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Mining dams disasters as systemic risks

Desastres em barragens de mineração como riscos sistêmicos

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ABSTRACT

Between 2015 and 2019, Brazil recorded the two most serious disasters involving mining dams of the 21st century. The purpose of this article is to offer an understanding of these disasters as systemic risks. They involve from global and national processes related to social determinants that materialize in a complex system of dams distributed throughout the country with their intrinsic risks. When they occur, result in a set of impacts with potential damage and immediate effects combined with secondary and tertiary impacts that can trigger chain reactions, which promote risk factors of heterogeneous and complex occurrence. Approaching these events from the point of view of systemic risk allows for a broader understanding of both the singularity of each of these disasters and their multiple exposure, risk and disease processes, as well as the structural characteristics in which social, political processes and dynamics and economic factors reproduce in multiple territories a common pattern of disasters and their effects. We conclude that the promotion of population health and sustainable territories should guide the organization of production processes and not the opposite, with the externalization of human, environmental and social costs of mining and its disasters.

Keywords: Disaster. Dam failure. Mining. Systemic risk. Disaster risk reduction.

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INTRODUCTION

Between the end of 2015 and the beginning of 2019, Brazil suffered two of the most serious disasters involving mining dams of the 21st century. In 2015, the mining company Samarco, in Mariana, Minas Gerais, was responsible for 19 deaths and spillage into the environment of a volume >50 million m³ of waste, which reached 36 municipalities in 650 km along the Rio Doce Basin. In the Vale S.A. disaster, in 2019, there were 270 fatal victims and the release of 13 million m³ of waste that reached at least 18 municipalities in the Paraopeba River basin[1]. Global and national data demonstrate that dam disasters are not rare and result in immense human, environmental, and social costs of the extractive industry to society.

For Public Health, it is important to understand them as social productions and systemic risks. Their impacts are far beyond the potential for immediate deaths and damage to society. They involve, in their origin, from global to local determinants with their social, political, and economic processes; and, in their systemic impacts and risks, they combine environmental contaminants that determine broader contexts of exposure and risk, abrupt changes in socioeconomic and environmental contexts and decisions in urgent conditions, fraught with uncertainty, to stop or reduce exposure, as well as to recover the most affected localities. On the one hand, they require specific strategies to respond to short-, medium-, and long-term health and illness problems and needs; on the other, broader policies that address the social determinants of disaster risk reduction (DRR)[1,2].

The objective of this article was to offer an understanding of these disasters as social productions and systemic risks.

WHAT ARE DISASTERS

Disasters in mining dams constitute the tip of an iceberg, materializing and enhancing environmental and health risks present in the territories where mining economic activities are carried out, as well as numerous incidents and accidents that occur in them.

Having as a reference the definition of the United Nations Office for Disaster Risk Reduction[3], disaster is any event or situation that results in a serious disturbance in the daily life of a community or society, producing a set of environmental, economic, and social impacts, as well as effects on life and health conditions, which will manifest themselves in the short, medium, and long term. Depending on the magnitude of the event, another characteristic is to exceed the capacities of the community or society to deal with all its impacts using its own resources.

For a disaster to take place, the combination of a set of factors is necessary:

1. A hazardous agent or process (natural or technological) or a combination of both, such as, for example, the rupture of a mining dam involving heavy metals;
2. The exposure of a territory and population to the triggering hazardous agent(s) or process;
3. Conditions of social and/or environmental vulnerability, which make territories and populations, or parts of both, suffer greater and more lasting impacts;
4. Risk reduction capabilities at the municipal, state, and national levels, which involve a set of bodies responsible for prevention (regulation, licensing, and monitoring), mitigation (environment, social assistance, public health, civil protection), and reconstruction/recovery in its various dimensions (economic, social, environmental, and health).

This set of factors that constitute disasters, deaths, symptoms, diseases, and immediate injuries are only a part of the effects and impacts of a complex non-linear system of social production with multiple causes and effects.

From this perspective, the effects of disasters involving mining dams cannot be reduced only to aspects related to the uniqueness of the type of dam, the magnitude of the rupture and the geographic extent of its impacts, the characteristics and biogeochemical composition of the tailings. They also involve the dynamics of society related to the social, political, and economic organization that sustain mining and its dams, as well as produce inequalities and inequities defining who will be affected and who will be free of responsibilities, who will have guaranteed dividends from mining profits and who will not have full right to the process of repair, rehabilitation, and reconstruction of their living and health conditions.

