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Hospitalizations in the public health system and mining disasters in Mariana and Brumadinho, Brazil

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Abstract

Background Mining occupies a prominent place in Brazil, which, if observed, means that one must work with the contingencies that arise from its activity. Mining disasters, such as those in Mariana and Brumadinho, exemplify the impact on the health system and are models for similar situations, so the study sought to investigate the impact of these disasters on hospital admissions in the Brazilian public health system.

Methods Through segmented regression, we sought to assess possible changes in the variables HAA (authorized hospital admissions), total admission value, and mortality rate in Mariana and Brumadinho. This measurement method allows the researcher to identify changes during the study period.

Results The study observed significant changes in the variable mortality rate in the city of Brumadinho. Although the other variables, both in Mariana and Brumadinho, do not present a level of significance compatible with possible effects, we can still say that they present a trend that can be inferred as an effect of the disaster.

Conclusions The mining disaster significantly changed the mortality profile in the city of Brumadinho, with implications for the health system. In Mariana, there have been no objective changes, but there is evidence of potential impacts.

Keywords Dam breaks, Hospital Admission, Unified Health System

Introduction

Mining in Brazil occupies an important position in the national economy, with significant participation in the composition of Gross Domestic Product (GDP). Mineral production generates jobs and is a highlight of Brazilian commodity exports [1]. According to Calijuri, there were about 1,400 mining companies in the country in 2013, which extracted metals such as manganese, gold, asbestos, copper, iron, and zinc. These companies produce water from mineralized rocks containing high concentrations of heavy metals for purification. These waters can lead to contamination in areas with varying levels of vulnerability, which can be intensified by human activity [1, 2].

In 2020, Brazil collected 7,296 contributions from the Financial Compensation for Exploitation of Mineral Resources (FCEMR), indicating the presence of approximately 7,000 mining companies in the national territory [3, 4]. Of these, in 2017, 135 were large, 992 were medium-sized, and 2,750 were small. In addition, there were 5,653 micro-sized mineral enterprises [3]. The

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growing increase in the number and size of mining tailings dams around the world results in potential environmental, social and economic costs. In addition, eventual failures in dam structures compromise the response capacity of public agencies and the most directly affected localities when disasters occur [5].

These data lead us to conclude that mining is not only an activity of unparalleled importance that will not influence human lives.

On November 5, 2015, in the municipality of Mariana in Minas Gerais, Brazil, the Fundão dam, operated by the Samarco mining company, burst, releasing about 50 million m3 of iron mining tailings and killing 19 people. It was one of the most significant environmental disasters to have occurred in Brazil [6]. Three years later, on January 25, 2019, another disaster occurred at the Córrego do Feijão Mine in Brumadinho, also in Minas Gerais, subjecting the community to incalculable damage [7]. Data released by the Association of Families of Victims and People Affected by the Córrego do Feijão Dam Break (AVABRUM) recorded 110 deaths, of which 71 have been identified, 192 have been rescued, 395 have been located, 108 have been displaced, and 238 have been missing [8, 9].

Both the Mariana and Brumadinho tragedies caused damage to the flora, fauna, soil, air, water, and inhabitants of the region and surrounding areas, causing the population to develop a series of symptoms and diseases that continue to this day. For Gerent and Silva (2019) reported that mud brought with it new and harmful health conditions, including respiratory, dermatological, gastrointestinal, and skin diseases [6]. There was also a threat of disease transmission by seriously ill animals, such as those with distemper and leishmaniasis, and the interruption of pest and vector control services in localities, increasing the possibility of a resurgence of diseases, such as dengue, schistosomiasis, Chagas, and problems with venomous animals [6, 10]. Health, epidemiological, sanitary, environmental, occupational health surveillance, and public safety services were disrupted [11].

Analysis of the impact of the disaster on the use of services provided by the Unified Health System (SUS) is a prerequisite for the entire health system to have references in similar situations and to build an adequate action plan. The analysis of expenditure serves as a starting point for crisis management and a mechanism for forecasting resources and actions for similar events.

In terms of population health, it is important to understand the two disasters in a context that considers not only the number of deaths and the most urgent emergencies but also the pathologies and illnesses that will become more pressing in terms of health over time. Disasters involving contaminants require action in situations of extreme urgency and insecurity to reduce and extinguish risks and contact, as well as deal with damage and illness, not only in the short term but also in the medium and long term [12].

The mining disasters brought consequences to the resident population, who had their existence suddenly transformed. Given this scenario, it is pertinent to raise questions about the health of the population and how the SUS was affected by the two disasters. Therefore, this research examined whether there were changes in the use of public hospital health services due to mining disasters. Thus, this study sought to evaluate the impact of mining disasters on the Unified Health System, based on the profile of the use of hospital services, through the amount of Hospital Admission Authorization (HAA), total value, and mortality rate in Mariana and Brumadinho in Minas Gerais, Brazil.

Methods

This is a cross-sectional, quantitative research on the use of inpatient services in Mariana and Brumadinho municipalities.

Thus, to characterize hospital services, the variables used were as follows:

- Approved HAA: Number of HAA approved during the period, including new admissions and extensions (long stay). Rejected HAA were not computed.
- Total value: Value referring to the HAA approved during the period. This value does not correspond to the value transferred to the facility because, depending on the situation of the units, they receive budget resources, or there may be withholdings and incentive payments not presented here. Therefore, this must be the approved attendance value.
- Mortality rate: Ratio between the number of deaths and the number of approved Hospital Admission Authorization (HAA), computed as admissions, in the period multiplied by 100.

We obtained data on the use of inpatient services from the Hospital Information System (SIH) available on the website of the SUS Computer Department (http://datasus.saude.gov.br). The data were organized in a Microsoft Office Excel spreadsheet and expressed as time series graphs to evaluate the impact of disasters on hospital morbidity outcomes.

The data were collected monthly, organized in a Microsoft Office Excel spreadsheet, and expressed in monthly series graphs that listed the years 2013, 2014, 2015, 2016, 2017 for Mariana and 2017, 2018, 2019, 2020 and 2021 for Brumadinho. The months of November 2015 and January 2019 were the base months of comparison, i.e. month 0, since these were the months when the Mariana and Brumadinho disasters occurred, respectively.

It identified earlier months from −24 to -1 and the later months were +1 to +24.

When analyzing the relationship between a response, y, and a covariate, x, it may be apparent that, for different intervals of x, different linear relationships occur. In such cases, a single linear model may not provide an adequate description, and a non-linear model may not be appropriate either. For this reason, segmented regression, which is a form of regression that allows multiple linear models to be fitted to the data for different ranges of x. Breakpoints are the values of x where the slope of the linear function changes. The value of the breakpoint may or may not be known prior to the analysis. In the present study, only one breakpoint was set at the month of occurrence of the disasters. The process of calculating the segmented regression line is detailed in Fig. 1.

