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Short Communication

The Samarco mine tailing disaster: A possible time-bomb for heavy metals contamination?

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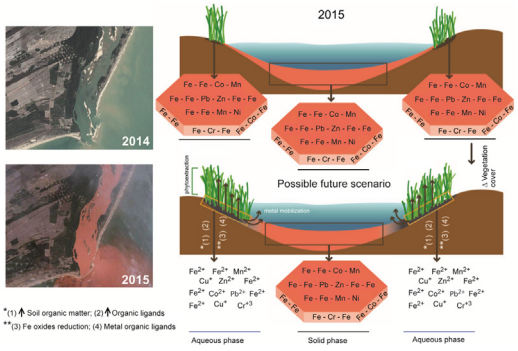
HIGHLIGHTS

- The largest dam failure occurred in SE-Brazil releasing tons of mine tailings.
- 17 days after the failure, the mine tailing reached an ecologically important estuary.
- The composition of estuarine soils indicates a trace metal enrichment caused by the disaster.
- <2% of the metals are readily bioavailable, being controlled by Fe-oxides.
- Fe reduction pathways may increase contamination risks.

GRAPHICAL ABSTRACT



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ABSTRACT

In November 2015, the largest socio-environmental disaster in the history of Brazil occurred when approximately 50 million m^3 of mine tailings were released into the Doce River (SE Brazil), during the greatest failure of a tailings dam worldwide. The mine tailings passed through the Doce River basin, reaching the ecologically important estuary 17 days later. On the arrival of the mine wastes to the coastal area, contamination levels in the estuarine soils were measured to determine the baseline level of contamination and to enable an environmental risk assessment. Soil and tailings samples were collected and analyzed to determine the redox potential (Eh), pH, grain size and mineralogical composition, total metal contents (Fe, Mn, Cr, Zn, Ni, Cu, Pb and Co) and organic matter content. The metals were fractionated to elucidate the mechanisms governing the trace metal dynamics. The mine tailings are mostly composed of Fe (mean values for Fe: 45,200 ± 2850; Mn: 433 ± 110; Cr: 63.9 ± 15.1; Zn: 62.4 ± 28.4; Ni: 24.7 ± 10.4; Cu: 21.3 ± 4.6; Pb: 20.2 ± 4.6 and Co: 10.7 ± 4.8 mg kg^{-1}), consisting of Fe-oxyhydroxides (goethite, hematite); kaolinite and quartz. The metal contents of the estuarine soils, especially the surface layers, indicate trace metal enrichment caused by the tailings. However, the metal contents were below threshold levels reported in Brazilian environmental legislation. Despite the fact that only a small fraction (<2%) of the metals identified are readily bioavailable (i.e. soluble and exchangeable fraction), trace metals associated with Fe oxyhydroxides contributed between 69.8 and 87.6% of the total contents. Control of the trace metal dynamics by Fe oxyhydroxides can be ephemeral, especially in wetland soils in which the redox conditions oscillate widely. Indeed, the physicochemical conditions (Eh < 100 mV and circumneutral pH) of estuarine soils favor

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Fe reduction microbial pathways, which will probably increase the trace metal bioavailability and contamination risk.

1. Introduction

In November 2015, the collapse of the Fundão dam (Samarco mining company) in Brazil led to the spillage of >50 million m^3 of mine tailings into the Doce River (*Rio Doce*, in Portuguese). The tailings were then transported 600 km downriver to the *Regência* estuary (Espirito Santo state, SE Brazil; Marta-Almeida et al., 2016). The incident represents one of the largest failures of a tailings dam ever recorded (Hatje et al., 2017) and caused extensive ecological and cultural damage (Carmo et al., 2017). The event led to the death of 19 people and thousands of fishes and invertebrates and is considered the largest socio-environmental disaster in the history of Brazil (Escobar, 2015; Fonseca and Fonseca, 2016).

Multidisciplinary studies have been conducted using different approaches to identify the ecological magnitude of the collapse and to investigate the impacts on the quality of the inland soils (Guerra et al., 2017; Silva et al., 2017), on estuarine benthic assemblages (Gomes et al. 2017), macrophyte growth (Bottino et al., 2017) and water quality (e.g. concentrations of dissolved metals and suspended solid material) along the river (Hatje et al., 2017). Although the baseline level of contamination was determined and early impact assessment of metal contamination on the Doce River basin was carried out (Gomes et al., 2017), the local drivers of trace metal bioavailability in the soils are not yet known. Knowledge of these drivers is crucial to understanding the environmental risks associated with the incident.

