Uptake and distribution of a copper, iron and zinc mixture in gill, liver and plasma of a freshwater teleost, *Tilapia sparrmanii*

V Wepener[1]*, JHJ van Vuren[2] and HH du Preez[2]

[1]Coastal Research Unit of Zululand, Department of Zoology, University of Zululand, Private Bag X1001, Kwadlangezwa 3886, KwaZulu-Natal, South Africa

[2]Department of Zoology, Rand Afrikaans University, PO Box 524, Auckland Park 2006, Johannesburg, South Africa

Abstract

Since polluted environments contain mixtures of different contaminants, the aim of this study was to investigate the time-integrated uptake of individual metals by a freshwater teleost, *Tilapia sparrmanii* following exposure to a metal mixture containing Cu, Fe and Zn. The metal concentrations used during the bioassays were chosen to represent ecologically relevant concentrations as found in the Olifants River, Kruger National Park, South Africa. The concentrations used in the bioassay were 0.16 $mg \cdot l^{-1}$, 4.3 $mg \cdot l^{-1}$ and 1.003 $mg \cdot l^{-1}$ for Cu, Fe and Zn respectively. Gill, plasma and liver were sampled at 0, 2, 4, 6, 12, 24, 24, 48, 72, 96 h and four weeks. Gill tissue is the initial site of accumulation of water-borne metals. Although the fish were exposed to a metal mixture, the interactions between metals and the external gill surface, as well as the subsequent uptake rate, were associated with the particular chemical properties of individual metals. The tendency of the individual metals in the metal mixture to bind to the external gill surface via ionic bonds, and to gill cytosolic compounds via covalent bonds, was Cu > Fe > Zn. The ensuing uptake rates into the extracellular compartment (blood) and intracellular compartment (liver tissue) were Zn > Fe > Cu. The toxic effects of Cu and Fe were, therefore, primarily exerted on the gill surface and in the gill cytosol, whereas the toxic action of Zn was primarily limited to the internal organs.

Introduction

Trace metals are introduced into the environment by a wide spectrum of natural and anthropogenic sources. Metals are non-biodegradable, and once they enter the environment, bioconcentration may occur in fish tissue by means of metabolic and biosorption processes (Hodson, 1988; Carpené et al., 1990; Wicklund-Glynn, 1991). From an environmental point of view, bioconcentration is important because metal ions usually occur in low concentrations in the aquatic environment and subtle physiological effects go unnoticed until gross chronic reactions (e.g. changes in populations structure, altered reproduction, etc.) become apparent (Kumar and Mathur, 1991). Although trace metals are essential for normal physiological processes, abnormally high concentrations can be toxic to aquatic organisms. Due to the insidious nature of metal bioconcentration, it would be too late to apply preventative measures to reduce the pollution effects by the time the chronic effects become visible.

Acute metal toxicity in fish is often characterised by gill damage and hypersecretion of mucus (Mallatt, 1985). Ensuing mortalities are, in turn, related to secondary physiological respiratory disturbances, resulting in ion-regulatory and acid-base balance disturbances (Goss and Wood, 1988). The extent of the physiological disturbances will depend on bioconcentration and uptake of the metal, which, in turn, is determined by the physical and chemical composition of the surrounding medium.

Most research has been concerned with the physiological effects and bioconcentration patterns of individual metals. Trace metals i.e. Cu, Fe and Zn are readily concentrated in different fish tissues (Villegas-Navarro and Villarreal-Treviño, 1989; Grobler-Van Heerden et al., 1991; Mohan and Choudhary, 1991; Peres and Pihan, 1991; Pelgrom et al., 1995). It has further been shown that uptake of sublethal concentrations of these metals leads to altered physiological processes, which reduces the normal functioning of the organism (Grobler et al., 1989; Wepener et al., 1992). As effluent from many sources enters natural waters, the negative impact on the aquatic ecosystem is due to a mixture of metals, rather than individual component metals. When metal mixtures are discharged into the environment they may show a number of effects, which are synergistic, antagonistic or additive in nature (Lewis, 1978; Tsai and McKee, 1980; Mukhopadhyay and Konar, 1985).

Research on the interaction of Cu, Zn and Fe and the subsequent tissue distribution is limited mainly to mammalian toxicological studies, investigating the absorption and metabolism of these metals under high and low dietary conditions (see Gawthorne, 1987 for extensive review). Very limited work, other than a study by Dethloff et al. (1999) investigating the uptake of Cu and Zn by gill and liver tissue of rainbow trout exposed to a metal mixture containing Cu and Zn, has been done on uptake of individual metals by fish following their exposure to a metal mixture.

Metal exposure concentrations were selected to represent ecologically relevant concentrations. The Olifants River (Mpumalanga) is known to contain high Cu and Zn concentrations, which are comparable to metal concentrations in large metal-polluted rivers in the northern hemisphere (Wepener et al., 2000). Concentrations selected for this study were based on actual measured values obtained during a metal monitoring programme in the Olifants River (Seymore et al., 1994). The purpose of this paper was to evaluate the bioconcentration kinetics and tissue distribution of individual metals from a metal mixture containing Cu, Fe and Zn in gill, liver and plasma in a freshwater fish, *Tilapia sparrmanii*. This information could contribute to understanding physiological responses following exposure to metal mixtures containing Cu, Fe and Zn.

* To whom all correspondence should be addressed.
☎(035) 902-6741; fax(035) 902-6750; e-mail: vwepener@pan.uzulu.ac.za
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