

PUBLIC DATABASES FOR DISASTER RISK COMMUNICATION: EXAMPLES OF TAILINGS DAMS IN EMERGENCY LEVEL

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Resumo – O risco de ruptura – mesmo sem se materializar - de barragens de rejeitos causa impactos socioeconômicos na área de inundação, principalmente nos casos de Nível de Emergência (NE) 2 e 3, que demandam evacuação da Zona de Autossalvamento (ZAS). Informações destas e outras barragens de mineração no Brasil estão disponíveis na base pública de dados SIGBM, desenvolvida pela Agência Nacional de Mineração (ANM). A fim de compreender a situação atual das informações de barragens em NE2 e NE3 divulgadas no SIGBM, estas foram analisadas quanto à duração do NE, minério, localização, empresa responsável, método de alteamento e ZAS. Observou-se que a declaração de NE2 ou NE3 pode demorar longos períodos, sendo que cinco barragens estão nestes níveis há seis anos. Existem residências nas respectivas ZAS destas cinco estruturas, exigindo evacuação. Além disso, seis das oito barragens em NE2 ou NE3 contêm rejeitos de minério de ferro, estão no Quadrilátero Ferrífero, são alteadas a montante e estão em descaracterização. Quanto à empresa, cinco barragens pertencem à Vale, responsável pela Barragem B1 que rompeu em Brumadinho em 2019. Como resultado desta análise, três recomendações foram feitas à aquisição de dados no SIGBM, a fim de incentivar a análise em arquivos editáveis. Conclui-se que bases públicas de dados podem melhorar a comunicação de riscos de barragens de mineração, caso o seu conteúdo, acessibilidade e credibilidade sejam considerados.

Palavras-chave – Barragens de mineração; Nível de emergência; Zona de autossalvamento; Dados abertos; Quadrilátero Ferrífero.

Abstract – Tailings dam failure risks – even without materializing – cause socioeconomic impacts in the inundation area, mostly in the cases of Emergency Level (EL) 2 and 3, which demand the evacuation of the Self-rescue Zone (ZAS). Information on these and other mining tailings dams is available on the database SIGBM, developed by the National Mining Agency (ANM) of Brazil. To comprehend the scenario of information disclosed on SIGBM about dams in EL2 and EL3, data was analyzed regarding EL duration, ore, location, responsible company, raising method, and ZAS. Declaration of EL2 or EL3 tends to take long periods, as five dams have been in these situations for six years at the time of writing. There are residences in the ZAS of these five dams, requiring evacuation. Moreover, six of the eight dams in EL2 or EL3 dispose of iron ore tailings are situated in the Iron Quadrangle, were raised with the upstream method, and are being de-characterized. Five dams belong to Vale, responsible for the B1 dam that failed in Brumadinho in 2019. As a result of this review, three recommendations were developed for data retrieval from SIGBM, to enhance data analysis in editable files. This research concludes that public databases could enhance the risk communication of tailings dams, in case their content, accessibility, and credibility are considered.

Keywords – Tailings storage facility; Emergency Level; Self-rescue Zone; Open data; Iron Quadrangle.

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1. INTRODUCTION

Failures of tailings storage facilities (TSFs) may lead to disasters, such as the catastrophic failures of the Fundão dam, in Mariana, in November 2015, and the B1 dam, in Brumadinho, in January 2019, both in the Brazilian state of Minas Gerais. These failures resulted in 291 fatalities and impacted the livelihoods of fishermen, agriculture, and traditional communities (Carmo et al., 2017; Silva Rotta et al., 2017). Nevertheless, facilities that did not fail also have caused worries downstream, majorly those in Emergency Level (EL). This classification, whose criteria was established by the Brazilian National Mining Agency (ANM) after both catastrophic failures, regards four levels of emergencies: Emergency Alert, EL1, E2, and E3, in ascending order of potential to compromise dam safety (ANM, 2022). Since November 2019, about 30 TSFs have been classified with Emergency Levels 2 and 3 (ANM, 2023; ANM, 2025), causing involuntary displacement, as demanded by law (ANM, 2022). In Minas Gerais, at least 1,257 people are estimated to have been displaced until March 2021 (Neri et al., 2021), causing real estate speculation, rumors, and tensions among communities (Neri et al., 2021). Therefore, the risk - without materializing into a TSF failure - causes social impacts and must be properly communicated to stakeholders and mitigated.

