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Mapping of the Decharacterization of Tailings Dams in State of Minas Gerais, Brazil

Ana Manoela de Castro Santos
Teacher, Unidade de Ensino Superior de Feira de Santana, Feira de Santana, Bahia, Brasil,, eng.manoelacastro@gmail.com

Felipe Costa Albquerque
MsC, Budapest University of Technology and Economics, Budapest, Hungary, fcalbuquerque@zoho.comb

ABSTRACT: In Brazil, the failures of the Mariana and Brumadinho dams in Minas Gerais resulted in approximately 300 fatalities and 4 additional disasters. These events caused widespread destruction of communities, environmental manipulation, and pollution of one of the largest regional rivers. Consequently, the legislative process accelerated toward the decharacterization of upstream mineral tailings dams, leading to the enactment of Law No. 23,291 in 2019. This law established the State Policy for Dam Safety in Minas Gerais, aligning with the National Safety Policy for Dams (PNSB). Therefore, this work aimed to map the deactivated dams and those in the process of being deactivated, analyzing the evolution of compliance with the deadlines established by Brazilian legislation. The legislation establishes different deadlines for the completion of decharacterizations, considering the volume stored in the structure. As of the present moment, 70.27% of the structures still require pending actions.

KEYWORDS: Decharacterization, tailings dams, mapping

1 INTRODUCTION

Despite dams being well-established geotechnical structures used for generations, the concept of “decharacterization” remains relatively uncommon in the field. However, recent dam failures have underscored the necessity of acquiring technical knowledge to safely manage and decommission these structures. The term "decharacterization" refers to the process of altering or dismantling dams, particularly those used for storing mining tailings, to reduce risks associated with their structural integrity and environmental impact.

In Brazil, the collapses of the Mariana and Brumadinho dams resulted in the loss of approximately 300 lives, with four individuals still missing. These disasters devastated numerous communities and caused significant environmental degradation and pollution in one of the region’s largest rivers. In response to these tragedies, there has been a significant shift in regulatory and public policy frameworks concerning dam safety and environmental management. The enactment of Law No. 23,291 in 2019 marked a critical milestone, mandating strict regulations for the decharacterization of dams constructed using the upstream method, which is prone to instability and failure under certain conditions. This legislative initiative aimed to prevent future disasters and ensure safer practices in the mining sector. Consequently, there has been a heightened focus on decharacterizing dams constructed using similar methodologies.

2 TAILINGS DAMS

Dams have been built by mankind for thousands of years for various purposes, such as water storage flow control, and hydroelectric power generation. With the advance of mineral exploration and the need for socio-environmental conservation related to it, tailings dams have been receiving great attention, mainly due to their harmful potential in case of failure. Azam and Li (2010) presented in the *Geotechnical News* magazine a world history of failures in mining dams, where according to the authors, about 1.2% of mining dams had some type of failure, against 0.01% of civil dams, in 100 years.

According to Duarte (2008), dams are typically divided into two types: civil and mining dams, basically civil or conventional dams intended to contain anything except mining tailings. In addition, it can be noted that a tailings dams is built in stages that follow the mining rhythm, that is, as the tailings are generated, the elevations are performed.

Following two catastrophic collapses of mining tailings dams in Brazil — Fundão in Mariana in 2015 and Córrego do Feijão in Brumadinho in 2019, both located in Minas Gerais — new legislation was enacted on February 25, 2019 (Law No. 23,291). This legislation prohibits the construction and environmental licensing of dams utilizing the "upstream" construction method, similar to those involved in the aforementioned disasters. It mandates that existing dams of this type undergo "decharacterization" within three years from the date of publication, setting the deadline for February 2022. Subsequently, Resolution No. 13 of August 2019, issued by the National Mining Agency (ANM), extended this requirement nationwide. This was further supported by the National Policy on Dam Safety in 2020, which provided longer deadlines compared to the mineral law.

This requirement represents a pioneering initiative globally, lacking comprehensive technical guidelines (Massignan and Sánchez, 2022). According to Sánchez, Silva-Sánchez, and Neri (2013), the term "decharacterization" is uncommon in dam engineering globally but is documented in Brazilian literature and used by Vale, one of the industry's largest companies, the concept refers to the process of safely decommissioning or altering dams, to mitigate risk associated with their structural integrity or environmental impact.

