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Prevalence of metal levels above the reference values in a municipality affected by the collapse of a mining tailings dam: Brumadinho Health Project

Prevalência dos níveis de metais acima dos valores de referência em município atingido pelo rompimento de barragem de rejeitos da mineração: Projeto Saúde Brumadinho

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ABSTRACT

Objective: To describe the prevalence of levels of arsenic, cadmium, mercury, lead and manganese above the reference values (RV) in the population of Brumadinho, after the rupture of the mining tailings dam and to verify the factors associated with these levels. **Methods:** Baseline study of a prospective cohort, in a representative sample of 3,080 residents (aged 12 and over) in Brumadinho, Minas Gerais. Exploratory variables (age, sex, skin color, household income, smoking and place of residence) were collected using a questionnaire and the levels of As, Cd and Hg in urine and Pb and Mn in blood were evaluated using the technique of inductively coupled plasma mass spectrometry. The distribution of prevalence of levels above the reference for metals was made, according to the exploratory variables. Multiple logistic regression analyzes were used to investigate the association between altered levels of metals and characteristics evaluated. **Results:** Concentrations above RV were found in 38.08% of the population for Mn, 33.37% for As, 5.04% for Pb, 0.76% for Hg and 0.17% for Cd. There was a significant association between age group and levels of Mn and Pb; and between place of residence and As level. **Conclusion:** The results show a high prevalence of levels above the reference for Mn, As and Pb, with small differences in relation to the other variables, suggesting that it is an exposure distributed throughout the municipality.
Keywords: Environmental exposure. Heavy metals. Health effects of disasters. Epidemiology of disasters.

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INTRODUCTION

On January 25th, 2019, at the Córrego do Feijão Mine, located in the municipality of Brumadinho, the B1 Dam of mining company Vale S.A. burst, spilling about 12 million cubic meters of ore tailings along the Rio Paraopeba Basin, causing 270 deaths and environmental, economic, and social impacts, as well as the health of affected communities[1].

The Newsletter of the Minas Gerais State Health Department on the quality of water for human consumption after the Vale S.A. disaster in Brumadinho[1] presented analysis results of 3,632 samples of surface and groundwater from the Paraopeba River, obtained over almost 2 years of monitoring in 16 municipalities, including 141 sampling points. Among the results of non-conformities, specific violations were identified for the parameters of antimony, arsenic, barium, chromium, mercury, nickel, and selenium.

The analyses of the tailings sludge, carried out immediately after the dam failure in Brumadinho, showed higher levels than the average of the soils in the region for barium, copper, iron, and manganese. The values found for aluminum were below the expected average for the soils of Brumadinho[2].

Of the aforementioned metals, arsenic, lead, mercury, and cadmium, due to their high degree of toxicity, are part of a list containing ten chemical substances of interest to public health prepared by the World Health Organization[3]. It should be noted that, in all samples of the tailings sludge from Dam B1 analyzed, manganese was above the average levels found in the soils of Brumadinho, according to the Technical Opinion of the Ministry of Health of No. 5/2019-DSASTE/SVS/MS (Process No. 25000.135307/2019-70; SEI No. 0010677631). In view of this, manganese became a metal of interest for the disaster in Brumadinho, since, although it plays an important role in the metabolic regulation of humans, in excess it can also cause neurotoxicity. Studies point out that high exposure to manganese can lead to a neurodegenerative disorder, with symptoms similar to those of Parkinson disease[4].

Exposure to metals can occur through their natural presence in the environment, water, food, soil, and air or through human actions, through industries, mining, tanneries, use of pesticides, among others. When absorbed by living beings, metals have the potential to bioaccumulate in organs and tissues, such as liver, heart, kidney, brain, and bones[5]. The inherent toxicity of the metal, the route of exposure, the intensity and time of exposure, as well as age, gender, genetics, nutritional status, and social and health conditions of the exposed individual, are conditioning factors in the illness process[5,6].

In Brumadinho, the Ministry of Health, when monitoring, through toxicological analyses, the health of search and rescue professionals who had prolonged contact with the tailings sludge, verified the presence of some metals above the reference limits, suggesting exposure to these elements by contact with the tailings sludge[2].

According to the Agency for Toxic Substances and Disease Registry[7], the metals arsenic, cadmium, lead, mercury, and manganese, when in chronic exposure, can cause toxic effects, especially on the cardiovascular, neurological, hematological, and immune systems, in addition to diabetes and alteration in child development.