Risk communication aims to exchange risk information among individuals, groups and institutions throughout the disaster risk management cycle: after, before, and during a disaster (Xue et al., 2022). Specifically to disaster preparedness, i.e. any period before a disaster, communication aims to increase awareness, informing about the (i) size of the risk and (ii) emergency procedures (Kondo et al., 2019). To cover a wide and diverse public, communication should be conducted in a variety of vehicles. In-presence formats, such as the distribution of leaflets and public audiences, enable targeting people who are vulnerable and exposed to disaster risks. In addition, multiple media should be adopted, including television, radio, phone, and internet. The latter includes not only fast and interactive communication in social media, but also public online databases, or digital platforms, which are websites that disclose risk information.

Public databases of TSFs are encouraged by the Global Industry Standard on Tailings Management (GISTM), launched in 2020 as a reaction to the failure in Brumadinho. The initiative was co-convened by the International Council on Mining and Metals (ICMM), the United Nations Environment Programme (UNEP), and Principles for Responsible Investment (PRI). In the same year, the first international database of TSFs was established with 1.743 TSFs, revealing instabilities risks, according to Franks et al. (2021). Moreover, another 11 databases from five countries were analyzed by Massignan and Sánchez (2024), however requiring improvements to comprehensively communicate risk information to multiple stakeholders.

In Brazil, the National Mining Agency (ANM) has maintained an online database of mining tailings dams, the *Integrated System of Mining Dams Management* (SIGBM), since 2020. As of February 2025, information about 919 facilities was disclosed, regarding dam and tailings characteristics, classifications, and inundation area. SIGBM ranked first in the international review of public databases of TSFs conducted by Massignan and Sánchez (2024), performing well in 16 out of 22 information categories. Nonetheless, shortcomings were identified in terms of disclosure of emergency procedures, update information, and inclusion of tailings dry-stacks. In addition, the motive for Emergency Levels for each facility is not explicitly described on SIGBM, although information disclosed could indicate their reasons.

Therefore, to investigate the current situation of information disclosed on SIGBM of tailings dams in Emergency Levels 2 and 3, public data was analyzed regarding emergency duration, ore, location, company owner, raise method, dam height, tailings volume and area of the ZAS. EL2 and EL3 were selected since they are more likely to implicate the dam safety and require evacuation, causing downstream socioeconomic impacts. Difficulties in the retrieval of information were analyzed and recommendations for improvement were made. We conclude by highlighting that public databases of tailings storage facilities have the potential to enhance tailings dam risk communication.

2. PUBLIC DATABASES FOR DISASTER RISK COMMUNICATION

Public databases are websites that dispose of open data, i.e. public and not confidential information, accessible with no cost, and without restriction of use or user (Attard et al., 2015). To meet their purpose, digital platforms of risk information of TSFs should feature accessible layouts, use plain language as much as possible (ISO, 2023); and be updated and credible to inspire confidence (Xue et al., 2022). Regarding risk communication literature, their content should not only inform the risk causes, but also how people are affected, which areas are exposed, when the disaster might happen, and emergency preparedness information (Coppola, 2015a). However, none of the 12 databases of TSFs analyzed by Massignan and Sánchez (2024) disclose emergency procedures, only the size of the risk.

On the one hand, stakeholders may face barriers to accessing public databases, due to internet, computer, or mobile phones restrictions. Moreover, low-level of education or digital illiteracy restricts the full utilization of the website. Therefore, public databases are viable options for risk communication, however other communication vehicles should be maintained to target all stakeholders.

