Original article

Núcleo de Estudos, Pesquisas e Projetos de Reforma Agrária – NERA, Presidente Prudente/SP, Brasil.
ISSN: 1806-6755
Rev. NERA | Presidente Prudente, SP | v. 28, n. 3 | e10861 | 2025.
DOI: 10.1590/1806-675520252810861en

The historical geography of iron ore tailings dams in Minas Gerais, Brazil

Thell Rodrigues
University of São Paulo (USP) – São Paulo, São Paulo, Brazil.
e-mail: thellvictor@hotmail.com

Ladislau Pereira Sanders Filho
University of São Paulo (USP) – São Paulo, São Paulo, Brazil.
e-mail: ladislausanders@gmail.com

Abstract

The article analyzes the proliferation of iron ore tailings dams in Minas Gerais, highlighting geological, economic, and administrative factors that have driven the implementation and expansion of these structures. The objective is to present a historical and geographical overview of the dams from 1970 to 2020. The research utilizes data from the Integrated Mining Dam Safety Management System (SIGBM) and the Brazilian Mineral Yearbook, in addition to a bibliographic review and field activities. The results indicate that the installation of the dams is linked to the beginning of itabirite exploitation, which led to the establishment of beneficiation plants and generated a large amount of tailings. The intensification of interregional competition from the 1960s pressured mining companies to seek low-cost solutions to expand production and reduce expenses, consolidating less expensive methods such as wet beneficiation and the disposal of waste in dams. The research also identifies the earliest records of socio-environmental problems associated with these structures, as well as a recurrence of issues since 2014, including the disasters in Mariana and Brumadinho and other episodes involving community evacuations due to the risk of new failures.

Keywords: Tailings dam; mining; environmental disaster; territorial impacts; capital crisis.

A geografia histórica das barragens de rejeito de minério de ferro em Minas Gerais, Brasil

Resumo

O artigo analisa a proliferação de barragens de rejeito de minério de ferro em Minas Gerais, destacando aspectos geológicos, econômicos e administrativos que impulsionaram a implementação e a expansão dessas estruturas. O objetivo é apresentar um panorama histórico e geográfico das barragens no período de 1970 a 2020. A pesquisa utiliza dados do Sistema Integrado de Gestão de Segurança de Barragens de Mineração (SIGBM) e do Anuário Mineral Brasileiro, além de levantamento bibliográfico e atividades de campo. Os resultados indicam que a instalação das barragens está relacionada ao início da exploração do itabirito, que mobilizou a implantação de usinas de beneficiamento e gerou grande quantidade de rejeito. A intensificação da concorrência inter-regional, a partir de 1960, pressionou as mineradoras a buscar soluções de baixo custo para ampliar a produção e reduzir custos, prevalecendo métodos menos onerosos como o beneficiamento úmido e a alocação dos resíduos em barragens. A pesquisa também identifica os primeiros registros de problemas socioambientais com essas estruturas, além de sinalizar uma recorrência de problemas desde 2014, como os desastres em Mariana e Brumadinho, além de outros episódios que envolvem evacuações de comunidades por risco de novos rompimentos.

Palavras-chave: Barragem de rejeito; mineração; desastre ambiental; impactos territoriais; crise do capital.

Geografía histórica de las presas de residuos de mineral de hierro en Minas Gerais, Brasil

Resumen

El artículo analiza la proliferación de presas de residuos de mineral de hierro en Minas Gerais, destacando los factores geológicos, económicos y administrativos que impulsaron la implantación y expansión de estas estructuras. El objetivo es presentar un panorama histórico y geográfico de las presas desde 1970 hasta 2020. La investigación utiliza datos del Sistema Integrado de Gestión de la Seguridad de las Presas Mineras (SIGBM) y del Anuario Minero Brasileño, así como un estudio bibliográfico y actividades de campo. Los resultados indican que la instalación de las presas está relacionada con el inicio de la explotación de itabirito, que movilizó la implantación de usinas de procesamiento y generó una gran cantidad de residuos. La intensificación de la competencia interregional a partir de la década de 1960 empujó a las empresas mineras a buscar soluciones de bajo coste para ampliar la producción y reducir costos, consolidando métodos menos onerosos como el procesamiento por vía húmeda y la reserva de residuos en presas. La investigación también identifica los primeros registros de problemas socioambientales con estas estructuras, además de señalar una recurrencia de problemas desde 2014, como los desastres en Mariana y Brumadinho, así como otros episodios que implican la evacuación de comunidades debido al riesgo de nuevas rupturas de presas.

Palabras-clave: Represa de resíduos; minería; desastre ambiental; impactos territoriales; crisis de capital.

Introduction

The disasters caused by Samarco in 2015 and Vale in 2019 resulted in hundreds of deaths, large-scale environmental destruction, and severe social consequences for the affected communities (Sanders Filho, 2019; Rodrigues, 2024). The magnitude of these tragedies highlighted the catastrophic potential of tailings dams. It underscored the urgency of critically examining the existence of such structures—particularly in Minas Gerais, the epicenter of these events.

Geographical approaches, especially those informed by Historical Geography (Rodrigues, 2019), can offer significant insights into the processes that led to the proliferation of tailings dams across the state. This perspective enables an investigation of how regional and global factors—operating through overlapping spatial and temporal dimensions—have shaped the installation, expansion, and even the deterioration of these infrastructures.

Accordingly, this article aims to present a historical and geographical overview of tailings dams in Minas Gerais, analyzing the geological, economic, and administrative aspects that have driven their implementation and growth within the state. In addition, it seeks to highlight some of the social and environmental implications associated with these waste disposal structures, demonstrating how their operation has generated socio-environmental disruptions since the 1970s, with intensifying effects in recent years. To this end, the article begins with a preliminary section that outlines the theoretical and methodological framework guiding the research, followed by six sections that explore the connections between iron ore production and the processes of waste generation and management.

The first of these six sections provides an overview of the current state of tailings dams in Minas Gerais, with a focus on their primary characteristics and the structural stability of the facilities. The second section revisits the historical context of dam construction since the 1970s, seeking to understand the influence of geological, economic, and political factors that have shaped the proliferation of dams in the state. The third section utilizes quantitative data to demonstrate how the extraction of itabirite has intensified mineral production and, consequently, increased the volume of tailings generated. The fourth section examines the role of interregional competition in influencing technological choices for iron ore extraction and waste management. The fifth section examines how the expansion of production and the growing scale of tailings had already signaled, as early as the 1970s, the emergence of socio-environmental problems in the state. Finally, the sixth section seeks to synthesize the issue of tailings dams in twenty-first-century Minas Gerais, briefly considering the impact of the "commodity super cycle" and the post-2014 sectoral crisis, marked by the recurrence of dam-related incidents across the state.

Theoretical and methodological considerations in historical geography and the question of tailings dams

According to Rodrigues (2019, p. 2), the distinctive feature of the field of Historical Geography lies in its "dense articulation of space and time." Such articulation demands a theoretical and methodological foundation capable of interpreting the production and transformation of space over time, shaped by technical practices, spatial forms, and the social relations that sustain them. On this basis, Rodrigues (2019) highlights the relevance of three methodological approaches in historical-geographical research: periodization, scale, and sources.

The periodization adopted in this study does not amount to a mere chronological division; rather, it represents an analytical construction guided by the research questions themselves, as suggested by Rodrigues (2019). Accordingly, the temporal scope is delimited from 1970 to 2020, structuring the analysis around transformations in iron ore production techniques—with particular attention to the implications of these changes for tailings generation and management. In this context, the technique is not limited to dam engineering per se. However, it refers more broadly to the set of productive procedures that underpin mining activity, with the dam emerging as a spatial expression of these productive choices.

The second methodological axis concerns the adoption of multiple scales of analysis, which are essential for apprehending the diverse determinants acting upon the object of study. In this case, the regional scale of the Quadrilátero Ferrífero—the principal iron ore production hub in Minas Gerais—is examined in articulation with the global scale, shaped by the dynamics of the international iron ore market. This multiscale approach enables an understanding of how interregional competition directly affects the organization of mineral production in the region, shaping productive strategies, technological choices for extraction, and tailings management practices.

The third methodological dimension refers to the mobilization of sources that can express the spatial-temporal articulation of the processes under investigation, enabling both theoretical and empirical interpretation of the research questions. To this end, the study draws on a range of sources, including quantitative data on annual mineral production, accounts from individuals involved in the analyzed processes (gathered through secondary sources), field observations, and dialogue with bibliographic material dealing directly or indirectly with ore production and tailings management.

