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The making of the Samarco disaster from the perspective of risk

A produção do desastre da Samarco sob a perspectiva do risco

La producción del desastre de Samarco desde la perspectiva del riesgo

La production du désastre de la Samarco sous l'angle du risque

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ABSTRACT

This article discusses the Samarco disaster, seeking a reading based on the risk approach – specifically criticizing the technical-economic foundation of risk analysis and the business rationality of maximizing economic results and reducing costs – paying attention to legal transgressions of mining companies and the inoperability of the law. At the end of the article, we state that, more than the dimension of risk within the scope of the conditions leading to disasters around mining, it is necessary to question neo-extractivism as a privileged model of development. To prepare this article, we used relevant literature, analysis of legislation regarding dams used for waste disposal and technical reports produced on the rupture of the Fundão dam.

KEYWORDS: risk; disaster; Samarco.

RESUMO

O artigo trata da produção do desastre da Samarco, buscando uma leitura a partir da abordagem do risco – mais especificamente, realizamos uma crítica ao fundamento técnico-econômico das análises de riscos e da racionalidade empresarial de maximização dos resultados econômicos e de redução

de custos –, atentando para as transgressões legais das mineradoras e para a inoperacionalidade da lei. Ao fim do artigo, afirmamos que, mais do que a dimensão do risco no âmbito das condições de produção dos desastres em torno da mineração, é preciso questionar o neoextrativismo enquanto modelo privilegiado de desenvolvimento. Para elaboração deste artigo, lançamos mão, sobretudo, de literatura pertinente, de análises da legislação no tocante às barragens de rejeitos e de relatórios técnicos produzidos sobre o rompimento da barragem de Fundão.
PALAVRAS-CHAVE: risco; desastre; Samarco.

RESUMEN

El artículo aborda la producción del desastre de Samarco, buscando una lectura desde un enfoque de riesgo – más específicamente, hacemos una crítica al fundamento técnico-económico de los análisis de riesgos y de la racionalidad empresarial de maximización de los resultados económicos y de reducción de costos –, poniendo atención a las transgresiones legales de las empresas mineras y la inoperancia de la ley. Al final, afirmamos que, más allá de la dimensión del riesgo en el ámbito de las condiciones de producción de desastres en torno a la minería, es necesario cuestionar el neoextractivismo como modelo privilegiado de desarrollo. Para la elaboración de este estudio, utilizamos, sobre todo, literatura relevante, análisis de la legislación sobre las presas de relaves e informes técnicos producidos sobre la ruptura de la presa de Fundão.
PALABRAS CLAVE: riesgo; desastre; Samarco.

RÉSUMÉ

Dans cet article, il s'agit de la fabrication du désastre de la Samarco, en l'examinant sous l'angle du risque – plus précisément, nous critiquons le fondement technico-économique des analyses de risques et de la rationalité entrepreneuriale de la maximisation des résultats économiques et de la réduction des coûts –, en prenant en compte les transgressions légales faites par des compagnies minières et la loi inopérante. À la fin de l'article, nous soutenons que, plus que l'étendue du risque dans le contexte des conditions de production des désastres autour de l'exploitation minière, il faut remettre en cause le néo-extractivisme en tant que modèle de développement privilégié. Pour la rédaction de cet article, nous nous servons, avant tout, de la littérature scientifique pertinente, des analyses de la législation concernant les

barrages de rétention de résidus miniers et des rapports techniques sur la rupture du barrage minier de Fundão.

MOTS-CLÉS : risque ; desastre ; Samarco.

INTRODUCTION

On November 5, 2015, the *Fundão* tailings dam, owned by the mining company Samarco, a joint venture of Vale and BHP Billiton, collapsed near the subdistrict of *Bento Rodrigues*, which belongs to the municipality of *Mariana*, Minas Gerais. This was one of the largest disasters involving tailings dams in the world (WANDERLEY; GONÇALVES; MILANEZ, 2020). The tailings traveled 663 km through the *Gualaxo do Norte, Carmo* and *Doce* rivers, flowing directly into the mouth of the *Doce* river, in the municipality of *Linhares*, on the coast of Espírito Santo, impacting around forty municipalities along the way. Nineteen people died immediately, in addition to one unborn child; communities were destroyed and, consequently, thousands of people were deterritorialized, that is, they suffered from forced displacement and/or territorial precariousness (HAESBAERT, 2007).

This article aims to consider the dimension of risk present in the making of the Samarco disaster, in its relationship with legal transgressions and the technical and institutional dimensions of the disaster. In this context, we carry out a critique of the technical-economic basis of risk analyses and the business rationale of maximizing economic results and reducing costs in the ore production process. To this end, in methodological terms, we draw mainly on pertinent literature, analysis of the legislation regarding tailings dams and technical reports produced on the collapse of the *Fundão* dam.

In the first topic, we refer to the origins and dissemination of risk analysis, fundamental to thinking about the technical-economic rationale that underlies the decision-making of companies that deal with risky activities and technologies. In the context of the critique of the technical-economic approach to risk, we refer to its growth and dissemination in the 1970s, based on the work of experts from the Ford Foundation and the RAND Corporation.

In the second topic, we analyze the legal transgressions of Samarco/Vale/BHP Billiton, in the field of law, and the technical dimension of the disaster in a critique of the hegemonic approach to risks. In the final considerations, we allude to the institutional dimension of the catastrophe with regard to environmental licensing, highlighting the fact that the *Fundão* rupture refers us to a broader "mining catastrophe", which is not limited to the issue of tailings dams and whose causes cannot be explained solely by the dimension of risk. The "mining catastrophe" must be understood from the perspective of extractivism as a privileged model of development, despite its fundamentally destructive nature of territories and different forms and ways of life.