On the other hand, digital platforms integrate much information in one website, in a standardized way (Franks et al., 2021), offering users to search, access, explore, and interact with the data (Attard et al., 2015). Moreover, public databases may reach a broader audience than in-person communication, increasing the disclosure of risk information. Therefore, not only exposed and vulnerable people would have access to this data, but also the academy and media, enhancing research and public politics development. Therefore, digital platforms of TSFs are potential risk communication vehicles, whose accessibility, content, and credibility should be enhanced.

3. PUBLIC DATA OF TAILINGS DAMS IN EMERGENCY LEVEL

The four degrees of emergencies are available on SIGBM, whose criteria are defined by ANM Resolution 95/2022. The Alert Level (AL) is the lowest potential to compromise the dam safety, regarding the identification of anomalies that do not immediately compromise the dam safety. If anomalies persist, the Risk Category (CRI) is high, or other situations in Table 1, the level changes to EL1. Again, if the identified anomalies are not adequately treated, the TSF is classified with EL 2, and the third level is adopted when 'the failure is inevitable or is happening' (ANM, 2022). Levels 2 and 3 imply evacuating and, only in EL3, activating the sirens in the Self-rescue Zone (ZAS) - a segment of the inundation area where there is no sufficient time for authorities to intervene in an emergency (ANM, 2022). The ZAS is defined as the area flooded 30 minutes after a failure, obtained from dam break models, or 10 km downstream of the dam, whichever is the longest length (ANM, 2022).

By February 2025, six tailings dams were in EL2 and two in EL3 (Table 2). In the sequence, their duration of emergencies situations, location, ore, company owner, raise method, and ZAS are analyzed.

Table 1. Summary of criteria for Emergency Levels and implications in the Self-rescue Zone

	Alert situation		Emergency Level (EL)	
	Alert Level (AL)	EL1	EL2	EL3
Criteria	Anomalies that do not immediately compromise the dam safety; or ANM criteria.	High Risk Category (CRI); Anomalies are not treated; or Any situation that might compromise the TSF safety.	Anomalies are not treated.	Failure is inevitable or happening.
Safety factor for drained condition (FSd)	-	1.3 \leq FSd < 1.5	1.1 \leq FSd < 1.3	FSd < 1.1
Safety factor for undrained condition (FS)	-	1.2 \leq FS < 1.3	1.0 \leq FS < 1.2	FS < 1.0
Implications in the ZAS	-	-	Company owner of the TSF and the Civil Defense must preventively evacuate the ZAS	Company owner of the TSF must communicate people in the ZAS aiming evacuation and sound the sirens

Source: ANM, 2022.

Table 2. Tailings dams in Emergency Level 2 and 3 in February 2025

Emergency Level (EL)	Tailings dam	Company owner	State	Municipality	Ore	Raise method	Operational status
EL2	<i>Bacia do Castanheira</i>	Buritirama Mineracao S.A. Falido	Pará	Marabá	Manganese	Single raise	Active
EL2	<i>Barragem do Vené</i>	Mineracao Aurizona S/A	Maranhão	Godofredo Viana	Gold	Centerline dam	
EL2	<i>Xingu Sul Superior Forquilha I Forquilha II Forquilha II</i>	Vale S.A.	Minas Gerais	<i>Mariana Barão de Cocais</i>	Iron ore	Upstream dam	In de-characterization
EL3	<i>Barragem Serra Azul</i>			<i>Itatiaiuçu</i>			

Source: ANM, 2025.

3.1. Duration of emergencies situations

Emergency Level of a tailings dam varies over time, according to their criteria. Among the records since August 2022 (Figure 1), EA and EL1 have the highest number of dams and fluctuations. Differently, Emergency levels 2 and 3 had lower numbers of dams and modestly varied throughout the time, since dams with EL2 and EL3 tend to take longer periods to re-stabilize. Among the eight dams currently in these levels (Tables 2 and 3), five had their EL declared in February 2019, a few days after the disaster in Brumadinho on January 25, 2019. Communities in the ZAS of *Forquilha I, II, and III*; *Barragem Serra Azul*; and *Sul Superior* have been evacuated since then. Therefore, long periods of Emergency Level 3 contradict its definition of ‘imminent failure’ (ANM, 2022).