The quantitative data were obtained from the Sistema Integrado de Gestão de Segurança de Barragens de Mineração (SIGBM) (Integrated Mining Dam Safety Management System) and the Anuários Minerais Brasileiros (Brazilian Mineral Yearbooks), published between 1970 and 2020. Based on these sources, a database was developed containing systematized information on the evolution of mineral production and the construction of tailings dams during the selected period.

The first stage of the analysis involved characterizing the current state of tailings dams in Minas Gerais, drawing on data from the SIGBM (Brazil, 2024a).[1] The information considered included location, type of stored tailings, technical characteristics, date of commencement of operations, and the Declaration of Stability Condition (Declaração de Condição de Estabilidade).[2] These data were organized into tables and subsequently

[1] The SIGBM data were extracted on 15 July 2024.

[2] It is worth noting that SIGBM currently constitutes the only publicly accessible database on mining dams in Brazil. Despite its significance, it is possible that the system does not account for all structures built over time, particularly those decommissioned before the portal's implementation or those that, for various reasons, were never officially registered. This limitation compromises the completeness of the historical record. Nevertheless, SIGBM includes some decommissioned dams, making it a valuable—albeit partial—source for analyzing the number of structures built between 1970 and 2020.

converted into georeferenced formats for use in the QGIS software environment. This systematization enabled an analysis of the spatial distribution of iron ore tailings dams, as well as the volume of each structure and their declared stability conditions. The results of this analysis are presented in the following section.

Quantitative data on mineral production and tailings generation were compiled based on information from each edition of the Anuário Mineral Brasileiro (Brazilian Mineral Yearbook), spanning the years 1972 to 2020 (Brazil, 1972–2020). To estimate tailings generation, the methodology developed by the Institute for Applied Economic Research (Instituto de Pesquisa Econômica Aplicada – IPEA) (2012) was employed. This approach is based on the difference between gross and processed mineral output, enabling the calculation of both the volume of tailings and the annual tailings generation rate using the following formulas:[3]

Tailings Volume (t) = Gross Production (t) – Processed Production (t)

Tailings Ratio = Tailings Volume (t) / Gross Production (t)

Data were compiled for the state of Minas Gerais and, for comparative purposes, for the state of Pará. The collected information was organized into spreadsheets and systematized in tables to consolidate data dispersed across different sources and facilitate subsequent analysis. These compiled data are publicly available on the Revista NERA page on SciELO Data[4]. The systematization aims to support the historical-geographical reconstruction of dam construction and management processes and to contribute to further research on the topic.

In addition, a survey was carried out of empirical and technical studies that address, either directly or indirectly, the issues of mineral production and tailings dams in Minas Gerais to contextualize the implementation of these structures. This effort made it possible to interpret, from both theoretical and historical perspectives, how interregional competition influenced decisions regarding new techniques for mineral extraction and dam construction.

[3] According to the Diagnóstico dos resíduos sólidos da atividade de mineração de substâncias não energéticas (Diagnostic Report on Solid Waste from Non-Energy Mineral Mining Activities), developed by IPEA (2012), quantifying the volume of solid waste (waste rock and tailings) produced by mining activities is a complex task due to the operational intricacies and the wide range of technologies used in extraction and processing. Moreover, data availability is limited, both from government agencies and mining companies. Despite these challenges, IPEA emphasizes the importance of estimating such figures using the available information and, to this end, has developed a methodology to estimate the total volume of tailings generated and the annual tailings generation rate.

[4] The complete dataset supporting the results of this study has been made available on SciELO Data and can be accessed at https://doi.org/10.48331/SCIELODATA.AHQPCF.

The analysis draws on records from the Vale company (2012, 2016), as well as the contributions of Humphreys (2015) and Minayo (2004).

To investigate the earliest historical records of environmental problems associated with the expansion of mining and tailings dams, documents from the 1970s were analyzed—such as the study by Freitas (1976), which identifies the first environmental impacts in the municipality of Itabira and reports by the João Pinheiro Foundation (1976; 1977) concerning the discharge of tailings into rivers in the Metropolitan Region of Belo Horizonte. Journalistic records of dam failures in 1986 and 2001, referenced by Ávila et al. (2021), were also taken into consideration.

Additionally, fieldwork involving observational activities was conducted in municipalities with a recent history of dam failures, risk situations, or conflicts related to tailings dams. The field visits took place in 2021 and 2022 in the municipalities of Barão de Cocais, Brumadinho, Congonhas, Itabira, Itabirito, Itatiaiuçu, Mariana, Nova Lima, Ouro Preto, and Rio Acima (cf. Rodrigues, 2024, p. 31-76). The in-loco observations conducted over the two years made it possible to identify various instances of social and environmental disruption linked to the operation of tailings containment structures. These visits were accompanied by informal conversations with residents, documented in a field notebook, to capture everyday elements affected by the ongoing risks posed by the dams.

A current overview of iron ore tailings dams in Minas Gerais

At present, Brazil has 938 dams associated with mineral extraction registered in the SIGBM, of which 339 are located in the state of Minas Gerais (Brazil, 2024a). Among these, 84 are explicitly classified as iron ore tailings dams nationwide, with 64 located in Minas Gerais—accounting for 76% of the total[5]. These structures are the responsibility of 19 companies[6] and are concentrated in 21 municipalities,[7] primarily situated in the central part of the state, mostly situated in the central part of the state, in the region known as the Quadrilátero Ferrífero (Iron Quadrangle). [8]

[5] The others are distributed among the states of Mato Grosso do Sul (14), Amapá (4), Alagoas (1) e Pará (1).

[6] The mining companies responsible for each of the dams are: Anglo American Iron Ore Brazil S/A (1), ArcelorMittal Brazil S.A. (1), CSN Mineração S.A. (3), Emicon Mineração e Terraplenagem Limitada (1), Gerdau Açominas S/A (2), Green Metals (1), Herculano Mineração Ltda (1), Itaminas Comércio de Minérios S.A. (1), Minar Mineração Aredes Ltda (1), Mineração Geral do Brasil S/A (2), Mineração Morro do Ipê S.A. (3), Mineração Usiminas S.A. (2), Minérios Nacional S.A. (2), Minerita Minérios Itaúna Ltda. (2), MSM Mineração Serra da Moeda Ltda. (4), SAFM Mineração Ltda (3), Samarco Mineração S.A. (1), Vale S.A. (32), and Vallourec Tubos do Brasil Ltda. (1).

[7] The municipalities are: Barão de Cocais (3), Brumadinho (5), Conceição do Mato Dentro (1), Congonhas (2), Igarapé (2), Itabira (4), Itabirito (12), Itatiaiuçu (5), Jeceaba (1), Mariana (3), Nova Era (1), Nova Lima (6), Ouro Preto (13), Rio Acima (2), Rio Piracicaba (1), Sabará (1), Sarzedo (1) e São Gonçalo do Rio Abaixo (1).

[8] In addition to these structures classified as tailings dams, Minas Gerais has four other wet-tailings containment facilities registered as "pit with constructed dam" and "hydraulically constructed, drained stacking susceptible to liquefaction." There are also other dams associated with iron ore mining that store only water and not tailings.

The data provided by SIGBM enable the identification of the year in which each registered structure began operating, allowing for the delineation of a historical pattern in the use of iron ore tailings dams. According to these records, such containment structures began to be implemented in 1970. During that decade, at least 10 dams were brought into operation. In the 1980s, this number more than doubled with the installation of at least 14 additional structures. Throughout the 1990s, an additional 14 dams were constructed. Between 2000 and 2014—prior to the onset of the sequence of dam-related incidents discussed in the final section—16 new dams entered into operation. Even after the first rupture in this recent series of disasters, which occurred in September 2014, at least 10 further structures still came into operation.

These structures implemented in the state differ not only in terms of their operational timelines but also in the magnitude of their reservoirs. Among the registered dams, 21 have a volume below 1,000,000 m³; 24 have volumes ranging from 1,000,000 m³ to 10,000,000 m³; and 12 reservoirs have capacities between 10,000,000 m³ and 50,000,000 m³. Additionally, six dams exceed 50,000,000 m³ in capacity, notably the Pontal Dam in Itabira, which holds approximately 218,000,000 m³ (Brazil, 2024a). This volume is roughly four times the size of the Fundão Dam, which failed in 2015 and caused one of the most devastating environmental disasters in Brazil's history (Serra, 2018).