2.1 Dam Construction – Upstream Method

Around 5 to 10% of the total cost of a mining operation (including mineral research, land preparation, equipment acquisition, auxiliary structures, and others) is allocated to the design, execution, and management of tailings dams. Tailings dams are structures that remain at permanent risk of rupture, and any damage caused by them persists even after the cessation of mineral exploration (Xin et al., 2011).

Despite being artificial structures, similar to natural geotechnical formations such as slopes, the passage of time can undermine their stability. Therefore, proper maintenance and monitoring are essential (Cardozo, Pimenta, and Zingano, 2016). There are three main construction methodologies for tailings dams: the downstream method, the upstream method, and the centerline method.

In the upstream method (Figure 1), the dam is constructed and progressively raised upstream from an already consolidated tailings deposit. This method is widely used by many mining companies but, according to Araújo (2006), it suffers from low construction control, which can lead to critical safety issues. According to Martin and McRobert (1999), this methodology presents significant geotechnical challenges due to induced tensions, liquefaction potential, and the non-consolidation of foundation materials

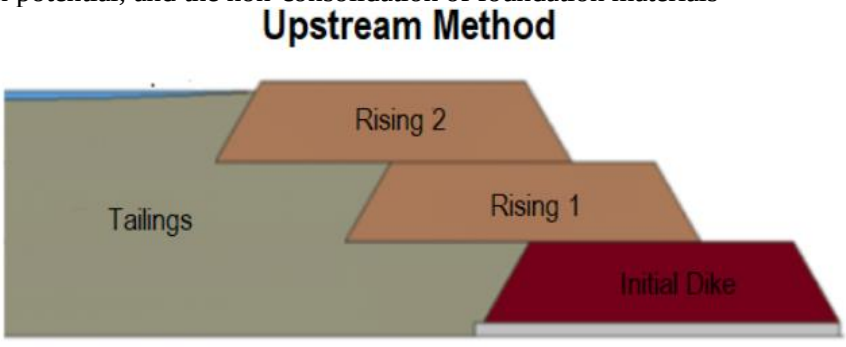


Figure 1. Upstream Method (Cardozo, Pimenta and Zingano, 2016)

Because this methodology uses heightening carried out partially over a pre-existing tailing, which generates savings in earth movement, this brings complexity to the construction control of the dam and drainage control.

The upstream method will be highlighted in this study because the Fundão and Córrego do Feijão dams were built using this methodology and new Brazilian legislation requires the decharacterization of all dams constructed in this way. According to Araújo (2006) and Martin and McRobert (1999), due to the heightening being carried out on previously arranged and unconsolidated materials that are in a saturated condition, they

tend to present low shear resistance and susceptibility to liquefaction by dynamic and static loads., in addition to problems associated with internal drainage. According to Rico et al (2008), dams built with this methodology accounts for 76% of dam failures.

2.2 Dam Closure

According to Bjelkevik (2011), planning for the closure of tailings dams must begin simultaneously with planning the structure to guarantee sustainable decommissioning and cost reduction. The selected disposal method, water balance management and tailings characterization (Pritchard, Jensen and Welsh, 2010) influence dam rehabilitation, whereas closure is made difficult by the extension of areas that have the potential for erosion and infiltration.

Pozzo et al (2006) suggest planning closure based on risk analysis in the areas of geology, geotechnics, seismicity, hydrometeorology, population and environment, whereas for Lacy (2005) documentation of the dam's history is fundamental, while for Prtichard, Jensen and Welsh (2010) it is necessary to carry out field tests with monitoring.

2.2.1 National Dam Safety Policy (PNSB)

This law established the State Dam Safety Policy in Minas Gerais, where the catastrophes of Mariana and Brumadinho occurred, to be implemented in conjunction with the PNSB (National Dam Safety Policy) and the National and State Environmental and Civil Protection and Defense Policies.