The coefficient of the first straight line that is in the reference months from −24 to -1 was expressed by β1 and the gradient (step) was expressed by β2, year of the disasters, the reference months from +1 to +24 are the post-disaster months which is β3. So when we refer to the betas (β) we are referring to the periods before the disasters, periods of the occurrence of the disasters and periods after the disasters. The β0 is where the straight line initially intersects the y-axis, the other β being the variation of this.

The segmented regression analysis allowed us to verify the sensitivity of the data to understand how the disasters may have affected the population of Mariana and Brumadinho. Such analysis was fundamental to identify the behavior of the study variables in the period before and after the disaster, which made it possible to verify whether the mining disaster affected the number of HAAs, the total value and the mortality rate.

In addition to these calculations, relative and absolute measures were taken regarding SUS spending and that of Supplementary Health beneficiaries as a way of complementing the data and information obtained.

According to the recommendations of the Resolution of the National Health Council (CNS) No. 466, December 12, 2012, the ethical principles of research involving human beings were respected, and the approval of the research ethics committee was waived because the study was conducted using secondary data obtained through public access, without the possibility of individual identification of the information. The study had a declaration of responsibility signed by the researchers, his supervisor, and the Head of the Department of Medicine at the Federal University of São Paulo, Dr. Álvaro Pacheco Silva e Filho. This ethics committee is called the Ethics and Research Committee of the Federal University of São Paulo, composed of the research team Paola Zucchi and Rita de Cássia da Silva, and signed and filed at the Department of Translational Medicine with contact e-mail: medicinatranslacional@unifesp.br. All methods were carried out in accordance with relevant guidelines and regulations and following the guidelines informed and required by the committee.

Results

By analyzing hospital admissions in the municipalities through the segmented regression lines, we observed that in Mariana, there were no significant changes in the number of HAA during the period before the disaster

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3$$

From:

$Y = response\ variable$

$X_1 = reference\ month \quad (X_1 = -24, -23, -22, \ldots, -1, 0, 1, \ldots, 22, 23, 24)$

$X_2 = disaster$ — if $X_1 \leq 0 \rightarrow X_2 = 0$; if $X_1 > 0 \rightarrow X_2 = 1$

$X_3 = disaster\ month$ — if $X_1 \leq 0 \rightarrow X_3 = 0$; if $X_1 > 0 \rightarrow X_3 = 1, 2, 3, \ldots, 24$

and the coefficients (estimated by regression analysis):
β0: intercept (1st segment)
β1: slope of the straight line before the accident
β2: change in the response variable right after the accident ("breakpoint" observed between the two straight lines, at the zero point)
β3: change in the line's inclination in the 2nd segment (sign of the "parallelism" between the two lines)

Fig. 1 Calculating the segmented regression straight

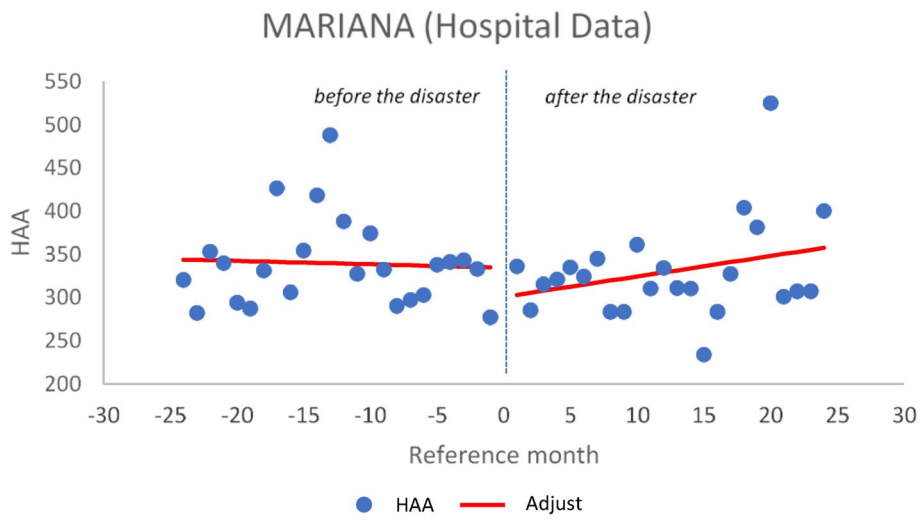

Fig. 2 Number of hospitalizations in Mariana. Source: Elaborated by the authors

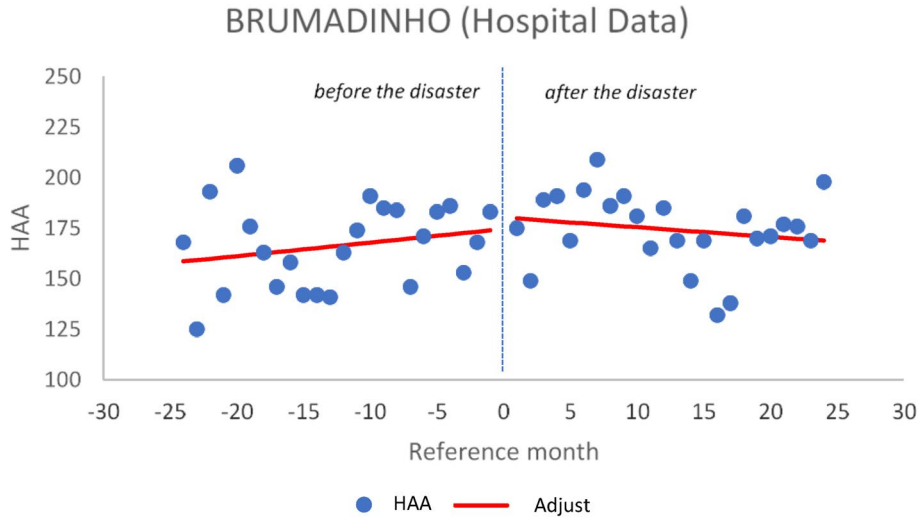

Fig. 3 Number of hospitalizations in Brumadinho. Source: Elaborated by the authors

(p=0.803). Despite the immediate reduction in the number of HAA immediately after the disaster, this variation was not significant (p=0.629). Similarly, there was a tendency for this number to increase in the 24 months following the disaster, but this increase was not significant (p=0.224) (Fig. 2).

When we analyze the hospital admissions in Brumadinho, the segmented regression line indicates no significant changes in the period before (p=0.257), in the disaster's month (p=0.629) and in the period after (p=0.171). Visually, the data indicate a very slight upward trend in the period before the disaster and a very slight downward trend in the period after the disaster (Fig. 3).

