

Determination and speciation of heavy metals in sediments of the Hartbeespoort Dam by sequential chemical extraction

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Abstract

The speciation of 10 heavy metals Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, V and Zn in Hartbeespoort Dam sediments was determined by applying a sequential extraction procedure.

Environmental risks associated with the potential remobilisation probability of these metals were evaluated. The results showed that with regard to total metal content, the sediments of the Hartbeespoort Dam would compare with moderately to heavily polluted fluvial systems in Europe and North America. The observed metal distribution patterns in the different sediment fractions, however, indicated that major proportions of most metals seemed to be associated with the inert fraction and could therefore be classified to be of geochemical origin. This result is supported by the extraordinary metal-rich rock types of the Transvaal complex in the area surrounding the Hartbeespoort Dam.

Introduction

The ecological significance of heavy metals follows from their general toxicity and the fact that they are non-biodegradable (Förstner, 1990). Metals released into an ecosystem tend to accumulate in sediments through various adsorption and precipitation processes. They thus become part of the ecosystem more or less permanently. Remobilisation processes in which natural waters provide the main pathways, can reintroduce these metals into the ecosystem in a bio-available form. The biomethylation of mercury in sediments by bacteria to form toxic methyl mercury is well-known. The destructive effect that such an event can have on fish and human populations was tragically demonstrated in Minamata, Japan, not so long ago (Ishimure, 1991). Metals can also be released into the water phase when conditions like pH, redox potential, ionic strength and the concentration of organic complexing agents, change (Calmano et al., 1990).

It is generally accepted that the composition of top sediment layers reflects the current quality of a natural water system. The determination of heavy metals in sediments and in particular the physico-chemical forms in which they occur, can provide information that is essential to the proper assessment of risk and to the long-term conservation and management of a natural water system. Speciation data can address the question of metal reactivity, which to a large extent determines its impact on the environment. Reactivity is dependent on the metal's physico-chemical form which in turn will dictate its interaction capacity with other components or biota and consequently its bio-availability and toxicity.

The physico-chemical forms of metals bound to sediment phases may be determined by sequential extraction procedures (Förstner, 1982). A series of chemical extractants are applied in order of increasing strength to extract metals from the sediment sample into each of 5 speciation categories. The contamination risks associated with polluted sediments can be assessed from the distribution of the metals among the different fractions of the sediment. The speciation fractions are essentially operationally defined by the chemical properties of the extractants used. Metals associated with the "adsorptive or exchangeable" fraction, the "carbonate", the "reducible" and organic fraction are considered to

be more mobile, therefore more easily released from the sediment and potentially more dangerous. These 4 fractions would include metals from anthropogenic sources and therefore give some indication of the degree of pollution to which a particular sediment has been exposed. Metals reporting to the "inert" fraction could be interpreted as originating from geochemical or natural sources.

In this study sediments from the Hartbeespoort Dam were subjected to the sequential extraction procedure proposed by Tessier et al. (1979). The purpose was to get some indication of metal distributions in the different sediment categories and to predict possible environmental risks associated with the 10 metals included in this investigation.

Metal speciation studies have been reported for many major natural water systems in Europe (Pardo et al., 1990; Rauret et al., 1989) and North America (Campbell and Tessier, 1987). Speciation data for South African natural water resources are, however, practically non-existent. This work is an attempt to make a contribution in this regard.

Materials and methods

Sampling and sample treatment procedures

Sediment samples were taken during March 1992 at 3 locations around the Hartbeespoort Dam as indicated in Fig. 1. A standard Ekman grab (Håkanson and Jansson, 1983) was used to collect about 1 kg of sediment at each of the sampling points. The inner core of each sample was transferred to polyethylene bottles and stored under nitrogen at -4°C.

Water samples were taken at Site 1 near the dam wall and analysed for major components by the Hydrological Research Institute at Roodeplaat Dam. The depth sampled varied between 0 and 22 m. Samples were taken at least every 2 weeks, totalling about 30 samples per month.

The moisture content of centrifuged sediment was determined in order to relate results to mass of dry sediment. The wet (i.e. centrifuged at 3 000 r/min for 30 min) equivalent of 1 g of dry sediment was used in the sequential extraction procedures. During all procedures samples were kept under nitrogen atmosphere to prevent oxidation of the anoxic sediments. Samples were analysed in triplicate. Sample treatment, extraction and subsequent analytical determinations were performed in a clean laboratory. All

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