Another key element distinguishing these structures—and potentially influencing public risk perception—is the construction and elevation method employed in each dam. According to SIGBM, in Minas Gerais, 27 dams use the upstream method, 14 employ the downstream method, 4 use the centerline method, and 19 are built using the single-step method (Brazil, 2024a).[9]

The operational status of the dams also varies. Currently, 20 are active, 32 are undergoing decommissioning, and 12 are inactive (Brazil, 2024a). This high number of dams undergoing decommissioning reflects the wave of dam-related incidents that will be discussed in the final section of this article. These events have prompted the introduction of new regulatory frameworks and intensified public pressure to question the legitimacy and safety of such infrastructure (Magno et al., 2023).

Finally, one last data point worth highlighting is the current safety status of these dams. According to SIGBM (Brazil, 2024a), nine structures are classified under Alert Level,

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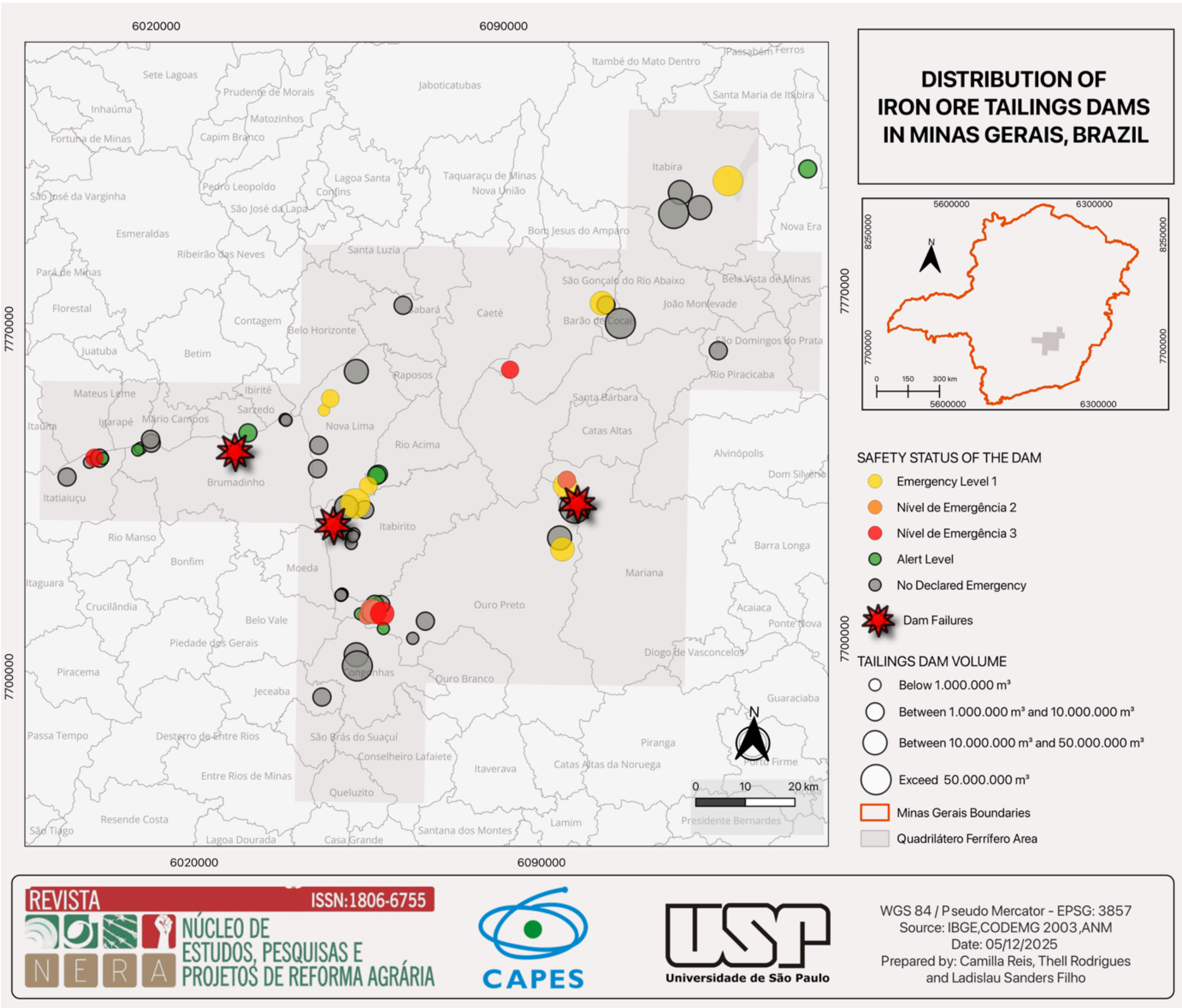
Although these types of structures were not considered in this study, they are equally relevant in terms of the socio-environmental risk they may pose to downstream areas.

[9] According to Soares (2010), the upstream method is more commonly used because it is more economical and quicker to build and raise. However, this method carries a greater likelihood of instability, especially concerning liquefaction—as occurred in the Samarco and Vale incidents that employed this technique. In contrast, the downstream method involves constructing an initial impermeable starter dyke, which provides greater stability and results in a safer, more compact embankment. Nevertheless, its implementation and operation are more complex and costly.

another nine under Emergency Level 1, four under Emergency Level 2, and three under Emergency Level 3.[10] This means that, among the 64 structures included in this analysis, approximately 40% are currently subject to some form of alert or emergency status. This figure illustrates that, even five years after the Vale disaster in Brumadinho, Minas Gerais remains a significant social and environmental risk posed by tailings dams. Map 1 illustrates the current panorama of iron ore tailings dams in Minas Gerais:

Map 1: Distribution of iron ore tailings dams in Minas Gerais – 2025.



Organized by The Authors and Camilla Reis (2025).

[10] According to ANM Resolution No. 95/2022, a dam must be classified at "Alert Level" when anomalies in the structure are identified, and corrective measures have not been implemented within 30 days. Suppose the operator still fails to adopt those measures after an additional 60 days. In that case, the structure is reclassified as "Emergency Level 1." "Emergency Situations" refer to adverse events that compromise the dam's safety and may cause damage to its structural and operational integrity, as well as harm to life, health, property, and the environment. Details on the emergency levels assigned to each structure since 2022 can be found in the Declaration of Condition of Stability history available in SIGBM (Brazil, 2024b).

The installation of dams and the beneficiation of itabirite

As previously noted, the construction of iron ore tailings dams in Minas Gerais began in the 1970s. In summary, this phenomenon is closely associated with the onset of itabirite exploitation. As will be demonstrated, tailings dams became a necessary element for waste disposal from the moment companies began extracting and processing itabirite on an industrial scale.

According to Takehara (2004), iron ore production in Minas Gerais primarily stems from the extraction of two types of rock formations: hematite bodies—typically characterized by iron content above 64%—and itabirites, which exhibit iron concentrations ranging from 20% to 55%.

This quantitative classification is significant, as conventional methods of pig iron and steel production require ore with at least 58% iron content, with market standards generally favoring materials containing over 62% iron (Smil, 2016). In other words, large hematite deposits can be marketed more easily and at lower cost, as they require only basic crushing and screening of the raw ore. Itabirite, by contrast, due to its lower iron content, can only be commercially viable if processed through beneficiation techniques (Vale, 2016). It is precisely this industrial processing of itabirite that generates large-scale tailings, which are mainly deposited in dams.[11]

According to historical accounts published by Vale (2012; 2016), the former Companhia Vale do Rio Doce (CVRD - Doce River Valley Company) began its iron ore production in Minas Gerais by extracting hematite. At that time, the production model did not involve complex machinery. As Minayo (2004) summarizes, during the company's early years—from 1942 to 1951—the production model was based on a simple division of labor and manual tools.[12] In essence, the stages of hematite-based production involved "extracting, crushing, transporting, and shipping the ore to international buyers" (Minayo, 2004, p. 131).

However, this "manual" production model was economically viable only because it was applied to hematite ore: a simple extraction process was sufficient to meet the quality specifications required by steel mills.

