Arsenic contaminated dust and the mud accident in Fundão (Brazil)

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ABSTRACT: On November 5th, 2015, Fundão tailings dam in Mariana (Minas Gerais) collapsed. This was considered the biggest environmental disaster in Brazil and one of the largest in the world. Mud wastes (more than 50 million m³) were dumped downstream of the Doce River basin. Hundreds of thousands of people living along the rivers have been affected. The aim of this study was to characterize dust samples collected after the mud deposition. Although iron mining wastes were classified as “not-hazardous” materials, our chemical analyses results pointed out the occurrence of potentially hazardous elements as As, Al, Mn and Pb at very high levels in the collected particulate material.

1 INTRODUCTION

Minas Gerais state faced its worst environmental disaster in November 2015: the rupture of a dike of Fundão tailings dam (owned by the mining company Samarco) at Mariana. This accident was the most devastating environmental disaster in the Brazilian history. So far, the magnitude of the impacts is unknown, as well as how much time it will take to repair all the damages generated by this tragedy. Iron mining wastes (sludge) were dumped downstream of Doce River basin (DRB), affecting all the basin ecosystem and also some coastal beaches located more than 660 km far from the accident site. Six months after the disaster, with the beginning of the dry season, people still living within the affected areas, started complaining because of the dust generated during wastes removal process. This study aimed to collect and characterize dust samples since: (i) the accident took place in an arsenic contaminated area, (ii) arsenic mobilization is totally likely; (iii) it is well known that arsenic and other contaminants may be carried not only by water but also by soil and dust and; (iv) the negative effects of particulate material (PM) to human health are not negligible and, (v) PM inhalation is a function of their size, the smaller the particle, the easier its inhalation and the higher would be its potential toxicity (Segura *et al.*, 2016).

2 METHODS/EXPERIMENTAL

2.1 Reagents, materials, software and equipment

Analytical grade reagents; disposable plastic flasks, buckets and bags; glass flasks; sieves. Software: Excell,

ArcGIS 10.1 and QGIS 2.18. Equipment: Mechanical sieve agitator, analytical scale, hot plate, Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES, Varian 725-ES), Total Reflection X-Ray Fluorescence–TXRF spectrometer (S2 Picofox, Brucker); Zetasizer (Nano, Malvern); portable global positioning system–GPS (Garmin).

2.2 Sampling and sample characterization

Sampling points were distributed along the course of the Gualaxo do Norte River (the first affected by mud). Plastic buckets (2 L, 1.80 m high) were distributed on the river banks (± 70 km), between Ouro Preto (OP), Mariana (M) and Barra Longa (BL) municipalities, at the very beginning of the dry season (June, 2016). A dried mud sample (GST) was collected as a reference material. After a 4-month interval, 23 dust samples were retrieved, dried (room temperature) and sieved (≤ 0.088 mm = PM). GST and dust samples with size distribution between 0.037–0.2 mm were used for quantitative chemical analysis (ICP_OES) after hot plate acid digestion. Dust and GST particles smaller than 0.037 mm were used for the determination of the Zeta potential and polydispersity index and chemical composition was accessed by TXRF.

3 RESULTS AND DISCUSSION

3.1 Dust samples – Physical properties

Point 1 (S 20°16.847', W 43°28.185') was located at OP, upstream of the dam. All other points were easily accessible and had been purposely distributed at high traffic areas (used for mud removal). Points

Table 1. Granulometric distribution – particulate matter (PM).

Granulometric distribution (PM) [%]				
	x<0.044 [mm]	0.044<x<0.053 [mm]	0.053<x<0.088 [mm]	x>0.088 [mm]
1	25,70	24,59	24,84	24,86
2	24,55	23,75	24,18	27,52
3	25,19	24,06	24,19	26,56
4	22,95	21,55	22,40	33,09
5	23,60	23,41	23,30	29,69
6	24,27	23,58	24,11	28,04
7	25,12	23,92	24,82	26,13
8	26,61	21,61	22,90	28,88
9	28,02	23,87	24,19	23,92
10	17,37	23,97	25,89	32,77
11	20,41	22,45	23,11	34,03
12	26,25	23,83	23,94	25,98
13	26,20	24,35	24,70	24,75
14	25,67	24,11	24,50	25,72
15	24,47	24,49	24,33	26,71
16	33,56	–	33,10	33,34
17	25,59	24,69	24,65	25,07
19	27,86	24,15	21,12	26,87
20	10,30	21,07	25,20	43,43
21	25,79	24,73	24,84	24,64
22	25,82	24,51	24,71	24,96
23	25,95	24,38	24,49	25,18
GST	9.44	28.80	53.01	8.75

GST, dried mud deposited and collected as a reference material.

2–10 were located in Mariana while the other 16 points were distributed at BL. Points 10 and 23 were close to residences affected by mud, on the banks of the Gualaxo do Norte River (S 20°18.142', W 43°14.987' and S 20°16.949', W 43°02.558'). Granulometric distribution of collected samples is shown in Table 1. Approximately 10 g of dust was deposited in each collector (2 L, 0.021 m²), representing an average deposition of ±476 g m². Of particular note are points 7 (S 20°17.578' W 43°15.160') and 23, were 38.241 and 63.4 g of dust, were collected. Fine GST particles showed a diameter of 0.8555 µm and a polydispersive index of 0.624 and a Zeta potential of –20.7 mV. Diameter and the negative charge of GST particles should be considered for the prediction of its physiological and toxicological behavior. As approximately 50% of the GST material was considered as fine particles and some particles were smaller than 1 µm, those particles would be easily inhalable and absorbable.

3.2 Dust samples – Chemical composition

Elemental analysis of GST and dust particles pointed to the presence of some potentially toxic trace elements such as As, Al, Cu, Mn, Pb and Zn, besides Fe (the main element). Our results showed that chemical composition vary depending on particle size. In the case of arsenic, GST average arsenic content was 23.34 mg As kg⁻¹. Dust samples averaged arsenic

content was 49.47 mg As kg⁻¹. The highest As content was found in sample 3 (S 20°16.257', W 43°17.802'), 194.52 mg As kg⁻¹, mainly found in the particles sized between 0.053 and 0.088 mm (462 mg kg⁻¹). Sample 21 (S 20°16.949', W 43°02.558') presented the second higher As content, 139.35 mg As kg⁻¹ and in that case, As was concentrated in the very fine particles (481 mg kg⁻¹). After the disaster, some reports were issued with the objective of ascertaining the situation of the affected area, these studies were carried out by both governmental and non-governmental organizations. Results of the analyzes of the water and sediment samples collected in the Doce River indicated contamination rates by As, Mn, Pb, Al and Fe, above the values allowed by Brazilian legislation (BRASIL Resolução 2005). The same elements were found in both mud samples collected immediately after the event (Segura *et al.*, 2016) and dust samples (present study). Such data, however, differ from those historically observed prior to the accident. Thus, changes in both air and water quality may be related to flooding by tailings sludge, as well as possible environmental changes and disturbances to the health of the inhabitants of affected areas (IGAM, 2015).

4 CONCLUSIONS

Even if in their origin, iron mining wastes were free of potentially dangerous elements like arsenic, it seems that the energy from the mud flooding was so intense that caused the re-suspension and re-solubilization of some very old sediments deposited at the river banks for centuries. Chemical elements from sediments were carried with the mud and are now mixed with the waste. Toxic elements mobilized during the artisanal gold mining are at the surface again and some of those particles are small enough to be classified as PM and therefore, being inhaled by human.

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