

# **Proposals for Reducing Damage Caused by Dams Collapse in Pitinga - Amazonas**

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## **Abstract**

*Mining is an extractive activity that interferes with the economic, environmental and social environment. Thus, its intrinsic characteristic is locational rigidity, environmental transformation and the generation of social and environmental risks. Thus, this study aimed to present in the literature what is the best mitigating measure to be adopted in order to try to reduce the impacts on possible collapses in the Pitinga tailings dams in the Amazon. From this study it can be stated that among the 29 dams located in the State of Amazonas, 8 are from ore tailings and are located in the municipality of Presidente Figueiredo, in the Pitinga region, as regards supposed risks of a disaster, the perceived scenario in Minas Gerais can hardly occur, since the tailings dams have a natural containment because they are built in valleys. However, in order to reduce damage and prevent possible collapse in ore enterprises, it is essential that mitigation measures are used to compensate for environmental damage caused by the practice of ore extraction.*

**Keywords:** Mining; Extractive activity; Collapse; Compensation;

## 1. Introduction

Dams are high geotechnical structures created by individuals, and for millennia have been built by mankind for various purposes and purposes, according to the need of each location where it is located, such as power generation, water storage and control. ore tailings, among others [1].

The tailings dam is a structure produced for the mining tailings stock and is identified as a residue from the separation of ore from the rock deposited in the dam. With the development of the need for social and environmental preservation and mineral exploration, the theme of mining tailings dams has been reaching prominence, due to its damaging capacity in case of failures [2].

In the state of Amazonas there are 38 registered dams, of these 8 dams are intended for the mining sector. Only at the Pitinga mine in Presidente Figueiredo does a dam present a high risk, according to the National Mining Agency [3]. Thus, the issue of safety of Pitinga tailings dams has been presented as a public concern. It has been observed in recent years, a huge amount of accident episodes that have occurred in the ore tailings dams, can be cited the rupture of large dams such as Mariana and Brumadinho, both in the state of Minas Gerais, which resulted in ore tailings dam disasters with fatalities, unprecedented in the history of Brazil.

Thus, this study aims to show what would be the possible environmental damage, caused by a disaster in an ore tailings dam in, and what would be the mitigating measures for likely collapses in the tailings dams in Pitinga in the Amazon.

## 2. Theoretical Foundation

### 2.1 Definition and Characteristics of Ore Dams

It is an extractive activity that produces many interferences in the social, economic and environmental environments. If, on the one hand, the characteristics of mining mark the economic evolution, on the other hand the negative impacts and consequent damages of the mineral exploration cannot be forgotten.

Mining contributes to the creation of numerous direct and indirect jobs, precisely by offering raw material for various types of industry. After all, what would be the vehicle assembly industries without steel, glass and petroleum derivatives, materials that come directly from mining. It is precisely this indirect relationship with other industries that makes mineral extraction one of the main sources of job creation [4].

By observing the characteristics of mining it is possible to identify its peculiarities about the activities developed. However, the mineral enterprise enables the operation of capitals, lighting, automobiles, household appliances, food already prepared for consumption, health institutions, schools, among others. An important point is that the Amazon mining that increases the demand for mineral goods and, consequently, their prices, encouraging the search for new deposits [5].

To follow a dam analysis pattern, it is necessary to determine some important points regarding the source of the tailings. Mining represents a set of steps aimed at obtaining essential substances, found in their natural state, to be verified and appropriate to their final destination. With these characteristics, the transformation of resources into economic goods will only occur when technology is part of the mining of discovered ores [6].

## 2.2 Brief History of Pitinga Ore District

Vila de Pitinga is a village located in the municipality of Presidente Figueiredo, 320 kilometers from Manaus, in the direction of Boa Vista (RR, BR174), in the state of Amazonas. It has approximately 2,500 inhabitants, being founded from the beginning of the Pitinga, a mineral exploration sector in which minerals are extracted, the main products are: niobium, iron, alloy, tantalum and tin and belongs to the mining company Taboca [7]. In Figure-1, the location map of the Pitinga mining district is presented.