According to Minayo (2004), this mode of production began to change in 1952, when the company initiated the mechanization of its operations. According to the author, there was a shift from manual extraction to the use of heavy machinery, redefining not only the technical characteristics of production but also its quantitative scale. With the

[11] It is worth noting that the mineral processing of hematite also produces tailings, although on a considerably smaller scale than the exploitation of itabirite.

[12] Minayo (2004) summarizes this work process by highlighting that the workers used hand-held drills to bore into the rock and place dynamite, sledgehammers to break stones, iron forks to collect the ore, and small mine carts for transport. Moreover, tools such as hoes, sickles, axes, and pickaxes were used to clear vegetation and build roads.

implementation of the Mecanizada 1 (Mechanized 1) (1952) and Mecanizada 2 (Mechanized 2) (1964) projects, mineral extraction intensified, allowing for large-scale production and export (Minayo, 2004; Vale, 2012).

However, this acceleration also hastened the depletion of hematite deposits. As recorded by Vale (2012, p. 377), by the 1960s, the dwindling of hematite resources had become a growing concern for the mining sector in Minas Gerais—prompting the industry to urgently expand the frontier of itabirite exploitation as a means of ensuring its own reproduction.

It was in this context that beneficiation plants, specifically designed to process itabirite, began to be developed, enabling the concentration of iron particles and thus increasing the iron content of the final product. Once itabirite began to be intensively exploited with the support of beneficiation plants, a new step was added to the production chain: the concentration process, which involved "wet high-intensity magnetic separation using Jones plates" (Vale, 2016, p. 30). As a result, itabirite came to be extracted, crushed, and concentrated. Moreover, because water is used in the concentration process, this results in the generation of large volumes of muddy (and sandy) tailings composed mainly of silica and clay.[13]

In other words, with the onset of itabirite exploitation, the mining sector in Minas Gerais expanded its usable reserves (by transforming a previously uneconomic material into marketable ore), increased production, and exponentially intensified tailings generation. In parallel with this transformation, tailings dams emerged as a technological and spatial "solution" for storing the vast quantities of wet waste generated by the beneficiation process. This is why the start-up dates of the earliest dams operated by the former CVRD coincide with the installation of beneficiation plants. For example, the Pontal Dam, dated 1972 (Brazil, 2024a), was contemporaneous with the commissioning of the Cauê Plant (Vale, 2016); similarly, the Conceição and Rio do Peixe dams, both dated 1977 (Brazil, 2024a), began operating simultaneously with the start-up of the Conceição Plant (Vale, 2012; Vale, 2016).

Although this pattern is more precisely documented in the case of CVRD in Itabira, it extended to other mining companies operating in the state. For instance, the report Impacto Ambiental da Mineração de Águas Claras (Environmental Impact of Mining in Águas Claras), produced by the João Pinheiro Foundation (1977), indicates that the former mining company MBR used water for concentrating iron ore from lower-grade rocks. This process generated substantial volumes of tailings, which were subsequently deposited in a dam (Fundação João Pinheiro, 1977). In parallel, the study by Kegler and Wolfgang (1982) on the Fábrica Mine,

[13] It is worth noting that, both in the manual and mechanized phases, the extraction of hematite bodies generated essentially dry waste—merely rock fragments that lacked the proper granulometry or were even barren because they included other embedded rocks, such as itabirite itself (Vale, 2016).

operated by the mining company Ferteco, also points to the integration of tailings dams with the beneficiation plant used to process itabirite.

Finally, the very formation of Samarco S.A. is itself tied to the correlation between the construction of tailings storage infrastructure and the installation of a beneficiation facility for itabirite. As Francisco Fernandes (1982) notes, since the 1940s, the company Samitri Mineração S.A. had been extracting iron ore deposits in the upper Rio Doce region. With the gradual depletion of hematite reserves in the late 1960s, Samitri shifted its focus to developing technologies for itabirite extraction, adopting a strategy similar to that of Vale, MBR, and Ferteco (Fernandes, 1982).

Against this backdrop, Samitri established a joint venture with the American company Marcona Corporation, which specialized in pelletizing low-grade iron ore, resulting in the creation of Samarco in 1971.

The company only began operations in 1977, focusing on the extraction and transformation of itabirite into pellets. The company only began operations in 1977, focusing on the extraction and transformation of itabirite into iron ore pellets. In other words, although Samitri had been extracting iron ore since the 1940s, it was only in 1977—with the start of itabirite exploitation and the adoption of new beneficiation technologies—that the company saw the need to construct a tailings dam, specifically the Germano Dam (cf. Samarco and Cepemar, 2004). This structure became exhausted in the early 2000s, creating the conditions under which the company rapidly constructed the Fundão Dam, which catastrophically failed in 2015 (Serra, 2018).

The expansion of mineral production through itabirite exploitation and the consolidation of Minas Gerais in the global market

Between the 1950s and the 1970s, the global economy experienced intense growth driven by the post-war reconstruction of Europe and Japan, which in turn generated strong demand for iron ore. During this period, many European mines were depleted, while Japan faced a scarcity of domestic reserves, heightening its dependence on imports. Although the United States remained self-sufficient in iron ore and scrap metal until 1973, it lacked surplus capacity for large-scale exports. This global scenario favored the consolidation of regions such as the Quadrilátero Ferrífero in Minas Gerais and Pilbara in Australia as strategic hubs of iron ore production for the international market (Humphreys, 2015).

According to Fernandes (1982), Minas Gerais produced approximately 9.9 million tons (Mt) of iron ore in 1960, of which 5.2 Mt were exported. In 1971, annual production reached 37.7 million tons, with exports amounting to approximately 31.1 million tons. These figures illustrate the rapid pace of mineral production expansion in the state and its increasing integration into the global market.

In 1972, the first beneficiation plants began operating, significantly boosting mineral output. That same year, the Anuário Mineral Brasileiro began publishing data that differentiated between gross and processed production—reflecting the distinction between raw rock and marketable ore, the latter being the result of itabirite processing, i.e., excluding the volume of tailings generated in the process. In that year, Minas Gerais reported 46.2 million tons of gross ore production and 39.1 million tons of processed ore. By 1980, these numbers had surged to 139.3 million tons of gross ore and 112.7 million tons of processed ore, clearly indicating the intensification of itabirite extraction across the state (Brazil, 1972-2020).

This process led not only to increased production but also to a substantial rise in tailings generation, as shown in Table 1.

Table 1: Iron ore production and tailings generation in Minas Gerais (1972-2020).

Period	Gross Production (t)	Processed Production (t)	Tailings (t)	Tailings ratio
1972-1980	869.220.755	718.112.880	151.107.875	17%
1981-1990	1.475.729.483	1.099.902.747	375.826.736	25%
1991-2000	1.903.595.627	1.361.555.988	542.039.639	28%
2001-2010	2.890.173.335	2.047.299.656	842.873.679	29%
2011-2020	3.784.908.501	2.607.523.286	1.177.385.215	31%
Total accumulated (1972-2020)	10.923.627.701	7.834.394.557	3.089.233.144	28%

Source: Brazilian Mineral Yearbook (Brazil, 1972-2020); Org: The authors (2025).

Over nearly five decades, the state produced an annual average of 63 Mt of tailings, amounting to approximately 3.08 billion tons over the entire period. In comparison, the state of Pará generated an average of 7.1 Mt of tailings per year—8.7 times less—reflecting distinct production conditions. This disparity is explained mainly by the type of ore extracted in each region, as well as the associated mineral processing technologies (cf. Rodrigues, 2024).

In Minas Gerais, since the 1970s, mining has concentrated on itabirite, which contains lower iron content, resulting in greater volumes of tailings—most of which have been directed to tailings dams and accumulated over the decades. By contrast, in Carajás (Pará), extraction focuses on high-grade hematite with iron content above 65%, requiring less processing and producing smaller volumes of tailings (Vale, 2012).

These differences are reflected in the infrastructure required to manage tailings. As previously noted, Minas Gerais currently has 64 iron ore tailings dams registered in SIGBM, while Pará has only a single dam on record.[14] This stark contrast can be interpreted through the lens of the geographically uneven development of capitalism (Harvey, 2013) in each region: in Minas Gerais, production conditions demand more robust infrastructure, including a larger number of dams, whereas, in Pará, the higher quality of ore and the more recent timeline of extraction have enabled operations to be carried out with only one tailings dam (Rodrigues, 2024).

