http://dx.doi.org/10.18623/rvd.v16i35.1567

THE DECOMMISSIONING OF TAILINGS DAMS AND THE MINE CLOSURE PLAN AS MINING RISK MITIGATION INSTRUMENTS

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ABSTRACT

Mining modifies the environment and produces socio-environmental risks, clearly seen from the occurrence of disasters that marked the trajectory of mineral exploration in Brazil. The objective of this paper is to analyze, from the perspective of the principles of prevention and the polluter pays, the effectiveness of the norms that prohibited the use of the so-called upstream dam method and determined the decommissioning of tailings dams, in addition to those that determine mine closure and repair of the area degraded by mining. The research was based on primary and secondary data consisting of analysis of legislative texts and law theory. It was possible to conclude that the government should encourage the implementation of the internalization of negative externalities by mining enterprises, requiring the adoption of preventive measures.

Keywords: dams; internalization; mining; negative externalities; risks.

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A DESCARACTERIZAÇÃO DE BARRAGENS DE REJEITO E O PLANO DE FECHAMENTO DE MINA COMO INSTRUMENTOS DE MITIGAÇÃO DE RISCOS NA MINERAÇÃO

RESUMO

A mineração tem como características a modificação do meio ambiente e a geração de riscos socioambientais, visualizados nitidamente a partir da ocorrência de desastres que marcaram negativamente a trajetória da exploração mineral no Brasil. O objetivo do trabalho é analisar, sob a perspectiva dos princípios da prevenção e do poluidor-pagador, a eficácia das normas que vedaram a utilização do método de alteamento de barragens denominado a montante e determinaram a descaracterização de barragens de rejeitos, além daquelas que preveem o adequado fechamento de mina e a recuperação da área degradada pela mineração. A pesquisa se valeu de dados primários e secundários consistentes na análise de textos legislativos e doutrina. Foi possível concluir que as normas jurídicas são relevantes instrumentos para a implementação da internalização das externalidades negativas, na medida em que exigem dos empreendimentos minerários a adoção de ações preventivas, especialmente no que tange à recuperação das áreas degradadas e à mitigação dos riscos inerentes às barragens de rejeito.

Palavras-chave: *barragens; externalidades negativas; internalização; mineração; riscos.*

FOREWORD

The social and environmental disasters that occurred in Bento Rodrigues and Brumadinho in 2015 and 2019, respectively, both due to the breach of mining tailings dams, showed the need for the government and private enterprises to adopt efficient measures for planned mine closures according to the sustainable development, prevention and polluter pays principles.

Active or deactivated tailings dams can be a major threat to human life and the environment when not properly monitored and decommissioned. Abandoned mines, in turn, pose an environmental liability that society is unwilling to bear.

Accordingly, this paper poses the following question as research problem: are the norms provided by the government to said socio-environmental liabilities efficient legal instruments for the internalization of negative externalities arising from mining, thus mitigating that activity risks?

The objective of this paper, therefore, is to analyze, from the perspective of the principles of prevention and the polluter pays, the effectiveness of the norms that prohibited the use of the so-called upstream dam method and determined the decommissioning of mining tailings dams, in addition to those that determine mine closure and repair of the area degraded by mining.

This research used consistent primary and secondary data for an analysis of legislative and law theory texts, as well as deductive reasoning capable of supporting the synthesis that the normative answers provided by the government – more specifically, those related to the ban on upstream dams and the requirement for decommissioning of tailings dams – contribute to the reduction of risks and vulnerability of mining activity.

The scarcity of literature related to the legal instruments necessary for the mitigation of mining risks based on the internalization of negative externalities justifies the choice of the proposed theme.

1 MITIGATION OF RISKS ARISING FROM MINING BASED ON THE INTERNALIZATION OF NEGATIVE EXTERNALITIES

It is acknowledged that mineral exploration was responsible for the occupation of our territory and has been essential for the economic growth

of Brazil. From the colonial period, with the mining of gold and diamond, throughout the Empire and the Republic, with the production of iron ore, the activity has been consolidated as one of the mainstays of the domestic economy.

The economic strength of the Brazilian mining industry, however, contrasts with the negative impacts and damage resulting from mineral exploration. It is an activity whose intrinsic characteristics is the modification of the environment and the production of social and environmental risks, clearly seen from the occurrence of disasters that negatively marked the history of mineral exploration in Brazil.

