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Brazil's worst mining disaster: Corporations must be compelled to pay the actual environmental costs

Letícia Couto Garcia,[1,4] Danilo Bandini Ribeiro,[1] Fabio de Oliveira Roque,[1,2] Jose Manuel Ochoa-Quintero,[1,3] and William F. Laurance[2]

[1]*Centro de Ciências Biológicas e da Saúde, Universidade Federal de Mato Grosso do Sul, CP 79070-900, P.O. Box 549, Campo Grande, MS, Brazil*
[2]*Centre for Tropical Environmental and Sustainability Science, College of Science and Engineering, James Cook University, Cairns, Queensland 4878 Australia*
[3]*Corporación para Investigaciones Biológicas, CIB, Cra 72 A No 78 B 141, Medellín, 050034 Colombia*

Abstract. In November 2015, a large mine-tailing dam owned by Samarco Corporation collapsed in Brazil, generating a massive wave of toxic mud that spread down the Doce River, killing 20 people and affecting biodiversity across hundreds of kilometers of river, riparian lands, and Atlantic coast. Besides the disaster's serious human and socioeconomic tolls, we estimate the regional loss of environmental services to be ~US$521 million per year. Although our estimate is conservative, it is still six times higher than the fine imposed on Samarco by Brazilian environmental authorities. To reduce such disparities between estimated damages and levied fines, we advocate for an environmental bond policy that considers potential risks and environmental services that could possibly be impacted by irresponsible mining activity. Environmental bonds and insurance are commonly used policy instruments in many countries, but there are no clear environmental bond policies in Brazil. Environmental bonds are likely to be more effective at securing environmental restitution than post-disaster fines, which generally are inadequate and often unpaid. We estimate that at least 126 mining dams in Brazil are vulnerable to failure in the forthcoming years. Any such event could have severe social-environmental consequences, underscoring the need for effective disaster-management strategies for large-scale mining operations.

Key words: biodiversity losses; compensation; environmental policies for mines; liability to damages; Payment for Environmental Services; rehabilitation; restoration; tailings dam failures.

Introduction

Mining-related disasters have frequently been in the headlines, most recently with the collapse of a major mining dam in southeastern Brazil. This collapse released an enormous flood of toxic mud that spread down the Doce River in the state of Minas Gerais (Fig. 1), the second-most extensive river of the Southeast Atlantic. Immediately, about 17 km^2 of land were directly destroyed by the event, including the uprooted vegetation of 8.35 km^2 of critically imperiled Brazilian Atlantic riparian forest (SOS Mata Atlântica and INPE 2015, IBAMA 2016*a*).

This disaster killed 20 people and millions of freshwater fish, degraded local indigenous lands, and polluted the sea in a vulnerable turtle-nesting area. One year later, the limits of the disaster are still uncertain. There is evidence that the 7000 km^2 of toxic plume has reached important biodiversity conservation areas in the Atlantic Ocean, including Abrolhos National Park, one of the most emblematic protected areas in Brazil, and three other marine protected areas, Costa das Algas, Santa Cruz, and Comboios in Espirito Santo state, threatening endemic and rare species of marine fauna (Morandini et al. 2009, Fioravanti 2016, IBAMA 2016*b*, Miranda and Marques 2016). Models of river discharge dispersion predict long-term consequences near the city of Rio de Janeiro (Marta-Almeida et al. 2016) and the consequences of the dam burst in the Atlantic Ocean are still not fully assessed. Chemical contaminants, which could accumulate in ocean sediments, can be reinjected into the water column by disturbances (e.g., storms, animal movements, human activities) resulting in recurring contamination over time (Mahiques et al. 2016).

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[4]E-mail: garcialcbio@yahoo.com.br