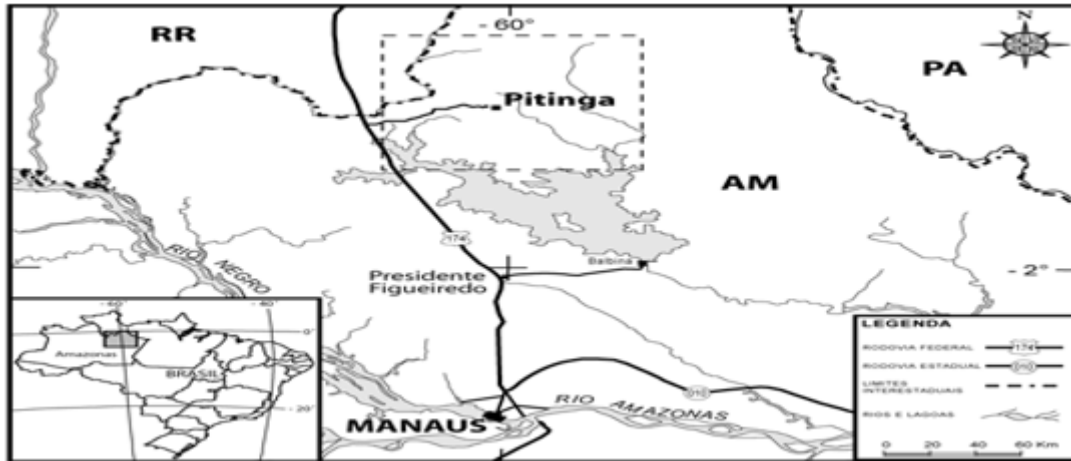


Figure 1 - Location map of the Pitinga mining district.

Source: Prado et al. (2007).

The existing ores in the mining district of Pitinga were unveiled in 1979 by the Mineral Resources Research Company (CPRM). Subsequently, exploration began through the Taboca S.A. Mining and in the late 1980s, the primary ore related to good water and Madeira granites was discovered [8].

Mining Taboca S / A was founded in 1969, characterized as the pioneer in metallurgy and tin mining in Brazil, also identified as the third largest tin manufacturer in the world. It has joined Minsur since 2008, has its own mine, its own Mining works are carried out at the Pitinga mine (Presidente Figueiredo-AM), working at the site, currently 2,000 employees [7].

In the Amazon Region itself, the company created an urban-industrial complex for education, health, housing, telecommunications and energy, making the Pitinga mine one of the most prominent industrial projects in the country. In Pitinga, the columbite and cassiterite ores are processed and mined.



In Figure-2, the Taboca Mining Crushing and Concentration site is highlighted.

Source: Google Earth (2019).

**2.3 Types and Locations of Pitinga Ore Dams**

According to information from the Amazonas Environmental Protection Institute (IPAAM) (2019), the state of Amazonas currently has 38 dams under the Dam Safety Law, including those for aquaculture, electricity, and mining. Among these dams, 8 are mining and are located in the Pitinga region and belong to the company Mineração Taboca SA, which operates in the exploration of Primary Tin Ore and set up in the group introduced in the National Dam Safety Policy (PNSB) [9].

In Table-1, some information about the Pitinga Mining Dams is presented.

Table 1: Main Pitinga Dams

Dam Name	Name of the entrepreneur:	Locality	Main Ore
0-1	Taboca S.A Mining	President Figueiredo	Primary Tin Ore
103 (Cross)	Taboca S.A Mining	President Figueiredo	Primary Tin Ore
111 (Indian)	Taboca S.A Mining	President Figueiredo	Primary Tin Ore
158 (A-1)	Taboca S.A Mining	President Figueiredo	Primary Tin Ore
161 (A-2)	Taboca S.A Mining	President Figueiredo	Primary Tin Ore
444 (A-3)	Taboca S.A Mining	President Figueiredo	Primary Tin Ore
81-1	Taboca S.A Mining	President Figueiredo	Primary Tin Ore
Pau D'Arco	Taboca S.A Mining	President Figueiredo	Primary Tin Ore

Source: National Mining Agency (2019).

