Arsenic levels in natural and drinking waters from Paracatu, MG, Brazil

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ABSTRACT: Inorganic Arsenic (As) is a known human-carcinogenic (Group I) and the most important human environmental exposure pathway is water ingestion. Gold mining may be an important source of As to the environment. The objective of this study was to evaluate the As levels in natural (superficial and groundwater) and drinking water in Paracatu, where the largest gold mine in Brazil ("Morro do Ouro") is located. The results showed low levels of As in drinking water, tap water and groundwater, which indicates that water ingestion may not be a significant pathway of exposure to local population. In contrast, the highest levels of As, above the legal criterion (10 lglL⁻¹), were found in freshwater of watersheds impacted directly by the present gold mining area or abandoned artisanal gold mining sites.

1 INTRODUCTION

The "Morro do Ouro" gold ore deposit presents Au grade from 0.4 to 0.6 g Au t⁻¹ and Arsenic (As) levels >4,000 mg L⁻¹. High As levels (1,000 mg L⁻¹) in soils and sediments were observed at watersheds located in the same direction of the gold ore body, generally associated with abandoned artisanal gold mines and low energy freshwater environment, and decreasing concentration as the mining site distance increases (Bidone et al., 2014). According to Prohaska & Stingeder (2005), the greätt range and the highest concentrations of As are potentially found in groundwaters. The average values for As in freshwaters range from 0.4 to 80 lglL⁻¹. These values can rise to several hundred lglL⁻¹ in streams near industrial and mining areas. Usual groundwater concentrations range from <0.5 to 10 lglL⁻¹. Wells in contaminated areas, e.g. in Bangladesh, can reach 2,500 lglL⁻¹. Given the fact that inorganic As is a known human carcinogenic (Group I) and the most important human environmental exposure pathway is water ingestion (ASTDR 2007), the potential contamination of natural water (superficial and groundwater) and drinking water in Paracatu was investigated. The majority of urban population (97%) is served by treated water, while rural communities consume drinking water from local groundwater sources. Drinking water in urban area is mainly from freshwater source, but, depending on its availability, it is complemented by urban groundwater sources.

2 METHODS

2.1 Sampling

Water sampling was performed during dry season (September and October). Under this climatological condition, water quality reflects the highest interaction with soils and rocks, and with pollutant loads, without dilution process and runoff impacts. Twenty eight freshwater (28) samples were collected along the three watersheds, sub-basins of Paracatu River watershed: (i) C6rego Rico watershed—it's spring is located inside the open pit mine site and at its medium segment is located at the Paracatu Municipality; (ii) Ribeirao Entre-Ribeiros watershed—it is downstream of tailing dam and potentially receives its effluents; (iii) Rio Escuro watershed—outside the direct influence of gold mining, it is considered as a reference area and it is the main drinking water source for urban population of Paracatu.
Additionally, 29 wells used for urban population consumption after treatment (9), for private human consumption (6), for rural communities consumption (4) and groundwater samples from monitoring wells (10) installed inside of the mining sites (gold mine -2 and lead and zinc mine - 8), spread of all over the municipality were sampled. Tillty-seven (37) drinking water system for urban population were sampled, including 12 watersources (9 groundwater and 3 freshwater), water reservoirs (4) and tap water from 21 houses in Paracatu. These selected houses represent critical areas (end-of-line) in the urban water system distribution.

2.2 Chemical Analysis

Physicochemical parameters (pH, electric conductivity-EC, dissolved oxygen-DO, total dissolved solids-IDS, temperature-T and oxy-redox potential-Eh) were measured at field by Multi Sonda (HANNA, HI 9828). The water samples were keep in plastic jars cleaned, acidified (pH < 2 HNO3, ultrapurp) and refrigerated until analysis. The concentrations of total As were determined by ICP-MS (Model442 IC-MS, Perkin Elmer MS). The limit of detection of As was 0.5 μg L-1. Precision and accuracy (RCM) was 90% and 95%, respectively. As in groundwater was analyzed by ICP-MS (Agilent 7500ce) with nebulizer (Micromist and Cross Flow camera). The detection of limit was <0.1 μg L-1. Precisio and accuracy (RCM) was 90% and 95%, respectively.