Mineral extraction is an ever-present operation that manifests itself in different ways and results in catastrophes that are becoming increasingly common, such as the Samarco disaster in the Rio Doce basin. In addition to the process of "brutal deterritorialization" (HAESBAERT, 2007) and the deaths caused by catastrophes, mining has different ways of killing, mutilating, making people sick, destroying and making territories precarious: through contamination, pollution and degradation of air, land and water; through the collapse of underground galleries and waste piles; through occupational "accidents"; rupture of mineral pipelines, etc.

THE TECHNICAL-ECONOMIC APPROACH TO RISK

According to Soraya Boudia (2013), the increase in risk in contemporary society, more than a recognition of a world filled with risks and uncertainties, is the result of conceptualization and scientific and political experimentation carried out in the 1970s by pioneering groups of experts in the United States. These groups worked within or in conjunction with the Ford Foundation[1] and the RAND Corporation[2]. In the case of the RAND Corporation, it diversified its field of intervention beyond the military sphere, taking advantage of the know-how of military techniques to build risk treatment technologies.

The design of technologies for addressing risk and their implementation are based on research initiated during the Second World War and developed in the context of the Cold War (BOUDIA, 2013). These studies provided a general framework for understanding "risk through risk," based on generic technologies and abstract techniques of system analysis, which can be applied in different situations (BOUDIA, 2013).

In this context, we cannot fail to highlight the military connections arising from corporate practices in their technical-economic approach to risk. RAND, by acting, for example, in the development of theories and instruments for decision-making in situations of uncertainty, mathematical modeling and simulation, network theory, game theory, cost analysis, systems analysis, etc., supported not only the military field, but also the private sector and the state,

1 The Ford Foundation, founded in 1936 by Edsel Ford, son of Henry Ford, became, in the decade following World War II, the first billion-dollar philanthropic fund (WIMPEE; RAYMUNDO, 2021). The foundation had experts and provided support for scientific research and American universities (WIMPEE; RAYMUNDO, 2021).

2 The RAND Corporation was created in 1948 to provide research and analysis to the United States Armed Forces. RAND diversifies its field of activity to social and economic problems, providing support for policy makers' decision-making, in which risk analysis stands out (BOUDIA, 2013).

in terms of planning and public policies. Therefore, RAND played a crucial role in the articulation between "military and business sciences" and in "their intervention models" (GAVIRIA, 2015, p. 4).

Robert McNamara's work is an example of this transition between the military, public and private sectors. After serving in the United States Army Air Force during World War II, McNamara joined a group known as the "Whiz Kids", dedicated to business development, made up of ten members of the United States Army, under the leadership of Commander Charles Thornton. In 1946, the "Whiz Kids" worked for the Ford Motor Company. Advances in various fields developed by the group within the Army Air Force during World War II were adapted and applied in corporations, such as Ford. Therefore, we can see a transfer of military knowledge to the business field, with current legacies, such as in the technical-economic management of risk.

In the 1960s, McNamara was the US Secretary of Defense under the John Kennedy and Lyndon Johnson governments, surrounding himself with experts from the RAND Corporation, which contributed to the dissemination of risk analysis. The risk framing technologies developed in this context were used to manage contexts of uncertainty and provide a "rational" response to issues, defining the criteria for decision-making and mathematically instrumentalizing analyses (BOUDIA, 2013). The theory of "rational choice", developed in the context of the Second World War, was central to this perspective and, according to Jean-Pierre Dupuy (2016, p.126), is the foundation of contemporary risk analysis: "all risk managers on the planet (...) think, calculate and reason" based on the "theory of rational choice".

The theory of rational choice, developed by researchers and experts from the RAND Corporation and the Ford Foundation, was designed to have universal validity (DUPUY, 2016, BOUDIA, 2013). Based on economic analysis and behavioral sciences, this theory assumes that individuals act according to a utilitarian logic and that actions need to satisfy or optimize interests (benefits need to be greater than costs) (BOUDIA, 2013).

The rational choice theory imports key assumptions from the neoclassical liberal approach, such as: methodological individualism (PAULA, 2005); the ideal of rational action/behavior (maximizing utility) of agents/individuals (AVRITZER, 1996); and the perspective that "contingencies can be predicted and their consequences evaluated" (ROMEIRO; FILHO, 2001, p. 92).

With regard to risks, rational choice theory can be translated into the cost-benefit relationship in which decision-making takes place. Through

cost-benefit analysis, it is possible to translate environmental and social risks into financial terms, merging different variables and situations into numbers (BOUDIA, 2013). The aim is to make different elements that can affect business decisions or the development of certain policies commensurable and comparable (BOUDIA, 2013). Thus, in the name of methodological operability and economic reasoning that guide "so-called rational choices", market mechanisms and rules encompass all aspects of life.

The knowledge that underpins research on risks comes from the fields of statistics and applied mathematics, economics, behavioral sciences and public policy analysis (BOUDIA, 2013). Behavioral sciences, the object of increasing investment by the RAND Corporation and the Ford Foundation since the 1950s, generally seek to understand the behavioral patterns of individuals in the face of risks, and aim to equip institutions and companies to manage conflicts linked to risks; to eliminate objections and questions; develop communication plans for interest groups; and, above all, build instruments to legitimize certain activities among the population (BOUDIA, 2013).

In this context, in the 1970s, research focused on the development of risk treatment technologies, and was concerned not only with the definition of criteria and decision-making methods in situations of uncertainty, but also with the social acceptability of risks (BOUDIA, 2013). The issue of social acceptance of risks is formulated in this context as a "problem of perception", based on a division between "objective risk" and "perceived risk", so that the difference between the two allows us to measure the degree of "social acceptability of risks" (BOUDIA, 2013). From this perspective, objections and questions are seen as manifestations of irrationality, a problem in risk communication.