The total value of Mariana is p=0.807 in the period before the disaster, p=0.942 in the disaster month, and p=0.647 in the later period, indicating the non-statistical significance of these numbers. In fact, we observed that the fitting straight lines of the regression are almost horizontal, and with no "breakpoint" between the periods before and after the disaster, corroborating the idea of the maintenance of these numbers throughout the observed period (Fig. 4). In the referenced figure, the values are described in Brazilian real currency (R$), which is equivalent to US dollars (USD) of 1 USD to 5.45 at the exchange rate of 25/06/2024.

In Brumadinho, we observed that the two straight lines presented themselves in ascending form, indicating an increase in the total value, although not significant in the period before the disaster (p=0.073), in the month of occurrence (p=0.247), and in the later period (p=0.462). In fact, we observed that in the 1st segment, statistical significance was very close to 5%, demonstrating the tendency for these numbers to increase. The lack of statistical significance in the 2nd segment only reveals the

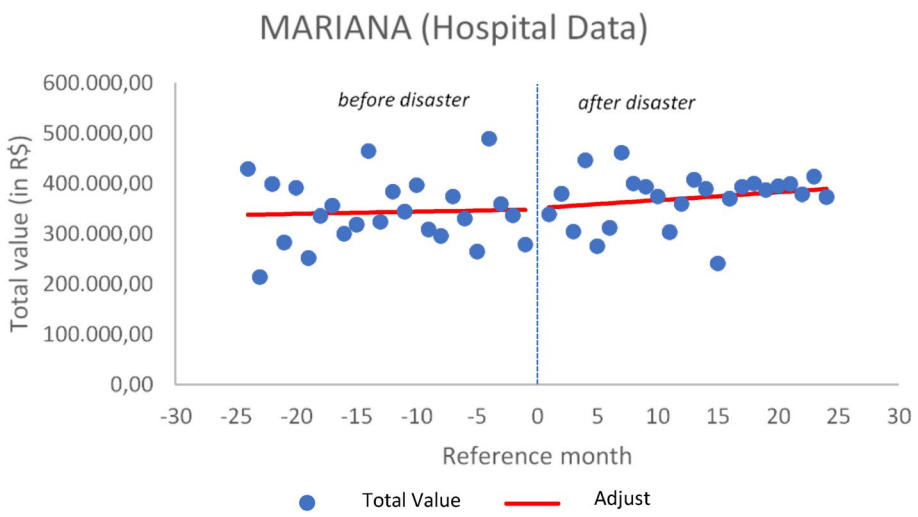

Fig. 4 Total Value in Mariana. Source: Elaborated by the authors

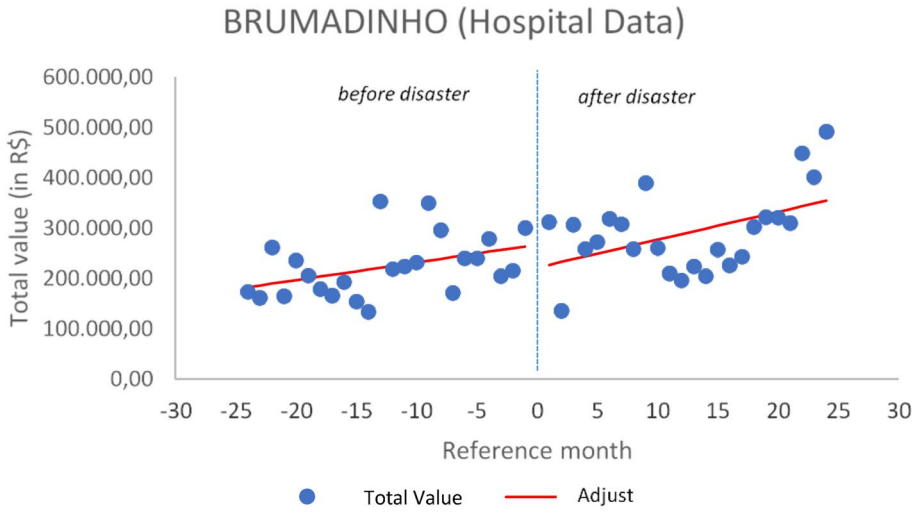

Fig. 5 Total Value in Brumadinho. Source: Elaborated by the authors

similarity (or "parallelism") between the two segments and their tendency to increase during this period (Fig. 5). As for the Total Value, the same applies to the previous figure regarding the exchange rate between R$ and USD.

An analysis of the mortality rate indicates that in Mariana, despite the values not being significant in the period before ($p=0.515$), in the disaster month ($p=0.722$), and in the period after ($p=0.113$), a slight tendency to decrease in the values in the period before the disaster and a slight tendency to increase in the period after the disaster is noted (Fig. 6).

In Brumadinho in the period before and during the disaster month, there is no change in the mortality rate ($p=0.989$ and $p=0.240$, respectively); however, in the period after the disaster ($p=0.024$), there is a significant increase in this rate (Fig. 7).

In the following tables, the ICDs that appear most frequently are Chapter I, described as infectious and parasitic diseases; Chapter II, described as neoplasms; Chapter IV, endocrine, nutritional, and metabolic diseases; Chapter IX, diseases of the circulatory system; Chapter X, which deals with diseases of the circulatory system; Chapter XI, diseases of the digestive system; Chapter XII, diseases of the skin and subcutaneous tissue; Chapter XIV, diseases of the genitourinary system; Chapter XV pregnancy, childbirth, and the puerperium; Chapter XVI diseases originating in the perinatal period, Chapter XlX injuries, poisonings and consequences of external causes, and Chapter XXI factors influencing health status and contact with health services.