Another important aspect of this law is Article 13, which states: 'The granting of an environmental license for the operation or expansion of dams intended for the accumulation or final or temporary disposal of industrial or mining waste that utilizes the upstream raising method.' Paragraph 1 specifies that the entrepreneur is responsible for the decharacterization of inactive tailings or waste containment dams that utilize or have utilized the upstream raising method. Additionally, Paragraph 2 mandates three years for the entrepreneur to transition to alternative technologies for the dam and complete its decharacterization.

2.2.2 Resolution No. 13, 08/08/2019

This Resolution establishes regulatory measures aiming to ensure the stability of mining dams, especially those built using the “upstream” method or a method declared as unknown. This Resolution extended the deadline for the decharacterization of mining dams or structures linked to the mining operational process for storing liquid effluents, located immediately downstream of the mining dam and whose existence may compromise the safety of the upstream dams until August 15, 2022. Therefore, all deadlines mentioned for decharacterization are:

i. Until September 15, 2022, for dams with a volume <= 12 million cubic meters, according to the National Registry of Mining Dams of the Integrated Mining Management System (SIGBM);
ii. Until September 15, 2025, for dams with a volume between 12 million and 30 million cubic meters, according to the National Registry of Mining Dams SIGBM;
iii. Until September 15, 2027, for dams with a volume >= 30 million cubic meters, according to the National Registry of Mining Dams SIGBM.

3 METHODOLOGY

The current panorama of Brazilian mining dams presented in this work was prepared on April 2024 and will be represented by Federative Unit (UF). The information presented was obtained through the public dam database made available by ANM. The flowchart of the process carried out is shown in Figure 2.

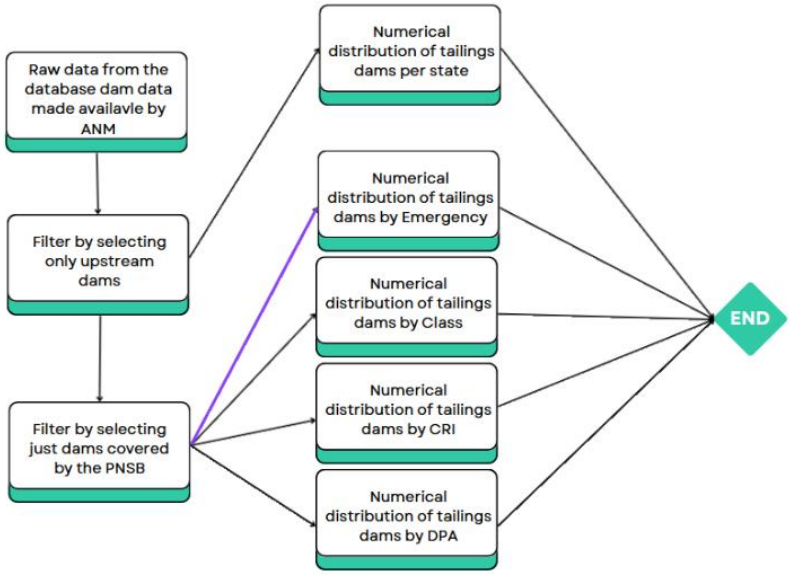


Figure 2. Process flowchart performed for the analyses developed in this study (Author, 2024)

Initially, data was collected from official sources and subsequently filtered to identify dams that fall under the upstream methodology. Next, dams were categorized by state distribution, enabling a regional analysis of safety conditions. Simultaneously, they were evaluated for coverage under the National Dam Safety Policy (PNSB), classifying them by class, risk category (CRI), potential damage (DPA), and emergency status. This analysis facilitated the identification of states with the highest concentration of dams under the studied methodology, as well as those requiring urgent actions. Furthermore, efforts were made to investigate the progress of proposed decharacterization plans by 2035 in the state with the highest number of dams.