Interregional competition as a driving force for itabirite exploitation and the choice to build tailings dams

The origin of iron ore tailings dams in Minas Gerais is linked not only to the depletion of hematite bodies but also to the modernization of the mining industry and the intensification of interregional competition. As previously discussed, from the 1970s onwards, mining companies in the state—especially CVRD—sought to strengthen their position in the global market by adopting new extraction and processing technologies (Minayo, 2004). This modernization, however, was not merely a market opportunity but a necessary response to commercial projections for the following decades. As will be discussed below, the turn to itabirite exploitation and the use of dams was driven primarily by the imperative to expand production and reduce operating costs in order to maintain regional competitiveness in the global market.

According to historical records from Vale (2012) and analyses by David Humphreys (2015), the transition from the 1960s to the 1970s signaled a growing competitive pressure in the global iron ore market. This was shaped, on one hand, by the start of mining operations in Western Australia and, on the other, by the discovery of the massive deposits in Carajás, northern Brazil, which would be exploited from the 1980s onward.

The entry of Australian mines into the global market in the late 1960s led to a significant increase in supply, accompanied by a decline in iron ore prices (Vale, 2012).

Moreover, from the 1970s onward, the global economy began to show signs of decelerating growth—a phenomenon referred to by some scholars as a "long downturn" (Brenner, 1999), "secular devaluation" (Harvey, 2013), or even "collapse of modernization" (Kurz, 1992). Paradoxically, it was during this economically challenging period that plans for

[14] It is worth noting that not all of the tailings produced go to dams. There are other ways to manage this material, such as stockpiling or reuse. This text presents only an average—based on data from SIGBM and the Brazilian Mineral Yearbook—to contextualize the number of tailings generated and its relationship to the construction and expansion of dams, especially when comparing the scenarios in Minas Gerais and Pará.

the construction and expansion of tailings dams in Minas Gerais were consolidated, in tandem with the region's consolidation as a key player in the global iron ore market.

The establishment of the Mineral Development Centre (Centro de Desenvolvimento Mineral – CDM) in 1965 aimed to research and develop new technologies for itabirite beneficiation, a direct response by CVRD to the intensifying competition and concerns about hematite depletion. This interpretation is supported by the testimony of a company manager, who describes the company's transformation as a matter of survival in an increasingly competitive environment:

> “Vale changed a lot, and it had to change. The whole world is changing. It was a matter of survival for the company. Either it changed and kept up with developments around the world, or it would be left behind in the iron ore production and marketing context,” said the current General Manager of Mines in Itabira, echoing the rationale the company has developed to justify the new direction it has taken in response to international competition: “The iron ore market is becoming increasingly competitive” (Minayo, 2004, p. 315).

The shift in the production model—focusing on automation, cost reduction, and scale increase—was key to CVRD's competitive positioning. The pursuit of more efficient technological alternatives aligned with new production standards reflects the logic of capital, in which technological innovation does not emerge in isolation but rather as a response to competitive pressure (Marx, 2017). Within this framework, the development of productive forces is not simply a reflection of scientific or technical progress—as it might appear—but a necessity imposed by the capitalist accumulation process, which demands technologies capable of reducing costs and increasing productivity to ensure the reproduction of capital in the marketplace (Marx, 2017).

During the development phase of the beneficiation plant projects, debates emerged over different technologies for ore processing and tailings management. This is evident in the account of a former Vale researcher:

> “At the time, the superintendent proposed setting up a mineral processing research laboratory in Itabira, which he himself would coordinate. But he never returned to the unit, and I ended up running the lab. For seven years, I conducted research on my own. I built a small dry magnetic separator and began studying itabirite without great ambition. But the cost was very high, as all the ore had to be dried. [...] Many alternatives failed because they were too costly or incompatible with our ore type. The dry magnetic separator didn’t work, so we built a pilot plant for high-intensity wet magnetic separation using Jones plates. But we were in a hurry, and it was built in parallel with the industrial plant. By the time we finished the pilot, the building for the full-scale separator was already three stories high. Everyone said we were crazy—that all the machinery we were developing would end up as scrap. But if we hadn’t persisted in those studies, Vale do Rio Doce wouldn’t exist today.” [Name withheld], retired, former superintendent of the Mineral Development Centre – worked at Vale from 1958 to 1991 (Vale, 2016, pp. 25, 30).

This professional describes the effort to develop a dry magnetic separation technique in Itabira. This method could have avoided the creation of tailings dams, which are more suited to managing wet tailings. However, the high cost of this solution and the urgency imposed by market competition were decisive in rejecting the dry method in favor of wet beneficiation. Despite its reliance on tailings dams for waste storage, wet processing proved more economically viable, aligning with the sector's demand for low-cost, high-throughput, and rapidly deployable solutions.[15]

This illustrates that the construction of tailings dams in Minas Gerais was not a purely technical decision but a strategic and economic response to a specific critical conjuncture. The imperative to adopt a production model focused on cost reduction and competitiveness led mining companies to opt for wet beneficiation, which generated large volumes of tailings and required the construction of dams for their storage.

Thus, the claim that wet beneficiation was vital for the company's survival should not be seen as an exaggeration but as a clear expression of the competitive pressures imposed by the global market. As Marx (2017) suggests, firms that fail to reach the necessary scale of production to reduce their operational costs risk losing competitiveness and ultimately being outpaced by more efficient rivals. According to the General Law of Accumulation (Marx, 2017), the advancement of productive forces—driven by the need to cut costs and increase productivity—is essential for the continuation of capital accumulation, which compels companies to continually transform their production processes (cf. Rodrigues, 2024).

Early reports of socio-environmental problems linked to tailings generation

As early as the 1970s, reports began to emerge pointing to socio-environmental problems associated with tailings dams in Minas Gerais. One of the first studies on the subject was Freitas (1976), which analyzed the impacts of the construction of the Pontal Dam in Itabira.

According to Freitas (1976, p. 266), the high concentration of wet tailings produced by mineral beneficiation created "a barrier to the flow of domestic sewage water, which began to accumulate in depressions near residential areas and became major breeding grounds for mosquitoes and sources of gas emissions."

[15] The choice of wet beneficiation, besides being cheaper, may also be related to the abundance of water resources available in the Iron Quadrangle. Such abundance makes intensive water use in mineral processing economically viable, unlike what occurs in mineral extraction in other contexts, such as desert regions. Due to this hydrogeological characteristic, some authors have referred to the region as the Iron-Quadrangle Aquifer (Coelho, 2012), which seems pertinent for uncovering the correlation between the aquifers and the mineral extraction techniques used in the area.

These problems reflected the dam construction model used at the time. According to the study, the mining company built the dam by integrating both upstream and downstream techniques directly into the municipal stream, mixing surface water, domestic sewage, and mining tailings. This configuration led to the siltation of the basin, restricting water flow and causing the accumulation of sewage waste in the muddy areas that formed. As a consequence, there was a proliferation of mosquitoes and foul odors in urban areas of Itabira.

Another issue highlighted by Freitas (1976) is that part of the tailings escaped the dam and was carried by river flow, contaminating downstream stretches of the river. This matter was raised during the discussion that followed the biologist's presentation:

> QUESTION — Acad. José Maria Miranda — Escola Politécnica—USP "If I'm not mistaken, at the beginning of your lecture you mentioned that, out of the 30 million tons of iron ore, 6 million are tailings that are dumped into the dam. I would like you to draw a comparison between the pollution potentially caused by these tailings and the pollution caused by the city's sewage." RESPONSE — "First, I'll give an example. A stream near Itabira, the Córrego do Girau, which receives no treatment whatsoever, is not directly affected by the tailings. There is a town approximately 25–26 km from Itabira, Santa Maria de Itabira, that receives these fully polluted waters—lacking transparency, turbid, and muddy with tailings. They even flow into what we call the 'murky river' there in Santa Maria de Itabira. That is to say, if those 6 million tons made their way downriver, they could reach the tributaries of the Rio Doce, and even the river itself might be affected during the rainy season. Many small springs would be covered along the way, reducing the river's water volume—which is already happening in many regions of Minas Gerais. So, this is a serious issue." (Freitas, 1976, p. 305)

Despite the socio-environmental problems associated with the installation of tailings dams, this method became consolidated from the 1970s onwards as the main technological alternative for managing wet mining waste. As shown, this situation was driven by the sharp increase in mineral production, which intensified tailings generation and demanded urgent solutions for their disposal.[16]

In many recorded cases, tailings were dumped directly or indirectly into riverbeds rather than being confined to proper containment reservoirs within the mining sites themselves. For example, according to a report by the João Pinheiro Foundation (1976), in the Metropolitan Region of Belo Horizonte, a significant portion of tailings from mining operations was discharged directly into watercourses without any containment measures,

[16] The report states: "We were at the source of the Oriolo Stream, a tributary of the Macena basin. Near that spot, MBR was building an embankment with sterile material—tailings from the Águas Claras mine—and, during the rains, this material would be washed directly into the Macena and then into the Cardoso, which could compromise the installations of the Morro Velho Mine, as well as cause siltation of the Água Suja and, ultimately, of the Velhas River. At the time we were accompanied by MBR representatives […] who, aware of the problem, informed us of their commitment to the immediate construction of three dams (Nos. 2, 3, and 4), shown on the attached plan, with completion scheduled before the start of this year's rainy season." (Jornal Nova Lima Notícias, 1979)

resulting in widespread water pollution. Although some companies adopted basic mitigation techniques—such as settling ponds—most operations failed to implement sustainable waste management practices.