Giddens (1991, p. 38) defines safety "as a situation in which a specific set of hazards is neutralized or minimized", that is, safety is achieved through risk management, through so-called "mitigated risk". The "safety experience is generally based on a balance" that involves "trust and acceptable risk" (GIDDENS, 1991, p. 38). Trust, according to the author, is built in the relationship with the "system of experts", which is fundamental for the social acceptance of risk. For Giddens, our modern society is characterized not only by the production of risks, but by "trust in expert systems",

by the confidence that technical systems will always work as expected[3]. However, considering that risks are not chosen, but imposed and, to a large extent, unknown (DOUGLAS; WILDAVSKY, 2012), trust ceases to be a choice and becomes a necessity, since subjects are purposefully deprived of instruments to evaluate the "black box of risks". In these terms, subjects become not only irremediably subjected to risks, but dependent and subjugated to the decisions of others.

From this perspective, for risk analyses, the problem is not so much the potential existence of harm, but its acceptance or not by a given population. With this, everything "becomes a question of 'balance'" between the definition of decision criteria for whether or not to proceed with a risky activity and the "'judgment' by the community", with a view to legitimizing decisions (BOUDIA, 2013, p. 62 – our translation). More than preventing "dangers", "risk managers" act, fundamentally, in the management of the population's "feeling of insecurity" (RANCIÈRE, 2003).

The technologies for framing different issues (health, environmental, social, political, economic) from the perspective of risk, developed by the RAND Corporation expert groups, were implemented in different public spheres and adopted by international organizations that contributed to their worldwide dissemination in new sectors, such as health and the environment (BOUDIA, 2013). Since then, all risk management tools have been based on economic calculation, resource optimization and the development of behavioral standards. Although the methodological tools adopted may be diverse, the objective is unequivocal: "to manage situations of uncertainty, optimizing the allocation of resources through economic calculation" (BOUDIA, 2013, p. 70 – our translation). Thus, what unites the variety of risk management technologies is the fact that they were forged in a "common matrix" by groups of experts who sought to build a universalizable knowledge base (BOUDIA, 2013).

The hegemonic approach to risks, applicable to a wide range of situations and problems, enables their manipulation according to certain interests. The power relations between social agents determine the injunction and hegemony in the approach to risks in their economic and technical-scientific framework and in their administration by the state and large corporations. Risk, therefore, through

3 Expert systems are "systems of technical excellence or professional competence that organize large areas of the material and social environments in which we live today" (GIDDENS, 1991, p. 35). They function as mechanisms of power-knowledge that produce "truth effects" in society (FOUCAULT, 2003).

statistics and calculations, prevents any type of questioning, acts to depoliticize the contexts of threat, proclaiming that, from the perspective of control, "the problem is solved, as they say in mathematics" (DUPUY, 2016, p. 63). From the perspective of technical-scientific control, "it is postulated that (...) [the] risks can be thought of independently of the "catastrophic" fate that the signs announce. (...) [The] intention is to reassure, but to control expenses" (DUPUY, 2016, p. 63).

From the perspective of control, risks will not be eliminated or avoided, but rather estimated and managed according to certain limits and a normalizing probability estimate, always aiming for a balance, optimal averages, and technically and economically efficient results for the determining interests (FOUCAULT, 1999; OLIVEIRA, 2009; HAESBAERT, 2014). The intention is to "maximize the positive elements" and minimize the risks, which, in the end, "will never be suppressed" (FOUCAULT, 2008, p. 26). This is a "minimax" logic, which seeks to "minimize", even if only on a discursive level, the "maximum risk", which, obviously, does not mean making it null (DUPUY, 2016, p. 104).

Within the scope of scientific criteria, "the circle of recognized risks and, therefore, relevant for action" tends to be "reduced to a minimum" (BECK, 2011, p. 75), mainly to the extent that their recognition implies costs for risk-producing companies. As Beck (2011, p. 73) explains: "This makes clear once again the degree of obviousness with which, in the technological development driven by science (...), a (...) cognitive interest" is historically validated, which aims to increase "productivity, which refers to the logic of wealth production and remains linked to it". The normalization, minimization or denial of risks are technically, scientifically, politically and socially produced, seeking to make "risks acceptable" for meeting economic and productive needs.

The "symptomatic and symbolic 'overcoming' of risk" (BECK, 2011) from the perspective of its technical-scientific control enables the generating sources to establish themselves and remain active. As a result, risks multiply and increase, which also benefits the market. To the extent that they can be managed, risks appear as market opportunities, driving an economy of "securitization," scientific research, security, and mitigation technologies. Risks, therefore, do not break with capitalist logic, but serve the accumulation and valorization of capital itself, under the hegemony of the technical-industrial complex. The economic system therefore takes advantage of the uncertainties, damages, and dysfunctions that it itself produces. Risks are "big business," as Beck (2011, p. 28 – author's emphasis) says, "a bottomless, endless, infinite, self-producing barrel of needs."

Finally, it is important to mention that decision-making regarding risks results in power asymmetries: there are those who define and benefit from risks and those who suffer the effects of their realization in the form of damage and catastrophes. In this context, even risks that are distributed globally are experienced locally and asymmetrically, since the conditions for dealing with them are extremely unequal. Furthermore, there are a myriad of risks that are not global, but that, within the "rational choice" in which decision-making takes place, are referred to certain historically subalternized groups, evidencing the strong relationship between risk and social injustice (ACSELRAD; PÁDUA; HERCULANO, 2004). Therefore, it is no coincidence that risky activities, enterprises or industries (mining companies, garbage dumps, incinerators, chemical industries, hazardous waste treatment plants or those that emit or store substances or materials with a high potential for socio-environmental damage, etc.) are located in poor neighborhoods, working-class neighborhoods or in rural and/or traditional communities.

CATASTROPHE THROUGH RISK: THE CASE OF THE *FUNDÃO* DAM

In the specific case of mining dams, in general terms, risk analysis is based on calculating the probabilities of rupture and the inoperability/anomalies of their components. The risk of rupture is "estimated based on the combined impact of scenarios", taking into account certain parameters, "probabilities of occurrence and associated consequences" (ALMEIDA, 2002, p. 8). Based on dam break analysis, which uses mathematical modeling, computer simulations, variable analysis, etc., mining companies must outline the potential impacts of a tailings dam rupture, delimiting the flood area in the event of a rupture (flood spot). It is based on this study that critical zoning of potentially floodable areas is carried out, "with implications for the licensing of land use" and "for setting insurance premiums" (ALMEIDA, 2002, p.18).

