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Distribution of heavy metals in sediments of a tropical reservoir in Brazil: Sources and fate

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ABSTRACT

Juturnaíba Lake has been utilized for the captation of water to supply over one million people in the Lakes Region, Rio de Janeiro, Brazil. The water treatment plant sludges have been directly disposed in the margins of the lake, constituting a potential threat for the water quality. The aim of the present work was to evaluate the geochemical processes that control concentrations and mobility of metals (Al, Cu, Fe, Mn, Pb and Zn) in the sediments of the Juturnaíba Reservoir, and whether they are affected by the disposal of the water treatment sludges. Sediment samples were collected from thirty-two stations in the Juturnaíba lake, and the total concentration of metals (pseudo-total concentrations), granulometry, total organic carbon, total nitrogen and total phosphorus concentrations were evaluated. Distribution maps and attenuation models were constructed. The results show that the metals concentrations are affected by the presence of large stands of the aquatic macrophyte *Egeria* sp. (Hydrocharitaceae). The sludges from the water treatment plants do not seem to contribute to the contamination of the sediments, probably because the mobility of the contaminants in the dumping piles is low.

1. Introduction

Heavy metals constitute an environmental threat, creating serious human health hazards and significant ecological effects through food chains. Once released in the environment, they may exhibit bioaccumulation and may be potentially genotoxic and carcinogenic, especially in animals that occupy the top of the trophic chain (Loska and Wiechula, 2003). They tend to accumulate in sedimentary environments, which become potential sources of these contaminants (Bidone et al., 1993). Metals may not remain permanently associated with the sediment; they can be remobilized into the water column, due to changes in environmental conditions, such as pH, redox potential, salinity or the presence of organic chelators (Soares et al., 1999). Zheng et al. (2008) observed that more than 90% of the heavy metals are swept away from the water column associated with the particulate matter and into the sediment. The major pathways of heavy metals to reservoirs are therefore the fluvial inputs.

In lakes like Juturnaíba (State of Rio de Janeiro), the sediment may be considered the ultimate destiny of heavy metals because solid substances accumulate over time, and soluble forms in the water may precipitate, flocculate, agglomerate and form complexes through adsorption to inorganic substances, which are ultimately deposited (Wasserman and Wasserman, 2008). Once settled, sediment concentrations show less variation over time and space with respect to the water column, and can provide an excellent indication of anthropogenic impacts, allowing a more consistent evaluation of the spatial and temporal variability of the contamination (Guevara et al., 2005).

Spatial surveys of metal concentrations in the sediment and comparisons between these concentrations and non-polluted baselines are a key step in understanding the transport and deposition of contaminants in aquatic systems (Alexander et al., 1993). However, relatively few studies in the tropical countries have focused on systems with dams, where heavy metals in the sediments might be affected by the prolonged water renewal time and increasing sedimentation rates (Kummu and Varis, 2007).

In the case of Juturnaíba Lake, part of the landscape was flooded after the construction of a dam (in 1982), without the removal of the riparian vegetation, favoring the development of anoxic conditions within the sediments and modifying the geochemical conditions, especially in the first ten years after the flood (Nowlin et al., 2005). The construction of the dam increased the water renewal

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time to almost 40 days (Bidegain and Völcker, 2003), thus favoring enrichment of the nutrients and stimulating the proliferation of aquatic macrophytes, particularly the species *Egeria* sp (Hydrocharitaceae). In turn, these organic matter enriched the sediments significantly interact with the metals, modifying its mobility and bioavailability (Hirata, 1985; Nissembaum and Swaine, 1976; Wasserman and Dumon, 1995).

Extraction of water for human use started in the early 1960s, long before the construction of the dam, with the installation of the Águas de Juturnaíba Water Treatment Plant in the margins of the ancient pond (Fig. 1). Some 3.5 km to the southwest of the first plant, a second treatment plant (PROLAGOS, Fig. 1) was installed in the late 1970's and until recently the sludge produced from the process of both stations was dumped directly into the pond next to the stations, forming large tailing piles. In 2012 the disposal of sludge was forbidden for both treatment stations, but the liability remains. The records of the activity of both stations show the application of aluminum sulfate and polyaluminum compounds to promote flocculation of suspended matter, but many other chemicals may be present in the sludge as well.

