Analysis and distribution of metals in the Paraopeba and the Das Velhas Rivers, Brazil

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Abstract

Instrumental neutron activation analysis (INAA) and inductively coupled plasma - mass spectrometry (ICP-MS) were used to analyse water and sediment samples of the Paraopeba and the Das Velhas Rivers in the state of Minas Gerais, Brazil to assess the impact of mining activities on the water environment. Elemental concentrations of Cr, Fe, Co, Ni, Cu, As, Cs, Ba, La and Ce were measured in water and sediment samples collected in different parts of the Paraopeba River, the Betim River, one of its tributaries, and in the lake near the confluence of these two rivers. Results indicate an increase in the concentration of these polluting metals in an area of industrial discharge. Elemental concentrations of Cr, Fe, Co, As and Au were also measured in water and sediment samples in the Das Velhas River. It has been clearly demonstrated that the pollution of the Das Velhas River is associated with mining exploitation. One of its tributaries, the Itabira River, carries large concentrations of Fe and Cr, and the Agua Suja tributary is highly contaminated with As from a 20-year-old deposit known as *Morro do Galo*, and Au from the waste of a 160-year-old gold mine, owned by the *Morro Velho* Company.

Introduction

Minas Gerais is the fourth largest state of Brazil and the world's second largest producer of Fe mineral, having produced 199×10^6 t in 1998. Brazil has the world's 6th largest reserves of this mineral containing 60.0 to 67.0% hematites and 50.0 to 60.0% itabirite. Seventy per cent of these reserves are found in Minas Gerais State (Quaresma, 1999).

Minas Gerais' freshwater sources contribute, by hydro-electric generation, nearly 20% of the electricity produced in Brazil. The Paraopeba and the Das Velhas Rivers run through an "Iron Quadrangle" region rich in Fe, Au, Mn ores, and flow into the São Francisco River which is called, "The National Integration River" because it runs through four states and is used for navigation, recreation and sources of electricity production (COMIG, 1994).

The Paraopeba River receives wastes from about 70 large industries and mining companies. One of its tributaries alone, the Betim River, receives wastes from 57 industries (FEAM, 1996a).

Intensive iron-ore mining is carried out in the Das Velhas River region, and approximately 58 companies are involved in gold-mining and precious and semi-precious stone mining (FEAM, 1996b).

While environmental management is practised by the bigger mining companies, the smaller mines release significant quantities of mineral waste in geological and aquatic environments. The accumulation and the dissolution of metal elements cause serious river pollution, a critical problem for Minas Gerais Government. Studies of freshwater ecosystems in Minas Gerais are just beginning and ecological problems have been identified in rivers, lakes and reservoirs (Coelho and Giani, 1994, Jordão et al., 1999). The Foundation for the Environment of the state of Minas Gerais (*Fundação Estadual do Meio Ambiente -FEAM*) is responsible for water quality control and monitoring the Paraopeba and the Das Velhas Rivers. The graphite furnace atomic absorption spectrophotometry (GFAAS) has been used as a method of metal analysis in these river waters.

In this paper two other more sensitive analytical methods are proposed in water and sediment samples: Instrumental neutron activation analysis (INAA) and inductively coupled plasma mass spectroscopy (ICP-MS). INAA is a very accurate method for the analysis of solid samples. It has also been widely used for river pollution studies (Ambulkar et al., 1992, Revel, 1999, Dupré et al.,1996). ICP-MS is a very rapid method for the analysis of liquid samples and it can analyse more than 100 samples daily. It has been recently used to determine the composition of river water and sediment for routine trace analysis (Jarvis et al.,1992, Date and Hutchison, 1987). These two methods are multi-elementary and allow high-sensitivity determination of traces of several metal elements (Vandecasteele and Block, 1993, Pinte et al., 1998).

Experimental procedures

Water and sediment samples were collected along the Paraopeba River, from the region close to the source up to a distance of 170 km. In the Das Velhas River, the same procedure was carried out within 80 km. Sampling areas are indicated in Fig. 1.

Water samples were collected near the river bank at a depth of 15 cm, put into 125 mℓ bottles (Nalgene) stored at 4°C. Temperature, pH and electrical conductivity were measured on site. There were no significant differences in the various samples. The average values were: temperature 25°C, pH: 7.2, electrical conductivity: 30 μS/cm. The samples were acidified on site with 5 drops of ultrapure nitric acid (pH~2). This acidification is believed to reduce any sorption on the bottle walls (Mart, 1979). No filtration process was used in this study because it was tested and verified that filtration can be an important source of contamination (Veado et al., 1997a, Veado, 1997b). Before the analysis, all samples were centrifuged at 4 300 $r \cdot min^{-1}$ for 10 min to remove all suspended materials (Bailey et al., 1981; Laxen and Harrison, 1981; Veado et al., 1997a).

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