The characterization of the population exposed to metals can support qualified health actions, considering their health, social, and demographic specificities. Therefore, the present article aimed to describe the prevalence of concentrations above the reference values (RV) for the metals arsenic, cadmium, mercury, lead, and manganese in the adolescent and adult population of Brumadinho, after the rupture of the B1 Dam in the Córrego do Feijão Mine, and to verify the sociodemographic and area of residence factors associated with these concentrations.

METHODS

The Brumadinho Health Project (*Projeto Saúde Brumadinho*) is a prospective, population-based cohort study conducted in a representative sample of the population aged 12 years old or older residing in the municipality of Brumadinho, Minas Gerais. The objective of this project is to produce information on the conditions related to the health of the population residing in the municipality, helping the health service in the planning of actions. More details can be obtained on the project website (http://www.minas.fiocruz.br/saudebrumadinho/) and in another publication[8,9].

The sample was designed in three estimation domains, which were constituted by the aggregation of census sectors from the Brazilian Institute of Geography and Statistics:
1. Region of those directly affected by the dam tailings sludge;
2. Residents of region with mining activity;
3. Random sample from the rest of the municipality.

In the first two domains, all households were visited (census); in the latter, seven households were drawn from each census sector. For the households visited, all residents aged 12 years old or older were invited to participate in the survey, with 3,080 (86.4% of those eligible) interviewees and 2,782 (90.3% of those interviewed) participants who provided biological material, constituting the cohort baseline.

The Brumadinho Health Project met all ethical requirements for conducting research with human beings. It was approved by the Research Ethics Committee of Fiocruz Minas (20814719.5.0000.5091) and all participants signed the Informed Consent or the Free and Clarified Assent Term of the minor, accompanied by the informed consent of their guardian.

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For the present article, data collected at baseline (2021) were analyzed, including, as outcomes, concentrations above the RV for the five metals studied (arsenic, cadmium, lead, manganese, and mercury). The explanatory variables, collected through the questionnaire and considering the literature[6,10-14], included sociodemographic variables (age range, sex, self-reported skin color, *per capita* household income in tertiles), daily smoking, in addition to place of residence (directly affected by the tailings mud from the dam, region with mining activity, sample of sectors not directly affected by the mud or mining). Daily smoking was assessed by reporting cigarette use every day in the last 30 days, among adolescents, and by reporting smoking daily, among adults.

Urine and blood tests for the measurement of metals were intended to analyze environmental exposure alone, and not intoxication. Blood and urine samples were collected at the participant's home, after registering the residents and carrying out the interviews, having been previously scheduled. Blood samples were collected by trained technicians, preferably from the veins of the antecubital fossa, using Trace Heparin, followed by homogenization. Urine collection occurred with at least two hours of urinary retention, in a universal bottle, after asepsis guidance, at the time of the home visit for blood collection.

These samples were transported in thermal boxes at refrigerated temperature to the central laboratory, for processing, carrying out the defined dosages and storage for future evaluations. Laboratory analyses of the metals were performed by the technique of inductively coupled plasma mass spectrometry (ICP-MS), using Agilent equipment. Samples were prepared by acid dilution and addition of an internal standard. The detection and quantification limit was 0.1 µg/L for As, Cd, and Hg in urine and Pb in blood; for Mn in blood, it was 0.8 µg/L. Total As was considered.

The analytical performance of metals was monitored through the use of five levels of internal quality control, with three controls prepared by the laboratory at pre-established concentration levels and two commercial controls of the ClinCheck brand. During the dosing period, the mean monthly coefficient of variation obtained for the considered analytes varied between 5.3 and 7.1%. To correct the concentrations of As, Cd, and Hg in the urine, creatinine was measured using Atellica CH Analyzer (Siemens) bio-

chemical analyzers, through the reaction of picric acid with creatinine in an alkaline medium. The reference interval for urinary creatinine, in which the correction was performed, was recommended between 0.3 and 3.0 g/L.

Chart 1 presents the RV of the analyzed metals adopted by the "Brumadinho Health Project", according to Technical Note No. 01/2021[15-18]. For the present study, an altered parameter was considered in the blood and urine analyzes when the levels of metals were above the reference limit value, as shown in the chart.

First, the variables included in this study were described to characterize the analyzed sample, through the estimation of proportions and respective 95% confidence intervals (95%CI). In addition, the distribution of metal levels (median and 25th and 75th percentiles) was included in the analysis.

