Surface Water on the Influence of the Carajás Mineral Province (Brazil) – Consequences to an Indigenous Community

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Abstract

The Cateté River belongs to the Itacaiúnas River watershed, including the most prominent mining area of Brazil with active mines of Fe, Cu, Ni, and Mn. This river has a high vulnerability associated with the drainage of mining effluents and crosses the "Xikrin-Cateté Indigenous Land".

Most water samples from Cateté river are neutral and poorly mineralized, but with high concentrations of Fe, Mn, Ni, Cu, Cr, Zn, and Pb. Some waters are contaminated and unsuitable for human consumption and agricultural activities. The water contamination is mainly associated with mine activities; however, Fe is also related to geological setting and lithologies.

Keywords: Potentially Toxic Elements, Mines, Itacaiúnas River, Contamination, Indigenous Communities

Introduction

The global concern is to ensure sufficiency in water quantity for public health, food security, and water access demand (UNESCO, 2019). Brazil contains the largest volume of freshwater of any nation in the world, with extensive rivers and containing about 12% of the availability of fresh water in planet (ANA, 2020). However, this natural resource is becoming scarce because of increased consumption, extended droughts, precarious distribution, inadequate treatment infrastructures, and water quality degradation, mainly associated to anthropogenic pressures (Val *et al*., 2019; Mello *et al*., 2020). Water resources are threatened not only by climate change scenarios but also by increasing levels of pollution, which has become a serious environmental problem on a global scale (Satapathy *et al*., 2009).

The diversity of geological environments gives Brazil one of the biggest mineral potential (Santana *et al*., 2020) and the second-largest producer of mineral ores in the world (National Minerals Information Center/US Geological Survey, 2017), with important reserves of iron, manganese, niobium, and nickel. Several Brazilian states, particularly Minas Gerais and Pará, are economically dependent on mining activities (Reis and Silva, 2015; Milanez *et al*., 2019). Mining activities, although relevant and indispensable for human socioeconomic development, accelerates natural processes and increases the likelihood of releasing toxic elements at higher rates in adjacent areas (Satapathy *et al*., 2009; Paraguassú *et al*., 2019; Alves *et al*., 2020). Mining regions constitute an important challenge in the management of water resources since its impacts could be an environmental risk and human health concern.

The generation of large amounts of solid waste and effluents, derived from mining activities, represents a potential source of contamination since potentially toxic elements (PTE) can be dispersed by the action of natural factors or accidentally leading to water by mine drainage (e.g., Lottermoser, 2007; Kipp *et al*. 2009; García-Lorenzo *et al*., 2012; Antunes *et al*., 2018).

Growing global concern about the protection of water quality has led to increasing attention to monitoring and risk assessment of PTE in water bodies (Sahoo *et al*. 2019). The main subject of this research is the evaluation of the water quality of the Cateté River, located in the south-eastern

region of the State of Pará - northern region of Brazil, and extensively used by an indigenous community.

Study area

The Itacaiúnas River watershed (05˚10´ to 07˚15´S latitude, 48˚37´ to 51˚25´longitude) is located in the Brazilian Amazonia, Carajás region, Pará State, Northern Brazil (Fig. 1). Amazonia contains most of the country's surface water (ANA, 2019). The population of Itacaiúnas River watershed is approx. 700,000 persons in an area of approx. 41,500 km^2.

Geologically, the area is in the southern portion of the Amazonian Craton, southwest region of the Carajás Mineral Province, one of the most important metallogenic provinces in the world, containing world-class Fe (iron) and Cu (copper) mines, as well as Mn (manganes) and Ni (niquel) ones (Vasquez *et al*., 2008; Sahoo *et al*., 2019). The Mineral Province of Carajás is divided into two geological domains: Carajás, specifically where the Xikrin TI of the Cateté River is located and Rio Maria domain (Vasquez *et al*., 2008).