Breaches of tailings dams, such as those of Mariana in 2015 and Brumadinho in 2019, both in the state of Minas Gerais, are unacceptable, mainly because they are due to failures in risk management, safety practices, strategic planning and timid technological innovation. There is no doubt that mining enterprises should seriously and more comprehensively take into account the risks arising from their activity in order to avoid, or at least minimize, the negative effects of that activity on the environment and society.

Leite and Canotilho (2007) say that we are living a stage of modernity when the threats produced by the economic model of industrial society begin to take shape. For Ulrich Beck (2010), what characterizes current modernity is the social production of risks, which systematically accompanies the production of wealth. A consequence of the constant pursuit of economic growth is the triggering of risks, enhancing self-threats to an extent hitherto unknown to humans.

It is imperative to recognize that the risks posed by anthropic activities need to be taken into account in all their production stages by the sources that use natural resources. Along those lines, Beck (2010) says that one of the trends for the analysis of the political dynamics of the potential for civilizational self-threats seen today is precisely the fight against the "causes" in the industrialization process. It cannot be forgotten that risks can have side effects not only on the environment, but also social, economic and political effects (THOMÉ, 2014) and, therefore, must be tackled at their source. In the same vein, Délton Winter de Carvalho (2019, p. 13) points out that disaster law "is closely related to risk management. Given the magnitude of these events, the motto 'better safe than sorry' is the core element of that branch of law.

Engelmann, Berwig and Wittckind (2017, p. 295) corroborate that view, when they say that

> Modern society experiences exposure to unprecedented technological risks, risks that have materialized in disasters with high destructive power. Bhopal (1984), Chernobyl (1986), the Gulf of Mexico (2010), Fukushima (2011) and Mariana (2015) are the best known ones, worldwide. All these events are due to the economic models of dynamic production that – connected by globalization – provided the opportunity for speedy development. On the other hand, the deficiency in the management of implied risks results in serious human and environmental damages that spread along the space and perpetuate in time.

The risks of today's society are not limited to the negative impacts that already happened. There is a future component to consider. Beck (2010, p. 39) teaches that "risks are [...] fundamentally related to anticipation, with destruction that has not yet occurred, but which is imminent, and which, in that sense, are already real today". It is precisely these imminent future risks that need to be avoided and, therefore, there are numerous instruments, including legal ones, that must be used (THOMÉ, 2014).

Such singularities demonstrate that the risks must be considered as actual effects of industrial activities, which cause and may come to cause serious damage to the environment and human health. It is necessary to give up the notion of risk adopted today (THOMÉ, 2014). The term risk cannot include the meaning of something that does not exist simply because it is often uncertain or imperceptible.

In order to fight against social and environmental risks at their source, it is essential, among other strategies, for the business to internalize the negative externalities arising from the productive activity in its own cost of production, in accordance with the polluter pays principle.

In other words, the costs resulting from the exploration of natural resources must be borne by the business itself. This means that the activity must bear the costs necessary to eliminate, neutralize or reduce the risk of environmental damage.

By fostering the internalization of negative socio-environmental externalities, the polluter pays principle aims to ascribe to the polluter (or potential polluter) the social cost of the pollution caused by it (or that may come to be caused by it). Whenever external social costs (for prevention, reparation and/or repression) that accompany the productive processes (negative externalities) are not borne by the economic agents themselves, they are borne by the collective (socialization of losses).

Derani (2008, p. 142), on addressing the polluter pays principle, teaches that

> [...] during the production process, in addition to the product to be marketed, **'negative externalities'** are produced. They are called externalities because, although resulting from the production, they are received by the community, as opposed to profit, which is perceived by the private producer. Hence the expression 'privatization of profits and socialization of losses', when negative externalities are identified. The application of this principle seeks to correct this added cost to society by enforcing its internalization.

When a mining company, which for years has made significant profits from mining, abandons a tailings dam, thus relegating an environmental liability to the community, there is a negative externality arising from the mining activity, as the negative impacts of that mining activity are transferred to society, which must then bear them. In this case, the privatization of the bonuses (profits) and the socialization of the burdens (social and environmental liabilities) can be clearly seen.