Table 1, which shows the main HAA (hospitalizations) in the city of Mariana, indicates that the leading cause of hospitalization (HAA) is pregnancy and that the disaster resulted in a 12.5% decrease in the number of occupied beds. The second most common cause of hospitalization was circulatory system diseases, which

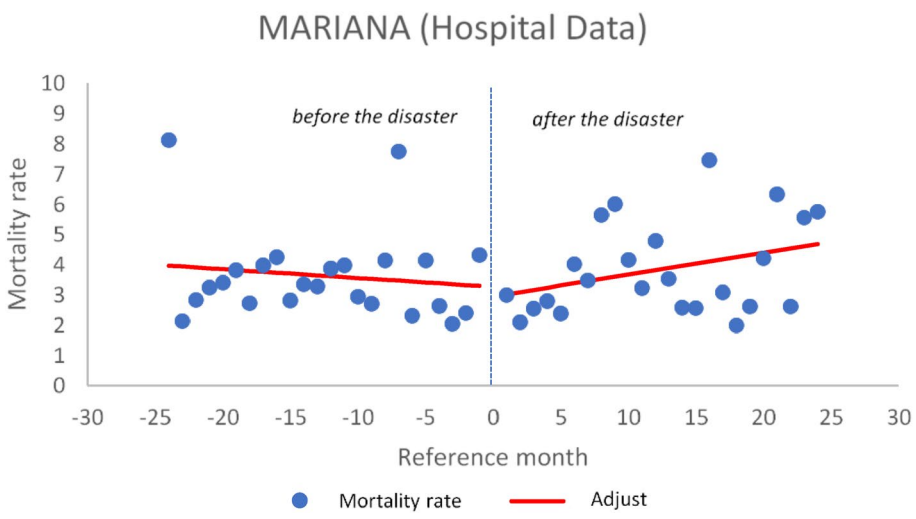

Fig. 6 Mortality rate in Mariana. Source: Elaborated by the authors

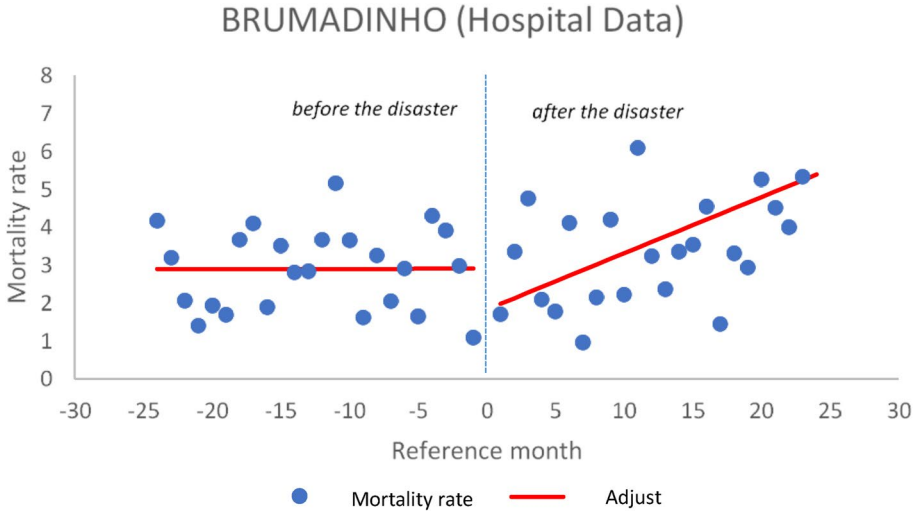

Fig. 7 Mortality rate in Brumadinho. Source: Elaborated by the authors

Table 1 Main causes of hospitalization (AIH) in the city of Mariana, Brazil

ICD	Before the disaster	After the disaster
Chapter I	399	246
Chapter II	360	438
Chapter IV	345	210
Chapter IX	1.040	1.124
Chapter X	726	848
Chapter XI	613	666
Chapter XIV	728	657
Chapter XV	1.776	1.554
Chapter XIX	877	976
Chapter XXI	293	173

Source: DATASUS

increased by 8.1% after the disaster. The third most common cause of death was Chapter XIX, injuries, poisoning, and external causes, which increased by 11.29%. In fourth place were circulatory system diseases (incidence: 16.9%. In fifth place were diseases of the genitourinary system, with a 9.8% decrease in the number of events. In sixth place we have diseases of the digestive system with an increase of 8.6%. In seventh place, we have neoplasms with an increase of 21.7%. Eighth place goes to infectious and parasitic diseases, with a 38.3% decrease. In ninth place, we have endocrine, nutritional, and metabolic diseases with a drop of 39%. Lastly, in the city of Mariana, we have factors that influence health status and contact with health services, with a decrease in hospitalizations of approximately 40.9% after the disaster.

Table 2, which shows the main causes of HAA in Brumadinho, shows that the city's highest number of

Table 2 Main causes of hospitalization (HAA) in the city of Brumadinho, Brazil

ICD	Before the disaster	After the disaster
Chapter I	184	331
Chapter II	303	297
Chapter IX	435	443
Chapter X	471	315
Chapter XI	387	323
Chapter XII	174	206
Chapter XIV	437	429
Chapter XV	644	683
Chapter XVI	77	111
Chapter XIX	342	481
Chapter XXI	88	116

Source: DATASUS

Table 3 Main causes of death in the city of Mariana, Brazil

ICD	Before the disaster	After the disaster
Chapter I	17	38
Chapter II	29	30
Chapter IV	24	16
Chapter IX	72	86
Chapter X	74	61
Chapter XI	29	18
Chapter XIV	19	15
Chapter XIX	13	16

Source: DATASUS

hospitalizations (HAA) is pregnancy, childbirth, and the puerperium, which increased by 6.06% in relation to before and after the disaster. In the second place, we have circulatory system diseases, with an increase of 1.84%. In third place, we have diseases of the genitourinary system, with a fall of 1.83%. In fourth place, injuries, poisonings, and certain other consequences of external causes showed an increase of 40.64%. In fifth place, respiratory diseases decreased by 33.12%. In sixth place was digestive system diseases, with a decrease in the number of hospitalizations by 16.54%. In seventh place, we have neoplasms with a drop in the number of hospitalizations of 1.99%. The eighth-place category goes to infectious and parasitic diseases, with an increase of 79.89%. In the ninth place, we have diseases of the skin and subcutaneous tissue, with an 18.40% increase in admissions. In tenth place, we identified factors influencing health status and contact with health services, with a 31.81% increase in the number of visits. Eleventh place was associated with perinatal conditions, with a 44.16% increase in the number of hospital admissions (HAA).

According to Table 3, which represents the main causes of death in the city of Mariana, the highest number of deaths was due to diseases of the circulatory system, where there was a higher mortality rate, with 19.44% between before and after the disaster. The second most common cause of death was respiratory diseases, with a mortality rate of 17.57% between before and after the disaster. The third leading cause of death is neoplasms, with a 3.45% mortality difference between before and after the disaster. In fourth place are infectious and parasitic diseases, with a 123.53% increase in the number of deaths in Mariana. In fifth place are diseases of the digestive system, with a 37.93% decrease in deaths. The sixth most common disease was endocrine, nutritional, and metabolic diseases, with deaths down by 33.33%. In seventh place were diseases of the genitourinary system, with a 21.05% decrease in deaths. And in eighth place, we have injuries, poisonings, and other consequences from external causes, with a 23.08% increase in deaths after the disaster.