A second report from the same João Pinheiro Foundation (1977) details the damage caused by MBR, the country's second-largest mining company at the time, whose tailings disposal severely impacted the Córrego das Mangabeiras stream, with sediment deposits exceeding one meter in some areas, affecting the local ecosystem. As mineral production continued to grow throughout the 1970s, the direct discharge of tailings into rivers became unfeasible, prompting the need for technological alternatives.

In this context, the 1976 report by the João Pinheiro Foundation itself recommended the construction of dams to contain tailings:

> “It is possible to conclude that there is considerable technical ease in addressing pollution caused by mining in the Metropolitan Region of Belo Horizonte. Since iron mining constitutes the region’s primary extractive activity, waste containment can be readily accomplished through dam construction, which would offer the following advantages: the use of fines in pellet production; sterile material for the reclamation of mined land; and the reuse of purified water for ore washing.” (Fundação João Pinheiro, 1976, p. 129)

As can be seen, beyond the broader economic context of a sector increasingly demanding more intensive and cost-efficient mineral processing, there was also political pressure at the local level to encourage the adoption of tailings dams for storing wet waste. This dynamic is further corroborated by a newspaper report published in *Jornal Nova Lima Notícias* in November 1979, which documented the direct discharge of tailings into riverbeds by MBR. Under pressure from the Nova Lima municipal government, the mining company agreed to build three dams designed explicitly for storing this discarded material.

Amidst a scenario marked by significant challenges for the sector, mining companies in Minas Gerais succeeded in converting previously discarded materials—such as itabirite—into economically valuable products. Indeed, this capacity to repurpose itabirite did not escape the attention of poet Carlos Drummond de Andrade, who, in 1977, recorded his observation on the subject:

> “The State-run Company was quite content with its hematite, itabirite, and jacutinga, loaded onto freight trains and cargo ships, bringing in good money. Nor did it neglect the iron’s waste—the coarse dust that breaks off from the blasted rocks and accumulates into mountains, the tailings, the refuse. And so, it began to make use of this second-rate material, turning it into pellets. Nothing goes unused in iron: its very waste is a source of revenue.” (Andrade, 1977, p. 5)

However, this model reveals a critical ambiguity: while it symbolizes productive advancement and economic development, it also carries a high potential for socio-environmental catastrophe. As Robert Kurz (2004) pointed out, the most significant technical achievements often conceal the most tremendous potential for disaster. The construction of tailings dams illustrates this duality well. On the one hand, they enabled production to scale up and helped sustain regional competitiveness; on the other, they introduced the possibility of large-scale devastation.

Two significant events would later demonstrate the destructive potential of these structures. The first, in May 1986, occurred when the tailings dam of the Fernandinho Mine—located in Itabirito (now Rio Acima) and operated by the Itaminas Group —collapsed, resulting in the deaths of seven people. Roughly fifteen years later, another dam failure in Minas Gerais reinforced the socio-environmental risks posed by such infrastructure. In June 2001, prior to the significant surge in Chinese demand that would later boost the mining sector, the dam operated by Mineração Rio Verde in the municipality of Nova Lima collapsed, resulting in five fatalities.[17]

These disasters, which resulted in human casualties and environmental damage, highlighted the vulnerabilities of a mining model that relies on tailings dams. Although these incidents are rarely documented in the history of Brazilian mining, they could have served as early warning signs of the inherent risks posed by such structures—risks that were only formally addressed through regulation in Brazil following the Vale disaster in Brumadinho (Magno et al., 2023).

The crisis of iron ore mining in Minas Gerais, the deterioration of infrastructure, and the recurrence of dam failures

The final quarter of the twentieth century was marked by transformations in iron ore production in Minas Gerais, consolidating the region—alongside Western Australia—as one of the world's leading iron ore exporters. However, this period—referred to by Humphreys (2015) as the "lean years" of mining—was characterized by substantial challenges. Mining companies faced mounting pressure to cut costs in a market saturated by increased production, particularly following the launch of operations in Carajás (Pará) in 1985, all while contending with limited financing and low profitability. The economic crisis in Japan and the stagnation in Europe exacerbated uncertainty, even as the sector underwent a restructuring process marked by mergers and acquisitions (Humphreys, 2015). Despite the adverse conditions, the surge in Chinese demand for iron ore at the turn of the millennium began to

[17] More information about these dam failures can be found in the text by Ávila *et al.* (2021).

signal a potential and significant recovery for the sector, albeit shrouded in concerns about the long-term sustainability of China's growth.

Between 2000 and 2008, Brazil's mining sector underwent a wave of market centralization, driven by a series of acquisitions led by major mining and steelmaking groups (Rodrigues, 2024). CVRD—later renamed Vale—led this movement by acquiring companies such as Socoimex, Samitri, Ferteco, MBR, and Mineração Apolo (Saes, 2017), thereby consolidating its dominance in iron ore production, which increased from 48.72% in 1999 to 84.98% in 2007 (Rodrigues, 2024).

This context explains why, of the 64 iron ore tailings dams in Minas Gerais, 32 are currently operated by Vale. Although the company was not responsible for constructing all of these structures, it inherited responsibility for them through the incorporation of other mining companies and the centralization of regional production.

In contrast to global stagnation and Japan's economic slowdown, China embarked on a path of rapid economic growth, becoming the world's second-largest economy by 2010. This growth fuelled China's steel industry, which became both the world's largest steel producer and the leading importer of iron ore. Between 2000 and 2013, Chinese imports of iron ore surged from 70 million tons per year to 820 million tons, triggering a "commodity supercycle" that drove up iron ore prices (Humphreys, 2015).

This period of prosperity led to a significant expansion in iron ore production in Minas Gerais, which in turn increased the volume of tailings—most of which were deposited in dams—resulting in the expansion of tailings infrastructure. According to the Anuário Mineral Brasileiro (Brasil, 1972–2020), in 2000, Minas Gerais produced 215.8 million tons of gross iron ore and 163.1 million tons of processed ore, generating 52.7 million tons of tailings with a tailings generation rate of 24%. By 2015—the year of the Fundão dam collapse in Mariana—gross iron ore production in the state had more than doubled, reaching 440.5 Mt, with 294.9 Mt of processed ore and 145.6 Mt of tailings, raising the tailings generation rate to 33%.

The prosperity of the early 2000s was interrupted by the subprime mortgage crisis in the United States, which triggered the global financial crisis of 2008 (Pitta, 2020). This crisis had a profound impact on the global economy, particularly affecting China and the mining industry, resulting in significant changes in the iron ore market. Among these was the shift in pricing mechanisms—from the Benchmark pricing model to a Spot pricing system—reflecting the new market dynamics of short-term contracts and greater price volatility. Although demand for the commodity did not experience a significant decline, prices began to fluctuate sharply from 2008 onwards due to global economic instability (Humphreys, 2015).

In response to the crisis, states, such as the Federal Reserve in the United States and China, undertook emergency interventions, including the expansion of mortgage credit. These measures intensified debt levels and exerted additional pressure on financial markets. Under these conditions, iron ore prices—which had risen by more than 400% by 2008—became unstable, fluctuating between approximately 200 US dollars from 2009 to 2011 and dropping below 100 US dollars from 2014 to 2019 (Rodrigues, 2024).

