Distribution of selected heavy metals in fluvial sediments of the coal mining region of Baixo Jacuí, RS, Brazil

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Abstract The geochemical distributions of Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn were investigated to provide information about the mobility and availability of these elements in polluted sediments from the Baixo Jacuí region, southern Brazil. Sediment samples were collected at eight sites in the Conde stream, near coal mining and waste disposal areas, and in the Jacuí river, downstream from industrial activities. Total extraction results showed higher metals concentration at some sites, when compared to background values, as well as indicated by the calculated enrichment factor and geoaccumulation index. However, the results were insufficient to establish the existence of anthropogenic contribution to the studied area. The contamination was better evaluated by the sequential extraction. The geochemical distribution in the sediments of the Jacuí river revealed the presence of high concentrations of Cr and Cu in the oxidizable fraction, in response to effluent discharge from coal fired power stations and a steel plant. Higher percentages of the available fraction were verified in the Conde stream for the elements Cu, Fe, Ni, Pb, and Zn, indicating the sediment contamination by coal-related activities.

Keywords Geochemical distribution · Mobility · Sequential extraction · Heavy metals · Coal · Sediment

Introduction

The southern part of Brazil is known for its coal deposits, representing about 60% of the total national production (3 Mt/a), which is mainly used for the generation of electric energy. In Rio Grande do Sul State, 19% of the total coal reserves are located in the Baixo Jacuí region, on the Jacuí river watershed, where coal-related activities – mining and combustion – are well established. Some watercourses in the Baixo Jacuí region, such as the Jacuí river, receive direct and indirect effluents originating from coal processing and steel industry activities. The Conde and Ratos stream watersheds, located on the south of the Jacuí river, are characterized by the presence of coal mines. The Conde stream receives a direct and significant influence from coal waste deposits, which were disposed of inadequately, from the processing plants of mining companies.

Coal mines and industries in the Baixo Jacuí Region have affected the quality of surface waters, especially at sites under more direct influence of coal activities, as in the Conde stream (Vecchio and others 1996). On the other hand, no alterations of water quality have been demonstrated in the Jacuí river. This can be attributed to its great volume and water discharge (average of 885 m³/s and maximum of 5,688 m³/s, as reported by Baisch 1994) and large dilution capacity, as well as to sedimentation processes. Therefore, the load of metallic pollutants discharged into the Jacuí river is probably being accumulated in the sediments. These pollutants would be adsorbed preferentially to the finest particles and in different phases of the sediments, which are generally bioavailable.

There are many extraction techniques available to determine the fraction of metals bound to the labile sediment phases. Among several techniques used to verify the existence of anthropogenic contributions, sequential extraction has been cited by several authors as a method to determine the chemical distribution of heavy metals from contaminated sediments (Förstner and Salomons 1980; Förstner and Stoffers 1981; Pickering 1981; Campagnola and others 1995). This technique consists of the addition of a series of selective reagents to each fraction. Although several sequential extraction schemes have been developed and applied to sediments, the technique proposed by Tessier and others (1979) has been the most utilized method. Recently, the European Community (Ure and
others 1993; Fiedler and others 1994; Quevauviller and others 1994; Lopez-Sanchez and others 1998) proposed a method for sequential extraction consisting of three steps. This sequential extraction technique was used on the sediments of Baixo Jacuí region, in order to determine the geochemical distribution of heavy metals and to predict the mobility and bioavailability of these elements in polluted sediments.

**General setting of study area**

The study area covers the Baixo Jacuí region, a 5,126 km² subtropical area, which totally or partially embraces the municipal districts of Guaiaba, Eldorado do Sul, Charqueadas, São Jerônimo, Triunfo, Arroio dos Ratos, Butiá, and Minas do Leão (Fig. 1).

The Jacuí river basin has a surface of 71,600 km². The headwaters are located at 730 m a.s.l., in the Medium Plateau, and the river extends about 740 km towards the south from the plateau to the Guaiaba Lake estuary. The Conde stream watershed, located on the south side of the Jacuí river, has 364 km² of drainage area and extends for 53 km with an average gradient of 3.6 m/km (i.e., 200 to 7 m asl; Andreatta 1997).

The geologic setting of Baixo Jacuí region consists of Paleozoic and Mesozoic sedimentary formations and Mesozoic extrusive rocks of the Paraná Basin. Paleozoic formations occur on the south side of the Jacuí river and are composed of Permian clastic sedimentary rocks of the

**Fig. 1** Study area: Baixo Jacuí region, Rio Grande do Sul State, Brazil. Location of sampling sites and potential sources of pollution.