

A pH-dependent sequential extraction procedure to determine mobilisation and transport of metals in sediments

L van der Merwe¹, PL Kempster¹, HR van Vliet¹ and JF van Staden²

¹Hydrological Research Institute, Private Bag X313, Pretoria 0001, South Africa
²department of Chemistry, University of Pretoria, Pretoria 0001, South Africa

Abstract

A pH-dependent sequential extraction procedure to determine mobilisation and transport of metals from sediments in the Vaal River-Koekemoerspruit confluence area was developed. The study was performed on the less than 0.2 mm particle size of the dried sediments. Ammonium/acetate extracting reagents were used and the extracts were analysed by using inductively coupled plasma (ICP) emission spectroscopy. The performance of the sequential extraction procedure was evaluated relative to a standard sediment. Differences can arise in using this sequential extraction procedure when naturally occurring soil types and ligands, which influence the extraction behaviour, are other than those used in this study. Arsenic, copper, zinc and manganese are mobile elements in the Vaal River-Koekemoerspruit confluence area and may have a possible environmental impact on the water phase.

Introduction

Sediments are important sources of trace metals as they receive physical debris and are sinks for a wide variety of chemicals (Adams et al., 1992; Adriano, 1986; Martin et al., 1987). They provide a matrix for living aquatic organisms (Pickering, 1981) and therefore, from the viewpoint of pollution to the environment, it is important to know whether trace metals in the sediment are in a readily available form. Metals are not necessarily permanently sorbed by sediments and can be released to the water column with changes in different environmental conditions such as pH, redox potential, concentration of inorganic and organic complexation agents (Adriano, 1986; Calmano and Förstner, 1983), salinity and dredging (Donze et al., 1990). Many workers (Aualiitia and Pickering, 1988; Brummer, 1986; Förstner et al., 1981; Gibbs, 1977; Meguellati et al., 1983; Tessier et al., 1979; Zeien and Brummer, 1989) have developed sequential "selective" extraction procedures for partitioning particulate trace metals into chemical forms likely to be released into solution under various environmental conditions. Non-selectivity of extraction procedures and trace element redistribution among phases during extraction are two major experimental problems with species-specific sequential procedures according to Kheboian and Bauer (1987). Furthermore, Nirel and Morel (1990) have shown that sequential extraction techniques cannot provide actual particulate speciation. For this reason it was decided to develop a sequential extraction procedure for a specific environmental problem.

South Africa is a water-poor country with considerable mining activities occurring inland. Treated acidic mine discharges into rivers inevitably have an impact on their water. Without doubt the resultant pH fluctuation will play a role in dissolving trace metals from the river bed sediment and changing the water-solid phase equilibrium. In investigating the effect of pH of extractant on the release of copper and lead from a sediment, Rauret et al. (1991) found that not only is the pH of the extractant solution of impor-

tance in release of metals, but also the rate at which the acid extractant is added as the pH is decreased. In the interior of South Africa rainfall tends to be sporadic and intense, with the result that rapid dilution of acid drainage occurs. During a rain storm large amounts of decomposing organic matter are washed into the rivers, thereby elevating ammonium ion concentrations. For this reason ammonium salt based buffers were used in designing the sequential pH extraction procedure.

The purpose of this study was to develop a sequential pH-dependent extraction procedure to determine whether various metals present in the sediment would be available to the water phase if the pH of the overlying water fluctuates. The data from the sequential extraction procedure will be useful in evaluating the pollution potential for mobilisation and transport of metals from the sediment under fluctuating pH conditions.

Materials and methods

Study areas and sampling

The Vaal River is one of the most important rivers in South Africa, being the principal water source for the many activities in the industrial heart of the country (Van Vliet, 1986). The catchment area is approximately 194 000 km². Industrial activity near the sampling site is dominated by the mining industry where mainly gold and uranium is mined. Using a core sampler, core sediment samples were collected from the riverbed at the Vaal River-Koekemoerspruit confluence region in the Vaal River catchment (Fig. 1). This area is geologically characterised by the Transvaal System which consists mainly of shale, quartzite and dolomite (Van Eeden, 1972). The reason these points were chosen was as a result of the historical study of Bruwer et al., (1983) who found high metal values in the sediments as well as in the water and because of the extensive mining activities in the Vaal River-Koekemoerspruit confluence area (Fig. 2). Ammonia is used in the uranium mining process and concentrations of approximately 1 mg/(N were found in the bottom waters. Periodic increases in ammonia are possibly due to releases from point and diffuse sources. The effluent standard for NH₄⁺-N in point sources in South

* To whom all correspondence should be addressed.

Received 1 April 1993; accepted in revised form 5 November 1993.