From 2013 onwards, with the decline of the mineral economy, mining companies such as Vale and Samarco underwent both productive and administrative restructuring to adapt to the new market conditions, especially in response to prices falling below the $100 threshold. Cost reduction and productivity enhancement became imperatives for maintaining operational competitiveness, particularly in Minas Gerais, where ore deposits have lower iron content and the geographical distance from China results in high freight costs. Nevertheless, this restructuring also led to a more negligent approach to tailings dam management, which may have contributed to the weakening of containment structures in the state (cf. Rodrigues, 2024).

In other words, when the so-called "commodities crisis" emerged in 2013 (Pitta, 2020), Minas Gerais was already facing a scenario marked by the continuous decline in iron content in its ore deposits, which led to an increase in the rate of tailings generation (as shown in Table 1). These tailings were primarily stored in dams, the number and dimensions of which steadily increased over time.

As highlighted by Milanez et al. (2019) and Bowker and Chambers (2017), in addition to the rise in both volume and rate of tailings generation, the declining iron content of ore deposits has direct implications for the management of mining operations. The authors argue that this reduction in ore grade can affect operational costs, as larger quantities of ore must be processed to produce the same amount of marketable product, thereby generating additional expenses. To offset these rising costs, mining companies often resort to cutting expenditures in areas such as safety, maintenance, and dam monitoring, which exacerbates the risks associated with operating these structures.

It was in this context that, between 2014 and 2020, a series of tailings dam failures occurred in Minas Gerais, resulting in multiple social and environmental impacts (cf. Rodrigues, 2024). The first case in this series occurred in 2014, when the collapse of the B1 Dam, operated by Herculano Mineração in Itabirito/MG, resulted in three fatalities. The following year, in Mariana/MG, one of the most significant socio-environmental disasters in Brazil's history unfolded with the collapse of the Fundão Dam, leaving 19 people dead. Shortly thereafter, in 2019, a third disaster took place—this time involving Vale S.A.—with the failure of Dam I in Brumadinho/MG, which led to 292 fatalities.

In addition, throughout 2019 and 2020, several social disruptions occurred due to the imminent risk of dam failures across the state. For instance, in the early hours of 8 February 2019—just fourteen days after the Brumadinho disaster—communities in Barão de Cocais/MG were hastily evacuated due to the risk of failure at Vale S.A.'s Sul Superior Dam. Simultaneously, a similar situation occurred in Itatiaiuçu, MG, where the communities of Pinheiros, Vieiras, and Lagoa das Flores were evacuated due to the risk of a dam owned by ArcelorMittal collapsing (Rodrigues, 2024).

Further incidents occurred between 2019 and 2020, including the evacuation of hundreds of residents in Nova Lima/MG, Itabirito/MG, Ouro Preto/MG, and Barão de Cocais/MG. These evacuations were prompted by the risks posed by the B3/B4, Forquilhas, Vargem Grande, Doutor, and Norte/Laranjeiras dams, all of which are linked to Vale S.A. In addition to these, there were other similar episodes involving different companies, such as the evacuation of homes in Rio Acima/MG due to the risk of collapse of the B2-Auxiliary Dam operated by Nacional Minério S.A. and in the community of Queias in Brumadinho/MG due to safety concerns regarding a complex of abandoned dams once managed by the now-bankrupt company Emicon (Rodrigues, 2024).

Beyond the emergencies directly associated with the identification of structural anomalies, there is also the broader social impact caused by the fear and constant tension among populations living downstream from these dams—even in cases where technical reports attest to their stability. The recurring problems with tailings dams have brought increased public scrutiny and underscored their catastrophic potential, profoundly affecting the daily lives of communities near these containment structures. This scenario is marked by distress, a persistent sense of risk stemming from warning systems and evacuation drills, and a generalized distrust toward the mining sector, particularly as some disasters occurred at dams previously deemed stable. In cities such as Itabira and Congonhas, where large dams are located near urban areas, the atmosphere of tension is especially pronounced. In these locations, residents of threatened zones have increasingly sought compensation and relocation as protective strategies against the fear of future disasters (Rodrigues, 2024).

Final remarks

It is essential to note that this research specifically focused on iron ore tailings dams, excluding structures associated with the extraction of other minerals, water retention, or those not registered in the SIGBM system, which may also pose socio-environmental risks. By narrowing its analytical focus to the dynamics of mineral capital reproduction and its effects on tailings management, this study necessarily left aside other important dimensions, such as the development of Brazilian environmental legislation since the late twentieth century or the origins and national adaptations of dam construction techniques.[18] Thus, this article aims to contribute to a broader research agenda that considers the proliferation of these structures through many other layers of analysis that remain largely unexplored in the present study.

It is crucial to acknowledge that any attempt to regulate or transform the sector must confront the limits imposed by the capitalist logic itself, in which the drive to maximize profits and reduce costs frequently overrides social and environmental concerns. In this context, the question of whether truly sustainable mining—one that does not perpetuate inequalities and risks but instead reconciles economic development with social and environmental justice—is still open. However, the historical geography of mining in Minas Gerais, as demonstrated by this research, suggests that such a balance may constitute an insoluble contradiction within the capitalist paradigm.

In sum, the regional dynamics established between 1970 and 2020—characterized by the exploitation of itabirite, the increasing generation of tailings, and their accumulation in dams—have resulted in the progressive build-up of mining waste and the expansion of containment structures. This process culminated in the emergence of multiple socio-environmental problems, the impacts of which became more severe from 2014 onwards, coinciding with the crisis in the mineral sector. The catastrophic potential of this model became even more evident in the disasters of Itabirito (2014), Mariana (2015), and Brumadinho (2019), as well as in the recurrence of other issues such as the forced displacement of communities and affected individuals—demonstrating that the issue of tailings dams remains a pressing concern.

In conclusion, this article has sought to denaturalize the presence, scale, and proliferation of iron ore tailings dams in Minas Gerais, as these structures—and the socio-environmental disruptions associated with them—cannot be attributed solely to the region's mineral abundance. While local geological characteristics have indeed shaped the restructuring of mining activities, administrative decisions—guided by the search for the most cost-effective waste disposal solutions—have been central to the consolidation of this tailings management model. Simultaneously, these decisions were made in a context marked by intensifying interregional competition within the global iron ore market, alongside local political pressures to mitigate water pollution.

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[18] A possible avenue for future research concerns replacing the construction of new dams with the vertical expansion of existing structures through successive raises. This strategy meets the pressure to increase production capacity. It avoids occupying new areas, but it has also resulted in a significant increase in the height, volume, and mass of accumulated tailings. Consequently, the potential risk associated with these structures in the event of a breach has grown. This represents a technical and historical dimension of dam engineering that, although not explored in depth in this work, deserves attention in further investigations on the topic.

References

ANDRADE, Carlos Drummond. A nova (possível) idade do ouro. **Jornal do Brasil**, Rio de Janeiro, 22 dez. 1977.

ÁVILA, Joaquim Pimenta et al. Segurança de barragens de rejeitos no Brasil: avaliação dos acidentes recentes. **Geotecnia**, n. 152, p. 435-464, 2021.

BOWKER, Lindsay Newland; CHAMBERS, David M. In the dark shadow of the supercycle tailings failure risk & public liability reach all time highs. **Environments**, v. 4, n. 4, p. 75, 2017.

BRASIL. Agência Nacional de Mineração (ANM). **Sistema Integrado de Gestão de Barragens de Mineração** (SIGBM). 2024a Disponível em: https://bit.ly/492CZ7B. Acesso em: 15 jul. 2024.

BRASIL. Agência Nacional de Mineração (ANM). **Resolução ANM nº 95**, de 7 de fevereiro de 2022. 2024b Disponível em: https://bit.ly/3Zk2vSU. Acesso em: 02 ago. 2024.

BRASIL. Departamento Nacional de Produção Mineral (DNPM) e Agência Nacional de Mineração (ANM). **Anuário Mineral Brasileiro**: principais substâncias metálicas, 1972-2020.

BRENNER, Robert. A crise emergente do capitalismo mundial: do neoliberalismo à depressão. **Outubro**, n. 3, 1999.

COELHO, Tádzio Peters. **Dependência e mineração no quadrilátero ferrífero-aquífero**: o discurso do desenvolvimento minerador e o Projeto Apolo. Dissertação (Mestrado em Ciências Sociais) - Universidade do Estado do Rio de Janeiro, Rio de Janeiro, 2012.