CHARACTERISTICS OF DISASTERS IN MINING DAMS

Dams is one of the alternatives for waste disposal and has been used on a large scale in the Brazilian territory[4]. The current stage of technology used in the industry allows mining in soils with low mineral richness[5], increasing the production of waste. On average, to extract one ton of ore, about 200 tons of waste are produced[4]. Despite the low economic cost associated, when combined with fragile policies and precarious inspection and control institutions, this technology constitutes a fruitful scenario for the occurrence of disasters[4], with the externalization of the human, environmental and social costs of this process.

The issue of safe waste storage could become even more challenging in the coming years. Bowker and Chambers analyzed 214 accidents in mining waste dams that occurred in the 1940s and 2010s. They showed an increase in the frequency and severity of disasters, with serious or very serious occurrences rising from 1/3 (between 1940 and 1989) to 2/3 of records between the end of the 20th century and the beginning of the 21st[5], accompanied by an increase in death records and the geographic extent of the impact, especially in large dams[6,7].

With regard to social determinants, mining dam failures make it possible to envisage risk scenarios that are not easily accessible in "normal situations". On the one hand, they expose characteristics of the global commodity market such as pressures to increase production, limited environmental licensing processes, cost reduction and public control in favor of private self-control, with the consequent precariousness of working and safety conditions[4]. On the other hand, it allows the visualization of a chain of events that favors its occurrence, but also amplifies and multiplies damages[4,8].

In addition to the potential for damage and immediate effects, the secondary and tertiary impacts of mining dam failures can trigger chain reactions, which promote complex and heterogeneous risk factors. Its environmental impacts, which involve dispersed and accumulated contaminants in different environmental compartments (air, water, soil, food, etc.), result in a multiplicity of effects on health, such as skin and respiratory diseases, expansion and/or aggravation of diseases, potentiation of the presence of contaminants in organisms, mental health, among others) — subclinical effects, development of disease and injuries or even death — depending on the harmfulness of the pollutant, the intensity and time of exposure, and individual susceptibility[1,8-10].

As they associate characteristics of disasters such as sudden floods and landslides with those of disasters involving environmental contaminants, dam failures represent immense challenges for Public Health in surveillance and long-term health care[11]. Its dynamics result in a complexity of health problems and needs that are transformed in space and time, in contexts that involve strong political disputes and powerful economic interests, scientific controversies and uncertainties, different actors and perspectives at stake[12,13].