The distribution of the prevalence of levels above the reference for all metals, according to the exploratory variables, was presented, and the associations between the altered levels and these variables were evaluated by the chi-square test with Rao-Scott correction. Finally, logistic regression analyses were used to investigate the association between altered levels of metals and sociodemographic characteristics and place of residence. The adequacy of the logistic models was performed using the Hosmer-Lemeshow test. For data analysis, STATA software was used, version 14.0, considering sample parameters (weight and design effect) and significance level of 5%.

RESULTS

Of the total of 3,080 research participants, income information was available for 88.1%, Mn and Pb for 84.8%, As and Cd for 87.8%, and Hg for 86.5%. For the other variables (age, gender, region of residence, and smoking), there was information on all participants.

Table 1 describes the characteristics of the study population. Of the total number of participants, 64.79% were between 18 and 59 years old, 56.65% were female, 57.77% responded that they were non-white, 40.10% had a *per capita* family income in the tertile 1 income range and 13.80% were daily smokers. Regarding the region of residence, 3.00% lived in the area directly affected by the tailings mud from the dam that broke, 1.70% lived in

Chart 1. Reference value for the analyzed metals. Brumadinho Health Project (MG), Brazil.

Metal	Biological material	Reference value	Reference
Total As	Urine	Lower than or equal to 10 µg/g of creatine	NR-7 MT-Brasil[16]
Cd	Urine	Lower than or equal to 2 µg/g of creatine	NR-7 MT-Brasil[16]
Hg	Urine	Lower than or equal to 5 µg/g of creatine	NR-7 MT-Brasil[16]
Mn	Blood	Between 4 and 15 µg/L	ATSDR/USA[17]
Pb	Blood	Lower than or equal to 10 µg/dL	Kosnett et al.,[18]

As: arsenic; Cd: cadmium; Hg: mercury; Mn: manganese; Pb: lead.

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the mining region of the municipality, and 95.30% lived in other areas of the municipality that were not directly affected by mud or mining. The median concentrations (25th and 75th percentiles) of the metals evaluated in this study were 13.20 (8.90–18.40) μg/L for Mn, 2.96 (1.80–4.70) μg/dL for Pb, 7.40 (4.90–11.70) μg/g creatinine for As, 0.10 (0.09–0.10) μg/g creatinine for Cd, and 0.10 (0.09–0.40) μg/g of creatinine to Hg (Table 1).

The prevalence of concentrations above the RV of the metals found in the general sample and according to categories of explanatory variables are described in Table 2. Considering the entire population, these values were 38.08% for Mn, 33.37% for As, 5.04% for Pb, 0.76% for Hg, and 0.17% for Cd. Regarding the explanatory variables, age range showed a significant association with the metals Mn, Pb, and As; and daily smoking was associated with Cd.

Table 3 presents the results of the multiple logistic regression, considering all explanatory variables included in the same model (p>0.05 by the Hosmer-Lemeshow test). For Cd and Hg, the test did not show a good fit, probably due to the low proportion of the population with concentrations above the RV. After adjusting for all explanatory variables considered, adults (18 to 59 years old) were less likely to have altered values for Mn and Pb, compared to adolescents, while aged people (60 years old and older) were less likely to have altered Mn values. Residents in the mining region were less likely to have altered values for As. Gender, skin color, household income, and daily smoking were not significantly associated with any of the analyzed metals.

DISCUSSION

The results of the present study demonstrate a high prevalence of metals above RV in the population of Brumadinho, especially Mn (38.08%) and As (33.37%). In addition, this prevalence was lower for Mn and Pb in the adult population and for Mn among aged people, compared to the group aged 12 to 17 years old. Values above reference levels for As were less frequent in the mining region, compared to the rest of the municipality.

The median values of Mn, Pb, and As levels in Brumadinho (13.20 μg/L, 2.96 μg/dL, and 7.40 μg/g of creatinine, respectively) were higher than those observed in the American population evaluated in the "National Health and Nutrition Examination Survey", in 2017–2018 (9.52 μg/L, 0.73 μg/dL, and 5.59 μg/g creatinine, respectively)[16]. The distribution of Cd and Hg levels was similar between the two populations, with much lower values: 0.10 μg/g of creatinine for both metals in Brumadinho, and 0.13 μg/g of creatinine for Cd and below detection limit for Hg in the United States[19].