The probability of disasters occurring is always considered in light of the technical control and engineering resources and safety technologies adopted by the company. In this logic, dam rupture is considered a low probability risk (especially when compared to other risks such as death in a car accident), despite its amplified consequences. As Silva (1999) warns, the notion of probability of occurrence can, in part, corroborate the denial of risk (there is no risk), its attenuation (the risk exists, but it is minimal) and even its generalization (the risk exists everywhere).

Under the logic of calculations, the safety of a mining dam is estimated and considered according to certain thresholds, more specifically through the so-called "safety factor". The "safety factor", established by Brazilian standard NBR 13028, is a number that measures the stability of a structure. This standard provides that, "for structures in normal operating conditions", the minimum safety factor is 1.5 (explanation by Samarco's Director of Operations and Infrastructure, Kléber Terra) (G1 MG, 2015, n.p.). "In adverse conditions, a safety factor of 1.3 is permitted". An index equal to 1 means "that the structure is at the limit of equilibrium" (G1 MG, 2015, n.p.). Thus, the establishment of "safety factors" and regulated "minimum values" establishes the threshold of what is permitted and translated to society as harmless and safe. From this perspective, an industrial activity that produces risk, the use of a certain dangerous technology, the consumption of or exposure to certain chemical substances are acceptable within certain "technically" defined limits. The technically and economically established limits, as Beck (2011) asserts, are a way of allowing risk, which, from this perspective, must be managed according to the recommended safety levels.

In the "Inventory of Dams in the State of Minas Gerais" by the State Environmental Foundation (FEAM, 2014), which preceded the Samarco disaster, the *Fundão* dam was considered stable, that is, in compliance with the legally determined safety factors. However, it is important to note that the mining company itself is the one who certifies the stability of the dam. At the time, companies sent the regulatory department, the DNPM (National Department of Mineral Production), now the ANM (National Mining Agency), the annual Declaration of Stability Condition (DCE) for the dam (according to DNPM Ordinance No. 416/2012).

Nowadays, with the tightening of legislation regarding mining dams, the DCE is now semiannual, although it is still certified by the company itself, which must send it to the ANM. In the first half of the year, the company is the one who presents the DCE and certifies its stability, and may or may not hire an external consultancy to do so. In the second presentation, in September of each year, the company is required to hire an external consultancy. However, even though it is considered an external consultancy, it is worth mentioning that the audit establishes an economic, contractual link with the mining companies, which may make the independence of the data issued questionable. This situation even occurred in the year of the dam collapse, in 2015, when the consulting firm hired by Samarco, VOGBR Recursos Hídricos

& Geotecnia LTDA, issued a report declaring the stability of the structure, omitting from the ANM the technical problems in the dam structure, according to complaints from the Federal Public Prosecutor's Office (2016, p. 29).

In business rationality, all decisions regarding risks are economically guided, based on cost-benefit balances. This guideline was decisive for the collapse of the *Fundão* dam. The dam in question was built using the upstream raising method, which is the most economical, easiest to execute and the "most critical from a safety point of view" (FEAM, 2010, p. 5). Although this construction method is considered unsafe, it is important to emphasize that environmental regulations, current legislation and environmental licensing processes only limit a technology or activity if the existence of damage is extensively proven. Prioritizing the lowest cost over safety, therefore, dams made with the upstream method are one of the most used by mining companies in Brazil (FEAM, 2010). According to ANM (2019), in 2019, there were 84 upstream dams in the country, of which 43 were classified as having high potential danger. Contributing to the catastrophic nature of the realization of the risk, we highlight that the cost-benefit analysis, aiming at cost reduction, was predominant not only in the construction method of the *Fundão* dam, but also in its location option. Wanderley et al (2016, p. 32), when analyzing the Environmental Impact Study and Report (EIA-Rima) that supported the granting of environmental licenses for *Fundão*, observed that:

> The option for the *Fundão* river valley was the only one of the three location alternatives that produced direct impacts and cumulative effects on the *Germano* and *Santarém* dams, which could generate an even more catastrophic domino effect in the event of a dam failure. It was also the only option that drained directly towards the rural community of *Bento Rodrigues*, in Mariana, further increasing the potential for socio-environmental risk and death. The analysis of the location justifications presented in the EIA-RIMA indicate that the choice for this option was primarily operational, taking advantage of the Germano-Santarém dam system in operation and reducing the costs of the construction and operation for the disposal of the waste. Furthermore, the EIA-RIMA risk analysis classified the possibility of the dam failure as the lowest level, "unlikely", disregarding the history of repeated failures in Minas Gerais, Brazil and the world.

The location option also disregarded the fact that, in the event of a dam failure, the large elevation difference between the construction site of the *Fundão* dam and the community of *Bento Rodrigues* would contribute to its overwhelming nature, as stated by Vervloet (2016, p. 114). According to the State Environmental Foundation (2010, p. 6), the variables considered to determine the best location option for the dams are limited to economic and

operational ones, since the disposal of tailings is still an investment with no return in the short or medium term. Therefore, for mining companies, tailings dams are simply reservoirs for mining waste, housing the undesirable product of the production process, initially without any exchange value[4]. Dams concentrate what is discarded and made superfluous in terms of matter and energy during the energy-intensive extraction-process, representing the cheapest technological option for companies, although the most unsafe. And, in the context of mega-mining, economically capable of exploiting reserves characterized increasingly by low mineral concentration, the amount of matter-energy made superfluous grows considerably (WANDERLEY et al., 2016).