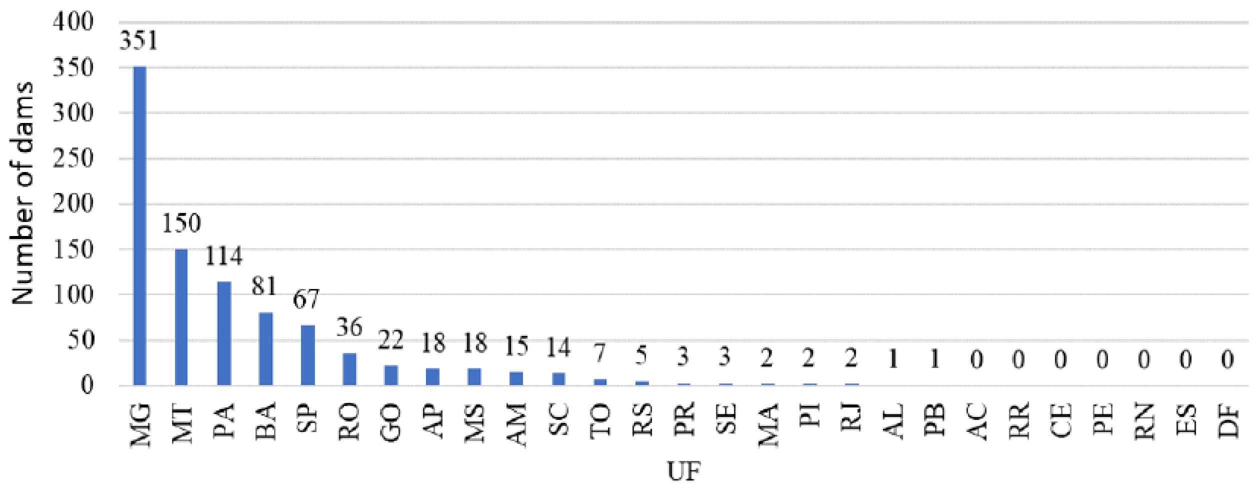
NATIONAL RISK SCENARIO

Until June 1st, 2022, Brazil had, registered with the National Mining Agency (*Agência Nacional de Mineração* – ANM), 912 mining projects that use dams for the disposal of waste in 20 states of the Federation[14] (Graphic 1) and which are present in 181 municipalities (Figure 1), with Minas Gerais accounting for over 1/3 of them (38.4%).

Of the 912 mining dams classified in the Mining Dam Safety Management System, 261 (28.6%) were classified as high potential damage (PD) and 114 (15.8%) as risk category (RC) high, with another 400 (43.9%) not classified in relation to PD and RC. Of the 375 classified ones, 37 were simultaneously in the high PD and RC categories (Table 1), of which 92% (n=34) were in Minas Gerais. It is worth mentioning that the Fundão dams, in 2015, and the Córrego do Feijão, in 2019, were classified as low RC and high PD.

Considering risk exposure as central to the debate on mining dams, buffers of 2, 3, 4, 5, and 10 km were simulated based on the geographic coordinate available in the ANM and evaluated the census sectors that intersected these buffers to estimate, though preliminarily, the amount of population and households that would be exposed to the impacts of mining in these territories. The 2 km scenario included 1,955 census sectors, 251,345 households, and 865,056 residents. When considering the 10 km scenario, it was possible to identify 21,979 sectors, 3,665,452 households, and 12,087,719 residents (Table 2)[15,16], with millions of households and residents exposed to mining risks.

These numbers, although imprecise, reveal the importance of broadening the debate on risks, exposures, and impacts of mining, as well as on the need for availability and transparency in data related to populations exposed to them. At the same time, the simulation of buffers should alert managers at the three levels of the Brazilian universal health system (*Sistema Único de Saúde* – SUS) about the urgent need to incorporate the



Graphic 1. Mining dams registered with the National Mining Agency by federative unit (*unidade federativa* – UF), Brazil, 2022[14].

problem into a broader discussion about risk scenarios and systemic risks in the health plans of municipalities with barriers and their surroundings, in the states and at the federal level. With this, it will be possible to structure agreements to gain scale for environmental monitoring and the health of the population from the process of implementation of the projects in the territories and throughout their existence and the dams — before, during and after any disaster.

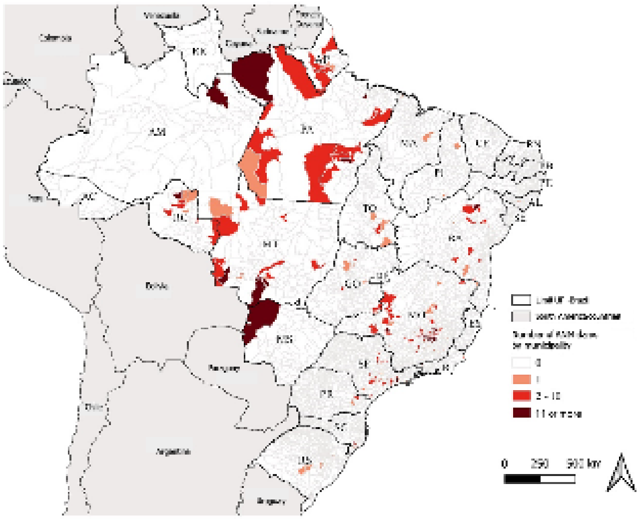


Figure 1. Number of dams registered with the National Mining Agency by municipality. Brazil, 2022[14].

MINING DAMS AS SYSTEMIC RISKS

Maskrey et al.[2] highlight the importance that the concept of systemic risk has been gaining in academic research and public policy on disasters. This concept is critical to understanding the health effects of mining dam disasters such as those of 2015 and 2019. The concept of systemic risk allows for a broader understanding of both the uniqueness of each of these disasters and their multiple exposure, risk, and disease processes, as well as the structural characteristics with which social, political, and economic processes and dynamics reproduce, in multiple territories, a common pattern of events and their effects.