Mn is an essential metal for humans, as it participates in the metabolism of several nutrients, in addition to having an important role in blood clotting and homeostasis, along with vitamin K. However, it can be toxic to the human organism when in very high levels, and the main route of exposure is the ingestion of water and food[20]. The prevalence of concentrations above the RV of Mn in the population of Brumadinho (38.08%) was similar to that found for the population of Rio Branco (37.00%)[10], in a study conducted among blood donors, but with a majority of men (75%). This high percentage of the Brumadinho population with levels above the reference is consistent with the result of analyses carried out in the tailings mud, soon after the rupture, when Mn contents were verified 27 times higher than the average contents found in the soils of the municipality[2].

The prevalence of levels above RV for Mn was higher among adolescents compared to other age groups, similarly to what was observed in other populations, in Brazil[11], the United States[21], and Mexico[22]. On the other hand, although in other studies Mn levels were higher among women[10,11,21-23], in Brumadinho there were no significant

Table 1. Participant characteristics. Brumadinho Health Project, 2021

Characteristics	Proportion (95%CI) or median (P25–P75)
Age range (in years)	
12–17	6.75 (5.40–8.41)
18–59	64.79 (61.72–67.75)
60+	28.46 (25.45–31.67)
Sex	
Male	43.35 (41.10–45.62)
Female	56.65 (54.38–58.90)
Skin color	
White	42.23 (38.84–45.70)
Non-White	57.77 (54.30–61.16)
Per capita income	
Tercile 1	40.10 (35.96–44.39)
Tercile 2	28.07 (24.19–32.31)
Tercile 3	31.83 (28.49–35.37)
Daily smoking	
No	86.20 (83.72–88.36)
Yes	13.80 (11.64–16.28)
Region of residence	
Sample of the rest of the municipality	95.30 (95.04–95.56)
Mud-stricken region	3.00 (2.82–3.19)
Mining region	1.70 (1.57–1.83)
Metals	
Mn (μg/L)	13.20 (8.90–18.40)
Pb (μg/dL)	2.96 (1.80–4.70)
As (μg/g of creatinine)	7.40 (4.90–11.70)
Cd (μg/g of creatinine)	0.10 (0.09–0.10)
Hg (μg/g of creatinine)	0.10 (0.09–0.40)

Mn: manganese; Pb: lead; As: arsenic; Cd: cadmium; Hg: mercury.

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Table 2. Prevalence of levels above the reference values for the analyzed metals, according to population characteristics. Brumadinho Health Project (MG), Brazil, 2021.

Characteristics	Prevalence of levels above the reference limits (95%CI)				
	Mn	Pb	As	Cd	Hg
Total population	38.08 (35.18–41.06)	5.04 (3.85–6.58)	33.37 (30.37–36.51)	0.17 (0.04–0.82)	0.76 (0.40–1.45)
Age range (in years)					
12–17	52.34* (41.58–62.90)	12.23* (6.90–20.77)	28.94* (19.07–41.32)	-	1.20 (0.20–6.98)
18–59	36.35 (32.64–40.24)	4.52 (3.08–6.58)	36.30 (32.56–40.21)	0.26 (0.05–1.28)	0.35 (0.13–0.92)
60+	38.22 (31.10–43.61)	4.39 (2.64–7.24)	27.86 (23.07–32.21)	0.01 (0.00–0.09)	1.56 (0.63–3.84)
Sex					
Male	41.17 (36.63–45.86)	5.93 (3.82–8.12)	32.88 (28.70–37.35)	-	1.15 (0.47–2.80)
Female	35.83 (32.36–39.46)	4.64 (3.19–6.71)	33.73 (29.84–37.85)	0.30 (0.06–1.40)	0.48 (0.20–1.12)
Skin color					
White	37.70 (33.28–42.33)	3.62 (2.24–5.80)	31.02 (26.85–35.53)	-	1.21 (0.52–2.80)
Non-White	38.17 (34.05–42.48)	5.91 (4.24–8.17)	35.18 (31.39–39.17)	0.30 (0.06–1.42)	0.43 (0.17–1.11)
Per capita income					
Tercile 1	35.91 (31.21–40.89)	6.64 (4.54–9.61)	34.17 (29.80–38.82)	0.36 (0.05–2.53)	1.10 (0.44–2.96)
Tercile 2	39.74 (34.01–45.77)	6.05 (3.71–9.70)	34.63 (29.14–40.56)	-	0.30 (0.06–1.63)
Tercile 3	38.29 (32.90–43.99)	2.82 (1.41–5.55)	31.47 (25.84–37.69)	0.01 (0.00–0.08)	0.95 (0.32–2.81)
Daily smoking					
No	38.07 (34.95–41.28)	4.78 (3.57–6.39)	33.56 (30.54–36.73)	0.05* (0.01–0.27)	0.72 (0.37–1.40)
Yes	38.16 (30.90–46.00)	6.64 (3.33–12.80)	32.15 (23.63–42.05)	0.98 (0.14–6.68)	1.05 (0.16–6.50)
Region of residence					
Rest of the municipality	38.02 (34.99–41.16)	5.02 (3.77–6.64)	33.52 (30.37–36.82)	0.18 (0.04–0.87)	0.73 (0.36–1.48)
Mud-stricken region	40.44 (37.18–43.80)	4.86 (3.61–6.52)	32.27 (29.34–35.28)	0.12 (0.02–0.82)	1.39 (0.80–2.43)
Mining region	36.85 (32.72–41.17)	6.75 (4.73–9.55)	27.27 (23.08–31.91)	-	1.30 (0.59–2.85)