Two of the main tributaries of Itacaiúnas River are the Cateté (western side) and Parauapebas (eastern side). The Cateté River has an extension of about 168.3 km and crosses the "Xikrin-Cateté Indigenous Land (XIL)" (Fig. 1). The Cateté and Itacaiúnas rivers supply the Indigenous Land, and water is considered by the indigenous community as a cultural and human belongs. However, the Cateté River has a high vulnerability associated with the drainage of effluents from mining activities and water contamination will promote a severe influence on the culture, leisure, and health problems of the indigenous community.

The XIL of the Cateté River corresponds to a national reserve area, which is traditionally occupied by indigenous communities, in an extension up to 438,000 ha, with a perimeter of approximately 360 km and a population of 1183 inhabitants, called "Caiapó-Xikrin population" (ISA, 2020). This reserve's territory is surrounded by agricultural activities and a contrasting between pasture vegetation and dense forest, with an abundance of species, especially chestnut (Costa, 2019). Rivers are the main determining factor on the human occupation and on the practice of indigenous culture, such as the natural human bathing, fishing activities and water management

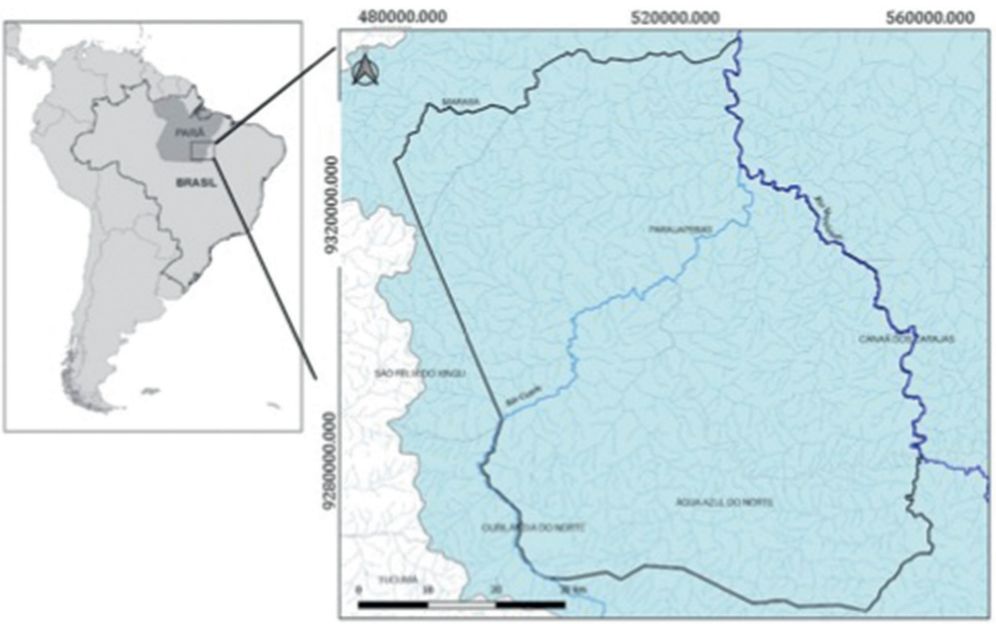

Figure 1 *Geographic setting of study area and delimitation of Xikrin-Cateté Indigenous Land area crossed by Cateté river.*

on indigenous food local production (e.g., manioc), as well as, on recreational activities (Corrêa, 2021). The indigenous community has been suffering severe impacts on cultural activities and health, because of the contamination of the water river.

Methods

A total of fourteen water samples were collected on the Cateté River around the area of Xikrin indigenous village (Fig. 2). The sampling water points were selected to characterize the water from Cateté River upstream and downstream the influence of mine drainage. The two villages - Cateté and Djudjekô – are located on the main influence of Cateté River and the river ports are represented by water samples PT06 and PT07, respectively (Fig. 2).