Table 4 Main causes of death in the city of Brumadinho, Brazil

ICD	Before the disaster	After the disaster
Chapter I	22	50
Chapter II	17	13
Chapter IX	14	25
Chapter X	23	23
Chapter XI	12	11
Chapter XIV	13	12

Source: DATASUS

Table 5 SUS hospital costs per hospitalized patient in Real, Minas Gerais, Mariana and Brumadinho

	Before	After	Percentage variation
Mariana	3.132.720,62	3.201.574,09	2,20% ↑
Brumadinho	888.315,40	834.023,55	-6,11% ↓
Minas Gerais 2013 – 217	3.318.399.066,62	3.369.371.469,35	1,54% ↑
Minas Gerais 2017–2021	3.508.834.289,87	3.821.155.343,91	8,90% ↑

Source: DATASUS

According to Table 4, which presents the deaths and their causes in the city of Brumadinho, infectious and parasitic diseases are in first place as the main cause of death, with a positive difference between before and after of 127.27%. In second place are respiratory diseases, which have a percentage difference in O%, implying no difference between before and after the disaster. In third place, diseases of the circulatory system caused a 78.57% increase in the number of deaths between before and after the disaster, resulting in increased mortality. In fourth place were neoplasms, with a 23.53% decrease in deaths. In fifth place were diseases of the genitourinary system, with a 7.69% decrease in deaths. Finally, diseases of the digestive system, with an 8.33% decrease in the number of deaths following the disaster in the city of Brumadinho.

The data presented in Table 5 show the total number of inpatient beds in Mariana, Brumadinho, and Minas

Gerais. It can be seen that Mariana saw an increase in post-disaster spending of 2.20%, while Brumadinho's spending decreased by 6.11%. Regarding Minas Gerais, during the Mariana disaster, post-disaster spending increased by 1.54%, whereas during the Brumadinho disaster, Minas Gerais saw an increase in spending of 8.90%. It can be seen that in both cases Minas Gerais ended up increasing spending, only in one case it was more substantial than the other. The values are described as real (R$), as mentioned above, and for conversion into dollars, see the exchange rate mentioned above.

Table 6 shows that Mariana saw an increase in the number of beneficiaries over the course of the disaster, with the percentage change between before and after being a positive 3.15%. Brumadinho, on the other hand, witnessed a drop in the number of beneficiaries after the disaster of 8.33%. In Minas Gerais, the drop was felt throughout the post-disaster period in Mariana and Brumadinho.

Discussion

Disasters produce health effects not only on people who experience the consequences of the entire process but also on health professionals and the entire infrastructure of service to victims. These consequences can range from an increase in the number of patients to service failure due to an overload of patients, which can generate a public health emergency complex. Some authors, such as Freitas et al., stated that the intensity of disaster impact is directly related to the characteristics of the event and the vulnerability it entails [13, 14].

The data analyzed in this study bring with them observations that although they reveal tendencies regarding HAA and Total Value, they present statistical significance only for the mortality rate of Brumadinho. Correlation between the data of the two cities, and understanding that alterations even if minimal have an impact, the HAA in Mariana in month zero presents a decrease in the number of hospitalizations, a decrease in the previous period, and an increase after the month of the accident. In Brumadinho, there is an upward trend in all periods. Similar studies, such as that by Freitas (2019), confirm that after natural disasters, the number of hospitalizations increases considerably, as in the case of the earthquake in Japan. Although there was a decrease in the number of hospitalizations in Mariana in month zero, an increase was noted in subsequent months, and in Brumadinho, it presented an increase in month zero, which may have been related to immediate care of the cases that arose, demonstrating the specificities of the disaster and the local system [15]. The only difference is in the number of HAAs in Mariana, which is almost a straight line, perhaps in part because the magnitude of the disaster in terms of the number of dead and injured at the time of the disaster was not as intense as in Brumadinho. Nevertheless, Mariana still showed a tendency to increase the number of HAAs. According to Freitas et al., the challenges posed by a disaster are great, as the number of hospitalizations increases in the months following the event, as we have shown in this study. For Freitas et al. kept some data from the first officials, and some diseases appear more than others immediately and over the years. For example, in the short term, we have parasitosis; diarrhea and gastroenteritis; dermatitis and upper respiratory tract infections due to contact with mud and dust, especially in children; anxiety; hypertension; and an increase in diabetes mellitus; as well as the reappearance of diseases that were controlled in the past, such as dengue [16].

Table 6 Beneficiaries of supplementary health care by municipality Mariana and Brumadinho and by state Minas Gerais

	Before the disaster	After the disaster	Percentage Variation
Mariana	254	262	3,15% ↑
Brumadinho	156	143	-8,33% ↓
Minas Gerais 2013–2017	4.672.718	4.357.360	-6,75% ↓
Minas Gerais 2017–2021	3.862.910	3.063.249	-20,70% ↓

Source: National Supplementary Health Agency

The data obtained in this study suggest that hospitalizations were indirectly influenced by the disaster in the sense that people were affected by illnesses that led them to seek immediate or delayed care at health centers. In the case of Mariana, the main variation in the number of hospitalizations, i.e. AIHs were a decrease in the factors that influence health status and contact with health services, which are cases of seeking examination, investigation, and screening for illnesses, as was the case in Brumadinho, which showed a significant percentage variation in this ICD chapter. Another notable cause of hospitalization is infectious and parasitic diseases, which are high in both Mariana and Brumadinho. These data show that it is possible to deduce from their habitats perturbations in the life cycle of vectors and hosts of diseases such as dengue, Zika, Chikungunya, schistosomiasis, and toxins, which may ultimately affect the populations of these places [10, 14]. In Mariana, the number of cases decreased, whereas in Brumadinho, the number increased, indicating different influences on the transmission of the disease, even though they had similar events.

Other hospitalizations indicate an increase in cases of certain morbidities, such as neoplasms, diseases of the circulatory system, diseases of the respiratory system, diseases of the digestive system and injuries, poisonings, and some other consequences of external causes in Mariana. In Brumadinho, there was an increase in diseases of the circulatory system, skin and subcutaneous

diseases, pregnancy and puerperium, perinatal conditions and injuries, poisonings, and some other consequences of external causes. This increase shows that in some diseases, there seems to be a supposed regularity in their appearance, which makes them a place for intimate knowledge of disasters [17].

Although disasters such as Mariana and Brumadinho are distinct from natural flooding disasters because the latter have an extensive character, while dam breaks have an intensive character, both have common aspects of risk management, since local vulnerabilities and impact dimensions are similar, but not equal [16, 18]. Understanding the impact and dimensioning of actions in affected areas can provide responses and actions that minimize risks and lead to more efficient actions. And enable managers to provide more appropriate responses that lead to recovery. This is related to the organization of actions in the short, medium and long term [16, 19].