Along these lines, Carneiro (2001, p. 72) comments that externalities – negative external effects or external diseconomies – "correspond to economic costs that circulate outside the market and, therefore, are not compensated in cash, but transferred without price, and borne by the community". For Nusdeo (2006, p. 359), "externalities can be defined as costs or benefits that are transferred from certain units in the economic system to others, or to the community as a whole, outside the market".

It is undeniable that social and environmental impacts are some of the major negative external effects of mineral production. In order to correct the negative externalities of mining, society usually relies on the action of a player outside the market, namely, the State, which responds by formulating public policies "intended to convince economic agents to take the social costs of environmental degradation in the environment into account in their private calculations" (CARNEIRO, 2001, p. 73). Public policies can be implemented through mechanisms such as the direct regulation of the behavior of economic agents and the adoption of incentives and instruments of an economic nature that would induce the polluter not to degrade nature (THOMÉ, 2019).

This paper is interested in analyzing, from an economic view of law, the state regulatory responses given after Mariana (2015) and Brumadinho (2019) directed at eliminating or reducing the risks arising from mineral

exploration. As Sarat (2009) teaches, one of the aspects where Law should deal with disasters is the reduction of future vulnerability. Therefore, it is important to analyze how the public authorities, from the drafting of legal norms, started to promote the internalization of negative externalities by mining enterprises, demanding the adoption of preventive measures, especially regarding the recovery of degraded areas and the mitigation of risks inherent to tailing dams.

2 MINE CLOSURE AND RECOVERY OF THE DEGRADED AREA

The depletion of the mineral deposit and the production of negative social and environmental impacts are characteristics of the mining activity that underlie the need for planning for mine closure and the recovery of the degraded area.

Mineral goods are non-renewable natural resources, which means they cannot be redone or regenerated by humans or nature. They are elements found in nature in the form of ore reserves or deposits that are undoubtedly finite.

It is also an activity that impacts the environment. The negative impacts of the exploration of mineral resources are related to the change in the topography, earthworks, the pollution of the waters, driving away of animal species, and others.

In initiating the exploration of a mineral deposit, the entrepreneur is therefore sure of at least two things: that the mine will be exhausted and that the activity will have negative impacts on the environment. These certainties are sufficient to require from the venture, from the early stages of environmental licensing, measures aimed at the proper closure of the mine and the recovery of the impacted area. With the end of the life of the mineral deposit, it is necessary to know what to do with the facilities used and how to reverse the negative social and environmental impacts resulting from their exploration.

The relevance of early mine closure planning was recognized internationally during the 5th Mining Ministries of the Americas Conference (CAMMA), held in 1999 in Vancouver, Canada (ARAUJO, 2015). It was agreed that

> [...] the decommissioning and closure stages of mineral projects must be considered from the beginning of project development, with the decommissioning plan

> being a necessary element to have mining contribute to sustainable development, thus facilitating the existence of clear and stable conditions to achieve economic, environmental and social welfare (SOUZA, 2003).

The phrase mine closure means the definitive cessation of mining operations, the final phase of the mining activity. In general, mine closure can be considered as a process of concluding the mining activities for technical, legal or economic reasons, due to the depletion or exhaustion of the mineral reserve or due to a lack of conditions that allow for the continuity of the mining of a mineral deposit (REIS; BARRETO, 2001).

At the closing stage, there is no ore extraction, as the deposit has been depleted or the activity having become technically and economically untenable. During this phase, actions and procedures aimed at the physical, chemical and biological stabilization of the impacted area are carried out, together with the recovery of the degraded environment and the restoring of local and regional socioeconomic balance to the project surroundings.

It is important to point out that only recently mine closure has been considered as one of the phases of the mining venture. Abandoned mines are not uncommon in many countries around the world. "In Ontario, Canada, there are over 6,000 abandoned mines (MITCHELL; MACKASEY, 1995 apud SÁNCHEZ, 2001); in the state of Queensland, Australia, there are about 50,000," reports Araujo (2015, p. 8). In Missouri [USA], it is believed to be about 8,000 abandoned mines. In Montana and Colorado, there are twenty thousand, and in Arizona, eighty thousand (DURKING; HERRMANN, 1996 apud SÁNCHEZ, 2001). The Chilean National Geology and Mining Service, in turn, has detected more than 520 (five hundred and twenty) abandoned pits in the Andes, which are responsible for contamination of water, soil and air. The greatest environmental impacts are located in the regions of Atacama, Coquimbo, Antofagasta, Metropolitana and Valparaiso (ARAUJO, 2015).

