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ORIGINAL ARTICLE

Arsenic in the groundwater of Ouro Preto (Brazil): its temporal behavior as influenced by the hydric regime and hydrogeology

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Abstract In the city of Ouro Preto (MG), water catchment for public supply originates from superficial drainage, springs, old abandoned mines and some driven wells. In the rocks of the region, As is originally found in gold-enriched sulphide-bearing mineral deposits. The weathering process introduces As into the hydrological system by dissolution of this element into the leachate. Measurement of the As content in the groundwater of some catchments was carried out during 1 year and these measurements demonstrated high As content—up to 224 μg L^{-1} of As(V)—during the rainy season (the maximum concentration limit according to World Health Organization is 10 μg L^{-1}). Lower values were observed during the dry season and in some sampling stations, As was not even detected. The As concentration variability during 1 year shows a strict and direct relationship to seasonal and hydrological conditions. For city authorities, responsible for public water supply, it is necessary to perform a complete inventory of the water sources used and constantly monitor the As content in the water.

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Introduction

Waters used for human consumption with arsenic concentrations above the limits established by the environmental control agencies are considered dangerous for human health (Hopenhayn-Rich et al. 1996; NRC 1999). Arsenic is one of the main inorganic contaminants of continental waters, responsible for dozens of millions of casualties all over the globe. In many parts of the world, health problems caused by the occurrence of As in groundwater from wells and fountains have been recognized and reported in the USA (Robertson 1989; Fuji and Swain 1995; Welch and Lico 1998), Mexico (Del Razo et al. 1990), Argentina (Nicolli et al. 1989), Chile (Cáceres et al. 1992), Mongolia (Smedley et al. 2001), India (Acharyya et al. 2000), and Bangladesh (Bhattacharya et al. 1997; Nickson et al. 2000; McArthur et al. 2001).

Several As compounds are present in the environment and in biological systems. This element is present in a long list of minerals such as sulfides, arsenides and sulfo-arsenides, the latter being the most common. In natural waters, As occurs in inorganic and organic compounds. In solution, the inorganic compounds encountered in waters with high to moderate Eh conditions are H_3AsO_4, $H_2AsO_4^-$, $HAsO_4^{2-}$ and AsO_4^{3-}, whereas H_3AsO_3 predominates in reducing conditions.

Arsenic is a toxic and carcinogenic element. Its toxicity depends on the chemical species. The decreasing order of toxicity of As compounds is: inorganic As(III) compounds > inorganic As(V) compounds > organic As(III) compounds > organic As(V) compounds (Anderson et al. 1986;

Burguera and Burguera 1997; USEPA 2000). As(III) is around 60 times more toxic than the pentavalent As(V) oxidation form (Mabuchi et al. 1979).

The most common forms of human exposure to As are: (1) consumption of contaminated water, (2) inhalation of gases, and (3) ingestion of dust. Exposure to As causes subacute, acute and even chronic toxic effects, involving the respiratory, cardiovascular and nervous systems (WHO 1981; USEPA 2000). The main pathologies caused by acute and chronic As intoxication are metabolic problems, skin tumors, ulcers, gastritis, diarrhea, heart arrhythmia, pancreatic and lung cancer, plus higher frequency of spontaneous abortions, low-weight fetus, headaches, confusion and anemia (Hutton 1987;Morton and Dunnette 1994;Chen and Lin 1994; USEPA 2000; WHO 2001).

The As concentration limits for potable waters cannot exceed 0.05 mg L^{-1}, as suggested by WHO (1993). Nevertheless, these limits were reduced by WHO to 0.01 mg L^{-1} in 1994, as a consequence of more recent studies. In Australia, the National Health and Medical Research Council recommends a maximum As limit in consumption waters of 0.007 mg L^{-1} (NHMRC 1996). In Brazil, the National Health Foundation (Funasa 2001) established 0.01 mg L^{-1} as a maximum limit.

