Bioaccumulation of chromium, manganese, nickel and lead in the tissues of the moggel, *Labeo umbratus* (Cyprinidae), from Witbank Dam, Mpumalanga

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Abstract

This paper focuses on the extent of Cr, Mn, Ni and Pb bioaccumulation in the different tissues of a cyprinid fish, namely the moggel (*Labeo umbratus*) from Witbank Dam in the Upper Olifants River catchment. The dependence of bioaccumulation on size, gender and seasons was specifically addressed. Bioaccumulation of Cr, Mn, Ni and Pb varied between the gills, liver, muscle and skin. The gills generally had the highest metal concentrations, due to their intimate contact with the environment and their importance as an effector of ionic and osmotic regulation. The liver, in its role as a storage and detoxification organ, can also accumulate high levels of metals. Muscles and skin accumulated much less metal concentrations. These two organs must be included in biomonitoring programmes because they are consumed by the general public. Accumulation of the metals decreased with an increase in fish length. Therefore, the smaller the fish the higher the body load of metals due to various bioaccumulation processes. The accumulation of Cr, Mn and Ni in the different tissues of male and female fish did not differ markedly. It is suggested that the male testes and female ovaries should also be compared, in order to obtain further data on the differences of accumulation of metals between males and females. The highest tissue concentrations of Cr, Mn, Ni and Pb with the exception of the muscle and skin tissues, were recorded in the summer of 1995. The higher metal concentrations in the summer, compared to autumn and winter, can possibly be attributed to a varied water temperature.

Introduction

It is well documented that pollutants, such as metals and organic compounds, can be accumulated by aquatic biota (USEPA, 1991). Bioaccumulation measurements refer to studies or methods monitoring the uptake and retention of pollutants like metals or biocides in organs and/or tissues of organisms, such as fish (Roux, 1994). This can only take place if the rate of uptake by the organism exceeds the rate of elimination (Spacie and Hamelink, 1985). There are five potential routes for a pollutant to enter a fish: via the food, non-food particles, gills, oral consumption of water and the skin. Once the pollutant is absorbed, it is transported by the blood to either a storage point (i.e. bone) or to the liver for transformation and/or storage. According to Heath (1991), if the pollutant is transformed by the liver it may be stored there or excreted in the bile or passed back into the blood for possible excretion by the gills or kidneys, or stored in fat, which is an extra-hepatic tissue. Therefore, the concentration found in different tissues, after environmental exposure, for a specific time, depends on several dynamic processes all taking place concurrently.

Chromium (Cr) is a relatively scarce metal, the occurrence and amounts thereof in aquatic ecosystems are generally very low (0.001 to 0.002 $mg \cdot \ell^{-1}$ - Moore and Ramamoorthy, 1984; DWAF, 1996). However, natural water may receive Cr from anthropogenic sources such as industrial effluents derived from the production of corrosion inhibitors and pigments (Galvin, 1996), which then becomes a pollutant of aquatic ecosystems and thus harmful to aquatic organisms (Srivastava et al., 1979). The toxicity of Cr is affected by species, body size and life stage of the organism as well as the pH of the water and, to a lesser extent, by hardness, salinity and temperature (Holdway, 1988). Fish are usually more resistant to Cr than other aquatic organisms, but they can be affected sublethally when exposed to concentrations ranging from 0.013 to 50 $mg \cdot \ell^{-1}$ (Olson and Foster, 1956; Van der Putte and Pärt, 1982) and lethally when exposed to concentrations ranging from 3.5 to 280 $mg \cdot \ell^{-1}$ Cr (Moore and Ramamoorthy, 1984; Van der Putte et al., 1981a; b). Chromium (VI) appears to pass readily through the gill membrane and accumulates rapidly in various tissues at higher levels than in the gills (Holdway, 1988), including the brain, gall bladder, gastro-intestinal tract, intestine, kidney, opercular bone, spleen and stomach (Fromm and Schiffmann, 1958; Buhler et al., 1977; Van der Putte et al., 1981b).

Manganese (Mn) is an essential micronutrient (Dallas and Day, 1993) and does not occur naturally as a metal in aquatic ecosystems (<1.0 $mg \cdot \ell^{-1}$ – Hellawell, 1986) but is found in various minerals and salts for example, $MnCaCO_3$ (rhodocrosite), MnO_2 (pyrolusite) and $MnSiO_3$ (rhodonite), with oxides being the only important Mn-containing minerals mined (Galvin, 1996). Although Mn demonstrates some significance as a pollutant (Hellawell, 1986), it is one of the first metals to show elevated concentrations in acidified waters (Bendell-Young and Harvey, 1986). According to Kempster et al. (1982), Mn is of moderate toxicity to aquatic organisms. Rouleau et al. (1996) recorded that Mn^{2+} uptake by brown trout was significantly increased at a low pH.

Nickel (Ni) occurs as four basic ores namely, arsenide, laterite, silicate and sulphide (Galvin, 1996). It is a natural ubiquitous element of the earth and in water (0.001 to 0.003 $mg \cdot \ell^{-1}$ – Snodgrass, 1980). Anthropogenic activities (i.e. mining, electroplating and steel plant operations) can result in Ni discharge into water and air (Galvin, 1996). Nickel ions tend to be soluble at pH values <6.5, and above 6.7 they mostly form insoluble nickel hydroxides (Dallas and Day, 1993). In aquatic ecosystems, dissolved Ni

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