**2.4 Imminent Risks in Tailings Dams**

The disaster that occurred at the Brumadinho ore tailings dam in the state of Minas Gerais on January 25, 2019, by Companhia Vale SA, has raised concerns about the risks of rupture of other dams throughout

Brazil, in the mining areas. ores, including those located in the village of Pitinga.

According to information provided by [9], if ore dams disruption occurs in Pitinga, the environmental impacts may be greater than in Brumadinho (MG), due to its factory, geographical layout and containment methodology. , be different. Since the Amazonian plain is totally at sea level, while the Minas Gerais plain was a totally mountainous place.

The constructive form used in the ruptured dams is upstream, the method where the tailings grow by steps made with the tailings itself over the initial dike, while the method used at the Pitinga mine is downstream, where the tailings only grow over it. same, towards the waste stream, which improves the stability of the structure, considered safer [9].

According to [3], among the eight tailings dams in Pitinga, seven are classified as type C, have low risk category and medium potential damage, only Dam 158-A1 has presented high associated potential, presenting risks of disruption.

According to [3] Dam 158-1 A1 is currently 30 meters high, a volume of 53,380,000.00 m<sup>3</sup> and is classified as Type B, which are dams that present a high risk or potential damage category and whose anomalies if present, they must be controlled, monitored and interventions may be implemented over time to maintain safe conditions.

Dam construction techniques are at the center of technical-scientific discussions, however, based on the new disruptions related to these containment works, they must respond to the requirements of environmental protection and safety, in addition to being part of the production process.

In Figure-3, the methods of construction of tailings dams are presented.

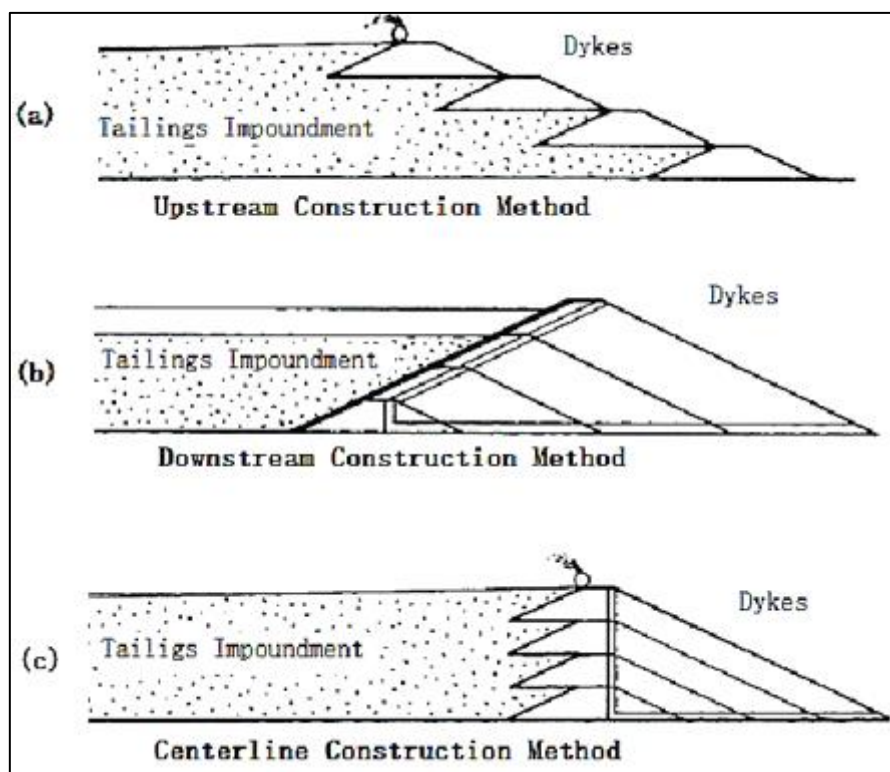


Figure 3- Methods of construction of tailings dams

Source: [21]

## ***2.5 Dam Safety Legislation***

The Law no. 12,334 of September 20, 2010, which established the National Dam Safety Policy (PNSB) aims to ensure compliance with safety standards, regulate, promote monitoring and monitor the safety actions employed by those responsible for dams, in order to reduce the possibility of accidents and their consequences, especially for the potentially affected population [10]. In compliance with this law, resolutions and ordinances were established, such as:

CNRH Resolution No. 143, of July 10, 2012, establishes general criteria for classifying dams by risk category, associated damage and reservoir volume.