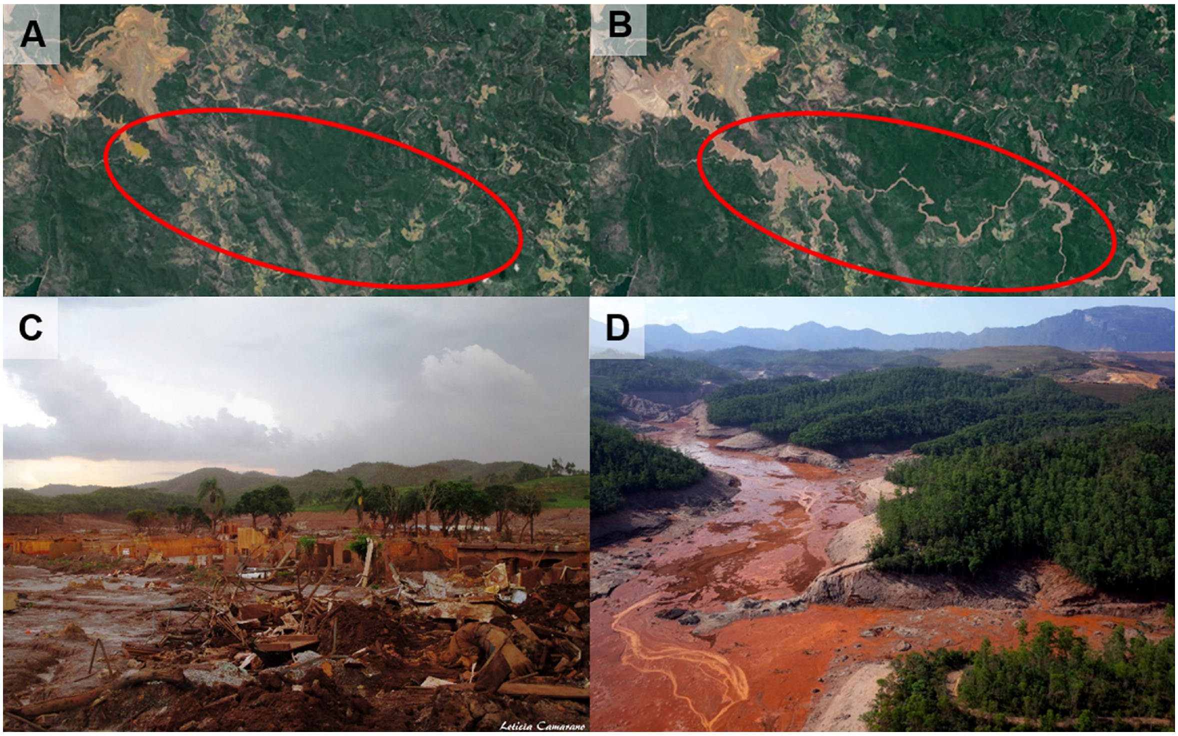

FIG. 1. The region near the mine-tailing dam in Minas Gerais, Brazil (A) before and (B) after the disaster (red circle). Also shown is the Doce River (C) immediately after the dam burst and (D) vanishing under an enormous wake of toxic mud. Photo credits: panels A and B, NASA/GSFC/METI/ERSDAC/JAROS and U.S./Japan ASTER Science Team; panel C, Letícia Camarano; and panel D IBAMA photo database. (Color figure can be viewed at wileyonlinelibrary.com.)

An independent network of scientists analyzed samples of the Doce River after the dam collapse and found elevated arsenic, lead, cadmium, chromium, nickel, selenium, and manganese, all above legally mandated levels (Escobar 2015, GIAIA 2016). Leaching/extraction tests also suggested that Ba, Pb, As, Sr, Fe, Mn, and Al have high potential mobilization from mud to water and toxicological bioassays in mud and soil samples indicated potential risks of cytotoxicity and DNA damage (Segura et al. 2016). This contradicts reports from the Samarco, the corporation responsible for the tailing (mine-waste) dams, and the government stating that heavy metals in the Doce River are within acceptable limits.

The Doce River and its tributaries host many endemic fish and molluscs, including recently described species (Roxo et al. 2014, Salvador and Cavallari 2014) that may be locally endemic. Besides chemical pollution, the heavy sludge that spilled into the river reduced oxygen availability, increased turbidity, interrupted reproductive movements of many migratory fish species, and may be altering the functioning of entire ecological networks (Lambertz and Dergam 2015, Massante 2015). In the heavily fragmented Atlantic-forest biodiversity hotspot, active habitat-restoration programs can require decades to restore some complex ecological interactions and functions (Garcia et al. 2015, 2016). A massive dam burst like that at the Doce River could require considerably longer time periods for rehabilitation and reclamation. Abandoned mines often retain high levels of associated metals over many decades (Younger 1997). Tailings spills that occur over large areas, such as at Doce River, could potentially contaminate sediments and groundwater for long periods if an effective effort is not made to remove the tailings by plowing contaminated soils (Fields 2001, Simón et al. 2001).

Environmental loss and corporate responsibility

The dramatic scale of this event raises a fundamental question: How can disaster-management strategies incorporate the risk of serious loss of biodiversity and environmental services?