Whether the concentrations in the sediment are lithogenic, atmospheric (wet or dry deposition) or from the sludges of the water treatment plants is a question, because most of these facilities in developing countries discharges their residues in the environment, constituting a threat to the human health. Not only aluminum, but other heavy metals may contaminate the system and a better understanding of their behavior in the sediments is needed, because the system serves multiple purposes: water supply, flood control, agricultural irrigation, recreation and fishing. Therefore, the objective of this study was to elucidate the geochemical processes that control the mobility and the sources of the metals Al, Cu, Fe, Mn, Pb and Zn, by analyzing their distribution and relationship with nutrients phosphorus, nitrogen and total organic carbon.

2. Experimental

2.1. Study area

The reservoir of the Juturnaíba dam receives waters from the Capivari River (southwest), the Bacaxá River (south) and the São João River (north). According to data from FEEMA (1986), the reservoir is classified as mesotrophic and the annual precipitation in the region varies between 1500 mm and 2500 mm. The climate in the region is hot and humid tropical, with yearly average

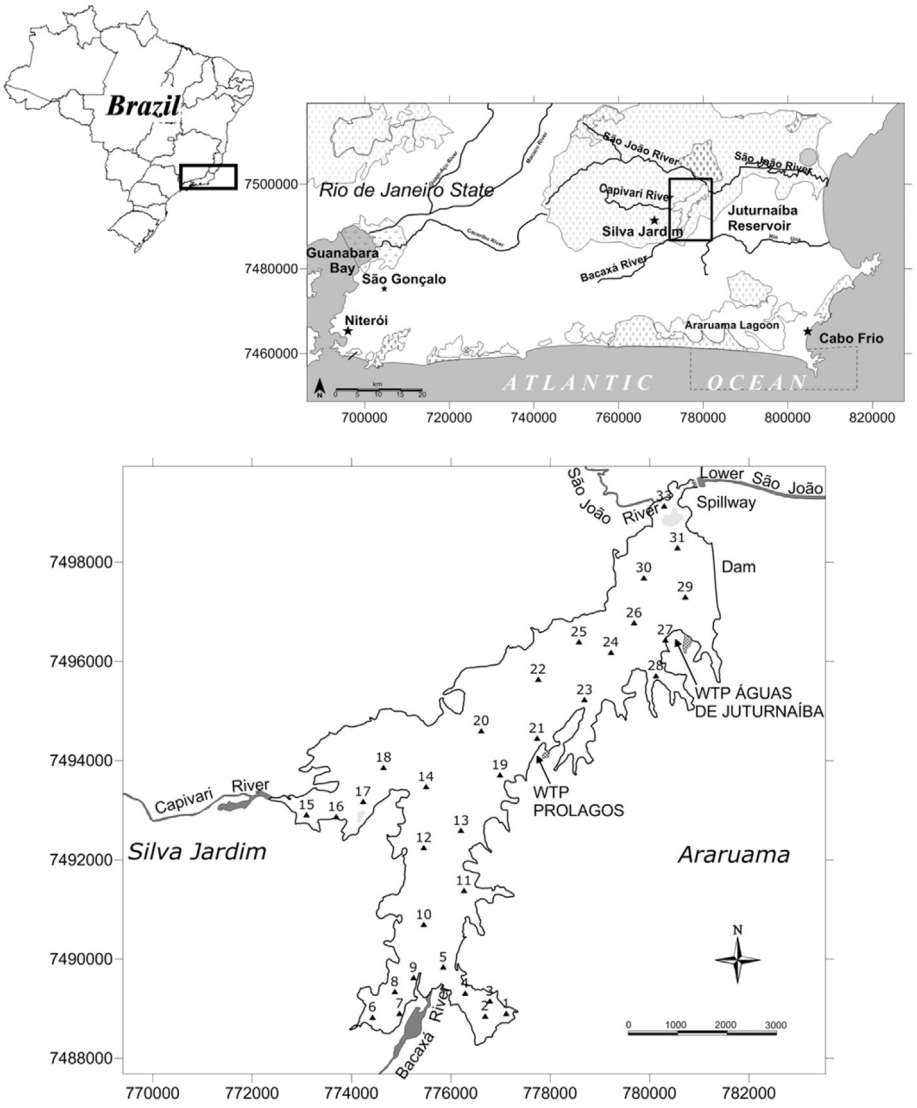

Fig. 1. Location of the study area and sediment sampling stations. WTP = Water treatment plant.