Resolution No. 144, of July 10, 2012, establishes guidelines for the implementation of the National Dam Safety Policy, the application of its instruments and the performance of the National Dam Safety Information System.

Resolution No. 13, of August 8, 2019, establishes regulatory measures aimed at ensuring the stability of mining dams, notably those built or raised by the method known as "upstream" or by method declared as unknown and other measures.

Resolution No. 4 of February 15, 2019, which establishes precautionary regulatory measures to ensure the stability of mining dams, the standard prohibits the use of the method of construction or elevation of mining dams called "upstream" throughout the national territory. .

Ordinance No. 14, of January 15, 2016, establishes deadline for presentation of proof of delivery of physical copies of the Mining Dam Emergency Action Plan (PAEBM) to municipal and state governments and civil defenses.

Ordinance No. 70,389, of May 17, 2017, creates the National Register of Mining Dams, the Integrated Management System for Mining Dams Safety and establishes the periodicity of execution or updating, the qualification of the responsible technicians, the minimum content level of detail of the Dam Safety Plan, Regular and Special Safety Inspections, the Periodic Dam Safety Review and the Mining Dams Emergency Action Plan.

## ***2.6 Mitigating Measures for Environmental Impacts***

### ***2.6.1 Preventive Mitigation Measure***

It is based on a measure that aims to reduce or eliminate adverse events that are capable of causing damage to environmental components evidenced in the physical, anthropic and biotic environments. It is widely used to precede episodes of negative impact [11].

According to Law no. 12.334, which established the National Dam Safety Policy (PNSB) the preventive measures are:

- Keep Dam Safety Plan up to date
- Conduct Periodic Dam Safety Reviews
- Perform Regular and Special Dam Safety Inspections
- Preventive Emergency Action Plan in the event of a claim.

### ***2.6.2 High Precision Laser (Trueline)***

According to [12], TrueLine is a device that is positioned in front of the structure to be monitored, would

be on inert ground, outside the busbar area, and would read multiple points in the structure of a dam. This gives you accurate information about the dam's stability and safety in real time 24 hours a day.

TrueLine generates a database of positions different from the monitored points. The analysis of the data collected by the artificial intelligence of the software goes through the behavior processing of the structures, indicating irregularities that may be occurring in the dams. These are sent to the cloud through reports, data, graphs and instantaneous values about the current behavior of structures, and can be accessed from anywhere, facilitating the user's access through computers or smartphones.

In addition, TrueLine combines weather data, date and time, and position readings of targets installed on the dam, providing true interpretations of structural safety status [12].

In Figure-4, the TrueLine equipment is presented.



Figure 4- TrueLine Equipment Illustration

Source: EPTV Reproduction, 2019.

### 2.6.3 Brazil Ozone

Brazil Ozone is a company that has developed a 100% clean technology that treats water contaminated by heavy metals, such as iron and manganese, the same residues found in the tailings dam of the Córrego do Bean Mine, through the transformation of oxygen from air in ozone. The idea is to treat contaminated water so that it can be returned to the rivers without harming the environment, as well as reducing the pressure on the dam so that it is not overloaded, minimizing the risk of rupture.

Ozone is a corrective treatment in these tailings, oxidizing the heavy metals that are diluted in water, allowing the filtration of these materials. This makes it possible to treat water by removing the waste and returning it to nature without risk to the ecosystem. All dams should have a water treatment system so as not to overload the structure [13].

In Figure-5, the illustrative method of ozone treatment is presented.



