ORIGINAL ARTICLE

Contaminated soils and sediments associated with Zn ore metallurgy near the São Francisco River, Minas Gerais (Brazil)

Isabel Ribeiro da Costa[1] · Rita Fonseca[2,3] · Catarina Pinho[3] · Alexandre Araújo[2] · Luísa Catarina Martins[3] · Nuno Dias[3] · Ana Isabel Janeiro[1,4] · Guilherme Freitas[5]

Abstract

Draining through industrial areas of the Minas Gerais mining state (Brazil), some tributaries of the São Francisco River constitute a potential environmental hazard for this great river and threaten the quality of the regional soils for agriculture and other activities. Extensive geochemistry and mineralogy of sediments, soils and alluvial plains from six selected areas within the Consciência drainage basin close to an important Zn-extraction plant, have been carried out. In this report, detailed mineralogy of those samples and supporting geochemical data are discussed, taking into account their specific climactic and environmental context. Petrographic and electron microprobe characterization of the sand-grained fraction of these materials was complemented by XRD on their finer fraction: the main contaminant minerals are willemite (one of the Zn ores used in the industrial plant) and jarosite, though their contents are quite variable in the studied areas and also with depth; minor amounts of Zn-, Pb-, Cd-, and Mn-bearing mineral phases are also frequent, usually as inclusions in willemite or in polycrystalline clasts, or adsorbed on the finer materials, such as clay minerals and associated Fe-hydroxides. Mineralogical contamination is responsible for high metal contents in the soils and sediments of the areas closer to the plant (e.g. Zn $\gg$ 2000 mg kg^{-1} and Cd $\gg$ 20 mg kg^{-1}, which are the Intervention Values for Industrial Areas) and the greatest contamination risks are related to the more labile phases that circulate throughout the alluvial plains, the shallow sediments and the stream bed. Monitoring the mineral/chemical contamination and its extent also constitutes a useful basis for future proposals to remediate and recover this industrial area in order to decrease medium- and long-term negative impacts of metal contamination on the local and downstream environments.

Keywords São Francisco River (Brazil) · Environmental hazard · Contaminant metals (Zn, Cd, Pb, Cu, As) · Willemite · Sphalerite · Jarosite

Introduction

In aqueous environments, the mobility, bioavailability and levels of toxicity of dissolved metals are greatly variable, and metal associations and behaviour are controlled by changes in physical–chemical conditions related to both biological and geological processes. Some of the metals leached from sediments often constitute a potential environmental hazard (Warren and Haack 2001). High metal concentrations in mining or industrial drainage areas have adverse effects on aquatic resources and prevent reclamation of lands which have been mining sites (Price 2003).

Notwithstanding its considerable water flow, the São Francisco River (Minas Gerais, Brazil) has been increasingly contaminated by several industrial plants, as well as by agricultural and housing projects along its margins (Marinho

✉ Isabel Ribeiro da Costa
    imscosta@fc.ul.pt

1   Geology Department, Faculty of Science, University of Lisbon, Campo Grande, Edifício C6 – 4º Piso, 1749-016 Lisbon, Portugal

2   Department of Geosciences, School of Sciences and Technology, Institute of Earth Sciences, University of Évora, Évora, Portugal

3   AmbiTerra, Laboratory of Environmental Biogeochemistry, University of Évora, Évora, Portugal

4   Institute Dom Luiz, Faculty of Sciences, University of Lisbon, 1749-016 Lisbon, Portugal

5   Department of Security, Health and Environment, Votorantim Metais Zinco, Três Marias Unit, Três Marias, Brazil