Specifically in the Quadrilátero Ferrífero (an important Brazilian gold province), previous studies reported As contamination in stream currents, surface and groundwater. In the Rio de Carmo stream sediments, Eleutério (1997) found an As content of 620.0 μg g^{-1} in summer and 1,268 μg g^{-1} in winter. In the Nova Lima and Santa Bárbara municipalities of the Quadrilátero Ferrífero, Mattschullat et al. (2000), studying the As contamination of 7- to 12-year-old children, found concentrations between 2 and 106 μg L^{-1} in their urine; 22% of the concentration values were higher than 40 μg L^{-1}. Pimentel et al. (2003) analyzed waters coming from old gold mines and springs in Ouro Preto, observing As concentrations from 0.07 to 2.30 mg L^{-1}. Borba (2002), carrying out studies in gold districts located in the Carmo, Conceição and das Velhas river basins, found As concentrations up to 4,000 mg kg^{-1} in sediments. In surface waters, As concentrations reached 350 μg L^{-1}, whereas, in the groundwater of Ouro Preto and Mariana mines, the total As concentrations were as high as 2,800 μg L^{-1}.

In the Ouro Preto municipality, the water supply for both domestic use and public fountains found in the streets and squares is furnished by the catchment and distribution of surface waters and springs, and groundwater drawn from tubular wells and old gold mines. The possibility of water contamination by As, due to the rock types that constitute the aquifers, could make this water inappropriate for human consumption.

This work presents a hydrogeochemical study of the waters supplied to the Ouro Preto population, by means of periodical monitoring of the As temporal behavior, from January 2003 to January 2004.

The study area

In the Quadrilátero Ferrífero gold deposits, such as Morro Velho and Passagem de Mariana, as well as a large number of smaller deposits, exemplify the mesothermal gold deposit model in shear zones affecting Upper Archean terrains.

The Quadrilátero Ferrífero gold mineralizations occur either in the metasedimentary and metavolcanic rocks of the Upper Archean Nova Lima Group or in contact with the Paleoproterozoic Minas Supergroup iron formations, which are sheared and hydrothermally altered, and host the gold deposits of the Ouro Preto and Mariana regions (Ladeira 1988). Gold occurs associated with pyrite, pyrrhotite and arsenopyrite, which are the most abundant ore phases, whereas base-metal (Cu, Zn and Pb) sulfides appear as subordinated phases.

Geographically, As is distributed in the Quadrilátero Ferrífero rocks in close association with sulfide-rich, gold-bearing rocks. The origin of As in waters, soils and sediments is due to a natural anomaly of this element in the region. Such an anomaly is related to the genesis of the gold deposits. Weathering of the rocks with anomalous As contents promotes the liberation of the metal to the environment. The highest As and heavy metal concentrations in sediments and sometimes surface and groundwater in the Quadrilátero Ferrífero are always related to the presence of contaminated soils, and effluents from mines or industrial plants.

Studies related to effluents of old gold mines, soils and river sediments in the Ouro Preto and Mariana by Eleutério (1997), Rawlins et al. (1997), Deschamps et al. (2002), Pimentel (2003) and Borba et al. (2002) attested for the punctual As presence in these municipalities.

Figure 1 presents the geological features of the study area according to Barbosa (1969) and a geologic profile modified from Zenóbio (2000). It is located in the southeastern portion of the Quadrilátero Ferrífero, which covers an area of 7,200 km^2 in the central–southern portion of the state of Minas Gerais State. Due to the area's major iron, gold, and manganese deposits and its special geological characteristics, several geological studies have been carried out in this region since the 18th century.

According to the Koeppen classification (Strahler and Strahler 1987), the climate of Ouro Preto corresponds to the Cwb type. The pluviometry is typical of a tropical regime, presenting an average of 1,723 $mm.year^{-1}$. The rainy

season (from October to March) represents 89.6% of the annual precipitation, while the dry season (from April to September) represents 10.4% of total precipitation. The average annual temperature is 18.5°C. January is the hottest month, with a maximum average annual temperature of 21.2°C, and July the coldest, with a minimum average annual temperature of 15.5°C (Coelho 1994).