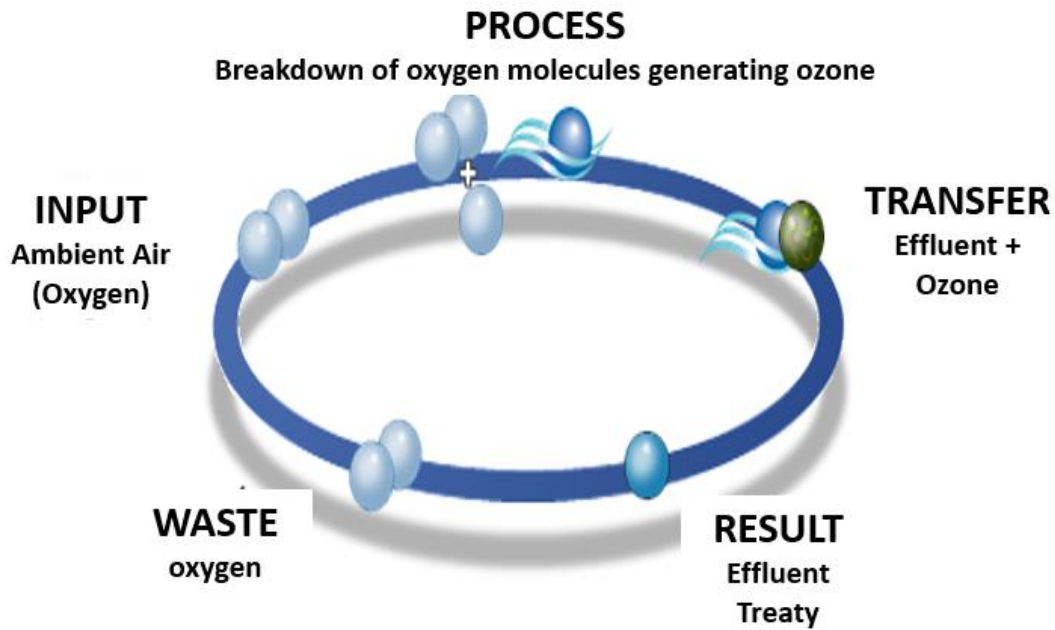


Figure 5- Ozone treatment process.  
 Source: Brasil Ozone Company, 2019.

A survey by the World Commission on Dams determines that for good mitigation, it is important to have a good phase of information, cooperation, from the beginning of environmental analysis, between dam designers, ecological and affected population, monitoring systematic, and analysis suffers from the effectiveness of mitigation measures [14].

### 3 Methodology

The development of this qualitative bibliographic research was divided into 3 phases, which were: general qualitative research, where articles were explored with the descriptors: Definition and Characteristics of Mineral Dams and data were collected from the National Dam Information System [15] . Restrictive selection occurred through the analysis of reports in the responsible bodies such as: National Confederation of Municipalities (CNM) [16], Brazilian Institute of Mining (IBRAM) [17], and in the body responsible for the supervision of Pitinga the Institute of Environmental Protection of Amazonas (IPAAM) [18].