Table 1. Number of dams by risk category and associated potential damage of dams registered with the National Mining Agency, Brazil, 2022[14].

		Associated potential damage				Total
		High	Medium	Low	Not classified	
Risk category	High	37	22	55	-	114
	Medium	32	40	14	-	86
	Low	192	100	20	-	312
	Not classified	-	-	-	400	400
	Total	261	162	89	400	912

Table 2. Simulation of the number of households and residents considering the 2010 Census sectors that intersect the 2, 3, 4, 5, and 10 km buffers – Brazil.

Buffer simulation	Number of census sectors that intersect the buffer	Number of blank sectors*	Rural sector	Urban sector	Number of Municipalities (census sectors that intersect the buffer)	Households†	% Households	Residents‡	% Residents
Impacto 2 km	1,955	418	758	1,197	250	251,345	0.44	865,056	0.46
Impacto 3 km	3,432	729	1,035	2,397	273	474,206	0.83	1,625,350	0.86
Impacto 4 km	5,146	1,081	1,313	3,833	293	737,935	1.29	2,519,382	1.33
Impacto 5 km	7,315	1,490	1,601	5,714	317	1,098,472	1.92	3,719,600	1.96
Impacto 10 km	21,979	3,671	3,126	18,853	466	3,665,452	6.39	12,087,719	6.37
Total Brasil	335,527	26,196	77,076	258,451	5,565	57,319,607	100	189,773,996	100

*Number of sectors with blank information on households and residents; †Permanent private households or persons responsible for permanent private households (Basic Table Census V001); ‡Residents in permanent private households or population residing in permanent private households (Basic Table Census V002). For metric calculations in SRC Sirgas 2000 geographic layers, the conversion of 1 degree=111,000 m was performed. Thus, 10,000 m is equivalent to approximately 0.09009 degree. As a maximum limit, a buffer of 0.09009 degree was structured in the layer of points of the dams that corresponds to approximately 10 km, defined by law (Ordinance no. 70.389, of May 17th, 2017)[15] as a self-rescue zone (SRZ: region of the valley downstream of the dam in which it is considered that warnings to the population are the responsibility of the entrepreneur, as there is not enough time for an intervention by the competent authorities in emergency situations, and the greatest of the following distances must be adopted for its delimitation: the distance that corresponds to an arrival time of the flood wave equals to thirty minutes or 10 km). As a minimum limit, a buffer of 2 km was used.

Source: Data extracted from the Census spreadsheets via the QGIS Plugin Census IBGE.[16]

These disasters present, in the routes of their mude, which contains heavy metals and different exposure routes, the interdependence of processes in the biological, environmental, social, and economic dimensions, involving ways and conditions of life and work. The ruptures of dams and their mud routes cause intense and sudden changes in the socio-environmental situation, which is the concept that allows us to bring together the four interdependent dimensions mentioned above. When they occur, they trigger a set of new processes — some of which are short and medium term, which can be more easily registered through direct health effects, such as injuries, illnesses and diverse traumatic experiences, and others in the long term, which are mediated and modulated by more complex processes[17]. These processes involve feedback dynamics and non-linear interactions between the risks that were already latent in the affected territories, with the new risks that arise from disasters[2]. In these new risk scenarios, overlaps and amplifications of the population's exposure to health risks constitute a new reality[8], so that health effects are not unique or unicausal, but involve multiple processes that can also result in cumulative cascading effects (direct effects that contribute to side effects) and/or compounds (combination of simultaneous or successive effects)[18].

Results of studies on the Samarco disaster carried out in 2015 point to an abrupt change in the expected pattern of health, cycles of vectors, and disease hosts months after the event[8,10]. Diagnosis carried out by Fundação Getúlio Vargas (FGV) to assess the impacts of the Fundão dam failure on affected communities[19], which compared the incidence of diseases and injuries per 100,000 inhabitants in the 45 municipalities considered affected and 85 controls, between 2015 and 2019 , projected a three-year reduction in life expectancy in the exposed population compared to the control population. Exposed populations also showed a positive association with the change in the expected pattern of mortality associated with arboviruses, especially yellow fever. There was an increase in outpatient care in the municipalities exposed to: chikungunya (increase in 38 municipalities); zika (in 39), yellow fever (in 30); American cutaneous leishmaniasis (in 13); syphilis (out of 27); human influenza by new subtype (out of 19); domestic, sexual and/or other violence (out of 34). Respiratory diseases and dengue stand out, which showed a tenfold increase in cases in the affected municipalities in relation to controls; and cases of "Creutzfeldt-Jakob", which emerged in the affected municipalities.