When we analyze the Total Value of hospitalizations, despite not being statistically significant in the segmented regression line, in Brumadinho, there is a tendency to increase, which is in line with those found in the literature, which report disasters as an important factor in increasing health expenditures [20], although such expenditures do not directly refer to mining disasters but flood disasters, according to Phillippi et al. (2019), are important benchmarks of expenditure on disasters and their correlates.

In Brumadinho, the Total Value previously pointed to a growth in spending that persisted after the disaster despite the step, the graphical alteration in month zero that was not significant, and that expressed a change in the growth trend, revealing that there has possibly been a change in the spending pattern. According to literature data, dam bursting has the potential for systemic impacts on the population and consequently on the Unified Health System ('UHS'). Such impacts are notoriously harmful and can lead to personal tragedies and collective suffering reflected in mortality, morbidity, and the emergence of diseases and health problems that impact the living conditions of populations [21].

The absolute and relative figures for SUS hospital costs point to a possible increase in hospitalization costs for patients in Mariana in the aftermath of the disaster, which rose by 2.20%, while the state of Minas Gerais also saw an increase of 1.54% in the same period. Brumadinho, on the other hand, did not keep up with the growth of Minas Gerais during the disaster period, with a decline in the percentage of hospitalizations, which was much lower than the growth of Minas Gerais during the period. These data suggest that the disaster had an opposite effect on both cities if analyzed from the perspective of hospitalizations, revealing that the disaster, in general, was a unique event for both cities and Minas Gerais, which followed a growth trend in both disasters.

In the case of beneficiaries of Supplementary Health, there was an increase in the number of members only in Mariana in the aftermath of the disaster, while in Brumadinho, there was a drop in members, which was accompanied by the state of Minas Gerais. This decrease in Minas Gerais occurred during both the Brumadinho and Mariana disasters, revealing a downward trend in private plan membership. As has been observed, records can be under-recorded, overestimated, or underestimated, which prevents a more precise and rigorous analysis, which is why studies on the subject are needed [22]. Despite this, the context of Supplementary Health has been undergoing rapid change over the last 40 years, with more drastic changes in the last 20 years, which are in a challenging and complex scenario where analysis and information are still incipient and superficial. This fact reinforces the need for more in-depth research on the subject and points to the possible lack of continuity in our data [23].

Regarding mortality rate, the data indicate that Brumadinho experienced a decrease in mortality level immediately after the disaster (month zero), although this was not significant for the segmented regression analysis. In the period after the disaster, the data show that the number of deaths increased sharply. During the period after the Mariana disaster, although there was a brief decrease in the zero period and a brief increase in the post-disaster period, this was not significant in the segmented regression analysis, which demonstrated a change in the mortality pattern. Although with different nuances and intensities, the two cities exhibited mortality rates that may be significant for public health management.

The changes in mortality patterns are in line with the findings of Ferreira et al. (2021), when he emphasizes that in flood situations, the number of diseases significantly increases. The data indicate the consequences of a disaster, thereby increasing medical attention and mortality [24]. Other authors attribute the Brumadinho accident to have caused diseases that can reflect in the health of residents, such as respiratory diseases, which lead to increased hospital care demands [18].

Another study suggested a drop in population in the disaster's vicinity, which did not happen with Mariana because of the magnitude of the disaster, and a well-organized health system with Brumadinho, which allowed the implementation of an integrated set of prevention actions, such as education and communication campaigns about contact with the mud, consumption of water and fish, as well as vaccination of military personnel and directly affected communities for diphtheria, tetanus, hepatitis A and B, measles, mumps, rubella, and yellow fever [25].

For Guha-Sapir and Chencchi, high mortality rates are an indicative sign of the severity of a disaster, and can point to harmful inadequacies in the relief effort and latent inequalities in the affected population [26]. The authors also state that accurate documentation of deaths from disasters and conflicts helps to establish actions that can be of great value for future actions in similar situations [27]. By establishing the identities of the deceased, how and where, basic epidemiological information, it is possible to help direct resources to the most vulnerable population, which increases the effectiveness of palliative and humanitarian measures.

The effects of disasters directly affect hospitalizations and death tolls, with up to 46 times more deaths than official records usually report [11]. In this regard, the death rate in Brumadinho stands out, with a level of significance that denotes expressive data and, from a statistical point of view, is conclusive. The major question that deserves future discussion because it was not the subject of this study is the extent to which disaster influences mortality. The data we identified regarding changes in the mortality rate possibly stem from the immediate aftermath of the accident. Future studies should identify whether these changes follow the same pattern over time for different reasons. Among them, we highlight the risks of exposure to diseases, which directly affect the population, as well as changes in the global scenario of complex and dynamic nature that affect the population [5, 28].

The cause of the number of deaths described in the survey shows that, among the main diseases, infectious and parasitic diseases stand out in terms of percentage variation, with a jump in the number of deaths. This finding may indicate that these diseases, which include leishmaniasis, malaria, mycoses, yellow fever, cholera, diarrhea, gastroenteritis, and tuberculosis, predominate over other pathologies. There are reports that African miners are more likely to have a high incidence of tuberculosis, approximately 2,500 to 3,000 cases per 100,000 people [29].

Other authors have pointed out that South African miners have three times as many diseases, such as silicosis and tuberculosis, as ex-miners and miners. The general mortality rate among ex-miners was 20% higher than that of the general population [30]. The author also concluded that among South African workers, there is a gross annual mortality rate of 23 per 1,000 over a period of 12 years in a study carried out in 2018 by the same author [30]. Similar research with miners in Lesotho between 1999 and 2001 found similar mortality rates of around 29 per 1,000 for former gold miners [31].

In Crowsnest Pass, British Columbia, and Alberta, at the beginning of the 20th century, from 1902 to 1926, more than 450 men died in "disasters", and this contingent does not include the many who died alone in fatal accidents or due to the lingering effects of injuries in mines. Two disasters of great magnitude actually recorded stand out, a fact that blames the coal mines for their action in these disasters, of these one can be said not to have been a direct mining event where, in Frank, in 1903, seventy-two individuals were killed due to a landslide from the top of Turtle Mountain into the valley, where the town was destroyed and two miners killed; and in the town of Hillcrest, in June 1914, a catastrophic explosion occurred in the mine and killed 187 men that destroyed many families [32].

According to their complex and dynamic nature, mining disasters have repercussions on social, economic, environmental, cultural, and health processes. Spatial thresholds are diffuse and depend on environmental variability and change, exposure, risk, damage, and disease, which directly influence collective health sensitivity [33].

The specifics of the health effects of mining tailings dam bursts do not come from the emergency management process itself but from the harmful effects of each occurrence. Because these events are reserved for proper dimensions, they cause environmental, social, economic, and, indirectly, health impacts [19, 34].