In Brazil, the case of Engenho D'Agua Mine, from Mundo Mineração stands out, interrupted its activities in the town of Rio Acima/MG a few years ago, leaving only roadsigns indicating the presence of toxic material such as arsenic and mercury, used in gold mining (MG TEM..., 2019). Araujo (2015, p. 9) says that

> Particularly concerning cases are abandoned coal and metal mines, as they can produce Acid Mine Drainage (DAM), characterized by the oxidation of sulfide minerals, which causes degradation of the quality of surface and groundwater, soil and sediments.

Araujo (2015) stresses as representative at the international level the case of the Zortman-Landusky gold mine in the state of Montana, in the United States, which was abandoned by Pegasus in 1998, leaving an environmental liability of ninety million dollars.

Numerous mines have been abandoned in recent decades without their impacts being assessed by the government and Brazilian society. According to data provided by Minas Gerais State Environmental Foundation (FEAM) in 2016, 400 (four hundred) abandoned or decommissioned mines were found in the Minas Gerais State alone (MG TEM ..., 2019), amounting to a significant socio-environmental liability.

In order to prevent similar situations from recurring, national environmental norms now require the venture to present to the public authorities the measures to be taken to avoid or minimize the social and environmental impacts of the final phase of mineral exploration, as well as for the recovery of area degraded by the venture.

The requirement for recovery of the area degraded by mining is based on Article 225, paragraph 2 of the 1988 Constitution, later regulated by infraconstitutional rules, such as Decree 97,632 from April 10, 1989, which, from a ruling provided for in Article 2, item VIII, of Law 6,938/81 (National Environmental Policy Law), made it mandatory for all mining ventures to submit a Degraded Area Recovery Plan (PRAD) together with the Environmental Impact Studies and Reports (EIA/RIMA).

PRAD must, therefore, provide for actions aimed at "returning the degraded site to a form of use, in accordance with a pre-established plan for land use geared at achieving environmental stability" (Art. 3 of Decree 97,632/89).

It must be acknowledged, however, that it was administrative norms rules issued by the former National Department of Mineral Production (DNPM)[3] that for the first time explicitly mentioned the mine closure stage. Mining Regulatory Norms (NRM), published in the Federal Official Gazette on October 18, 2001 (Ordinance 237), provide for the submission to the body with jurisdiction on the matter of a Plan for Closure, Suspension and Resumption of Mineral Operations as a requirement for the mining grant (item 1.5.1, i). Said plan must be subject to periodic reviews throughout the project's life (item 20.4.2.1); it must also be part of the Plan for Economic Exploitation (item 1.5.7), another document that must be provided by the project (BRASIL, 2001).

3 Replaced by the National Mining Agency (ANM).

The requirement to provide the Mine Closure Plan (PFM) together with the Plan for Economic Exploitation (PAE) as a requirement for obtaining the mining grant was confirmed with the issuance of Decree 9,406 from June 12, 2018, which regulates mining activity throughout Brazilian territory.

> Art. 32. The economic recovery plan, signed by a legally qualified professional, is a mandatory document for the mining grant application and must contain, in addition to the documents and information required by Art. 39 of Decree-Law no. 227 of 1967 – Mining Code, a description of processing facilities, indicators related to reserves and production, and the mine closure plan, pursuant to ANM Resolution (BRASIL, 2018).

It is important to point out that the PRAD provided for in Decree 97,632/89 is not to be confused with the PFM regulated by federal mineral legislation. Decree 9,406/2018, which regulated the Mining Code (Decree-Law 227/1967), determines that the company must submit to National Mining Agency (ANM), as one of the requirements for the mining grant application, the Plan for Economic Exploitation (PAE), which includes, among other documents, the Mine Closure Plan (PFM), (Art. 32 of Decree 9,406/2018). Thus, the PFM required by the Mining Code is an economic requirement (for the mining grant), while the Degraded Area Recovery Plan (PRAD) required by Decree 97,632/89 is an environmental requirement (for environmental licensing purposes) and must be submitted to the appropriate environmental licensing body. These documents, although directed to different public agencies, are similar in that they present actions aimed at the physical, chemical and biological stabilization of the impacted area, together with the recovery of the degraded environment and the restoring of local and regional socioeconomic balance to the project surroundings.

