Bull Environ Contam Toxicol (1984) 32:575–579

Bulletin of Environmental Contamination and Toxicology

Interference of Aluminium and pH on the Na-Influx in an Aquatic Insect *Corixa punctata* (Illig.)

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An increased emission of sulphur dioxide (SO_2) and nitrogen (NO_x) to the atmosphere has been noticed for thirty years. These products orginate mostly from the combustion of fossil fuels. Due to the deposition of acid nitrogen and sulphur compounds, especially in Europe, North America and Canada, an acidification of some ecosystems is observed (Likens & Bormann 1974, Dovland & Semb 1980). Percolation of rainwater with elevated H^+-concentrations into soils with a low neutralisation capacity, appears to be the cause of an enhanced leaching of minerals and heavy metals from the soil (Voigt 1980). The mobilized aluminium, for example, is further transported to near surface waters (Cronan & Schofield 1979). Consequently, measurements of the aluminium concentration indicated highest levels in the most acid waters (Dickson 1980, Vangenechten 1983).

Some investigations concerning the impact of acid precipitation on aquatic biota, assess possible toxic effects of aluminium in relation to low pH. But those studies mainly refer to the survival of fishes under these stress conditions (Baker & Schofield 1980, 1982, Brown 1983, Driscoll et al. 1980, Grahn 1980). Few studies on the physiological basis of combined acidity and aluminium-stress in fish have been found (Muniz & Leivestad 1980a, 1980b, Rosseland 1980). Experiments with some aquatic invertebrates (crustaceans and insect larvae) on mortality under pH and aluminium-stress indicated that aluminium should be the key additional toxic factor in acid water (Havas & Hutchinson 1982).

In this paper, data are presented on the influence of different aluminium-concentrations in relation with a low pH-value, on the Na-influx and haemolymph Na-concentration in the adult waterbug *Corixa punctata* (Illig.).

MATERIALS AND METHODS

The waterbugs were captured in an acid boglake (pH 4.0, and 0.2 mg Al/l) at least three days prior to the experiment. They were kept during these 3 days at a constant temperature of 18°C in filtered (0.45 μm Millipore) boglake water (mean pH 4.0, ranging from 3.9 to 4.5, mean Na-concentration 6.6 mg/l and mean Al-concentration 0.3 mg/l) without any food.

Experimental solutions were prepared from this natural boglake water by addition of 0.1 N HCl to obtain pH 3 and pH 4; and by addition of $AlCl_3$ to obtain higher Al-concentrations. Besides the natural Al-concentration (0.3 mg/l) a lower Al-concentration (0.15 mg/l) was obtained by filtering (0.10 μm Millipore) the original prefiltered water (0.45 μm Millipore) at pH 4.5, by which some of the aluminium was retained by the filter.

The animals were placed individually in polyethylene beakers, each with 50 ml of an experimental Al-solution. The waterbugs were exposed to the experimental solutions for 20 hours. The Na-influx in the animals was determined as follows. After labeling the experimental solution with ^{22}Na (1.5 kBq/ml), the animals were allowed to pump up the ^{22}Na for about 5 hours. Then ^{22}Na-radioactivity was determined in the water and in a haemolymph sample (1-5 μl). After measurement of the Na-concentration in the water by plasma emission spectroscopy, the Na-influx was calculated and expressed as μmole Na/ml haemolymph/hour (Vangenechten et al. 1979). The Na-concentration in the haemolymph sample was measured by plasma emission spectroscopy.

RESULTS AND DISCUSSION

The animals were all thriving well during their stay for 20 hours in the experimental Al-solutions. No mortality was noticed. The Na-influx values are illustrated in Figure 1 and the haemolymph Na-concentrations are given in Table 1.

A decrease of the Na-influx with increased Al-concentration in the water is noticed at pH 3 and pH 4. The decrease amounts to 50 % when comparing the lowest Al-concentration with the 10 mg Al/l solution at both pH-values and is statistically significant ($P < 0.001$). It must be pointed out that Al-concentrations up to about 10 mg/l have been measured in acidified Belgian boglakes (Vangenechten 1983).

Although a 50 % decrease in Na-influx was measured at elevated Al-concentrations, significantly increased ($P < 0.005$) haemolymph Na-concentrations were observed (only measurements at pH 4 were made).

Previous experiments on the effects of pH on Na-regulation in *C. punctata*, captured in an acid boglake (pH 4) showed comparable results (Vangenechten et al. 1979, Vangenechten & Vanderborght 1980). The data showed a 50 % decrease of the Na-influx from pH 6 to pH 3, whereas the Na-efflux remained unchanged. The haemolymph Na-concentration however, was higher at pH 3 than at pH 6 after a stay for 24 hours in the experimental solutions. A net Na-flux from the tissue compartment, which contains 70 % of the total body sodium content, to the haemolymph was suggested to compensate the lowered Na-influx at pH 3 (Vangenechten & Vanderborght 1980).