Compensation payments are one useful policy instrument for bringing some justice to those affected by human activities that cause social and environmental disasters. In the case of the Doce River, beyond the human death toll and water and soil contamination, important socioeconomic activities such as fishing will have to be halted indefinitely. In addition to funding needed for rehabilitation and reclamation activities, the compensation process should account for the loss of key environmental services (Neves et al. 2016), including the loss of provisioning services like fishing. Mining disasters have stimulated proposals of compensation frameworks and mechanisms that account for environmental services and restoration time lags (Laurance 2008, Bai et al. 2011, Vela-Almeida et al. 2015). One way to set the appropriate compensation level is to multiply the per hectare environmental service value of the Doce River region before the disaster by the Doce River watershed area. A contingent valuation survey before the disaster estimated a US\$62.53·ha^{-1}·yr^{-1} of Payment for Environmental Services (PES) in some site of the watershed (Oliveira et al. 2013). The Doce River watershed spans 83400 km^2 (Euclydes 2010), roughly the size of Austria. The main river was completely jeopardized as well as some tributaries (the extension of water bodies directly affected was >650 km), releasing toxic substances that can bioacccumulate through the entire food web (Miranda and Marques 2016). Hence, the spill likely impairs the whole watershed. Multiplying the PES and watershed area values yields a total value of US\$521 million per year (values in Portuguese can be found in Appendix S1). This value is conservative, as it does not incorporate some vulnerable environmental services (such as the value of individual species, pollination and seed dispersal processes, genetic resources, and oceanic impacts).

This estimated annual loss is still nearly six times higher than the sum of all seven fines imposed by the Brazilian Environment Agency (IBAMA), which totaled ~US\$90 million (the values of the applied fines have reached the maximum value allowed by Law). Subsequently, several levels of Brazilian governments and Samarco tried to reach an agreement on further restitution (~US\$6.15 billion; BHP Billiton 2016*a*), but the Brazilian Superior Court of Justice suspended these negotiations (STF 2016). Even in the unlikely event that this entire agreed-upon amount was reinstated and solely allocated to rehabilitation and reclamation activities, it would only cover 12 years of environmental service losses. Twelve years is only a fraction of the time required for full environmental reclamation over such a large and severely affected region. More hope for more appropriate restitution comes from the Public Civil Suit filed last May by the Brazilian Federal Public Prosecution Service (~US\$47.7 billion; BHP Billiton 2016*b*). This suit includes 200 different requirements for social, environmental, and economic compensation. However, even if this suit is successful, it will be very challenging to get Samarco to pay. Until now, Samarco has appealed on all fines, the Public Civil Suit, and a number of ongoing legal cases. According to Brazilian Environmental Agency (IBAMA), from 2011 to 2014, only 8.7% of all levied environmental fines were paid in Brazil. Hence, there is not much hope that the fines imposed by the courts in this case will be paid.

In addition to setting appropriate compensation payments, a clear policy for compelling corporations to maintain high levels of environmental risk management could help prevent disasters (Gerard 2000, White et al. 2012, Edwards and Laurance 2015). For example, consider the current policy on the management of tailing ponds. Tailings of ores deposited in dams are not considered "hazardous waste," so they are not subject to the Brazilian Environmental Crimes Act. This means that the hazardous waste-management plans, including measures to reduce the volume and danger of waste and liability insurance for damage to the environment or public health, are not required for tailing ponds. A bill is being considered by the Brazilian Congress to close this loophole for dams near human communities, but this proposal does not include protections for biodiversity. As pointed out by Meira et al. (2016), the mining lobby in Brazil is so powerful that the Samarco fine payments have been made contingent on the company being allowed to