At this point, it should be noted that Brazil follows along the same lines of some mining countries that have already included in their rules actions aimed at adapting the mine closure stage to the precepts of Environmental Law.

In Chile, Law 20,511/2011 determines that all mining operations must have an approved mine closure plan prior to the commencement of operations. In Germany, the 1994 Berlin Guidelines regulate mining and mine closure. The document has a section on mine closure planning and rehabilitation, divided into three steps: (a) planning phase; (b) active care phase related to the closure process; and (c) passive care phase related

to mine site monitoring (HOSKIN, 2005 apud SCALON, 2014). In Canada, in the province of Ontario, the mine closure guidelines provide for requirements aimed at stabilizing the mined area for at least 200 years (DORAM; McINTOSH, 1995 apud SÁNCHEZ, 2001; ARAUJO, 2015).

Therefore, the closure of a mine involves a series of measures aimed at decommissioning the project and the socio-environmental recovery of the area impacted by the activity. Decommissioning a mine means deactivating it and dismantling its structure by "splitting" it into smaller structures. Decommissioning actions, complements Taveira (2003), are intended to make the transition between the closure and future use of the area.

It is worth stressing that the proper closure of the mine and the recovery of the degraded area are the responsibility of the mining venture, which should, from the early stages of mineral exploration, include the amounts to be spent for its implementation in its budget, thus internalizing the negative externalities arising from its activity at its own production cost. By performing these actions, the activity reduces future vulnerability and significantly decreases the likelihood of socio-environmental damage.

Pérez and Peña (2014) teach that "a mine consists of a set of facilities that have a variable life span, depending on the nature and characteristics of the production processes. It can include various productive zones and divers activities within its geographical area". One of the structures of a mine that requires decommissioning, including its reclassification, due to the proven risks posed to society, is the mining tailings dams, which therefore merit further analysis.

3 DECOMISSIONING OF MINING TAILINGS DAMS

Dams were designed hundreds of years ago with the initial purpose of controlling water flow. With the Industrial Revolution and the increase in energy demand, they were also used for the production of hydroelectric power. From then on, these huge structures have been used for various activities and purposes, such as for the retention of industrial waste and waste from other production processes. According to Toledo, Ribeiro and Thomé (2016, p. 15),

> These dams then are a specialized category of this type of material containment structure, which has a distinct size and proper functioning, when compared to hydroelectric and water flow control dams. In this context, a dam can be defined as any structure in a permanent or temporary watercourse for the purpose of containing or accumulating liquid substances or mixtures of liquids and solids, including the dam and associated structures (Art. 2, I of Law 12,334/2010).

The mining activity uses the practicality of the dams to contain the tailings resulting from the mining of mineral deposits. The most common method of disposal of mining tailings is their discharge into settling ponds (hydraulic landfills), which are contained by dams (PASSINI; THOMÉ, 2018). Due to the increase in waste generation driven by the worldwide demand for mineral products, the size of these structures has been increasing in recent decades. For Soares (2010), technical improvements associated with higher environmental requirements result in the use of low grade ores, which increases the amount of tailings produced in relation to the plant's feed mass.

It should be noted that the disposal of mining tailings in dams has been, especially in recent decades, environmentally and socially inadequate. The risks inherent to these containment structures have been confirmed by numerous dam breaches, such as that of Bafokeng Dam in South Africa in 1974, the Arcturus mine in Zimbabwe in 1978, and a mine in Trento, Italy in 1985. In in the 2000s, we can mention the breach of the dam of the Kingston coal plant in the United States in 2008, the Talvivaara mine in Finland in 2012, and the Obed Moutains mine in 2013, in Canada, where the Mount Polley mine dam failed in 2014.