In our present experiments, measurements of the Na-efflux and the total body Na-concentration were not made. The increased haemolymph Na-content could result from a net Na-flux from the tissue compartment to the haemolymph. This explanation could be put forward to explain the strikingly analogous effects of acid pH and elevated Al-concentrations on the Na-concentration in the haemolymph. Otherwise, the increased haemolymph Na-content could result from a decreased Na-efflux at the highest Al-concentrations. In this case, the toxic action of aluminium could be explained as an adsorption phenomenon, resulting in an inhibitory action on both the Na-efflux and the Na-influx.

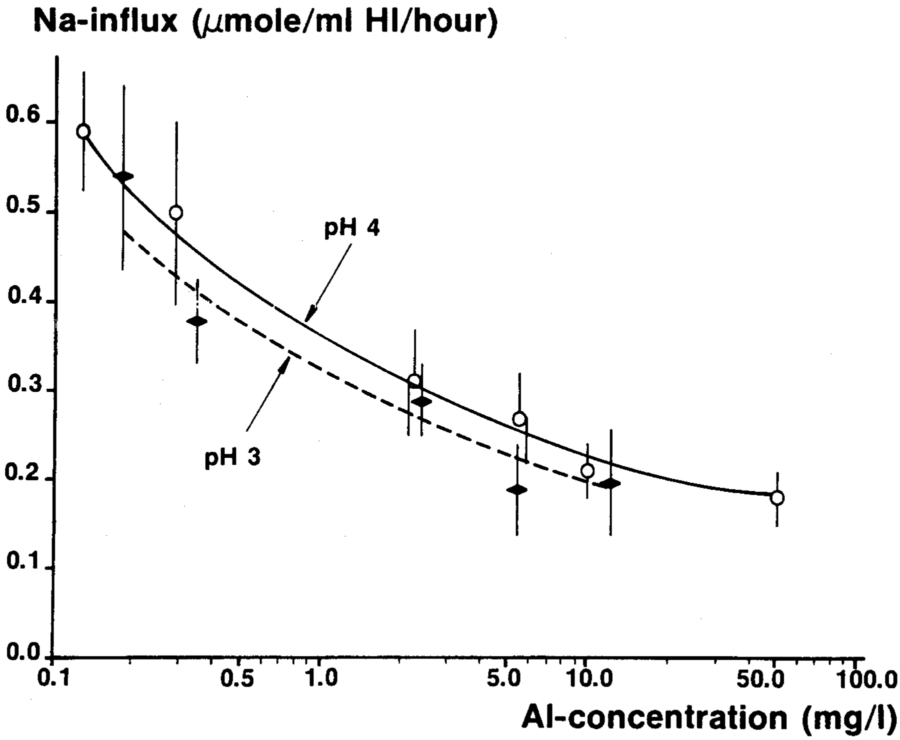

Figure 1

The Na-influx (mean values ± 95 % confidence limits) in *C. punctata*, after a stay for 20 hours in boglake water at pH 4 or pH 3, and with different Al-concentrations

Table 1

Haemolymph (= Hl) Na-concentration in *C. punctata*, after a stay for 20 hours in boglake water at pH 4, with different Al-concentrations.

Al-concentration (mg/l)	0.3	10	50
Haemolymph Na-concentration	112	125	123
± 95 % conf. lim. (µmole/ml Hl)	± 5	± 6	± 7

Muniz & Leivestad (1980a, 1980b) investigated the toxic action of aluminium on the brown trout *Salmo trutta* L. Low aluminium levels (< 1 mg/l) caused a rapid loss of sodium and chloride from the bloodplasma, as was also noticed under conditions of acid stress. It seems that the gill is the target organ for the toxic action of aluminium in fishes, as was also observed by Rosseland (1980). An excessive mucus production, hyperventilation and lowered blood oxygen tension were noticed. It is remarkable that these effects were due to the acute toxicity of aluminium at pH-levels which are normally not physiologically harmful (pH 4.5 - 5.5).

To understand the toxic action of aluminium in fishes and in aquatic invertebrates, as the waterbugs, more knowledge about the several chemical forms of aluminium and their behaviour in natural acid waters is a necessity.

From our observations, we may conclude that elevated Al-concentrations in acidified surface waters cause a depression of the Na-influx even in *C. punctata*, a natural inhabitant of acid lakes.
It further was noticed that short term exposure (20 hours) to high Al-concentrations (about 10 mg/l) was not harmfull to the haemolymph Na-concentration in *C. punctata*.

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Received August 27, 1983; accepted September 22, 1983