When the *Fundão* dam collapsed, Brazil was experiencing the end of the commodities megacycle (period between 2003 and 2013), mainly due to the lower demand for ore from China (WANDERLEY et al, 2016). The price of iron ore went from US$ 196/t (in 2007) to approximately US$ 40/t at the beginning of 2016 (INDEX-MUNDI, 2023).

To minimize the effects of the drop in commodity prices, mining companies increased production and, consequently, the production of tailings. Samarco, specifically, during the commodity crash period, was able to increase its production by a third due to the "Fourth Pelletizing Project" (P4P)[5], inaugurated in 2014, which expanded the structures necessary to increase its iron ore production (WANDERLEY et al., 2016; IN THE MINE, 2014).

Due to the P4P, the company's net debt increased, going from R$2,928.00 million in 2010 to R$9,531.00 million in 2014 (VITTI, 2019). Due to the drop in commodity prices and Samarco's debt, in order to maintain its income, the mining company sought to increase its production and reduce its costs. In the company's cost reduction policy, according to the final investigation report into the causes of the Fundão dam collapse by the Minas Gerais Civil Police (PCMG, 2016), there was a 29% reduction between 2012 and 2015 "in Samarco's budget allocated to the geotechnical sector, responsible for controlling and monitoring dams" (WANDERLEY et al., 2016, p. 55).

Several expert assessments and reports were carried out to identify the causes of the Fundão collapse (MTPS, 2016; PCMG, 2016). The immediate

4 However, in a context of high commodity prices, the waste disposed of in old dams (with a greater quantity of remaining ore) can be reprocessed (ANDIFES, 2019, n.p.).

5 The "Fourth Pelletizing Project" (P4P) includes a fourth pelletizing plant in Anchieta-ES; a third mineral pipeline, which passes through 25 municipalities in Espírito Santo and Minas Gerais; and a third concentrator in the Germano unit, between the municipalities of Ouro Preto-MG and Mariana-MG (IN THE MINE, 2014).

technical cause was the liquefaction[6] of the dam's sandy tailings (over which the raising dikes were built), favored by construction, operational and monitoring issues of safety conditions (PCMG, 2016).

At the Legal Seminar "Two Years of Mariana", at the Dom Helder Câmara High Education School in Belo Horizonte, in November 2017, the then superintendent of IBAMA in Minas Gerais, Marcelo Belizário, listed numerous situations that contributed to the *Fundão* collapse:

> Well, this is a socioeconomic and environmental disaster that was built, as we will see. (...) a lot of disrespect was done to this structure (...). It increased the mining company's production by a third. It reduced the price of the commodity, and you still had a profit on the margin, so you increased the level of production, and in the end... The result remained the same as the initial objective. Additionally, there was a *Vale do Rio Doce* mud discharge pipe inside the Samarco basin. This pipe was discovered during IBAMA's work on a shift in November... People were almost living inside Samarco, and they discovered one of the... The plans showed a *Vale* mud pipe. So when we went to look, this pipe was not even known to the licensing, okay? There were chronic problems with the dam and critical drainage, from the beginning and all... Throughout its useful life, repeated problems with drainage at the limit, okay? We started to observe leaks with dirty water. When you see a leak of dirty water in a dam, it means that material is being removed from the dam. You are removing its body, creating pores, making it lighter, and as a result, it loses... It loses mass, right, its weight, and becomes more susceptible to rupture. A change was made to the geometry of the dam project. So, looking at the bottom right corner [of the presentation slide], you see it rising, until it forms an S, right? [Explains the reason for the change in the geometry of the dam:] (...) there is also a pile-up by *Vale do Rio Doce,* a pile-up of tailings. To avoid this pile-up, this S solution was given, and in addition, an accelerated expansion of the tailings dam. So, heightenings were made that were not foreseen in the project. They were done every few years, every few decades. They were supposed to be raised, but they were being done every few years, right? Well, why did this [the disaster] happen? It was the exposure to a sequence of risks, which represented the abdication of the economic, social and environmental sustainability of the company itself (Verbal information – our emphasis).[7]

According to the IBAMA Superintendent, there was a deliberate violation of technical and environmental standards that increased the risk over time. Based on the speech transcribed above and on reports and expert opinions, we present a summary table of the factors (although incomplete, because there

6 Liquefaction: when a sandy soil begins to act like a material in a liquid state (it loses friction between particles).

7 Transcription of an excerpt from the lecture by IBAMA Superintendent, Marcelo Belizário, during the legal seminar "Two Years of Mariana", Dom Helder Câmara Higher Education School, Belo Horizonte, on 11/17/2017.

are numerous technical details and incidents that could be added) that made the disaster-crime, which could have been avoided, inevitable (see table 1):