The physico-chemical properties - colour, turbidity, pH, Total Dissolved Solids (TDS), Biological Oxygen Demand (CBO5) and Dissolved Oxygen (DO) - and selected PTE – Copper, Chromium, Iron, Manganese, Nickel, Zinc, Lead, Mercury, and Aluminium from water were determined. To obtain a space-time water characterization, the water sampling was obtained twice in a year, to represent the raining season (January) and the wet season (June). The water parameters were determined in a certified laboratory, the Multi-Analysis Laboratory (Belém do Pará, Brazil) and according to Brazilian water frameworks and Standard Methods for the Examination of Water and Wastewater (CONAMA, 2005; Carvalho, 2015).

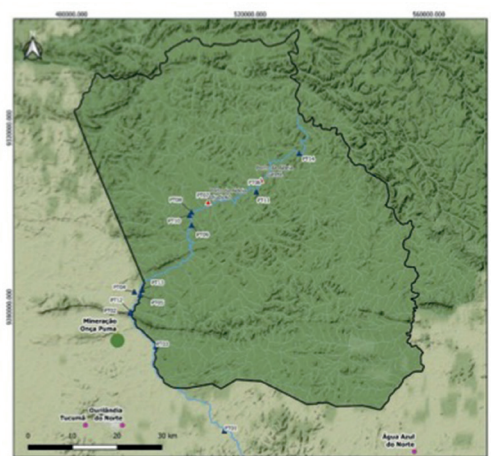

Figure 2 *Xikrin-Cateté Indigenous Land area and location of Cateté river sampling points (▲ – water sampling point; ▲ – river ports; ● – mine area).*

Results

Most water samples have pH values ranging from 6.0 to 8.0, are moderately oxygenated (Dissolved Oxygen = 5.4–10.4 mg/L) and poorly mineralized (TDS = 18–72 mg/L). The waters are slightly alkaline and are classified as mixed Ca-Na-HCO_3- type, indicating that they are mainly influenced by silicate rock weathering (Sahoo *et al.*, 2019). The variation of pH values from the water will be able to promote the increase in PTE contents absorbed into particulate matter (sediments). The relation between TDS and major ions suggest that rock weathering is the dominant process controlling water composition (Sahoo *et al.*, 2019).

Almost major ions and TDS water contents from Cateté river are higher in the rainy season than in the dry season like as been found in other surface waters from the Itacaiúnas River watershed (Sahoo *et al.*, 2019). The water of the Cateté River shows high concentrations of chemical elements, such as Cr (up to 0.09 mg/L), Fe (up to 13.3 mg/L), Mn (up to 1.78 mg/L), Ni (up to 0.04 mg/L), Zn (up to 0.5 mg/L), Cu (up to 0.13 mg/L), Al (up to 0.39 mg/L) and Pb (up to 0.05 mg/L).

In general, in the rainy period, there are higher Cr, Mn, Ni, Zn and Cu than in the dried period (Fig. 3), which could be associated to the increase of surface water flow and the mobility of these elements from sediments to water. Otherwise, Fe water contents tend to have higher values in the dry season probably due to a concentration effect. The Fe concentration in the water from Itacaiúnas river watershed and its tributaries, such as the Cateté river, is mainly associated to the natural geology of the area (Salomão *et al.*, 2020). However, the highest Fe content on the Cateté river water were found downstream the influence of mining activities (sample points PT08 and PT09; Fig. 3). So, the presence of Fe in the waters of the Cateté River is related with the geological setting and local lithology but is also influenced by the mining activities.

Some water points are contaminated with Fe, Mn, Ni, Cu, Cr, and Zn, and unsuitable for human consumption and agricultural activities (Fig. 3), according to CONAMA (2005). The water contamination of the Cateté river is mainly associated with mine activities developed in the area.