FERNANDES, Francisco Rego Chaves. **Os maiores mineradores do Brasil**: perfil empresarial do setor mineral brasileiro. Brasília, DF: CNPq, 1982.

FREITAS, José Rabelo de. Controle de poluição aquática no sistema de rejeito de concentração de itabirito. **Geologia e Metalurgia,** n. 40, VI Simpósio Brasileiro de Mineração, p. 264-306, 1976.

FUNDAÇÃO JOÃO PINHEIRO. Diretoria de Tecnologia e Meio Ambiente. **Situação ambiental na RMBH**. Fundação JP, Belo Horizonte, 1976. Disponível em: https://bit.ly/40W22Hq. Acesso em: 17 set. 2024.

FUNDAÇÃO JOÃO PINHEIRO. **O Impacto Ambiental da Mineração de Águas Clara**. Fundação JP, Belo Horizonte, 1977.

HARVEY, David. **Os limites do capita**l. São Paulo: Boitempo, 2013

HUMPHREYS, David. **The remaking of the mining industry**. Basingstoke: Palgrave Macmillan, 2015.

IPEA: INSTITUTO DE PESQUISA AVANÇADA. **Diagnóstico dos resíduos sólidos da atividade de mineração de substâncias não energéticas**. Brasília: IPEA, 2012.

KEGLER, Jürgen; JACOBS, Wolfgang. Montangeologische Bearbeitung der Hämatit-Reicherzlagerstätte Fábrica der Ferteco Mineraçao SA im Eisernen Viereck von

Minas Gerais/Brasilien. **Zeitschrift der Deutschen Geologischen Gesellschaft**, p. 169-183, 1982.

KURZ, Robert. **O Colapso da Modernização**: da derrocada do socialismo de caserna à crise da economia mundial. São Paulo: Editora Paz e Terra. 1992.

KURZ, Robert. **Com todo vapor ao colapso**. Juiz de Fora: Editora UFJF. 2004.

MAGNO, Lucas; WANDERLEY, Luiz Jardim; IORIO, Gustavo Soares; MILANEZ, Bruno.Territórios corporativos da mineração: barragens de rejeito, reconfiguração espacial e deslocamento compulsório em Minas Gerais – Brasil., **Revista NERA**, v. 26, n. 66, 2023. https://doi.org/10.47946/rnera.v26i66.9034.

MARX, Karl. **O Capital**: Crítica da economia política. Livro 1: O processo de produção do capital. Boitempo Editorial, 2017.

MILANEZ, Bruno *et al*. Minas não há mais: avaliação dos aspectos econômicos e institucionais do desastre da Vale na bacia do rio Paraopeba. **Versos - Textos para Discussão PoEMAS**, v. 3, n. 1, p. 1-114, 2019.

MINAYO, Maria Cecília de Souza. **De ferro e flexíveis**: marcas do Estado empresário e da privatização na subjetividade operária. Rio de Janeiro: Garamond, 2004.

PITTA, Fábio. O crescimento e a crise da economia brasileira no século XXI como crise da sociedade do trabalho: bolha das commodities, capital fictício e crítica do valor-dissociação. **Sinal de Menos**, v. 1, n. 14, p. 38-146, 2020.

RODRIGUES, Glauco Bruce. Geografia Histórica. Notas sobre a metodologia. Terra Brasilis. **Revista da Rede Brasileira de História da Geografia e Geografia Histórica**, n. 12, 2019.

RODRIGUES, Thell Victor de Andrade. **Quadrilátero Ferrífero, a região catastrófica**: interpretações sobre a recorrência dos problemas com barragens entre os anos de 2014 e 2020. 2024. Dissertação (Mestrado em Geografia Humana) - Faculdade de Filosofia, Letras e Ciências Humanas, Universidade de São Paulo, São Paulo, 2024. doi:10.11606/D.8.2024.tde-20082024-101638. Acesso em: 12 mai. 2025

SAES, Beatriz Macchione. **Comércio ecologicamente desigual no século XXI**: evidências a partir da inserção brasileira no mercado internacional de minério de ferro. 2017. 1 recurso online (213 p.) Tese (doutorado) - Universidade Estadual de Campinas, Instituto de Economia, Campinas, SP. Disponível em: https://hdl.handle.net/20.500.12733/1630593. Acesso em: 21 outubro de 2024.

SAMARCO e CEPEMAR. **Estudo de Impacto Ambiental (EIA)**. Terceira Pelotização da Samarco em Ponta Ubú. Relatório Técnico. 2004. Disponível em: https://bit.ly/3Z0IIGn. Acesso em: 10 de agosto de 2024.

SANDERS FILHO, Ladislau Pereira. **De ribeirinho a atingido**: a luta pela terra da comunidade de Entre Rios, no contexto do Desastre da Samarco. 2019. Dissertação (Mestrado em Geografia Humana) - Faculdade de Filosofia, Letras e Ciências Humanas, Universidade de São Paulo, São Paulo, 2019. doi:10.11606/D.8.2019.tde-06042021-190833. Acesso em: 12 mai. 2025

SERRA, Cristina. **Tragédia em Mariana:** a história do maior desastre ambiental do Brasil. Editora Record, 2018.

SMIL, Vaclav. **Still the iron age:** iron and steel in the modern world. Butterworth Heinemann, 2016.

SOARES, L. Barragem de Rejeitos. In: **Tratamento de minérios.** 5.ed. Rio de Janeiro: CETEM/MCT, 2010. Cap. 19, p. 829-896.

TAKEHARA, L. **Caracterização geometalúrgica dos principais minérios de ferro brasileiros–fração sinter feed**. 2004. 419 f. 2004.

VALE. **Memória da Tecnologia da Mineração em Itabira: Da Hematita ao Itabirito Compacto**. 2016.

VALE. **Nossa história**. Rio de Janeiro, RJ: Verso Brasil, 2012.

About the authors

Thell Rodrigues – PhD candidate and Master in Human Geography from the University of São Paulo (USP), with a Bachelor's degree in Geography from the Federal University of Minas Gerais (UFMG). Currently, he is a teacher at Centro Paula Souza and coordinator of the Common National Curriculum Base (BNCC) at Etec Cepam. He is a member of the board of AGB São Paulo Local Section (2024–2026 term), serving as part of the secretariat collective and Coordinator of Publications. His research focuses on Economic Geography, Regional Geography, and Historical Geography, with an emphasis on mineral exploitation in Minas Gerais, analyzed through a critical perspective on modernization and the crisis of capitalist social reproduction. **OrcID** – https://orcid.org/0000-0002-9816-8121.

Ladislau Pereira Sanders Filho – Holds a Bachelor's degree in Geography from the Federal University of Espírito Santo (UFES) (2013), a Master's degree in Human Geography from the University of São Paulo (USP) (2019), and is currently a PhD researcher in Human Geography, also at University of São Paulo (USP). His research focuses on agrarian geography, territorial disputes and social movements, peasant class reproduction, agriculture, and regional formation under the development of the capitalist mode of production. He has been studying the regional context of the Doce River mouth following the collapse of Samarco's mining tailings dam in November 2015, with particular attention to damage reparation and the production of the affected subject. **OrcID** – https://orcid.org/0009-0007-0484-455X.

How to cite this article

RODRIGUES, Thell; SANDERS FILHO, Ladislau Pereira. The historical geography of iron ore tailings dams in Minas Gerais, Brazil. **Revista NERA**, v. 28, n. 3, e10861, jul.-set., 2025. https://doi.org/10.1590/1806-675520252810861en.

Individual Contribution Statement

The scientific contributions presented in the article "The Historical Geography of Iron Ore Tailings Dams in Minas Gerais, Brazil" were jointly developed by the authors **Thell Rodrigues** and **Ladislau Pereira Sanders Filho**. Author **Thell Rodrigues** was responsible for the roles of conceptualization, data curation, formal analysis, investigation, methodology, supervision, and writing (original draft, review, and editing). The second author, **Ladislau Pereira Sanders Filho**, was responsible for the roles of formal analysis and writing (original draft, review, and editing). We emphasize that these roles correspond to those described in the CRediT (Contributor Roles Taxonomy).

Received for publication on February 27, 2025.
Returned for review on April 16, 2025.
Accept the publication on June 6, 2025.

This article was edited by Lorena Izá Pereira and Camila Ferracini Origuela.