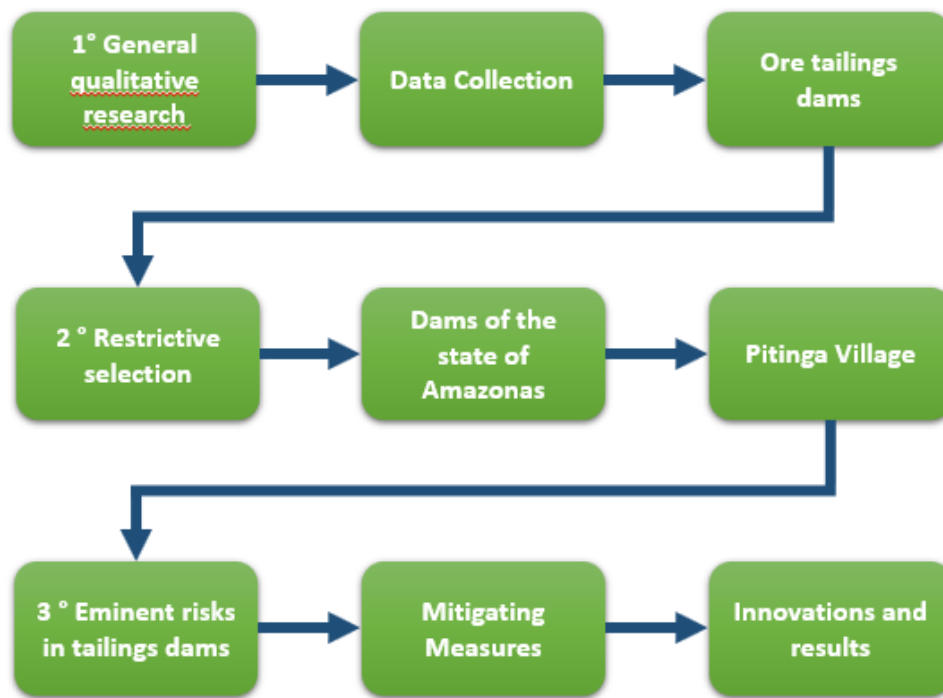


Figure 6- The flowchart of the methodology of this study is presented.

Source: Own Authorship (2019).

Observing the imminent risks on the website of the National Mining Agency (ANM) [19], mitigating measures proposed by (ANM) were presented, and the new technologies found to prevent collapse of ore tailings dams. Thus showing the best mitigation measure to be adopted to try to reduce the impacts on possible collapses in the Pitinga tailings dams in the Amazon.

#### 4 Results and Discussion

From the development of this study, it can be seen that there are some factors that contribute to the collapse of tailings dams. Rico (2008) [20], states that dams become more vulnerable to rupture due to a number of particular characteristics, among the factors that can be cited are: the landfills formed by area-origin fillings (coarse waste, soil); overload of tailings operations; phases of dam elevation to withstand the growth of tributary and stored solid material and stability of dams that require successive control and monitoring during the implementation, construction and development of activities.

In the event of a possible breach of the 158-A1 dam, all existing material would reach the environment like a gigantic wave of mud, with magnesium iron, copper and other substances that will be agglomerated with the clay, creating a virtually non-existent oxygen mud.

Figure 7- The possible affected areas are shown if the 158-A1 dam rupture occurs.



Figure 7- Areas of influence of Mineiro tailings dams in Pitinga.

Source: Adapted from Google Maps (2019).

In the event of the dam's disruption, as the project is a potential hazard, environmental impacts may occur throughout the region. Thus, there is a need for an analysis that configures and evaluates the impacts caused by the rupture of the Pitinga dams, which may affect downstream communities, water bodies, the Uatumã Sustainable Development Reserve Units and the Uatumã Biological Reserve. Vila Waimiri, both in the area of influence of the Balbina Hydroelectric Power Plant.

The preventive mitigating actions follow the procedures of execution of each stage of the dam, accompanying any and all signs that the dam may present, especially in its technical aspects. Investments in new technologies covered in 2.6.2 and 2.6.3 provide reports on the dam's stability and real-time safety, as well as the analysis of disease control or progression. Therefore, it is recommended to perform integrated mitigation measures, which will provide preventive solutions in the Pitinga Ore Tailings Dams.

## 5. Final Considerations

It is understood that the failed methods in the inspection of the Ore Tail Dam in Mariana and Brumadinho result not only from the constructive method being the most risky, but also from the neglect of the responsible company, with poor safety and health management, and the inefficient system of the bodies that regulate and supervise the dams in the state of Minas Gerais.

Due to these disasters, the Government of the state of Amazonas convened a delegation with the presence of the Amazon Environmental Protection Institute (IPAAM) and the National Mining Agency (ANM), in February 2019 to visit and assess the risk categories, and potential damage associated with the disruption

levels of all Taboca Mineradora tailings dams in Pitinga.