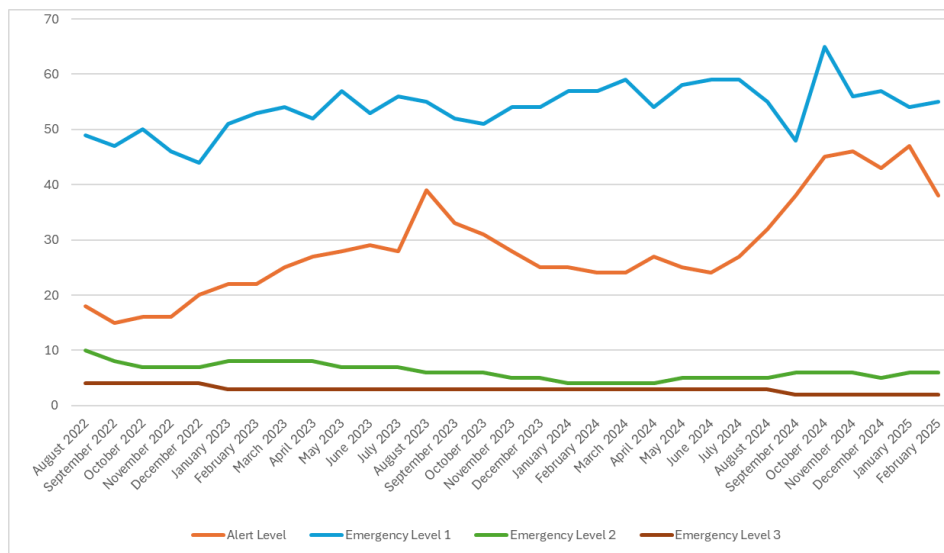


Figure 1. Records of emergencies situations since August 2022 (ANM, 2025)

Table 3. Declaration dates of emergencies situations of tailings dams currently in Emergencies Levels 2 and 3

Tailings dam	Feb. 2019	Mar. 2019	Apr. 2020	Sep. 2020	Oct. 2020	Apr. 2024	May 2024	Aug. 2024	Dec. 2024	Jan. 2025
<i>Bacia do Castanheira</i>									EL1	EL2
<i>Barragem do Vené</i>						EA	EL2			
<i>Xingu</i>			EL1	EL2						
<i>Sul Superior</i>	EL3							EL2		
<i>Forquilha I</i>	EL2	EL3			EL2					
<i>Forquilha II</i>	EL2	EL3								
<i>Forquilha III</i>	EL2									
<i>Barragem Serra Azul</i>	EL2	EL3								

Where: EL – Emergency Level; EA – Emergency Alert.

Sources: ANM, 2023; ANM, 2025; Bond, 2024; Cabral, 2025; Jucá, 2019.

3.2. Location and company owner

Only two of the six dams in EL2 are located outside Minas Gerais: one in Pará and one in Maranhão. The other four facilities in EL2 and two in EL3 are located in Minas Gerais and relate to iron ore, in the ‘Iron Quadrangle’ - the same region of the municipalities of Mariana and Brumadinho (Figure 2). In fact, out of the 334 tailings dams in Minas Gerais, 209 (63%) are located in the *Iron Quadrangle*, including nine EA and 15 EL1 (ANM, 2025). Situated in the center south of

Minas Gerais, this region is the most populated of the state, whose socioeconomic development is intertwined with historical mining. Intensive iron ore mining was established in the middle of the 20th century, preceded by a gold mining boom in the 18th century (Machado and Figueirôa, 2020). Moreover, Kamino et al. (2020) showed that the tailings dam in the *Iron Quadrangle* spatially overlaps protected and priority conservation areas. Therefore, this region combines at least two disaster conditions: exposure of communities and valued natural areas and hazards (TSFs).

