Chromium, copper, iron and manganese bioaccumulation in some organs and tissues of *Oreochromis mossambicus* from the lower Olifants River, inside the Kruger National Park

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Abstract

The bioaccumulation of chromium, copper, iron and manganese by *Oreochromis mossambicus* was investigated at two localities (Mamba and Balule) in the lower Olifants River, inside the boundaries of the Kruger National Park. The Cr, Cu, Fe and Mn concentrations, recorded in the tissues of *O. mossambicus* at Mamba and Balule, did not differ much from each other. However, it was generally found that the highest accumulation of metals by the fish occurred at Mamba, except for iron, where the opposite occurred. The metals investigated during this study mainly accumulated in the liver and gills, followed by the skin, and lastly the muscle.

Introduction

Biological systems function within relatively narrow physical and chemical limits. Pollution of natural aquatic ecosystems occurs frequently as population densities lead to increasing mining and industrial activities (Ellis, 1989). The release of metal ions into river systems poses a serious threat to aquatic life, and causes secondary effects upon water quality (Rehwoldt et al., 1971). Two factors which contribute to the damaging effect of metals as environmental pollutants are: Firstly, the inadequacy of biological degradation to inert metals - as in the case of most organic pollutants - and secondly, the trend of metals to accumulate and largely remain in the aquatic environment (Förstner and Prosi, 1979).

Metal ions are commonly present and are readily taken in by aquatic organisms through the digestive system, gills and integument. These ions are individually, or in combination, important factors of water pollution (Calamari and Marchetti, 1973). Ellis (1989) states that the effect of two or more toxicants may be additive, antagonistic or even synergistic. There are several factors which affect the toxicity of pollutants to aquatic organisms, and they can be divided into biotic factors, such as tolerance (Sprague, 1971), growth and reproduction (Cross et al., 1973), species variation, inter- and intraspecific variation (Abel, 1989) and nutrition (Lanno et al., 1989), and abiotic factors, such as organics (Mouvet and Bourg, 1983), pH (Alabaster and Lloyd, 1980), temperature (Cairns et al., 1975), alkalinity and hardness (Sprague, 1970), metal interactions (Lloyd, 1965), sediment (Burton et al., 1992) and dissolved oxygen (DO) (Lloyd, 1992).

A typical "dynamic" environment is a system where mechanical, biological and chemical phenomena take place, with strong gradients of chemical parameters (E_h, pH) and variations in time (e.g. biological activities). For example, changes in water hardness may lead to the release of certain metals into the aquatic environment (Lloyd, 1992), and furthermore, the position that an organism occupies in the food chain may also play a role (Aoyama et al., 1978). The presence of heavy metals in the aquatic ecosystem becomes harmful to organisms when the concentrations rise above the natural background in water and sediment. These metals must be in a bioavailable chemical state to cause significant heavy metal uptake by organisms (Abel, 1989). It is thus clear that the physico-chemical parameters which influence metal bioavailability, play an essential role in the bioaccumulation and toxicity of metals in aquatic organisms.

In the aquatic environment Cr, Cu, Fe and Mn are commonly present. Cr is essentially present in the oxidation states 3+ and 6+, which are pH dependent (Dyg et al., 1990). It is, furthermore, known that Cr is one of the trace metals which, at low concentrations, is least toxic, and that the hexavalant ion (Cr^{6+}) is the most toxic in elevated concentrations (Kraybill et al., 1978; Wittmann, 1979; Duffus, 1980; Dallas and Day, 1993). Copper, a common metal (i.e. >5 g·cm^3) in the environment (Duffus, 1980), occurs in nature as Cu^+, Cu^{2+} and Cu^{3+} oxidation states (Leckie and Davis, 1979; Thornton, 1979; Cole, 1983), and is toxic at high concentrations (Lee et al., 1990), as is the case with most other metals. The toxicity of Cu is largely attributed to Cu^{2+} (Sylva, 1976; Luoma, 1983; Abel, 1989) and $CuOH^+$ (Luoma, 1983), which is only present in small quantities in freshwater (Boyle, 1979). The cupric form of Cu speedily forms complexes with inorganic and organic substances and can be adsorbed onto particulate matter. As a result, free Cu ions rarely occur freely in water, except in acidic soft waters (Alabaster and Lloyd, 1980).

Fe exists commonly in two oxidation states in solution, i.e. the ferrous (Fe^{2+}) and the ferric (Fe^{3+}) (Wetzel, 1975; Cole, 1983; Department of Water Affairs and Forestry, 1993), with the latter the most common state found in surface waters (Department of Water Affairs and Forestry, 1993). The concentration and chemical behaviour of dissolved Fe is greatly influenced by organic complexing agents. According to Förstner (1979) and the Department of Water Affairs and Forestry (1993), Fe only exists as Fe^{3+} under highly oxygenated and in slightly acidic to alkaline conditions. On the other hand, the solubility of Fe^{2+} is facilitated by the presence of dissolved oxygen under strongly acidic conditions, usually at pH 3, as in the case of acid mine drainage (Förstner, 1979; Department of Water Affairs and Forestry, 1993). According to Wetzel (1975), the cycling of Fe is largely attributed to the oxidation-reduction conversion reactions, which are interdependent on other constituents and properties, of which microorganisms - belonging to the *Thiobacillus-Ferrobacillus* group - act as major mediators (Duffus, 1980; Cole, 1983; Department of