The environmental problems resulting from mining reinforce the need to analyze the management of appropriation of assets found in nature. It can also be said that there are permanent impacts inherent to the activity, in the landscape and in the soil, and the environmental practice can be evidenced with a mechanism to prevent this degradation.

Given the importance of mineral extraction for the generation of direct and indirect jobs and its contribution to the national GDP caused by the development of such activities, it is stated the need to discuss the proposals of new legal framework and its regulatory diploma, directing to the concern. how companies seek to reduce impacts on communities and the environment around their business.

The integrated monitoring of dams is extremely important for analyzing their conditions. Human presence is indispensable for assessing the risk of dam failure. Therefore, 100% automated monitoring is not advisable, but the integration of periodic, special inspections with technology optimizing the safety level of a dam.

However, it was noted that there is still much to be developed with regard to protection against environmental damage, so that the inspection of licensing methods is more effective, the collective and / or individual participation of the Public Administration, the Public Prosecution Service is necessary. and Judiciary Power that as supervisory and responsible bodies are prevented crimes on environmental damage.

## 6. References

- [1] Cardoso, F. A. C.; Pimenta M. M.; Zingano, A.C. Métodos Construtivos de Barragens de Rejeitos de Mineração: Uma Revisão Holos. [Revista em Internet] 2016 agosto. [Acesso 05 de outubro de 2019]; 32(08). Disponível em: <http://www2.ifrn.edu.br/ojs/index.php/HOLOS/article/view/5367>
- [2] Samarco [home page na internet]. O que é uma barragem. [Acesso em 17 de set 2019]. Disponível em:< <https://www.samarco.com/wp-content/uploads/2016/08/o-que-e-uma-barragem.pdf>>. Acesso em: 01 set. 2019.
- [3] Agência Nacional de Mineração [home page na internet]. Cadastro Nacional de Barragens 2019 [acesso em 1 de out 2019]. Disponível em: <http://www.anm.gov.br/assuntos/barragens/pasta-cadastro-nacional-de-barragens-de-mineracao/classificacao-oficial-anm>
- [4] Vale [home page internet]. Qual a importância da mineração para economia do país [acesso em 1 de out 2019]. Disponível em: <http://www.vale.com/brasil/pt/aboutvale/news/paginas/qual-a-importancia-da-mineracao-para-a-economia-do-pais.aspx>
- [5] Amazônia Real [homepage na internet]. Amazônia e a Mineração. [Acesso em 29 de ago 2019]. Disponível em :< <https://amazoniareal.com.br/amazonia-e-a-mineracao-2/>
- [6] THOMÉ, R; PASSINI, M.L. Barragens de rejeitos de mineração: Características do método de alteamento para montante que fundamentaram a suspensão de sua utilização em Minas Gerais. Ciências Sociais Aplicadas em Revista - UNIOESTE/MCR [revista em internet] 2018. [Acesso em 05 de setembro de 2019] v.18 - n. 34 - 1º sem. p. 49 a 65, 2018. Disponível em: < <http://e-revista.unioeste.br/index.php/csaemrevista/article/view/19480>
- [7] Amazônia Real [homepage na internet]. Mina do Pitinga, 35 ANOS DE Controvérsias e Nada a

Comemorar [acesso em 29 ago 2019]. Disponível em <https://amazoniareal.com.br/mina-do-pitinga-35-anos-de-controversias-e-nada-a-comemorar/>

[8] Taboca [homepage na internet]. Sobre nós [acesso em 02 set 2019]. Disponível em: <http://www.mtaboca.com.br/paginas/sobre-nos.aspx>.

[9] Instituto de Proteção Ambiental do Amazonas [home page na internet]. Relatório sobre Barragens de Mineração no Amazonas [acesso em 23 de set 2019]. Disponível em: <http://www.ipaam.am.gov.br/governo-anuncia-fiscalizacao-e-divulga-relatorio-sobre-seguranca-em-barragens-de-mineracao-no-amazonas/>

[10] Agência Nacional de Mineração [home page na internet]. Legislações Barragens [acesso em 1 de out 2019]. Disponível em: <http://www.anm.gov.br/assuntos/barragens/legislacao-barragens>

Brasil. A Lei n. ° 12.334, de 20 de setembro de 2010. Cria o Sistema Nacional de Informações sobre Segurança de Barragens e altera a redação do art. 35 da Lei no 9.433, de 8 de Janeiro de 1997, e do art 4º da Lei no 9.984, de 17 de julho de 2000.