According to Varajão (1988), the main Quadrilátero Ferrífero geomorphological characteristics are associated with variations in altitude, resulting from lithostructural diversity and controls and also differential erosion. A large part of the urban area of Ouro Preto city is located in a valley formed between the Itacolomi and Ouro Preto ridges, with elevations varying from 1060 to 1420 m (Fig. 1).

Hydrogeology

The geological constitution of the Ouro Preto region (Fig. 1) encompasses a group of metasedimentary and metavolcanic rocks of the Minas and Rio das Velhas Supergroups, which, in principle, characterize a predominant fractured aquifer system. High compaction and foliation, leading to a lack or very reduced amount of voids in these rocks, explain their low primary permeability. In this aquifer, water fills spaces represented by fissures or fractures, joints or even faults.

Some rock types, however, present good porosity and function as granular or granular-fractured aquifers. This results from the high density of fracture surfaces, allied to the action of weathering and leaching processes on the rocks. On the other hand, these aquifers still keep the heterogeneity and anisotropy as fundamental characteristics of the fractured media (Carvalho 1994).

Besides the aspects related to permeability, the aquifer systems were grouped and individualized, considering the geological environment of the study area as a function of the predominant rock type (Table 1).

Three categories of aquifer systems were identified: a granular medium, characterized by weathering mantles and undivided detrital covers; a granular-fractured medium, constituted by itabiritic rocks; and a fractured medium, represented by schistose and quartzitic rocks.

Aquifers in weathering mantle and detrital covers This system constitutes the superficial aquifers associated with the weathering mantle (saprolites, colluvia, lateritic covers, and canga) and detrital deposits of the Tertiary-Quaternary cover. Its mineral composition and thickness are variable and intimately related to the original rock type and the prevailing climatic conditions.

In the study area, the aquifers of the weathering mantle are not important in terms of availability of exploitable water, due to the uneven relief and strong declivity. They