In the Brazilian territory, especially in Minas Gerais, which has an undeniable mining history, a series of dam breaches was responsible for human losses and immeasurable environmental damage. The breach of the Fernandinho mine dam in 1986, in the town of Itabirito/MG, started this unfortunate series. In 2001, in Sebastião das Águas Claras/MG, the breach of another dam killed five workers, silted 6.4 kilometers from the Taquaras stream bed, and hit 43 hectares of vegetation. In 2007, in Miraí, in the Zona da Mata region of Minas Gerais, four thousand residents and twelve hundred homes were hit by the breach of the mining enterprise dam. Miners workers were buried in 2014 when they were doing maintenance work on the slope of a deactivated tailings dam located in the State of Minas Gerais (TOLEDO; RIBEIRO; THOMÉ, 2016).

Due to its size and scope, two tragedies marked the history of Brazilian mining negatively and definitely: those of Bento Rodrigues/MG in 2015 and Brumadinho in 2019. On November 5, 2015, "the mud from the Fundão dam breach invaded Bento Rodrigues, a district of the historic town of Mariana (Minas Gerais), leaving nineteen dead, dozens of families homeless, and causing an incalculable negative impact on the region's environment "(TOLEDO; RIBEIRO; THOMÉ, 2016, p. 66). It was believed

to be the biggest environmental disaster in the history of Brazil. Not really. Just three years and two months later, on January 25, 2019, the dam of Córrego do Feijão, in Brumadinho/MG, gave way and the sea of mud coming from there took the lives of at least two hundred and forty-four people (NÚMERO DE VÍTIMAS..., 2019) and caused one of the greatest environmental tragedies in world history.

These remarkable developments have therefore made the adoption of new methods of mineral exploration and safer and more socially and environmentally sound techniques for the final disposal of mining unavoidable.

The first normative responses to dam breaches happened at the state level, with the enactment of Decree 46,993/2016, subsequently amended by Decree 47,158/2017, which temporarily suspended, in Minas Gerais, the environmental licensing for new tailings dams where the upstream elevation method was intended to be used and the existing structures intended to use this method.

It is worth mentioning that the upstream elevation method is one where the various steps of the dam are raised as the amount of tailings increases, and are built against the embankment or the wall that supports the structure (GERAQUE, 2015). It is considered the most common and economically advantageous method for companies, and the one requiring the greater maintenance care, compared to other construction methods (LAGO; THOMÉ, 2017).

Law 23,291/2019, which lays down the Minas Gerais State dam safety policy, explicitly forbids, in its Article 13, the environmental licensing for the operation or expansion of dams intended for the accumulation or the final or temporary disposal of tailings or industrial or mining waste using the upstream elevation method.

At the national level, Resolution 4 of National Mining Agency (ANM) from February 15, 2019 provides to the same effect, prohibiting the use of the upstream construction or elevation method for mining dams throughout the Brazilian territory.

The ban on the upstream dam method, the most cost-effective one for companies and the least safe for the population and the environment, is relevant in that it prevents future mining enterprises from using it to dispose of the activity's tailings. However, we must keep in mind that numerous dams in operation are already built and raised using this technique and that many others are deactivated or abandoned, posing a huge risk to the whole of society.

It is therefore not enough to prohibit the raising of new dams using the upstream method. Dams already built must be decommissioned and reclassified (decommissioned), thus removing the possibility of new disasters. Pursuant Article 18 of Federal Law 12,334/2010, which establishes the National Dam Safety Policy, "the dam that does not meet the safety requirements under the relevant legislation shall be recovered or deactivated by its business venture, which shall notify the supervisory body of the measures taken".

Araújo (2018) notes that "most companies in the mining industry saw tailings dams as an end point of their production line". However, in recent decades, reality has shown that the mining activity does not end with the disposal of tailings in dams. Numerous actions must be carried out from the containment of tailings, such as the recovery and re-purposing of substances disposed in mining tailings, the decommissioning of dams, and the recovery of the degraded area.

Just as mines must comply with the planning provided for in the Degraded Area Recovery Plan (PRAD) and the Mine Closure Plan (PFM) for the proper termination of their activities, tailings dams must follow the same rationale, as it is not acceptable for such structures, once deactivated, to remain wedged in the ground waiting for their natural integration into the environment. Even active dams that used the upstream method for their elevation must be decommissioned to prevent further disruption.

For Chambers (2015), the damage caused by the breaching of mining dams would have been much less if the mine waste was less fluid. This finding confirms the need for deactivation and decommissioning of tailings dams (hydraulic landfills), especially those raised using the upstream method.