[11] RCA. Medidas Mitigadora, Compensatórias e Potencializadoras. Relatório Técnico – RT ECV 057/17 - Revisão 00 – Junho/2017 [Acesso em: 02 set. 2019]. Disponível em:< [https://iema.es.gov.br/Media/iema/Downloads/RIMAS/RIMAS\\_2017/Estudos%20Ambientais/2018.03.06%20-%2009.%20Medidas%20Mitigadoras.pdf](https://iema.es.gov.br/Media/iema/Downloads/RIMAS/RIMAS_2017/Estudos%20Ambientais/2018.03.06%20-%2009.%20Medidas%20Mitigadoras.pdf)

[12] Incubadora de Empresas de Base Tecnológica de Itajubá. Laser de Alta Precisão (Trueline) [acesso em 01 de out 2019]. Disponível em: <http://www.incit.com.br/startup-da-incit-desenvolve-tecnologia-para-monitorar-barragens-o-prottipo-da-solver-tecnologias-em-desenvolvimento-h-um-ano-est-sendo-testado-em-uma-mineradora-de-grande-porte-em-minas-gerais/>

[13] Brasil Ozônio [home page na internet]. Tratamento de água contaminada por metais pesados [acesso em 29 de ago 2019]. Disponível em: <http://www.brasilozonio.com.br/pages/aplicacoes/cd:12/titulo:Metais%20pesados/n:5>

[14] WCD, WORLD COMMISSION ON DAMS. Dams and development: a new framework for decision-making. The report on the World Commission on Dams. Londres, 2001. Dezembro de 2001 [acesso em 28 set 2019]. Disponível em: <https://pubs.iied.org/pdfs/9126IIED.pdf>

[15] Sistema Nacional de Informações sobre Segurança De Barragens (SINISB). [Acesso em 30 set 2019]. Disponível em: <http://www.snisb.gov.br/portal/snisb/o-que-e-snisb>

[16] Confederação Nacional dos Municípios [home page internet]. Dados do Município de Presidente figueiredo [acesso em 27 de set 2019]. Disponível em:< Confederação Nacional dos Municípios. 2019. Disponível em:< <https://www.cnm.org.br/>>. Acesso em: 27 ago. 2019.

[17] Instituto Brasileiro de Mineração. O IBRAM representa as principais empresas e instituições ligadas ao setor mineral [acesso em 27 de ago 2019]. Disponível em: <http://www.ibram.org.br/>

[18] Instituto de Proteção Ambiental do Amazonas. Responsável pelo Controle Ambiental no Estado do Amazonas [acesso em 27 de ago 2019]. Disponível em: <http://www.ipaam.am.gov.br/a-instituicao/>

[19] Agência Nacional de Mineração. Promove o planejamento e o fomento da exploração mineral [acesso em 27 de ago 2019]. Disponível em: <http://www.anm.gov.br/acesso-a-informacao/institucional>

[20] Rico, M.; Benito, G.; Salgueiro, A.R; Díez-Herrero, A &Pereira, H.G. (2008, April). Reported tailings dam failures: the european incidentes in the worldwide context. Journal of Hazardous Materials, 152(2),

pp. 846-852. doi: [org/10.1016/j.jhazmat.2007.07.05](https://doi.org/10.1016/j.jhazmat.2007.07.05). Disponível em:  
<http://www2.ifrn.edu.br/ojs/index.php/HOLOS/article/view/7423/pdf>

[21] SIMEONI, Lucia et al. The Stava catastrophic failure of July 19, 1985 (Italy): technical-scientific data and socioeconomic aspects. *CSE-City Safety Energy*, v. 1, p. 17-30, 2017.