Disasters also bring with them other possible aggravating factors, such as harmful chemical elements present in the mud, which can cause not only a risk of death and trauma but also intoxication due to exposure. In addition, there is an alteration in the landscape that will reflect the health of the population, which will have a powerful influence on local dynamics [11, 27].

Inferred that the impacts of disasters will not only occur in the short term but also in the medium and long term and will be felt over the years by those who will be at the site of the occurrence and its surroundings [27, 35].

In the short term, soon after exposure, there is concern about physical trauma, water- and food-borne diseases, acute intoxication by chemical contaminants, and medication replacement for those who use them continuously (hypertensives, diabetics, and others). In the medium and long term, concerns arise regarding the local epidemiological situation and regional structure [35, 36].

These disasters and others result from a lack of planning and preparation for conditions that may overlap municipalities and expose them to imminent risks of accidents. Even under normal circumstances, it is presumable that situations such as Mariana and Brumadinho will have a contingency plan in place for the risks that such an undertaking may bring about [18, 24]. The lack of investments in prospective prevention processes, ranging from territorial planning regarding land use and occupation to the cession or remodeling of dams with archaic technology by new dams with more protected technology, is an aggravating factor. Thus, even in situations regarded as predictable and safe, it bodes well to

adopt action and response plans. These plans involve strengthening preparedness and response capabilities to imminent dangers related to flooding and breaching mining tailing dams, a ready and effective health system, the recovery of life, ecosystems, and the surrounding area.

Although the hospitalization data may lead us to make some conjectures that could possibly be applied to other areas of the health sector, we need to reflect on the emergent nature of issues, such as the unique nature of the city in which the disaster that is the subject of our research took place. An analysis that can effectively be complete must involve some nuances that are worth mentioning: The public health systems, such as the SUS, as providers of the population's health needs, are not in charge of all the care for the population; we also have to address Supplementary Health, the so-called private health, which also plays a role in both cities. Despite the fact that our data shows that only in Mariana there was an increase in the number of beneficiaries in the post-disaster period in supplementary health, an increase of 3.15%, which was not felt in Minas Gerais, the peculiar nature of health care must still be taken into account, so attention must be drawn to this data, and it must be said that health is idiosyncratically diverse, and that the data here are indicative of a reality that may be different in each city, and that cannot be fully generalized for public health uniformly. Mariana has peculiar characteristics, as does Brumadinho, that make them analyzable, but not generalizable as a single health scenario.

Conclusion

Regarding the HAA data, the cities of Mariana and Brumadinho did not present significant results that could actually prove changes in hospitalizations from the point of view of the segmented regression line. However, there are signs of a trend that indicate that something is happening: in the case of Mariana, there is a decline in the month of the disaster that begins to rise in the post-disaster period, which could be an indication of an increase in the number of hospitalizations after the disaster. Brumadinho, on the other hand, has an increase that declines over the post-disaster period.

The Total Value of hospitalizations did not indicate any statistically significant changes in the two cities, despite the fact that Mariana shows an increase in spending in relative and absolute numbers, the graph tells us that the trend is continuous and therefore insignificant. Brumadinho, on the other hand, has seen a drop in hospitalizations and an increase in the trend in the aftermath of the disaster, which it is worth stressing is insignificant from a statistical perspective but which reverberates a possible indication that something is happening in the city.

The mortality rate in Mariana did not indicate statistically significant data that could relate to the disaster, but in Brumadinho, we found an increase, this time with statistical significance indicating reaction to the disaster. In the case of mortality, there was an upward trend in the aftermath of the Mariana disaster, and in Brumadinho, there was a strong upward trend, statistically significant, which indicates that mortality was expressive.

It is worth emphasizing that although many of the data are statistically insignificant, they tend to reveal that something is going on and that this may have had a marked or slight effect.

Another point is that although the two cities analyzed were joint, they still have particularities that make them unique from the perspective of health, which we have tried to address, but which still requires a more detailed approach to deal with this information in all its complexity.

Finally, it should be noted that although some changes were observed after the two disasters, they should be carefully monitored for further analysis.

Abbreviations

NSHA	National Supplementary Health Agency
AVABRUM	Association of Families of Victims and People Affected by the Córrego do Feijão Dam
ICD	International chapter of diseases
FCEMR	Financial Compensation for Exploitation of Mineral Resources
GDP	Gross Domestic Product
HAA	Hospital Admission Authorization
UHS	Unified Health System

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Authors' contributions

EPV, RCCS and PZ conceived and designed the study, EPV prepared figures, collected the data and wrote the manuscript, RCCS and PZ reviewed and approve it for publication.

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Availability of data and materials

Availability of datasets used and/or analyzed during the current study is available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

According to the recommendations of the Resolution of the National Health Council (CNS) No. 466, December 12, 2012, the ethical principles of research involving human beings were respected, and the approval of the research ethics committee was waived, since the study was conducted from secondary data, of public access, without the possibility of individual identification of the information. This ethics committee is called the Ethics and Research Committee of the Federal University of São Paulo, and chaired by Doctor Álvaro Pacheco Silva e Filho and composed of the research team Paola Zucchi and Rita de Cássia da Silva and signed and filed in the Department of Translational Medicine, with contact e-mail: medicinatranslacional@unifesp.br, which states waiver of analysis and submission to the committee and only signature of the declaration of responsibility by the members/researchers. All methods were carried out in accordance with the relevant guidelines

and regulations and following the guidelines informed and required by the committee.