In addition to similarities to disasters in Mariana and Brumadinho, five of the TSFs in EL2 or EL3 in Minas Gerais belong to Vale, which is the owner of the Córrego do Feijão mine and Fundão dam, the latter with BHP in the joint venture Samarco.

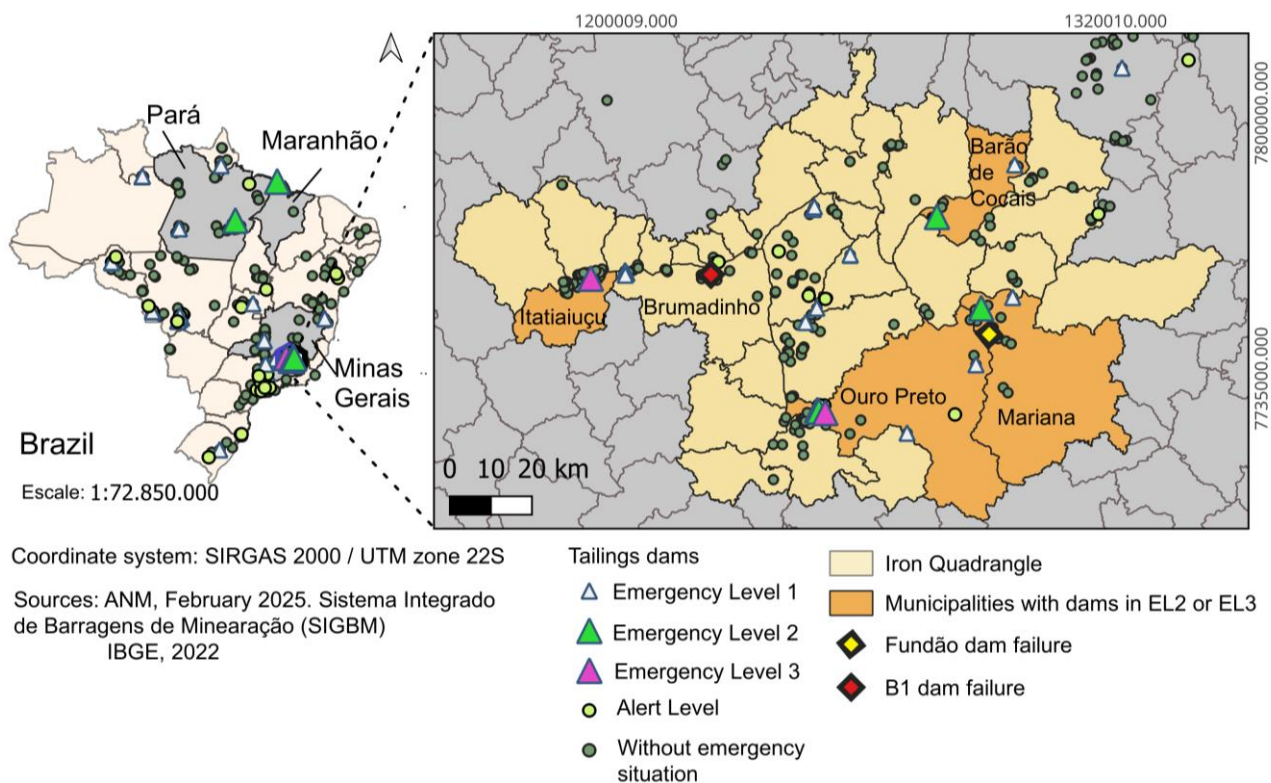


Figure 2. Emergency situation of tailings dams

3.3. Raise method and operational status

Moreover, all dams in EL 2 and 3 in Minas Gerais were constructed with the upstream method, the same as the Fundão and B1 dams. This raising method is less safe and has more propensity for liquefaction, not suitable for seismic regions and for storing large quantities of water or fine grain-size tailings (Vick, 1990). After the disaster in 2019, upstream dams were prohibited in Brazil, and existing upstream dams were demanded by law to be 'de-characterized', i.e. decommissioned and reintegrated into the environment (Massignan and Sánchez, 2022). Therefore, after *being de-characterized*, a dam tends to reduce its failure risk.