Conclusions

The Itacaiúnas river basin is located in one of the most important mining areas in Brazil, which includes mining activities with the exploration of lateritic nickel deposits. The Cateté River belongs to the Itacaiúnas River basin and has been the main receptor of effluents from these mining activities. These rivers supply the villages of the Indigenous Land, crossing the Xikrin Indigenous Community of the Cateté River. Rivers are determining factors in the positioning of indigenous communities, and their culture is heavily dependent on water, from daily activities that include the practice of fishing and the production of food products, as well as their use in recreational and fun activities.

The results of this study provided valuable information on PTE contamination in water resources located in an area from Itacaiúnas watershed occupied by an indigenous community. The characterization of surface water from Cateté river indicate that Fe, Mn, Ni, Cu, Cr, and Zn are potential contaminants, and exhibited higher concentrations that the reference values established by Brazilian national frameworks.

Although Fe and Ni mines are active in the region, high enrichment of Fe and Mn is not only related to mining, but rather to geological conditions ineherent to the Amazonian region, that where reinforced by land use changes (Salomão *et al.*, 2018). Very high concentration of Fe and Mn is the common geochemical signature of surface water in the Itacaiúnas river watershed (Sahoo *et al.*, 2019). The occurence and spatial distribution of PTE reflect different local geological and antropogenic factors active in the Itacaiúnas river watershed (Sahoo *et al.*, 2019). The main contamination source in the region is associated to mining activities, but also to natural geological background.

The obtained results in surface water reinforce the evidence of environmental and human health risks associated with mine activities and the relevant application of adequate preventive and monitoring methodologies. The mining sector has produced water quality degradation and environmental disasters in recent years. Enforcement of environmental laws, inspection and control from environmental agencies, application of measures and pressure from society are strongly needed to avoid water quality contamination from mining and continued disasters.

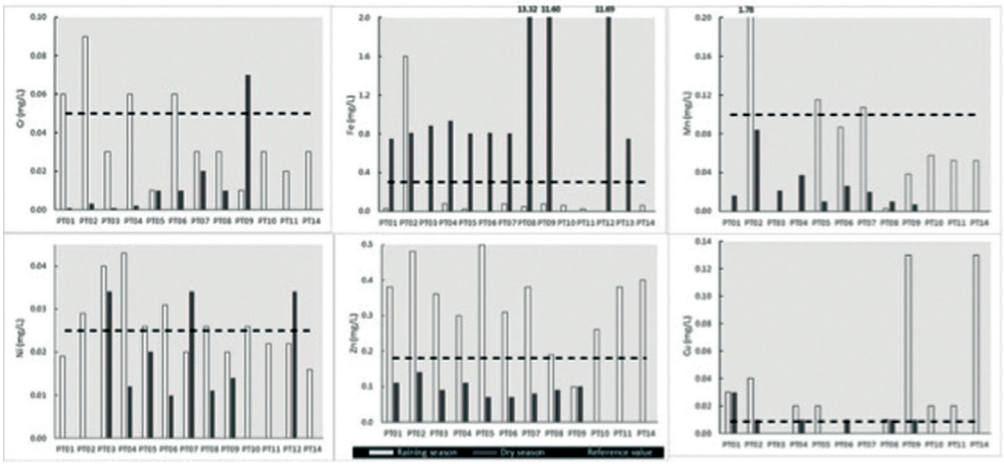

Figure 3 *Seasonal chemical variation in waters from the Cateté river. Reference value (CONAMA, 2005).*

This study will be a useful tool for the authorities responsible for environmental management, especially when assessing the impact of economic activities, such as mining and agriculture, on water resources in this climate region. Further studies that continue to monitor and assess the level of contamination of water resources in the watershed are crucial to preserving access to safe freshwater sources. The main motivation for this study comes for the recognition of the importance of the mining sector in Brazil and the significant environmental, social, and economic impacts attributed to the mining extraction processes. To the future is necessary more specific frameworks and tools for sustainability performance evaluation especially suited to the mining sector.

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