Table 1 – Factors that triggered the *Fundão* dam collapse

Technical factors that triggered the Fundão collapse	Description/explanation/additional information
Critical drainage problems, persistent throughout the operation of the Fundão dam.	Occurrence of surges (technical term to indicate the appearance of water) in 2013, 2014, 2015 in the dam structure. Confirmation of the existence of large cracks in 2014, which demonstrate that the Fundão dam "presented problems in relation to the percolation of water through its structures" (MTPS, 2015, p. 114).
Presence of a clandestine Vale pipe releasing waste into the Fundão dam.	VALE's contribution of sludge is equivalent to 27% of the total sludge disposed of in the Fundão dam (PCMG, 2016).
Upstream heightening beyond what is due and foreseen in the project approved in environmental licensing, due to the large volume of waste deposited in the dam.	International technical literature recommends that heightening be carried out at a maximum rate of 10 meters per year (PCMG, 2016). The Fundão dam was raised at an average rate of 20 meters per year (PCMG, 2016).
Monitoring failures.	Failures in the continuous monitoring of water levels and pore pressures along with the sandy waste deposited inside the dam and along with the waste constituting the heightening dikes carried out" (PCMG, 2016, p. 159); defects or lack of monitoring equipment (MTPS, 2016, p. 116; PCMG, 2016) and failures in the operationalization of the monitoring itself (MTPS, 2016).
Vale's Fábrica Nova and Alegria mines border Samarco's Germano Complex. The runoff of rainwater from a Vale waste pile towards the Fundão dam has caused repeated technical problems for the dam.	In 2012, Samarco found a technical anomaly in the Fundão dam due to the high water level in the region of Vale's waste rock pile (MTPS, 2016, p.118). In October 2013, the Prístino Institute, at the request of the Public Prosecutor's Office of the State of Minas Gerais, presented a technical report regarding the revalidation of the dam's operating license. This report highlighted the overlapping areas of influence between the Fundão dam and Vale's waste rock pile as a problem, with a synergy of impacts that could generate drainage problems, saturation and slope destabilization.
Change in the axis of the dam (setback in "S"), to avoid interference from the flow of water generated from Vale's waste rock pile (problem described above), which caused the saturation of part of the raised dikes of Fundão.	The alteration was carried out in noncompliance with the original licensed project. In 2014, the ITRB (Independent Tailings Review Board) report indicated the existence of several cracks and saturated areas in the area of the shaft setback. The ITRB report recommended filling the setback area "as soon as possible" (MTPS, 2016, p. 110). Given the ITRB's findings, Samarco estimated that filling the setback would take a year, but in November 2015, it had not yet been completed (MTPS, 2016, p. 110). The total rupture began precisely in this area of the shaft setback (and the collapse at this point may have triggered liquefaction in the rest of the dam) (ALMG, 2016).

Source: Produced by the authors, based on the following technical reports MTPS (2016); PCMG (2016); ALMG (2016).

In this context, it is important to say that companies, instead of following standards, calculate economic results and, therefore, continually relax standards, often exceeding the threshold of legality. The rationalization of actions always occurs based on a dynamic of maximizing profitability, aiming at productivity and cost reduction. The logic of risk management, in turn, considers anomalies and dysfunctions as something natural and inevitable, which should only be treated when they exceed certain limits, from the palliative perspective of technical and engineering adjustments. Arbitrariness in technical-organizational decisions in disregard of the law, the company's disregard of problems pointed out in internal and external audit reports and a certain *laissez-faire* in actions before the catastrophe happened, are part of the business economic logic that aims to reduce costs in decision-making in relation to risks.

The transgression of legal limits regarding the *Fundão* dam can also be seen in the inoperability of the existing emergency plan and in the absence of a contingency plan for the populations downstream. The inoperability of the emergency plan, which existed pro forma, is made plain by the fact that there was no audible alarm system, an elementary technology as a warning tool in the event of a breach.

The company dealt with the concerns of the residents of *Bento Rodrigues*, located only 6 km from the Germano Complex dams, limiting itself to simply stating that the reservoirs were safe, that is, the "risk was unreal" and that catastrophe was impossible. *Bento Rodrigues* was located in the so-called Self-Rescue Zone of the Germano Complex dams. The "self-rescue zone" (ZAS) (technical-legal term for "sacrifice zone") includes the

> region of the valley downstream of the dam where it is considered that warning notices to the population are the responsibility of the developer, as there is not enough time for intervention by the competent authorities in emergency situations, and the greatest of the following distances should be adopted for its delimitation: the distance that corresponds to a time of arrival of the flood wave equal to thirty minutes or 10 km (BRASIL, 2017 – our emphasis).

In the event of a disaster, the Civil Defense and other public agencies are responsible for issuing evacuation alerts to potentially affected populations in the Secondary Rescue Zone, which covers the flood area not included in the ZAS. However, if requested by the Civil Defense, the developer must also install an alert system for the potentially affected population in the ZSS (BRASIL, 2017). When the alert system is activated, the area must be evacuated, according to the Emergency and Contingency Action Plans produced, respectively, by the company and the municipal government.

The downstream communities also did not have access to the dam contingency plan, which should be drawn up by the municipality, based on information provided by the mining companies. The Samarco disaster, therefore, was exacerbated by the lack of preparation of public agencies and the complete disregard by the mining company for the downstream communities, which lacked any instructions or instruments to facilitate evacuation in the event of a dam rupture (such as the lack of warning sirens, evacuation training in the ZAS, etc.). Communicating the risk to the downstream communities (installing warning sirens, conducting evacuation training) would make them understand that the risk was real, which was not in Samarco's interest. Furthermore, as Dupuy (2016) mentions, for "risk managers", a catastrophe is always unlikely.

In this context, it is important to mention that the instruments and actions that must be activated in emergency situations, aimed at downstream communities, require individuals to take responsibility for the risks that are produced by mining companies. In the self-rescue zone, as the name suggests, the individual must have the capacity (including physical capacity) to rescue themselves, upon hearing the company's warning system. Therefore, the problem, more than the lack of instruments and evacuation plans in areas under the threat of mining dams, lies in the fact that territories and lives were (without choice) under the yoke of necro-engineering. In other words, the problem is that *Fundão, Santarém, Germano* and so many other dams exist. The recommended emergency actions aimed at downstream communities would not prevent the catastrophe, nor the destruction of *Bento Rodrigues, Paracatu de Baixo* and parts of the communities of *Camargos, Ponte do Gama, Paracatu de Cima, Pedras, Borba, Campinas, Gesteira* and the city of *Barra Longa*, but they could contribute to reducing the number of deaths, or not, since the proximity to the dam makes any evacuation a matter of individual resilience and even luck.

In the case of dams, the trade-off between economic benefits and costs in which decisions regarding risks are made even establishes an expected number of human lives lost, the reduction coefficient of which depends on the safety factors adopted (ALMEIDA, 2002). In other words, the death of people can be economically worthwhile for certain economic sectors and can even be calculated as socially acceptable within certain limits[8]. In this necroecono-

8 Risk acceptability is calculated through the so-called Socially Acceptable Risk (SAR), which considers, among other aspects, estimated losses and the potential number of victims, which makes us reflect on the existence of a maximum number of deaths that would be considered socially acceptable in a disaster (ALMEIDA, 2002).

mics (ARÁOZ, 2020), life is priced and becomes a mere economic factor to be considered in the cost-benefit calculation of risks. The technical-economic control of risks, therefore, is nothing more than "a set of tactics and subterfuges" to "deal with the immoral side of technological choices" (SILVA, 1999, p. 17).