In contrast, *Bacia do Castanheira* was constructed in a single raise and *Barragem do Vené* is a centerline dam. Both construction methods are considered more stable than upstream dams, and adequate for rainy regions (Vick, 1990). Hence, not only upstream dams might be in EL, but any facility due to flaws in construction, planning, or management. Furthermore, both are active dams, although the company owner of *Bacia do Castanheira* declared bankrupt, which might compromise the dam management.

3.4. Tailings volume and dam height

Due to the single raise method, *Bacia do Castanheira* is the smallest facility in Emergency Level 2 or 3, with 10 m high and approximately 496 million m³ of tailings (Figure 3). All facilities with EL2 or EL3 are smaller than the Fundão dam, which had 55 million m³ and released 40 Mm³. However, four facilities have a current volume of tailings bigger than the B1 dam, of 12 Mm³ (Figure 4), which released 10 Mm³. Similarly, the heights of the dams are smaller than the Fundão dam, although with much less difference than comparing the volume. Three dams dispose of more tailings volume than the B1 dam. Therefore, most dams in EL2 or EL3 are similar to the B1 dam in height and volume.

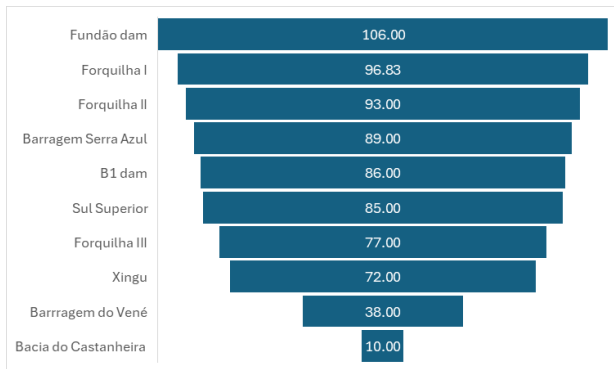


Figure 3. Tailings dam height (m)

Sources: ANM, 2025; CSP2, 2022.

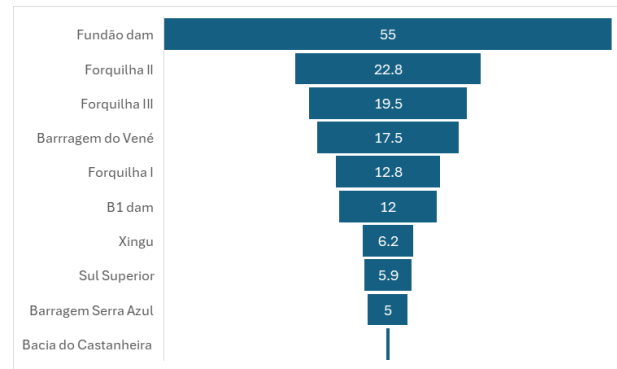


Figure 4. Tailings volume (Mm³)

3.5. Self-rescue zone (ZAS)

The eight TSFs that must evacuate the ZAS are classified with the highest 'Potential Associated Consequence' (DPA) (ANM, 2025). Analyzing the ZAS of these dams, *Barragem do Vené* has the largest one, with 1,645.8 ha, located in an Environmental Protection Area (APA) of Maranhão, and in the Coastal Marine-System of Brazil (Figure 3). *Vené* and *Castanheira* dams are located in the Amazon region, although the latter has the ZAS in an agricultural area. The second largest ZAS belongs to the *Forquilha* dams, with 1,221.0 ha, limited downstream by a 'back up dam' – facility constructed to reduce the inundation area of dams in *de-characterization* and Emergency Level. The *Sul Superior* dam also has a back up dam, although its ZAS has the major amount of residences, among the facilities in Figure 3, and intersecting an APA of Minas Gerais. *Xingu* is the only dam in the *Iron Quadrangle* without residences in ZAS, which is the smallest in Figure 5.

