). High water Na^+ concentration also has a mitigating effect on fish exposed to toxic aluminium, probably by counteracting an increased net loss of Na^+ over the gills (Brown, 1981; Dietrich et al., 1989). However, Lydersen et al. (2002a) suggested increased water ionic strength as an alternative explanation for the mitigating effect of Ca^{2+} and Na^+ , by reducing the ability of aluminium to bind to the gill surface. The purpose of the present study was to further illuminate the possible effect of ionic strength under slightly different conditions, and to extend the study by incorporating Mg^{2+} and K^+ that also contribute to water ionic strength.

Ionic strength (I) is defined as $I = 0.5 \sum c_i z_i^2$, where c_i is the molar concentration and z_i , the charge of each ion in the solution. Due to their high charge compared to ionic radius, monomeric inorganic Al species may easily bind to negatively charged sites on the gill surface by ionic bonding. However, increased ionic strength will reduce the rate of ionic binding between oppositely charged molecules because of enhanced competition between ions (Atkins, 1982). Firstly, base cations may suppress the interaction between aluminium and the gill surface by competing for the negatively charged sites on the gill. Secondly, anions may compete with the negatively charged gill surface for the cationic Al species. The layer (κ) above the gill surface in which ions can be influenced by its charge extends further into the solution in lower ionic strength water than in higher ionic strength water ($\kappa^{-1} = 2.8 \times 10^{-8} / \sqrt{I}$ (cm); Chu, 1967). Due to this, the availability of monomeric inorganic Al species, which can bind to the gill surface by ionic bonds, is lower in high ionic strength water than in low ionic strength water.

Here we have compared Al toxicity at various combinations of non-steady state transient Al chemistry (three regimes) and base cations (Ca^{2+} , Na^+ , Mg^{2+} , K^+). By this experimental approach we have tested the following hypotheses: (1) when a base cation is added to Al rich water to increase the ionic strength, the exposed fish will survive for a longer time compared to fish exposed to Al rich water without base cation addition; (2) independent of which base cation is added, an equal increase in ionic strength will decrease mortality equally. This implies that the concentration of the monovalent Na^+ and K^+ must be higher than the concentration of the divalent Ca^{2+} and Mg^{2+} to have the same effect on mortality; (3) the effect of ionic strength is most evident when a major part of the dissolved aluminium is present as low molecular weight cationic species.

2. Material and methods

2.1. Experimental animals

One year old brown trout (*Salmo trutta* L.) parr (total length 8.5 ± 1.4 cm, weight 7.2 ± 3.7 g) were obtained from a local hatchery near Oslo. The fish were brought into the fish holding department at the University of Oslo, and placed directly in the exposure channels (Fig. 1). The fish were not fed during the exposures.

2.2. Test conditions and experimental protocol

We used a flow-through exposure system for the experiments (Fig. 1). The test medium was led into two parallel exposure channels, 218 cm long, 42 cm wide, and 16 cm deep. The fish were placed in exposure chambers within the channels (Fig. 1). The water was well aerated on its way through the channels, and the water flow of 3 l/min provided at least 8.7 l of water per gram of fish per day. This is well above 2.0 l/g/day which is recommended for pollutant bioassays using fish (Sprague, 1973). The fish were sheltered by covers over the channels.

The fish holding tank received dechlorinated Oslo tap water (Table 1). The non-steady state transient Al chemistry was prepared by the addition of an acidic Al stock solution ($\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ dissolved in distilled water, resulting pH 2.6) to the tap water (pH 6.5). Due to the low pH of the Al stock solution, the total amount of aluminium was present as Al^{3+} . When the pH rapidly increased to 5.6, as the Al stock solution was mixed with the tap water, Al^{3+} started to polymerise into larger molecules (Hem and Robertson, 1967; Poléo, 1995). The residence time of the water, after the addition of the acidic Al stock solution, was manipulated to create three

Download English Version:

<https://daneshyari.com/en/article/9456502>

Download Persian Version:

<https://daneshyari.com/article/9456502>

[Daneshyari.com](https://daneshyari.com)