Mn: manganese; Pb: lead; As: arsenic; Cd: cadmium; Hg: mercury. *p-value of the chi-square test with Rao-Scott correction <0.05

Table 3. Association between population characteristics and levels above the reference values for the analyzed metals. Brumadinho Health Project (MG), Brazil, 2021

Characteristics	Adjusted odds ratio (95%CI)		
	Mn	Pb	As
Age range (in years)			
12–17	1.00	1.00	1.00
18–59	0.50 (0.30–0.83)	0.35 (0.16–0.76)	1.45 (0.77–2.74)
60+	0.51 (0.30–0.87)	0.45 (0.16–1.21)	1.02 (0.52–2.00)
Sex			
Male	1.00	1.00	1.00
Female	0.81 (0.63–1.04)	0.75 (0.41–1.37)	0.97 (0.73–1.29)
Skin color			
White	1.00	1.00	1.00
Non-White	0.97 (0.74–1.28)	1.57 (0.81–3.02)	1.18 (0.91–1.53)
Per capita income			
Tercile 1	1.00	1.00	1.00
Tercile 2	1.26 (0.91–1.76)	1.10 (0.56–2.15)	1.03 (0.74–1.44)
Tercile 3	1.21 (0.87–1.70)	0.53 (0.22–1.28)	0.97 (0.67–1.41)
Daily smoking			
No	1.00	1.00	1.00
Yes	1.13 (0.77–1.64)	1.65 (0.68–3.97)	0.96 (0.60–1.56)
Region of residence			
Sample of the rest of the municipality	1.00	1.00	1.00
Mud-stricken region	1.04 (0.84–1.30)	0.72 (0.43–1.21)	0.89 (0.71–1.10)
Mining region	0.90 (0.70–1.15)	1.16 (0.69–1.96)	0.69 (0.52–0.91)

Mn: manganese; Pb: lead; As: arsenic. For all three models, the p-value of the Hosmer-Lemeshow test was >0.05.

differences in the prevalence of altered values between the genders. In addition, indicators of socioeconomic status were also not associated with these levels, similarly to other populations[11,21].

Regarding Pb, a prevalence of 5.04% of concentrations above RV was observed in the entire population of Brumadinho, similarly to what was reported in other locations. In environmentally exposed adults in the surroundings of the Estancia Ecológica Sesc Pantanal, in Mato Grosso, 7.57% of the samples analyzed for Pb were above RV[24]. In individuals aged 0 to 16 years old from Complexo de Manguinhos, in Rio de Janeiro, the prevalence was 5.00% for values above the reference[25]. In the population of Detroit, USA, 28% had above-average levels for Pb, a value higher than that found in Brumadinho[26].

In the present study, Pb was more prevalent among adolescents, similar to the US population, where blood Pb levels decreased with age[27]. Conversely, among children and adults in the Czech Republic[12], as well as in the Spanish[28] and the Korean populations[13], blood Pb levels increased with age.

It is worth mentioning that exposure to Mn and Pb in children and adolescents has a greater risk of impact on neurodevelopment, as it can cause deficits in cognitive and behavioral performance, as well as delay in physical growth during childhood and puberty[7,29], demonstrating the relevance of this result for the population of Brumadinho, which reveals a higher prevalence among adolescents.