Although Emergency Levels are temporally, a long period may take to re-stabilize TSFs, which is the case of the *Forquilha* I, II and III; *Serra Azul*; and *Sul Superior* dams (Table 2). The long period of uncertainty produces speculations among the evacuated people, in addition to interruption of social relations, space bonds and production activities (Neri et al., 2021). Moreover, the Secondary Safety Zones (ZSS) - defined as the inundation area not classified as ZAS (ANM, 2022) – were not analyzed in Figure 3. However, people in ZSS also have socioeconomic impacts, such as real estate devaluation and stress (Neri et al., 2021).

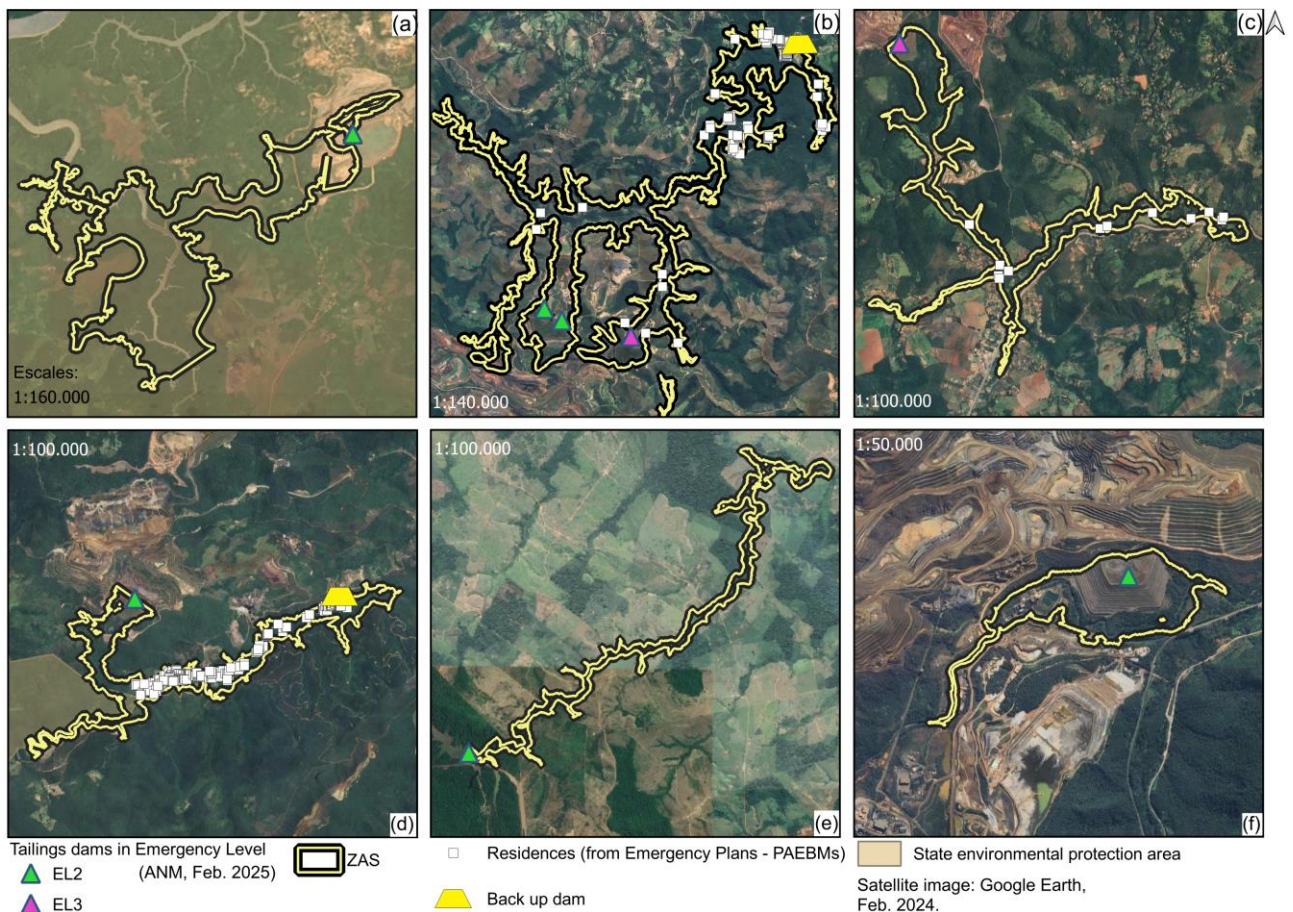


Figure 5. Self-rescue zone (ZAS) of tailings dams in Emergency Level 2 and 3. In descendent order of the area of ZAS: (a) *Barragem do Vené*; (b) *Forquilha I, II, and III*; (c) *Barragem Serra Azul*; (d) *Sul Superior*; (e) *Bacia da Castanheira*; and (f) *Xingu*.

4. ANALYSIS OF RETRIEVAL OF INFORMATION FROM SIGBM

Public databases should enable the retrieval of information in editable files, enhancing further analysis. Editable tables and geospatial files are available to download on SIGBM, however the need for improvements was identified when retrieving the analyzed data. Three suggestions are listed in the sequence.

Firstly, the table available to download does not include the complete information available on SIGBM, such as those in Table 1. However, on another governmental website, the 'Open Data Portal' (Brasil, 2025), the retrieval of the whole content of SIGBM in an editable table is available. Hence, the latter could be disclosed on SIGBM.

Secondly, the records of Emergency Levels (Figure 1) are not available to download in table format, hampering analysis. Moreover, SIGBM data only regard data from August 2022, although ANM claimed maintenance of records since November 2019 (ANM, 2023). Disclosing the complete records back to 2019 could enhance the analysis of ELs evolution.

Thirdly, the inundation areas are available to download in a .shp file, requiring the use of *ArcGIS* or *QGIS*. Although online visualization of the area is available on SIGBM, disclosing files compatible with *Google Earth* could make spatial data available to a wider range of users and enhance their use and analysis. Furthermore, there is no option to download all inundation areas at once, requiring more time and effort to retrieve the files.