Following the breach of Fundão Dam in Brumadinho in 2019, a legislative reaction was observed, albeit late in coming, to determine the decommissioning of tailings dams using the upstream elevation method.

Under the terms of paragraph 1 of Article 13 of Law 23,291 from February 25, 2019, in the State of Minas Gerais, the business venture is "obliged to carry out the decommissioning of inactive tailings or residue contention dams that use or have used the upstream elevation method".

In the case of dams still in operation, the aforementioned state normative instrument determines that the business venture shall migrate to alternative technology of the accumulation or disposal of tailings and waste, and the decommissioning of the dam within up to three years from the enactment of the law.

The objective of the state norm of implementing the internalization of negative externalities by determining, that mining enterprises must bear the necessary costs for the replacement of technology or the decommissioning of tailings dams is clear. Making a profit (privatization of bonuses) from mining is legitimate, just as it is legitimate for society to demand from mining enterprises that they take responsibility for eliminating risks and shoulder prevention costs.

If these external (prevention) social costs that accompany production processes are not borne by the economic agents themselves, they will eventually be borne by the community. This is the above-mentioned case of the Engenho D´Água mine, in Rio Acima/MG, abandoned by the Australian company Mundo Mineração, which left significant environmental liabilities to the Minas Gerais society, including two dams with the potential to render the capture of water responsible for supplying 50% of the metropolitan region of Belo Horizonte/MG unfeasible. The costs of treating the dams, which have been born by the State since 2017 (with taxpayer resources), is significant: around R$ 15,000,000.00 (fifteen million reais), R$ 8,000 (eight million reais) of which are used for the treatment of dam water, six hundred thousand reais (R$ 600,000.00) employed in the engineering design and seven million three hundred thousand reais (R$ 7,300,000.00) invested in the works, in addition to expenses with studies and monitoring of structures (PARREIRAS, 2019).

To keep situations such as those of Engenho D'Agua mine dams from recurring, both inactive and operating dams that used or use the upstream elevation method must undergo a decommissioning procedure; that is, they cannot operate as a sediment or tailings containment structure, as their nature as dams must be suppressed. Such structures should, therefore, be deactivated or given a different purpose, at the venture's own expense (article 13, § 3 of Law No. 23,291/2019). According to the Minas Gerais State Secretariat for the Environment and Sustainable Development (SEMAD), there are in the state, scattered throughout sixteen towns, forty-nine dams raised using the upstream method, twenty-seven of which are in operation and twenty-two, paralyzed (RESOLUÇÃO OBRIGA..., 2019).

Vale company, for example, reported on June 8, 2019 the intensification of decommissioning activities of nine iron ore dams, heightened using the upstream method. The intention is that two dams should be completely decommissioned within three years, and in another five migration to the downstream method before decommissioning should be carried out. The

company also stated that the safety factor will be increased in two other dams before the decommissioning works (VALE ANUNCIA ..., 2019).

It is clear, therefore, that the normative reactions of the public authorities on banning upstream elevations and determining the decommissioning of mining tailings dams were adequate from the standpoint of both the prevention and the polluter pays principle, both of which guide the norms of environmental law.

In compliance with the deterrence principle, the rules analyzed determined the adoption of measures to mitigate the risks involved in the breaching of dams, increase the safety margin and, consequently, reduce the likelihood that future disasters from occurring. For Carvalho (2019, p. 14),

> [...] the National Dam Safety Policy places a strong emphasis on the deterrence principle (known and foreseeable risks), without necessarily precluding the assessment of uncertain or unquantifiable risks (as provided for in the National Policy on Protection and Civil Defense, Law 12,608/2012). What is clear is that foreseeable risks must necessarily be dealt with effectively and using reasonable measures to prevent catastrophic damage from occurring. The risks faced in this case seem to be clearly quantifiable (or predictable at the state of the art). However, even unquantifiable and uncertain risks, when they have the potential to be catastrophic or irreversible, require decisions based on an "adequate safety margin". This should occur even in cases where the probability is very remote or cannot be demonstrated quantifiably.