In this context, although for "risk managers" the catastrophe appears impossible, its occurrence makes its inevitability evident, as a result of legal violations and cost-benefit analyses in which decisions regarding risks are made. Samarco created the possible and, at the same time, the catastrophic reality (DUPUY, 2016), through the accumulation and perpetuation of risks, which are implied in the very rationality that prevails in its management. The technical problems, the "anomalies" (to use the company's jargon) involving the dams were normalized and treated in corrective and palliative terms by the mining companies. Under this logic, the "anomalies", the abnormalities, have their own normality. This is how, for example, the ideas of "accidents" at work and "accidents" in mining are constructed.

The perpetuation of danger through the use of unsafe techniques or technologies, of an "unsafe technical culture" (FIRPO, 2007), becomes an integral part of the process of accumulation by plunder (HARVEY, 2005), making production cheaper and fulfilling the interests of an entire production chain and a global consumer mass. This accumulation arises, in the case of mining ventures, from the attribution of unlimited risks to measure unlimited profit and from the socialization of the industrial burden, the bonus of which is always private. In other words, the so-called socio-technological risks produced are externalized to the surrounding population and to society in general, and are not considered or accounted for in business costs.

ARE TAILINGS DAMS THE ISSUE?

It was only when society was shocked by two consecutive disasters, that of Samarco and Vale in Brumadinho-MG, that changes in legislation were implemented and "acceptable risks" became "unacceptable sources of danger" (BECK, 2011, p. 95). After the Samarco disaster, at the state level, as determined by Decree No. 46,933, of May 3, 2016, upstream heightening dams in Minas Gerais became the target of: 1) "Additional Technical Audit of Dam Safety"; 2) an action plan to adapt the stability and operating conditions specifically for these structures; 3) suspension of the issuance and formalization of environmental licensing processes for both new dams and the expansion of existing upstream dams.

In the wake of the Vale disaster in Brumadinho-MG, whose collapsed dam was also raised upstream, Resolution No. 4 was enacted at the federal level on February 15, 2019, prohibiting the use of the upstream mining dam raising method throughout the national territory, making it mandatory to de-characterize the structures or adapt them to the "downstream" or "centerline" raising construction method by August 15, 2021. However, Resolution No. 4 was revoked by Resolution No. 13 of August 8, 2019, which relaxed the deadline for de-characterizing the structures (in the name of process safety), establishing a variable temporal gradation with the size/volume of the dam, with dams with larger volumes (above 30 million m³) being able to be de-characterized by September 15, 2027.

At the state level, it is important to mention the enactment, on February 25, 2019, of Law 23,291 (known as the Mud Sea Never Again Law), also with a strong focus on prohibiting and de-characterizing dams raised using the upstream method (the advances of the aforementioned law within the scope of the state dam safety policy have still been hindered by the postponement of the regulation of its articles by the executive) (DOTTA, 2020 apud MILANEZ; WANDERLEY, 2020, p. 10). As a result, under the horizon of norms, laws and regulations, always mobile and unstable, the risk that has always existed ceased to be veiled and became imminent, resulting, in March 2019, in the closure of 54 dams and the evacuation of 998 people in Minas Gerais (FERNANDES, 2019, n.p.).

The focus, therefore, of legal changes and inspection, control and safety actions became upstream tailings dams. However, in addition to dam failures, there are countless disasters involving mining, such as underground tunnel collapses, waste pile collapses (on November 4, 2018, a pile collapse occurred at the Canadian company Equinox Gold, in Godofredo Viana), fatal or life-limiting "accidents" at work, people being run over by trains, deaths from dynamite explosions, contamination and various illnesses, leaks in reservoirs (such as the bauxite tailings dam of the Norwegian company Hydro Alunorte in Barcarena, in February 2018, which contaminated the *Pará* River basin, affecting around 80 communities) and in pipelines (such as the ruptures of Anglo American's pipelines, from the Minas-Rio mining-port project, in March 2018, in the municipality of Santo Antônio do Grama-MG, with immediate impacts on the *Santo Antônio* stream). and to the *Casca* River).

Furthermore, the tightening of legislation on mining dams occurs in a context of relaxation of legislation on environmental licensing (see Law No.

21,972/2016[9] and Normative Deliberation 217/2017 of COPAM[10]). Environmental licensing is, in the end, a rite that enables and legitimizes large undertakings that have been creating risks and catastrophes, which tend to increase as current legislation becomes more flexible. Therefore, there is no point in the state tightening legislation on upstream tailings dams and relaxing environmental licensing processes, since the risks and catastrophes surrounding mining are not limited to tailings dams.

In addition to environmental licensing, it is important to highlight the dimension of the inspection of licensed projects. The institutional vulnerability (FIRPO, 2007) of environmental and regulatory agencies is caused by the lack of public investment and the deliberate dismantling and scrapping of these institutions, which is reflected in the lack of human and technical resources and material conditions for external inspection and monitoring actions – a situation that is common to the National Mining Agency (NMA) itself, which is responsible for inspecting dams in the sector.

Therefore, it is important to clarify: are mining disasters a technical issue, a problem of tailings dams with upstream elevation? For mining companies, the state and certain economic segments, it is better for the issue to be treated as a technical one, that is, one that can be solved at the technical level. Disasters, therefore, should be treated as a problem limited to the issue of tailings dams and, more specifically, to a specific method of building dams. The issue is also technical. The Samarco disaster is technological, but it is far from being merely technical. Technology should not be "exonerated", but reducing mining disasters and that of Samarco itself to a "technological problem" hides the core of the issue: unbridled extractivism, the power of the mining business segment to dictate and transgress norms, and the catastrophic nature of mining and the neoliberal extractivist model itself.