Exposure to chemical contaminants is also an important factor to monitor and evaluate. In a study of risk assessment to human health in affected locations, which adopted the Ministry of Health's reference methodology for environmental contaminants, those of interest were considered and routes of human exposure were established[20]. In the municipalities of Mariana and Barra Longa (both in Minas Gerais), the first two municipalities downstream of the Fundão dam, topsoil was established as a complete exposure route (past, present, and future) for contaminants of interest cadmium (Cd) , lead (Pb), copper (Cu), zinc (Zn), and nickel (Ni). In Barra Longa, the Cd element stands out for presenting, at the same time, the complete exposure route in the domestic environment, when considering exposure to household dust. In Linhares (in Espírito Santo), at the mouth of the Rio Doce and at a distance of 600 km from the disaster site, the existence of complete exposure routes for the environmental compartments surface soil, household dust, and water for human consumption was verified, considering the elements arsenic (As), antimony (Sb), Zn, Pb, and Cd were found — this latter contaminant having been established as being of interest to topsoil. Among the conclusions of this study, it is highlighted that both municipalities close to the disaster site (Barra Longa, Minas Gerais) and those hundreds of kilometers away (Linhares, Espírito Santo) were classified in category A: urgent danger to public health.

These different results of research carried out on the Samarco disaster in 2015 reveal the complexity of the impacts of such events, demanding that we advance in systemic and long-term approaches on impacts and effects that are multiple and non-linear, that transform over time and overlap

FINAL CONSIDERATIONS

Knowing the territories impacted by the disasters and the health problems and needs of the exposed and affected populations, incorporating the lessons learned from other technological disasters that occurred in Brazil and in the world, is fundamental for DRR policies, in general, and also for the improvement of the Brazilian universal health system. Within the scope of public management of the health system, state and municipal health plans must consider the analyses and risk scenarios of dams as a public health problem, as well as integrate prevention, alert, preparation, response, reconstruction, and health recovery actions in disasters.

It is the promotion of the population's health and sustainable territories that must guide how production processes should be organized, and not the opposite, with the externalization of their human, environmental, and social costs. Thus, it is essential that the health system, in all areas of the country where there are mining activities, organizes itself to rethink how to deal with the health of the population and mining projects, from its licensing, implementation, and operation process to decommissioning — moment in which the structure's activities end and which also has an impact on health, as we have been following at the Mining Disaster Observatory — Risk Reduction and Human Rights, at Fiocruz, Minas Gerais.

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RESUMO

Entre 2015 e 2019, o Brasil registrou os dois mais graves desastres envolvendo barragens de mineração do século XXI. O objetivo deste artigo é oferecer a compreensão desses desastres como riscos sistêmicos, que envolvem desde processos globais e nacionais relacionados aos determinantes sociais que se concretizam em um complexo sistema de barragens distribuídas pelo País com seus riscos intrínsecos. Quando ocorrem, resultam em um conjunto de impactos com potencial de danos e efeitos imediatos combinados com impactos secundários e terciários que podem desencadear reações em cadeia, promovendo fatores de riscos de ocorrência heterogênea e complexa. Abordar esses eventos com base no conceito de risco sistêmico permite uma compreensão mais ampla tanto da singularidade de cada um desses desastres e seus múltiplos processos de exposição, riscos e doenças, como também das características estruturais com que os processos e dinâmicas sociais, políticas e econômicas reproduzem, em múltiplos territórios, um padrão comum de desastres e seus efeitos. Concluímos que a promoção da saúde da população e de territórios sustentáveis deve orientar a organização dos processos produtivos e não o contrário, com a externalização dos custos humanos, ambientais e sociais da mineração e seus desastres.

Palavras-chave: Desastre. Rompimento de barragens. Mineração. Riscos sistêmicos. Redução de riscos de desastres.

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