It is worth mentioning that anthropogenic disasters (caused by human action) can, through proper risk management, be avoided, unlike natural disasters that, as Engelmann, Berwig and Wittckind (2017, p. 295) note, "do not allow for control when the event begins, but only on its consequences (emergency response, mitigation and remediation)".

In accordance with the polluter pays principle, the norms enacted after the Mariana and Brumadinho disasters are also adequate, requiring the mining enterprise to adopt, at its expense, measures aimed at preventing damage and restoring the degraded environment. Thus, negative externalities are internalized in the activity's own production costs, avoiding the production of environmental liabilities that would eventually be borne by the whole community.

In order to further strengthen the financial guarantees directed to the internalization of negative externalities arising from mining activities, Law 23,291/2019 adds, as a requirement for obtaining a Preliminary License for new dams in the State of Minas Gerais, the inclusion of environmental

security to be provided by the business venture and, for obtaining the Operating License, proof of the effective implementation of this guarantee. The amounts advanced as collateral are intended to ensure both social and environmental recovery in cases of environmental damage, as well as the deactivation of tailings dams.

Economic guarantees are relevant instruments, provided for in the legal system of several countries, and aimed at eliminating the environmental liability of mining activity. Araujo (2015, p. 11) notes that

> In order to encourage rehabilitation efforts during the operational stage of the mine and the effective implementation of the mine closure plan, most global regulatory systems require mining companies to provide some financial security to cover closure and post-closure expenses (ROBERTS, VEIGA, PEITER, 2000; SÁNCHEZ; SILVA-SÁNCHEZ; NERI, 2013). In the case of the United States and Canada, capital market regulation also imposes the need for mining companies to make accounting provisions for the recovery of degraded areas and mine closure (SÁNCHEZ, 2007).

Collaterals, environmental insurances and other economic guarantees play an important complementary role in internalizing the negative externalities of mining, and at least indirectly act as inducers of preventive action, as enterprises tend to adopt all necessary measures to mitigate the risks of the activity when they allocated significant amounts for reparation, in case of social and environmental damage.

CONCLUSION

The tailings dam disasters in Mariana/MG, in 2015, and in Brumadinho/MG, in 2019, made clear the need for safer and more sustainable mining practices.

Inadequate management of the risks inherent to each step of the activity can lead to socio-environmental liabilities of different magnitudes. In this paper we have analyzed negative impacts detected, generally, in the last stage of the mining activity, commonly called mine closure. These impacts are related to the poor management of the closure of activities and decommissioning of structures used during mineral exploration, such as tailings dams.

Abandoned mines without any closure planning cause several environmental liabilities for society, such as contamination of surface and groundwater by acid drainage, destruction of the impacted area, unstable pits, and ground sinking, in the case of underground mines.

Active or abandoned tailings dams pose significant risks of social and environmental damage. The decades-old use of the upstream dam elevation method, the most vulnerable tailings containment technique, has proven that there are flaws in the risk management of these structures.

To reduce risks and, consequently, the vulnerability of the mining activity, legal norms are presented as a relevant instrument for the implementation of sustainable public policies. Preventing new social and environmental liabilities from being produced is therefore one of the main objectives of environmental law norms based on the principle of prevention.

Another important function inherent to environmental legal norms is to foster the internalization of negative externalities in mining. According to one of the definitions of the polluter pays principle, one which uses or intends to use natural resources (polluter) should be encouraged to bear the social cost of the pollution it generates. Whenever external social costs (for prevention, reparation and/or repression) that accompany the productive processes (negative externalities) are not borne by the economic agents themselves, they are borne by the collective (socialization of losses).

The central idea that drove this paper was met by demonstrating that public authorities, from the drafting of legal norms, are charged with promoting the internalization of negative externalities by mining enterprises, demanding the adoption of preventive measures, especially regarding the recovery of degraded areas and the mitigation of risks inherent to tailing dams.

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Article received on: 21-Jun-19.

Article accepted on: 26-Aug-19.

How to quote this article (ABNT):

THOMÉ, R.; RIBEIRO, L. G. G. The decommissioning of tailings dams and the mine closure plan as mining risk mitigation instruments. *Veredas do Direito*, Belo Horizonte, v. 16, n. 35, p. 59-80, may/aug. 2019. Available at: <http://www.domhelder.edu.br/revista/index.php/veredas/article/view/1567>. Access on: day month. year.