Acknowledging damage and disasters as inherent to extractivism, for corporations, is to create a state of alert and denial in society and, mainly, in the surrounding populations, in relation to mining projects, ultimately increasing

9 Law No. 21,972/2016 creates SUPPRI, which is responsible for evaluating so-called "priority projects" in order to expedite projects deemed relevant to the state. This law makes it possible to simultaneously issue environmental licenses, with two or three licenses issued in a single act.

10 Normative Deliberation 217/2017 establishes changes in the parameters for classifying polluting enterprises/activities. As a result, projects that previously required "more complex" licensing (three-phase – prior license, installation license and operating license) would undergo "simpler" licensing through, for example, the granting of a concomitant environmental license.

the cost of implementing and maintaining the projects. Therefore, economically and politically, it is more interesting for the mining sector to define a single "enemy" for the media and society – upstream tailings dams – and seek solutions within the scope of engineering works and technical paraphernalia.

The understanding of the issue of tailings dams, in terms of technique and risks, can only be broadened if we consider such necro-engineering as an expression of a given rationality: behind mining dams lies the extractive-industrial-financial rationality. More than a technology for storing waste from the extractive process, dams not only integrate, but also reveal the extractive mode of production and reproduction. The disproportionality of the end (from extractivism to scarcity, for endless accumulation) is reproduced in the disproportionality of the means (of catastrophic mining dams). Recalling the famous quote by Marcuse (1973, p. 19): "Technology cannot, as such, be isolated from the use to which it is put; technological society is a system of domination that already operates in the concept and elaboration of techniques". In other words, technologies are not neutral; they contain intrinsic values that play in favor of or against certain rationalities. Technology, the technical system, as Porto-Gonçalves (2006, p. 332) reminds us, does not operate in a material vacuum and outside of social and power relations. However, considering that a technological change is enough to resolve issues that are at the heart of power and production relations only reconstitutes socio-environmental problems and disasters on new bases.

Criticism should be directed not only at a means – tailings dams – but also at their ultimate end: mining, which only aims at its reproduction through accumulation. The purpose of the "ultimate end" is to provide the production of the means with its raison d'être (ANDERS, 2011 [1956]). If, with the critique of the ends, the raison d'être is questioned, the principle of the sacrosanct production of means for this purpose is consequently attacked (ANDERS, 2011 [1956]). This is what Paul Virilio (2005, p. 25) also invites us to do in "L'accident originel" when he states that whether it is "the sinking of the Titanic or the explosion of the Chernobyl power plant (...), the problem raised by the catastrophic event is not so much the iceberg that appears in the North Atlantic one night in 1912" and the "divergent nuclear reactor one day in 1986", but "the construction of the 'unsinkable' transatlantic liner" and the "construction of an atomic power plant (...)". In these terms, we can paraphrase Marcuse (1973, p. 13), transmuting his observation about the threat of an atomic catastrophe into the threat of catastrophes involving tailings dams in Brazil:

wouldn't the limited focus on mining dams serve "to protect the very forms that perpetuate this danger? Wouldn't efforts to prevent such a catastrophe overshadow the search for its potential causes in contemporary extractive society, displacing the dams from their context?

FINAL CONSIDERATIONS

A catastrophe only becomes possible by "making itself possible" (DUPUY, 2016), that is, mining-related catastrophes and, more specifically, the Samarco catastrophe are revealed as "a made-to-order event" (BECK, 2011, p. 62). A myriad of factors made it possible for the risk to become a disaster, such as the business logic of risk management, in which cost-benefit analyses and the economic dimension prevail in decision-making, the legal transgressions of Samarco/Vale/BHP Billiton, the inoperability of the law and the dismantling of oversight bodies. Finally, beyond the most immediate and technical causes that made the *Fundão* dam collapse possible, this article points to a "state of exception" (AGAMBEN, 2004) that is in force in large investment projects. In the "state of exception", the law comes into force after its suspension, its loopholes and its flexibilization by the state, which guarantees large corporations the right to act as they deem necessary, to the detriment of human rights and those that prevail in the environmental sphere.

Furthermore, more than treating risk as a trigger for the Fundão dam collapse, in its relationship with legal transgressions and the technical and institutional dimensions of the disaster, we criticize its management approach and its technical-economic logic. In the context of criticism of the technical-economic approach to risk, we refer to its growth and dissemination in the 1970s, from the think tanks of the Ford Foundation and the RAND Corporation, and to its foundation in system analysis and cost-benefit analysis, in the "theory of rational choice", in economic and behavioral sciences (BOUDIA, 2011; DUPUY, 2016). The business approach to risk management goes back to its origins. From this perspective, risk is something that must be managed, according to cost-benefit analyses, mitigated (which does not mean eliminated) and externalized. In the inequality that permeates the risks of large projects, they fall, above all, on the most vulnerable populations, particularly with regard to race, as Wanderley (2015) demonstrates in the case of Samarco.

Finally, as we mentioned in the last topic of this article, addressing the Samarco disaster from its causes and production conditions goes beyond questions related to tailings dams, since the confrontation needs to take place

from the extractivism perspective, in its relationship with the mechanisms and rationalities that make it possible. Reducing the Samarco disaster to the issue of risk surrounding dams is a way of limiting criticism of the mining sector, by providing society with the perspective that the issue is solely the tailings dams built using the upstream raising method and not mining and the modus operandi of mining companies. Discussion limited to dams reduces the scope of the problem, displacing it from its context and opening it up to a purely technological solution (revolving around technologies for disposal and reuse of tailings), which ignores the mining catastrophe, which is much broader. More than a technical truth, the Samarco disaster reveals itself as a political, economic and historical truth. ●

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Tádzio Coelho: structuring the article, contributions to the methodology, part of the introduction and writing part of the final considerations, general revision of the article.
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