3 RESULTS AND DISCUSSION

a) Superficial freshwaters. (i) Côrrego Rico watershed: As levels resulted from <0.5 μg L-1 to 40.10 μg L-1 (13.21 ± 12.38 μg L-1; n = 11). At a sampling point, very close to Morro do Ouro, As levels attained 23.60 μg L-1, and where Paracatu city urban area ends, As levels were 40.10 μg L-1. From this point, the arsenic concentration decreased to <10 μg L-1 as far as its confluence with Paracatu river. (ii) Ribeirao Entre-Ribeirios watershed: As levels resulted from <0.5 to 29.10 μg L-1 (10.75 ± 10.61 μg L-1; n = 11). The highest As levels are associated with abandoned open pits and small scale gold mining sites (SSGM). As level downstream of the tailing dam (7 km) was 5.0 μg L-1. (iii) Rio Escuro watershed: As levels resulted from <0.51 μg L-1 and 0.80 μg L-1 (0.63 ±0.151 μg L-1; n = 4). As level at the drinking water source that supplies Paracatu population was <0.5 μg L-1. b) Drinking water at the urban system: As levels were lower than the limit of detection(< 0.51 μg L-1) for all samples, including all tap water samples, except for 2 groundwater sources, with low As levels 0.61 g L-1 and 1.81 g L-1. c) Groundwater samples: As levels in groundwater for rural communities consumption, for private urban human consumption as well as monitoring wells resulted below of limit of detection (<0.11g L-1).

4 DISCUSSION

As maximum permitted level in freshwater and groundwater is 10 μg L-1 (Resolution n. 357/2005 CONAMA-Conselho Nacional de Meio Ambiente and Ordinance 518/2004 Ministry of Health of Brazil). All of the drinking water (surface and groundwater) samples used to the urban or rural communities' consumption and the tap water samples showed As levels below the quality limit. Actually, almost all samples were below the limit of detection, which is 4 to 10 times lower than the quality limit. On the other hand, 42% of freshwater samples are above 10 μg L-1. These samples are from Corrego Rico and Ribeirao Entre-Ribeirios watershed, under direct influence of gold mining site and/or abandoned artisanal gold mining sites, respectively. Ladeira et al. (2002), when investigating arsenic adsorption capacity of soil from Morro do Ouro region, showed the maximum loading capacity between 0.7 and 3.6 mg As L-1 soil, which results in As concentrations from 700 to 3,600 mg L-1. These values are similar to those measured in soils from Paracatu (Bidone et al., 2014). Therefore, As would be trapped inside the groundwater and transferred to freshwater, mainly at remobilized soils and exposed rocks. In Latosok, as found in Paracatu which are well drained, As may move down a profile with leaching water (as the fine particulate material, complexed with Fe and Al oxides). The organic matter retention at low energy river segments (swamps, small dams and abandoned SSGM open pits) may favor the accumulation of As and, as a consequence, might contribute to the arsenate reduction to the more soluble and toxic chemical form, arsenite. In these sites, physicochemical parameters showed reduction condition (negative or lower levels of Eh, low levels of DO and neutral pH), fact that lead to suppose the stability of the arsenite forms in water. Finally, the equilibrium between water and sterile phyllites (the host rocks of the ore body), with low levels of As, could explain concentrations <0.1 g L-1 in almost all samples of groundwater. These aspects are under study.

5 CONCLUSIONS

As levels were lower than the limit of detection (< 0.5 μg L-1) for all water samples, including tap water, groundwater and surface water that is the
main source of the drinking water supply for urban population. Even in rural areas, all drinking water samples showed low levels, even below \(<0.1\) g L\(^{-1}\). Then, As levels in drinking water in Paracatu are around one order of magnitude lower than the limits established by the Brazilian law. Therefore, the As main human exposure pathway (i.e. oral ingestion of water) might not represent significant risks on human health. As levels above \(10\) g L\(^{-1}\) were observed in impacted watershed, under direct influence of gold mining site and/or abandoned artisanal gold mining sites. The relationship between As in soils, sediments and natural water are under study.

REFERENCES