Estuarine wetland soils, which are very active ecological systems with a wide range of ecological functions and roles, are characterized as highly productive ecosystems (Barbier et al., 2011; Reed, 2005). Trace metal dynamics in these ecosystems are controlled by factors such as the frequency and duration of inundation, freshwater inputs, bioturbation and climatic variation, which control the redox potential (Eh), pH and organic matter content (OM) (Chapman and Wang, 2001; Ferreira et al., 2010; Du Laing et al., 2007; Machado et al., 2010). Because of the highly dynamic and variable characteristics of estuarine soils (Otero and Macias, 2002; Otero et al., 2017a, 2017b), sequential fractionation is a useful tool for environmental studies, providing valuable information about the association between elements and the solid phase and enabling assessment of the environmental impacts (Bacon and Davidson, 2008; Clark et al., 2000).

The objective of this study was to assess the contamination levels in the wetland soils affected by the tailing spillage in the Doce River estuary, thus providing baseline levels of contamination and identifying the drivers of the dynamics of the contaminants. This study also aims to contribute to assessing the potential effects that metal bioavailability may have on the impacted estuarine ecosystem.

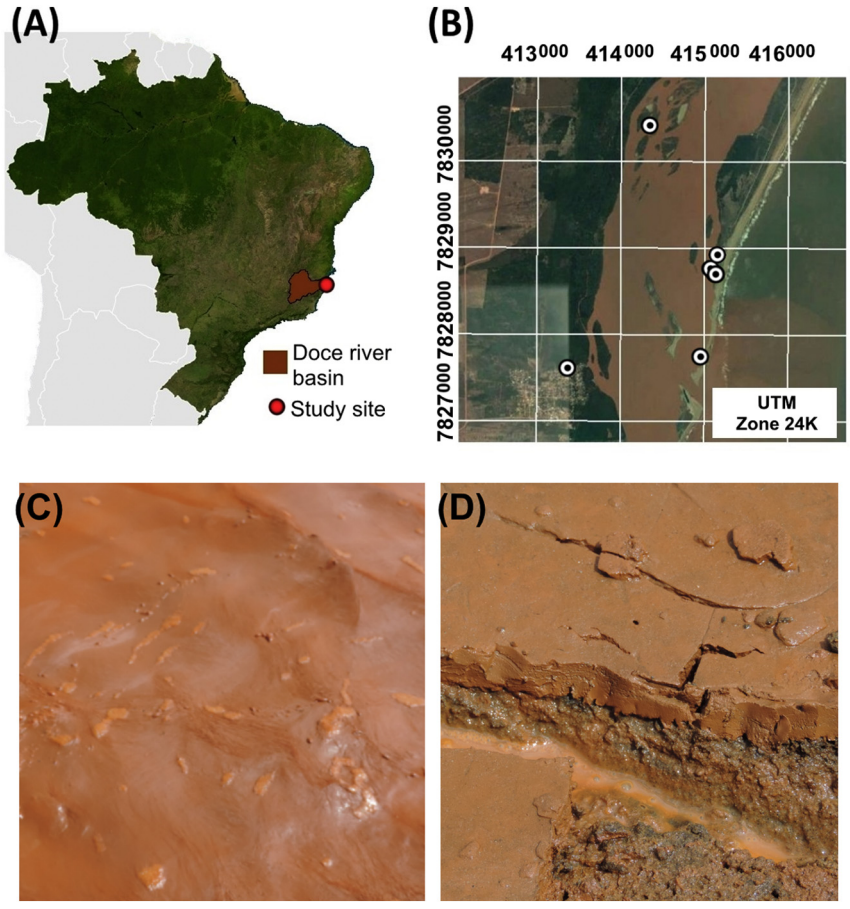

Fig. 1. (A) Location of the Doce River basin and (B) the sites sampled. In detail: (C) the water in the Doce River after the tailings spillage and (D) deposition of the tailings along the coastal wetland soils.