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Essays and Perspectives

Deep into the mud: ecological and socio-economic impacts of the dam breach in Mariana, Brazil

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ABSTRACT

We review the ecological and socio-economic impacts of the catastrophic dam failure in Mariana, Brazil. Tailing management practices by Samarco mining company ultimately caused a dam breach that abruptly discharged between 55 and 62 million m^3 of tailings into the Doce River watershed. On November 5th, 2015, a tsunami of slurry engulfed the small district of Bento Rodrigues, loading the Doce River and its estuary with toxic tailings along a 663.2 km trajectory, extending impacts to the Atlantic coast. Acute ecological impacts will adversely affect livelihoods of more than 1 million people in 41 riparian municipalities by reducing local access to fisheries resources, clean water, crop production sites, hydroelectric power generation and raw materials. The threats to riverine human communities are

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particularly critical for the disadvantaged populations from remote areas that rely on subsistence agriculture and fisheries, and are uniquely vulnerable to long-term heavy metal exposure. At the landscape scale, we predict multiple negative impacts, ranging from alterations of the genetic diversity of fish populations to long-term vegetation loss and poor regeneration in contaminated areas. Consequently, compromised soil stability and runoff control will increase the risk of further geomorphologic disturbance, including landslides, bank failure and mass movements. We propose spatially explicit long-term monitoring frameworks and priority mitigation measures to cope with acute and chronic risks. We posit that, from a national perspective, disastrous impacts like that of Doce River may become more frequent, given the recent regulatory changes that undermine both institutional governance structures and enforcement of environmental regulation.

Introduction

On November 5th, 2015, Brazil experienced its worst ecological disaster when an iron mine dam (Fundão dam) failed in the municipality of Mariana, State of Minas Gerais (MG), releasing metal-rich tailings waste in concentrations that endanger human and ecosystem health. Imprudent management practices by the mining company Samarco (co-owned by the Brazilian Vale and Australian BHP Billiton) caused a breach that discharged 55–62 million m^3 of iron ore tailings slurry directly into the Doce River watershed (GFT, 2015). The volume of tailings released by the Fundão Dam represents the largest tailings dam burst in modern history, exceeding magnitudes of the two previously largest incidents in the Philippines in 1982 (28 million m^3) and 1992 (32.2 million m^3) (IBAMA, 2015a). The slurry tsunami engulfed the small district of Bento Rodrigues, destroying cultural heritage dating to the 1700s, displacing its entire population (600 people) and killing at least 19 people (MB, 2016). The mine slurry filled hydrologic networks along 663.2 km of the Doce River through the states of Minas Gerais (MG), and Espirito Santo (ES) before reaching its estuary, in the city of Linhares (ES) (INPE, 2015). The disaster currently represents the longest travelled distance by tailings in a dam failure event in South America (previous record being ca. 300 km in Bolivia in 1996) (IBAMA, 2015a). Due to the action of northward ocean currents in the Atlantic, fine suspended sediments have spread through marine habitats of the Brazillian coast (Bianchini, 2016). Consequences at broader spatial scales, including international waters through the transboundary movement of suspended sediments, remain largely unknown.

The Fundão tailings dam breach can be considered one of the worst in the last century regarding the volume of tailings released to the environment and the magnitude of socio-economic and environmental damages. Current cost estimates for restoration of the threatened Brazilian Atlantic rain forest ecosystems are around 20 billion dollars (GFT, 2015). The interwoven ecological and socio-economic impacts have affected hundreds of thousands of people in 41 cities across the Doce River basin (GFT, 2015). The destruction of riparian, freshwater and marine ecosystems eliminated irreplaceable natural resources and ecological processes that support traditional livelihoods, disrupting fisheries, agriculture, tourism and provisioning of fresh water. Here, we analyze the ecological and socio-economic impacts of the incident, highlight the lessons learned and propose integrated management and policy solutions for monitoring, mitigation and prevention of future catastrophic tailings from dams in Brazil.

Impacts to landscapes and habitats

Effects on flora and aquatic habitats were severe and most likely persistent throughout the entire watershed. A few days following the disaster, analysis of surface reflectance data in Landsat-8 images allowed measurements of the extent and intensity of the damage by the released tailings. Spatial analys developed according to the protocols of the GeoForschungsZentrum-GFZ-Postdam team, Germany (Mielke et al., 2014, 2015), identified significant vegetation loss and deposition of tailings with extreme high concentration of iron along the Doce River, at altitudes ranging from 0 m on the river delta, in Resende (ES), to 950 m in Mariana (MG) (Figs. 1 and 2). The devastation impacted approximately 1469 ha of natural vegetation and 90% of the riparian habitats of the Fundão, the North Gualaxo and the Carmelo Rivers (Fig. 3).

The tailing deposits were scattered over the affected regions, reaching widths of more than 1 km in areas immediately downstream of discharges in the city of Mariana (Fig. 1). Waste slurry, sediments and enormous volumes of uprooted plant biomass filled the main downstream channels, creating irreversible damage to 663.2 km along affected watercourses (Fig. 4). The potential extent, magnitude and reversibility of the impacts of sediment deposition over pelagic habitats, coral reefs, seaweed beds, and mangroves in the affected regions of the Brazilian coast are unknown. Preliminary data have indicated that suspended sediments may have spread for up to 200 km into the ocean resulting in even broader-scale impacts on marine systems, resulting from mobility of particulate-associated contaminants (Bianchini, 2016).

The Doce River Basin has 98% of its area inserted within the Atlantic Forest biome (83,400 km^2), one of the world's 34 hotspots for biodiversity conservation due to high levels of