5. CONCLUSIONS

The situation of the eight tailings dams currently in Emergency Level 2 and 3, which demand ZAS evacuation, was analyzed using public data from SIGBM. The records of EL declarations indicate that facilities in EL2 and EL3 tend to be in these situations for long periods, as highlighted by the *Forquilha I, II, and III*; *Serra Azul*; and *Sul Superior* dams. Moreover, six of the eight dams in EL2 or EL3 are located in the *Iron Quadrangle*, a populated region with mining liabilities, including previous disasters of the *Fundão* and *B1* dams. These six dams were all raised by the upstream method and are currently in *de-characterization* process. Moreover, all facilities are smaller than the *Fundão* dam, although four dispose more tailings volume than the *B1* dam. Hence, the location, ore, and raise method of most dams in EL2 or EL3 are similar to the *Fundão* and *B1* dams.

Furthermore, the geospatial files of ZAS were retrieved, enabling visualization of the evacuated areas. Residences were not identified in the ZAS of three tailings dams, although anthropic and natural areas were exposed, including environmentally protected areas by *Barragem do Vené* and *Sul Superior*. However, residences were recognized in the ZAS of *Forquilha I, II, and III*; *Serra Azul*; and *Sul Superior* dams – facilities in EL2 or EL3 for six years. Therefore, the long periods of these emergencies demand evacuation for long periods, causing socioeconomic impacts.

To reduce these impacts, enhance understanding of the risks, and promote emergency preparedness, evacuated people from ZAS and those currently in inundation areas should have easy and quick access to risk information on tailings dams. Considering the data retrieved from SIGBM and that risk communication should combine multiple media, public databases are viable vehicles to disclose risk information of TSFs to a wide public. It is important to highlight that digital platforms do not substitute other communication vehicles, which disclose information from SIGBM. However, web platforms could increase the disclosure and analysis of information, in case their content, accessibility, and credibility are properly considered.

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