

# Determination and partitioning of heavy metals in sediments of the Vaal Dam System by sequential extraction

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## Abstract

The partitioning of heavy metals in sediments of the Vaal Dam system was determined by applying a sequential extraction procedure. Environmental risks associated with the potential remobilisation of these metals, the capacity of the sediment to continue functioning as a sink and the possible origin of the metals were assessed. Despite the fact that the water level was at record lows, ca. 13% in the Vaal Dam, the extractable metal content of the sediments was low, indicating a relatively unpolluted system. Major proportions of most metals seemed to be associated with the inert phase and could be classified as of geochemical origin.

## Introduction

Approximately 99.5% of all water abstracted and treated by Rand Water is surface water obtained from the Vaal Dam and the Vaal River Barrage. Rand Water supplies potable water to some 60% of South Africa's industrial undertakings and to about 9 m. people. The raw water abstracted from the Vaal River Barrage is normally of inferior quality when compared to the water abstracted from the Vaal Dam. The Vaal Dam water is low in electrolytes, turbid and relatively unpolluted, and drains a rural agricultural area. The Klip and Suikerbosrant Rivers, draining the industrialised Witwatersrand area, are high in mineral content and have low turbidity. Approximately 55% of Rand Water's purified water is supplied to the southern side of the Witwatersrand divide. Of this water, 65% finds its way into the Vaal River Barrage as treated domestic and industrial effluent, mainly through the Klip River (Information from Rand Water).

Since the Vaal Dam is of great importance to millions of people, it is necessary to monitor the quality of the water. This is done on a continual basis by various organisations like Rand Water, Department of Water Affairs and Forestry and the CSIR. It is, however, not enough to monitor only the water quality and not the condition of sediments, since sediments accumulate pollutants, in particular trace metals. The resuspension of sediments and remobilisation of pollutants from sediments because of shifts in water/sediment equilibria, can substantially affect water quality. Analytical data on the particulate speciation of metals in different sediment phases could therefore provide valuable information to assess the condition of the system and to predict potential environmental risks.

The ecological significance of heavy metals follows from their general toxicity and the fact that they are non-biodegradable. The composition of sediments, in particular the top layers, affects the current quality of the natural water system. Sequential extractions (Batley, 1989) have been used for more than a decade to obtain data regarding the particulate speciation of metals in sediments. A series of chemical extractants is applied in order of increasing strength to extract metals from the sediment sample into each of four speciation categories. The contamination risks

associated with polluted sediments can then be assessed from the distribution of the metals among the different phases of the sediment. Despite many pitfalls in the interpretation (Nirel and Morel, 1990) of sequential extraction data, the procedures are widely used in Europe (Pardo et al., 1990). With extensive validation (Coetzee et al., 1995) of the procedure and the proper appreciation of the chemistry of the extraction processes involved, we believe that sequential extraction can provide useful information to environmental scientists, water authorities and sedimentologists. The procedure is very successful in distinguishing between metals originating from anthropogenic sources and metals of geochemical origin.

Particulate speciation data on sediments of rivers and lakes are common in Europe and North America. Speciation data for South African river and dam sediments are, however, not readily available. Coetzee (1993) studied the sediments of the Hartbeespoort Dam by sequential chemical extraction using the Tessier scheme. Kempster et al. (1991) carried out sequential pH extractions for iron, manganese, copper and vanadium on the sediments of the Loskop Dam and Phalaborwa Barrage.

In this work we applied the BCR (Community Bureau of Reference, Paris, France) protocol. This procedure (Ure et al., 1993) is being proposed as a standard method for sequential extractions which will enable comparison of results on a global basis when in general use. The BCR extraction scheme was validated by Coetzee et al. (1995) using defined model sediments prepared by mixing appropriate natural components found in typical South African sediments. The BCR procedure was used to obtain data on the sediments of the Vaal Dam system at a particularly interesting time in its historical cycle. Samples were taken in February 1995 when the dam was at a record low of 13%.

## Materials and methods

### Instrumentation and reagents

A Heto F.D. 1.0 freeze-drying apparatus was used to freeze-dry the sediment samples. Centrifugation was performed using a BHG Roto Uni II centrifuge. An ARL 35 000 sequential inductively coupled plasma atomic emission spectrometer (ICP-AES) was used for all metal determinations. Particle size determinations were performed on a small amount of freeze-dried sediment sample suspended in water by photo-correlation spectroscopy using a Malvern Zetamaster. A Phillips PW 1700 X-ray powder

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