4 RESULTS

Data collection and information processing were sequenced, as shown in Figure 3. Thus, initially, information was obtained on the number of dams per State, after which those that were built following the upstream methodology were filtered and, subsequently, among which are covered by the PNSB

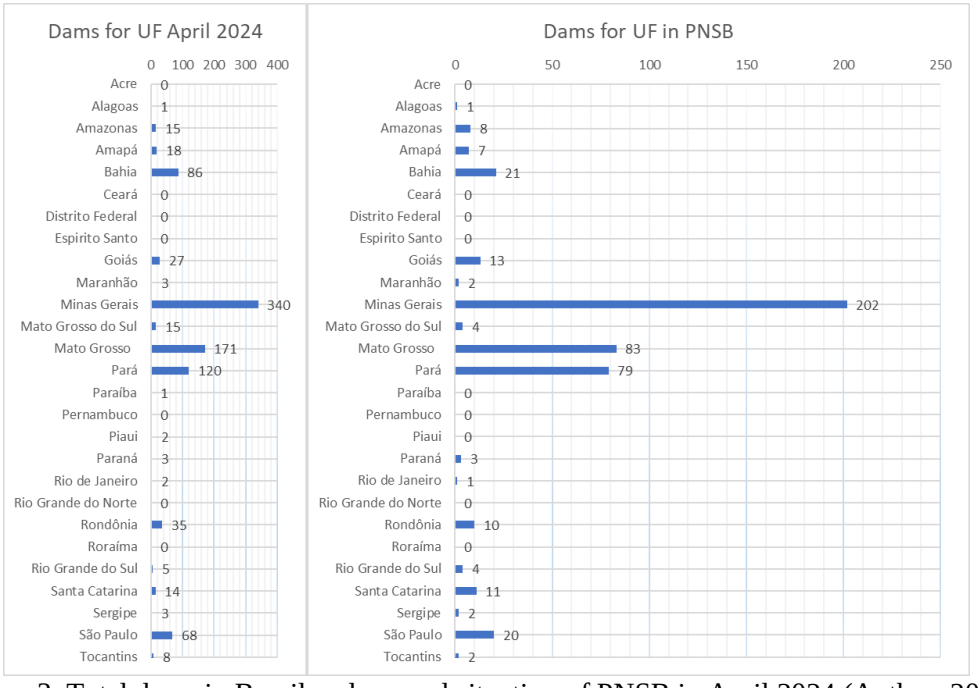


Figura 3. Total dams in Brazil and general situation of PNSB in April 2024 (Author, 2024)

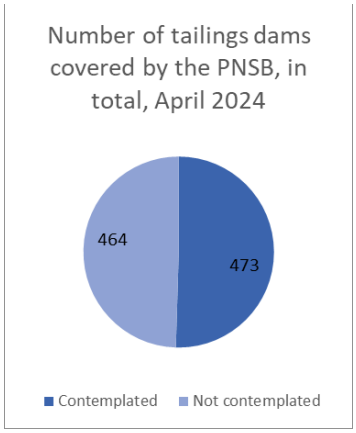
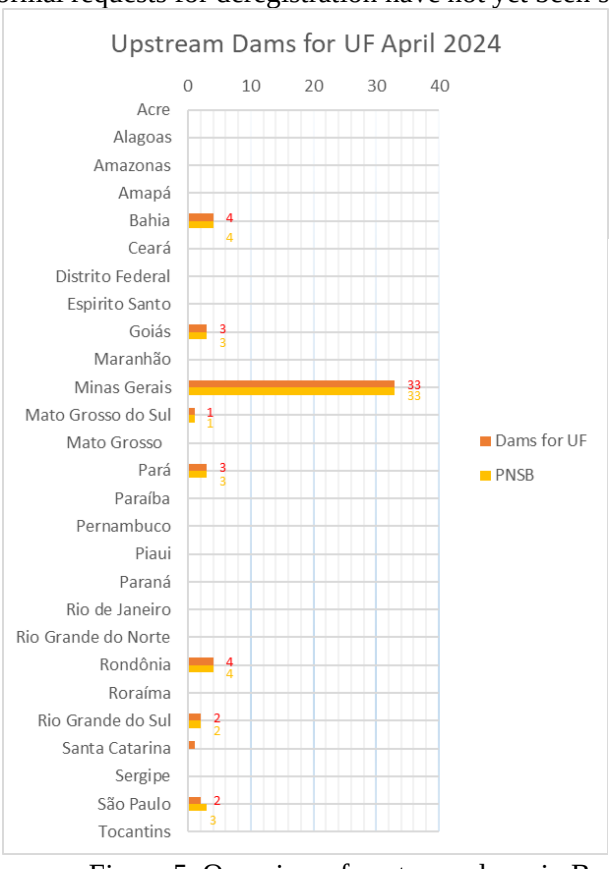