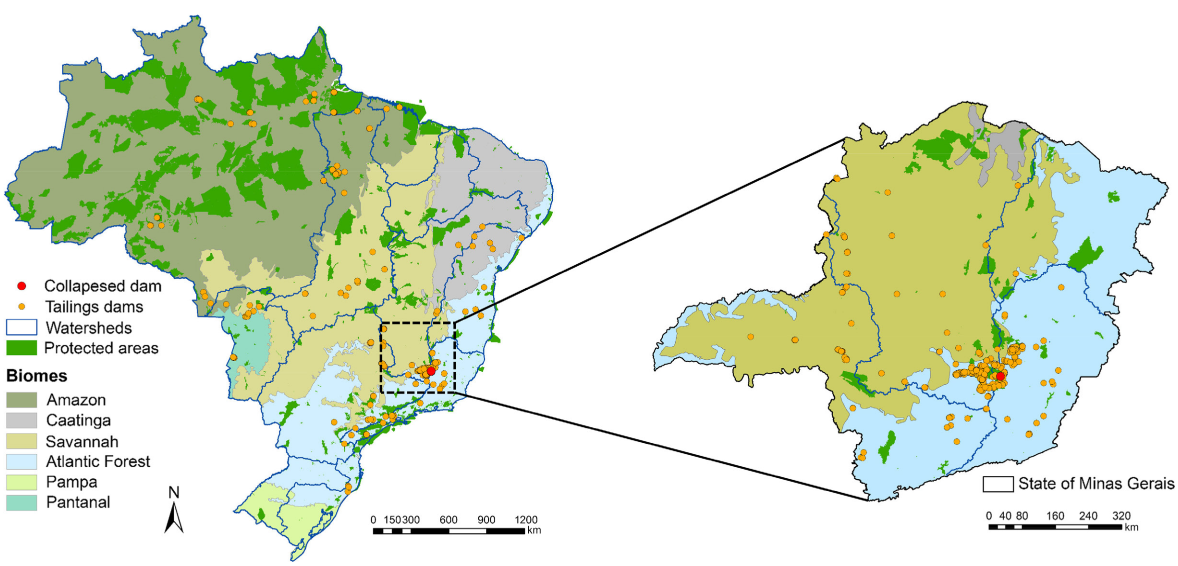

FIG. 2. (A) Available database of active mine-tailing dams in Brazil (orange circles) in different watershed region boundaries, showing their distance from various conservation units (highlighted in green). Although 662 tailing dams are registered in Brazil, coordinates are available for only 317 tailing dams from the national mining-dam cadaster in Brazil (DNPM 2015). (B) Inset of 293 available coordinates of tailings dams in Minas Gerais state, with the Bento Rodrigues Dam shown in detail (red circle) (see Data S1, available data [up to 12 May 2016] for 426 registered mine-tailings dams from the Foundation of the State Environment; Minas Gerais [FEAM]). (Color figure can be viewed at wileyonlinelibrary.com.)

reopen other mining activities in the region. In addition to better laws and policies for controlling mining operations, new techniques for waste-storage facilities, such as removing free water in tailings ponds, is essential strategies for reducing risk (Franks et al. 2011, Jones and Boger 2012).

As part of an environmental policy for mines, environmental bonds could also be used to incentivize mining companies to improve monitoring systems and management. In this case, an environmental bond is created when corporate funds are deposited in advance of a mining activity and are held in escrow until the end of mining and released when reclamation operations are successfully completed (Gerard 2000). The financial coverage provided by this bond could be based on the relative risk of the mining activity and the potential loss of the environmental services. By making bonds mandatory, companies that do not have the capital to cover potential accidents or propose very risky operations will not be able to go ahead with their initial plans. Hence, they will have to reduce the potential size and/or risk of their operation to move forward. If well planned, this policy could markedly improve enforcement of environmental regulations while encouraging mining corporations to minimize their risks and liability, thereby increasing environmental safeguards. It would certainly be better than the status quo. Although, some bills have been introduced to legislate minimum compulsory environmental insurance (e.g., Senate bill PL 767/2015), so far, Brazil has lacked a clear policy strategy and regulatory framework for environmental bonds and insurances. For instance, last July, the Minas Gerais state Public Prosecution Service filed a bill (#3695/2016) originated in a popular initiative that includes an "environmental bond" to social-environmental responsibilities in case of damages, which would be mandatory for prior mining licensing (Legislative Assembly of Minas Gerais 2016). There are several environmental bond or insurance strategies used in other countries, including Australia and the USA (Gerard 2000, Boyd 2002, White et al. 2012), which could serve as a model for a similar policy in Brazil.

The urgency of such actions is underscored by the fact that there are hundreds of active mine-tailing dams in Brazil (Fig. 2), with watersheds in Amazonia, the Pantanal, Cerrado, Caatinga, and Atlantic Forest biomes being at risk. According to the national mining-dam cadaster in Brazil (DNPM 2015), the collapsed Doce River dam was considered a low accident risk, and only 8% of existing tailings dams are considered high risk. We believe these risks are underestimated. Brazil has had more than 80 mine-related environmental disasters, and an inventory of South American mining sites over the last century found an overall failure rate of 19% (Azam and Li 2010, Nazareno and Vitule 2016). On that basis, and given the large number (662) of existing tailings dams in Brazil (DNPM 2015) (Fig. 2 and see Data S1 for existing tailings dams in Minas Gerais), we estimate that 126 existing mining dams could eventually be expected to fail.

Mining activities are having huge environmental and social impacts in Brazil. The loosening of certain environmental laws (Ferreira et al. 2014, Sugai et al. 2014, Brancalion et al. 2016, El Bizri et al. 2016, Meira et al. 2016), the granting of new mining concessions in protected areas, and a ban on new protected areas in regions of high mineral potential are being hotly debated both publicly and in the Brazilian Congress. Despite recent reverses in environmental law, there are bills that aim to avoid new disasters currently being considered in the Brazilian Congress (PL 4286, 4287/2016).The Doce River calamity serves as a timely warning that urgent actions are needed to limit the risks of serious mining damage both in Brazil and worldwide.

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