The prevalence of increased levels of Pb in the blood did not present significant differences in relation to the other variables of the study. These associations still seem to differ greatly between populations, but most describe, for example, higher concentrations of this metal among men compared to women[12,13,26,30].

As is a metal that can be present in more than 200 minerals, including Pb and Mn ores and most often related to gold[31]. Metal smelting and, to a lesser extent, pesticides or coal burning are sources of As of anthropic origin. The most common route of exposure to As is through ingestion of water and food, and this metal, when exposed chronically, increases the risk of some health conditions, such as bladder, lung, skin, and kidney cancer[32,33].

In Brumadinho, a high proportion of the investigated population had concentrations above the RV for As (33.37%). In the present study, the only variable with a significant association with As was the region of residence. This lower chance of having altered As levels in a mining region is consistent with a study conducted among blood donors in Acre that identified lower As levels among metal mining workers[10], although the results were evaluated in the blood of the participants.

Conversely, in Paracatu, Minas Gerais[34], and in the Alto Vale da Ribeira region, between the states of São Paulo and Paraná[14], higher levels of As were observed in residents of neighborhoods closer to mining areas. Another study ex-

plains that the occurrence of As is common because, in addition to the metal being associated with various ores, during extraction, water contamination occurs after mining and processing of the ore, resulting in low pH of these waters[31].

It should be noted that, in the mining region, where a lower prevalence of levels above the RV for As was observed, about 82% of the participants receive water from a water truck and 95% report mineral water as the main source to drink, differently from what was observed in the other analyzed regions (data not shown). Provided water is an important source of exposure to As[10,32,33], this result may explain, at least in part, the lower prevalence in this group, given that there is greater consumption of mineral water in this place.

The analysis shown in this article has some limitations. Due to the cross-sectional characteristics of the study, the associations do not demonstrate a temporal relationship between the variables, although it was possible to detect some groups that are more vulnerable to having high levels of metals in the body. In addition, the origin of the metals, the activities and behaviors of the adolescents and occupational exposure were not considered, as it is a more homogeneous exposure region, due to the magnitude of the dam failure and the presence of mining. Finally, only information on the daily habit of cigarette was used, without considering passive smoking, due to the absence of this information in the study, which could also have an influence on the levels of metals in the body.

On the other hand, this is the first population-based study to consider exposure to As, Cd, Pb, Mn, and Hg in the adolescent and adult population of Brumadinho, after the dam failure. Results show a high prevalence of levels above the reference for Mn, As, and Pb (in this case, mainly among adolescents), with small differences in relation to the other variables, suggesting that it is a broader exposure throughout the municipality. This knowledge can help in the surveillance of environmental exposure, as well as in the structuring of other health services, for the purpose of detecting the sources of exposure and monitoring the groups exposed by the local health service.

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RESUMO

Objetivo: Descrever a prevalência dos níveis dos metais arsênio, cádmio, mercúrio, chumbo e manganês acima dos valores de referência (VR) na população de Brumadinho, após o rompimento da barragem de rejeitos de mineração, e verificar os fatores associados a esses níveis. **Métodos:** Estudo da linha de base de uma coorte prospectiva, em amostra representativa de 3.080 residentes (12 anos ou mais de idade) de Brumadinho, Minas Gerais. As variáveis exploratórias (idade, sexo, cor de pele, renda domiciliar, tabagismo e local de residência) foram coletadas por questionário, e os níveis de As, Cd e Hg na urina e de Pb e Mn no sangue foram avaliados pela técnica de espectrometria de massa com plasma indutivamente acoplado. Fez-se a distribuição das prevalências de níveis acima da referência para os metais, segundo as variáveis exploratórias. Análises de regressão logística múltipla foram utilizadas para averiguar associação entre os níveis alterados de metais e as características avaliadas. **Resultados:** Encontraram-se concentrações acima do VR em 38,08% da população para Mn, 33,37% para As, 5,04% para Pb, 0,76% para Hg e 0,17% para Cd. Houve associação significativa entre a faixa etária e os níveis de Mn e Pb; e entre o local de residência e o nível de As. **Conclusão:** Os resultados demonstram elevada prevalência de níveis acima da referência para Mn, As e Pb, com pequenas diferenças em relação às demais variáveis, sugerindo se tratar de uma exposição distribuída em todo o município.
Palavras-chave: Exposição ambiental. Metais pesados. Efeitos de desastres na saúde. Epidemiologia de desastres.

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