Figure 4. Proportion of dams covered and not covered by PNSB in April, 2024 (Author, 2024)

Figures 4 and 5 illustrate that among Brazil's 24 Federative Units, only 17 have dams, with 50.48% of these covered under the National Dam Safety Policy (PNSB). Subsequently, dams constructed using the upstream methodology were filtered from this group. Figure 8 provides a comprehensive overview of upstream dams in Brazil and their inclusion, or exclusion, in the PNSB.

According to the Quarterly Report of the National Mining Agency (ANM) (April 2024), 17 upstream dams have already been decharacterized and removed from the Integrated System of Mining Rights (ISMR) since 2019, leaving 52 dams remaining. Among these, 20 are currently in the preparation phase of their executive decharacterization projects, 19 are in the process of implementing planned interventions, 7 are under monitoring following the completion of engineering works, and 2 have been fully decharacterized, although formal requests for deregistration have not yet been submitted.



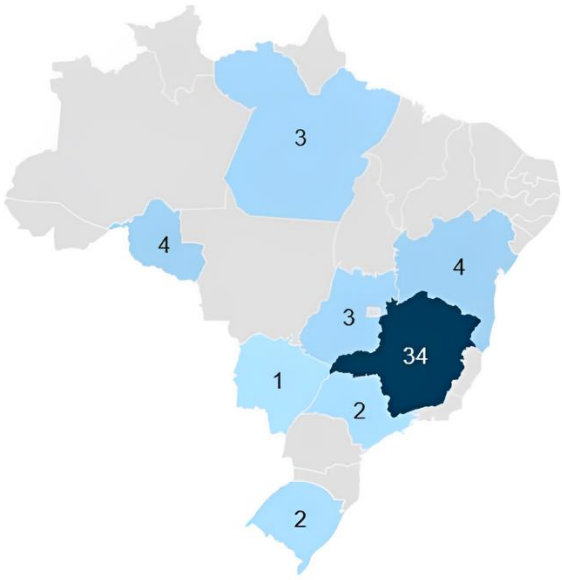


Figure 5. Overview of upstream dams in Brazil and their coverage by PNSB (Author, 2024)

It is possible to verify the significant number of dams that follow this methodology in the State of Minas Gerais, where the Mariana and Brumadinho catastrophes occurred, thus highlighting the panorama of decharacterization in this state. According to Vale's Dam Decharacterization Program, the largest mining company in Brazil, there are 17 structures left to be decharacterized by 2035, with expectations that 3 will be fully decharacterized by the end of 2024, as depicted in Figure 6.