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References

1. Agência Nacional de Mineração. Anuário Mineral Brasileiro. [Online]. 2017. cited 2021 Março 20. Available from: http://www.anm.gov.br/dnpm/publicacoes/serie-estatisticas-eeconomia-mineral/anuario-mineral/anuario-mineral-brasileiro/amb_2018.pdf.
2. Porto MFdS. A tragédia da mineração e do desenvolvimento no Brasil: desafios para a saúde coletiva. Caderno de Saúde Pública. 2016; II(32).
3. Calijuri MC, Cunha DGF. Engenharia Ambiental: Conceitos, tecnologia e gestão. 2nd ed. São Paulo: Elsevier; 2013.
4. Instituto Brasileiro de Mineração. Informações sobre a economia mineral brasileira 2020. 1st ed. Brasília: Instituto Brasileiro de Mineração; 2019.
5. Organização Pan-Americana das Saúde MdS. Desastres Naturais E saúde no Brasil. Brasília: Organização Pan-Americana da Saúde, Ministério da Saúde; 2014.
6. Vormittag EdMAdA, Oliveira A, Gleriano JS. Avaliação de saúde da população de barra longa afetada pelo desastre de Mariana, Brasil. Ambiente & Sociedade; 2018.
7. Gerent J, Silva JCL. Rerpercussões psiquiátricas da catastrofe anunciada de Brumadinho: a complexidade dos Danos Ambientais difusos e individuais. Unisanta Law Social Sci. 2019; VIII(2).
8. Oliveira, Kd. Rohlf, Garcia. O desastre de Brumadinho E a atuação Da Vigilância em Saúde. Epidemiologia Serv Saude 2019; I(28).
9. Peixoto, Asmus CIRF. O desastre de Brumadinho e os possíveis impactos na saúde. Ciência e Cultura. 2020 Junho; LXXII(2).
10. Rocha EFL, Fernandes IN, Borges JSSS, Rocha RM, Santana S. Impacto De Desastres naturais no sistema de saúde do Brazil. Brazilian J Health Rev. 2021 September; IV(5).
11. IBAMA. Impactos Ambientais decorrentes do desastre envolvendo o rompimento da barragem de Fundão, em Mariana, Minas Gerais. Laudo técnico preliminar. Mariana: IBAMA, Diretoria de Proteção Ambiental; 2015.
12. Rocha EM, Moraes LGMd A, LVd, Dalvi R, Andriato LC, Bergamaschi LK et al. Impacto do rompimento Da barragem em Mariana-MG na saúde da população ribeirinha da cidade de Colatina-ES. Tempus, actas de saúde coletiva. 2016; III(10).
13. Freitas Md, Silva DRX, Sena ARMd, Silva EL, Sales LBF, Carvalho ML et al. Desastres naturais e saúde: uma análise da situação do Brasil. Ciência & Saúde Coletiva. 2014; XIX(9).
14. Md F, Ad S, Cd M. O desastre na barragem de mineração da Samarco: fratura exposta dos limites do Brasil na redução de risco de desastres. Ciencia E Cultura. 2016; LXVIII(3).
15. Ayoyagi T, Yamada M, Kunishima H, Tokuda K, Yano H, Ishibashi N et al. Characteristic of infectious diseases in hospitalizes patients during the early phase after the 2011 great east Japan earthquake. Chest. 2013; II(143).
16. Freitas Md, Barcellos C, Asmus CIRF, Silva. Da Samarco Em Mariana à Vale em Brumadinho: desatres e, barragens de mineração e Saúde coletiva. 35th ed. Cadernos de Saúde Pública; 2019.
17. Ald LF, Firmo JOA, Mambrini JVM, Peixoto SV. Souza Júnior PRBd, Nascimento MMGd. Uso de psicofármacos por população em área atingida pelo rompimento de barragem de rejeitos: Projeto saúde Brumadinho. Revista Brasileira de Epidemiologia. 2022; XXV(Especial).
18. Campos C, Nascimento-Souza MA, Monteiro C, Firmo JOA, Souza Júnior PRB, Peixoto V. Doenças respiratórias crônicas e sintomas respiratórios após o rompimento de barragem de mineração: Projeto saúde Brumadinho. Revista Brasileira De Epidemiologia. 2022; II(1).
19. Lucchini RG, Hashim D, Acquila S, Basanets A, Bertazzi PA, Bushmanov A et al. A comparative assessment of major international disasters: the need for exposure assessment, systematic emergency preparedness, and lifetime health care. BMC Public Health. 2017; XVII(46).
20. Philippi SW, Beiter K, Thomas CL, Sugarman OK, Wennestrom A, Wells K et al. Medicaid utilization before and after a natural disaster in the 2016 baton rouge-area flood. AJPH Open-Themed Res. 2019; I(54).
21. Ministério da Saúde. DATASUS. [Online]. 2021 [cited 2021 Março 25. http://www2.datasus.gov.br/DATASUS/index.php?area=060805&item=3.
22. Md F. Silva IVdMe, Xavier, Silva Le, Barcellos. Desastres naturais e seus custos nos estabelecimentos de saúde no Brasil no período de 2000 a 2015. Cadernos de Saúde Pública. 2020 Janeiro; VII(36).
23. Carvalho. A importância das soft skills na área da saúde suplementar. Revista de Administração em Saúde. 2023 Setembro; XXIII(92).
24. Ferreira AP, Ferreira YCLV, Boiani LE, Dorigon EB, Almeida SM, Manuela GP. Pós alagamento e saúde pública em um município do oeste catarinense: Principais patologias infectocontagiosas. IBEAS- Instituto Brasileiro de Estudos Ambientais. 2021. p. 1–4.
25. Barbosa SC. Reação do mercado acionário frente às catrástrofes envolvendo a mineradora VALE S.A: Um estudo de evento. Mariana. 2020.
26. Guha-Sapir D, Checchi F. Science and politics of disaster death tolls. BMJ. 2018;362:k4005.
27. Silva Ad, Carlos MdF. Desastres tecnológicos em barramentos de rejeitos de mineração: Impactos, danos e perspectivas de gestão de risco. Reduçãodo risco de desastres e a resiliência no meio rural e urbano. 2020;(2).
28. Morita T, Nomura S, Tsubokura M, Leppold C, Gilmour S, Ochi S et al. Excess mortality due to indirect health effects of the 2011 triple disaster in Fukushima, Japan: a retrospective observational study. J Epidemioloy Community Health. 2017;(71).
29. World Bank. Benefits and costs of reducing tuberculosis among Southern Africa's mineworkers. The World Bank. 2014. p. 1–3.
30. Bloch K, Johson LF, Nkosi M. Ehrlich. Precarious transition: a mortality study of South African ex-miners. BMC Public Health. 2018;XVIII.
31. Brown BVG, Neil W, White R, Ehrlich GJC. The burden of silicosis, pulmonary tuberculosis and COPD among former Basotho goldminers. Am J Ind Med. 2008; IX(59).
32. Belshaw JD. Death, danger, and disaster in the Crowsnest Pass mines. Project Muse. 2020; LXXXVII(1).
33. Centers for Disease Control and Prevention. Centers for Disease Control and Prevention. [Online].; 2016. cited 2021 Março 22. http://www.cdc.gov/healthyplaces/hia.htm.
34. Cureau, Sandra. Os impactos socioculturais decorrentes da construção de usinas hidrelétricas no Brasil. In: MAIA, Leonardo Castro; CAPELLI, Silvia; PONTES JÚNIOR, Felício (org.). Hidrelétricas e Atuação do Ministério Público na América Latina. Porto Alegre: Letra e Vida; 2013. p. 205–224.
35. Shoaf K. Organizing the health sector for response to disasters. Ciênc saúde Coletiva. 2014; IX(19).
36. Silva Le. Silva MAd. Segurança de barragens e os riscos potenciais à saúde pública. Saúde e Debate. 2020; XLIV(2).

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