Bioaccumulation of chromium, copper and iron in the organs and tissues of *Clarias gariepinus* in the Olifants River, Kruger National Park

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Abstract

An investigation was undertaken into the bioaccumulation of Cr, Cu and Fe in the gills, liver, muscle and skin of the fish *Clarias gariepinus* from two sites on the Olifants River in the Kruger National Park. During 1994, four surveys (February, May, July and November) were undertaken. Metal bioaccumulation was analysed using atomic absorption spectrophotometry and was then applied to differentiate between the concentrations found at the two locations, and between all of the surveys. The greatest concentration of Cr was detected in the gills, suggesting that this was the prime site of absorption and loss of Cr to and from the aquatic environment. The concentrations of Cu and Fe were highest in the liver, which is a storage and detoxification organ for metal, followed by the gills. Mamba and Balule generally showed very little difference in the concentration of bioaccumulated metal. However, the gills as in the case of Cr generally showed high concentrations at Mamba, while the liver as in the case of Fe, showed consistently higher concentrations at Balule. The possible effects that temperature, pH, hardness and salinity have on the individual metals, as well as bioaccumulation of these metals, are discussed in detail. The continuous monitoring of the quality of water in the Olifants River is imperative for the future sustainability of the Kruger National Park.

Introduction

In nature, aquatic animals are constantly exposed to metals. The species and concentrations of metals in water are determined by geochemical processes and large scale releases into the aquatic environment by human activities (anthropogenic activities) (Wittmann, 1979). Rapid industrial development, as well as the use of metals in production processes have led to the increased discharges of heavy metals into the environment (Koli et al., 1977). According to Förstner and Prosi (1979) the harmful effects of heavy metals as pollutants result from incomplete biological degradation. Therefore, these metals tend to accumulate in the aquatic environment. Since heavy metals are non-biodegradable, they can be bio-accumulated by fish, either directly from the surrounding water or by ingestion of food (Patrick and Loutit, 1978; Kumar and Mathur, 1991). In addition, Heath (1987) indicates that when metals reach sufficiently high concentrations in body cells they can alter the physiological functioning of the fish.

Toxic substances cannot easily be defined due to a number of factors that can influence and modify the toxicity of these substances. Metals are of particular interest in this regard. Some of the factors that can influence the toxicity of metals include:

- the metal species in the water;
- the presence of other metals or pollutants;
- abiotic factors such as temperature, pH, dissolved oxygen, hardness, salinity, etc.;
- biotic factors such as age, size, sex, stage in life history, adaptive capabilities; and
- Behavioural responses (Bryan, 1976b; Van Vuren et al., 1994).

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Chromium (Cr)

In natural waters the concentration of Cr is low and is within the range of between 1 and 2 μg/ℓ dissolved Cr (Moore and Ramamoorthy, 1984). Cr is used in industry for electroplating, steel-making alloys, in chrome plating, rubber manufacturing, leather tanning and for fertilisers (Babich et al., 1982). The toxicity of Cr is dependant on its chemical speciation and thus associated health effects are influenced by the chemical form of exposures (Holdway, 1988). There are four states in which the Cr ion is found: Cr^{2+}, Cr^{3+}, Cr^{5+} and Cr^{6+}. It is in the hexavalent form where Cr is allowed to cross biological membranes of aquatic organisms. Doudoroff and Katz (1953) indicated that hexavalent Cr behaves toxicologically in a manner quite different from most heavy metals. Because hexavalent Cr can readily penetrate gill membranes by passive diffusion and concentrate at higher levels in various organs and tissues, it can manifest its toxic action internally as well as on the gill surface (Knoll and Fromm, 1960; Buhler et al. 1977). Cr is particularly dangerous as it can accumulate in many organisms, sometimes as much as 4 000 times above the level of the surrounding environment as was noted in aquatic algae (Duffus, 1980).

Copper (Cu)

Copper is one of the most abundant trace metals and for almost all organisms it is an essential micronutrient (Duffus, 1980). Natural concentrations in water are at ≤5 μg/ℓ (Alabaster and Lloyd, 1980), but according to the Department of Water Affairs and Forestry (1993b) levels of 12 mg/ℓ have been recorded in South Africa. The increase in Cu pollution can be attributed to geological weathering, atmospheric deposition, municipal and industrial sewage (Moore and Ramamoorthy, 1984), the discharge of mine tailings and fly ash (the major source of solid Cu pollution), fertiliser production and algaecide and molluscicide runoff (Felts and Heath, 1984; Moore and Ramamoorthy, 1984).