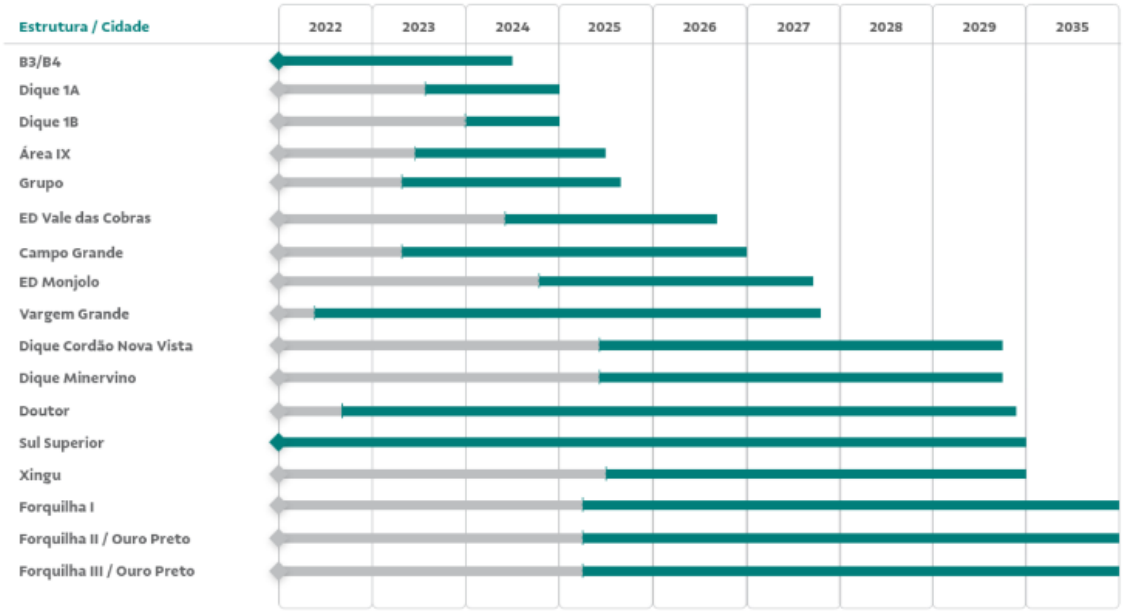


Figure 6. Schedule of the Upstream Dam Decharacterization Program in Brazil (Vale, 2024)

In this way, it is possible to visualize in Figure 7 the general panorama of decharacterization of upstream dams in Brazil. Where the states Mato Grosso and Santa Catarina lost 100%, Pará 66.67%, São Paulo 50% and Minas Gerais 36.36%

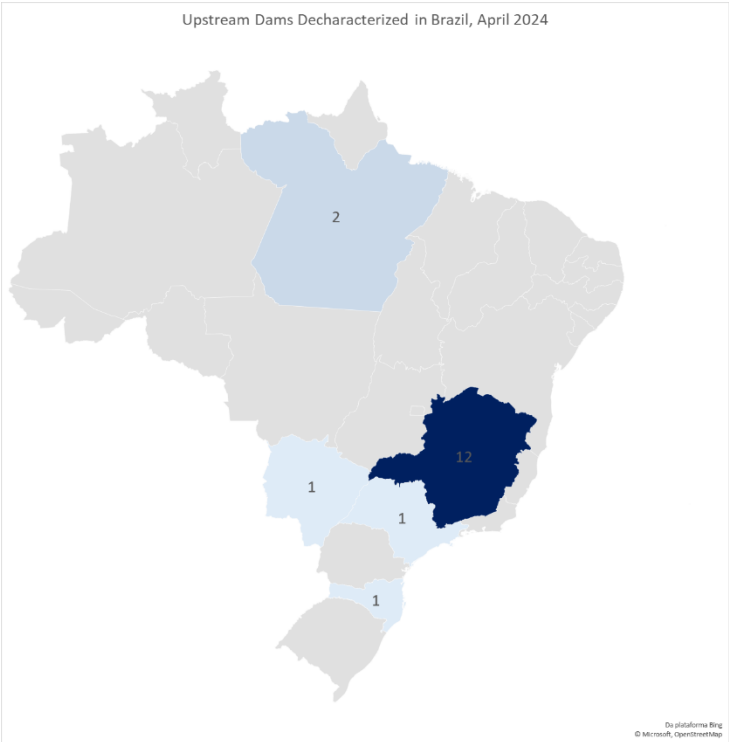


Figure 7. Decharacterization in Brazil by State (Author, 2024)

5 CONCLUSION

According to the data collected, it can be observed that the states of Minas Gerais, Mato Grosso, and Pará have the highest number of dams covered by the National Dam Safety Policy (PNSB), with 202, 83, and 79 units, respectively. Out of the 473 dams covered by the PNSB, only 74 were slated for decharacterization, of which 17 have already completed the process since 2019.

Regarding dams under Vale's responsibility, only 17 remain active, representing a decharacterization rate of 43.33%, demonstrating adherence to the company's projections and meeting the deadlines stipulated by law. These findings underscore the need for ongoing vigilance and proactive measures to ensure the safety and sustainable management of dam infrastructure in Brazil in the future.

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