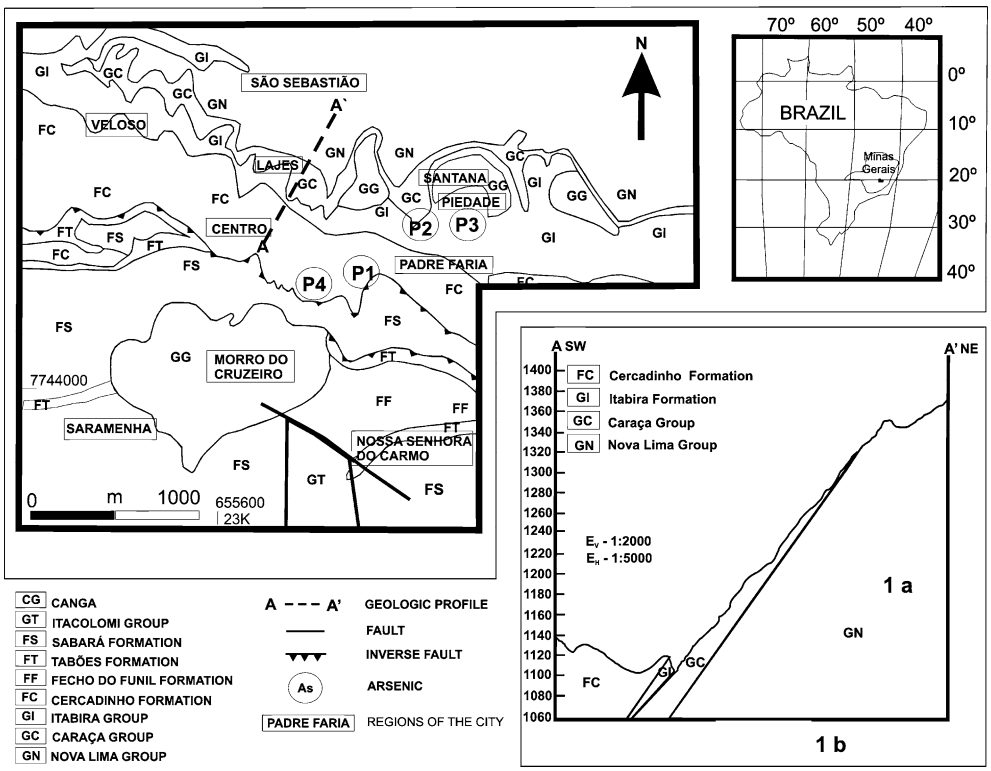

Fig. 1 **a** Geologic map of Ouro Preto city modified from Barbosa (1969) and Dorr (1969). **b** Geologic profile A-A′ (Zenóbio 2000)

Table 1 Chemical composition and physical chemical parameters of waters of Ouro Preto municipality along the year 2004

		pH	T (°C)	EC (μS/cm)	Eh (mV)	As(III) (μg/L)	As(V) (μg/L)	Na (mg/L)	Mg (mg/L)	K (mg/L)	Ca (mg/L)	Al (μg/L)	Mn (μg/L)	Fe (μg/L)	Ba (μg/L)	Sr (μg/L)
P1	Jan/04	7.43	19.7	21.38	397	<5	27.0	1.06	0.26	0.94	1.35	<4	58.8	<9	7.87	<0.1
	Mar/04	6.62	19.0	25.15	433	<5	14.8	1.80	0.40	1.03	1.35	<4	128	<9	6.27	<0.1
	May/04	6.67	17.5	25.99	488	<5	<5	1.78	0.50	1.03	1.23	<4	124	<9	5.96	7.7
	Jul/04	6.37	18.3	25.90	398	<5	<5	1.58	0.49	1.00	1.20	<4	53.1	<9	26.9	8.0
	Sep/04	6.30	20.0	25.35	383	<5	<5	1.61	0.48	1.04	1.22	<4	7.58	<9	14.1	8.2
	Nov/04	6.59	20.6	22.63	387	<5	<5	1.68	0.44	0.88	1.23	<4	18.1	<9	4.75	7.2
P2	Jan/04	7.16	19.6	80.85	399	<5	71.0	7.15	1.12	2.80	4.28	<4	10.3	<9	9.03	<0.1
	Mar/04	6.24	19.4	73.33	497	<5	62.9	7.32	1.02	2.62	2.97	<4	15.5	<9	7.42	<0.1
	May/04	6.28	18.6	71.49	469	<5	48.0	7.00	1.10	2.53	2.45	1.76	14.9	4.33	7.59	7.7
	Jul/04	6.67	18.2	75.45	335	<5	25.0	6.90	1.08	2.60	2.43	<4	15.0	<9	39.6	8.6
	Sep/04	7.92	19.5	74.65	412	<5	25.0	7.14	1.02	2.64	2.46	3.13	15.4	5.05	28.5	8.7
	Nov/04	7.31	20.7	73.90	365	<5	26.5	1.26	0.44	0.35	1.22	38.2	9.49	12.3	4.72	4.7
P3	Jan/04	7.21	18.7	69.50	420	<5	29.0	5.65	0.93	2.30	3.63	3.35	29.6	<9	13.6	<0.1
	Mar/04	6.65	18.6	73.55	488	<5	22.8	6.70	1.00	3.17	3.38	7.97	31.5	<9	12.9	15.2
	May/04	6.61	18.4	69.83	517	<5	<5	6.23	1.07	2.92	2.75	5.83	32.4	<9	12.1	13.2
	Jul/04	6.55	18.1	75.75	414	<5	<5	5.65	1.04	2.78	2.73	<4	27.2	<9	25.3	14.3
	Sep/04	6.53	19.0	64.88	400	<5	15.2	5.46	0.99	2.72	2.73	3.83	31.6	<9	22.2	13.8
	Nov/04	6.73	20.4	61.13	408	<5	9.0	6.60	1.12	2.93	3.58	4.49	30.3	<9	13.2	16.4
P4	Jan/04	7.00	19.2	135.7	420	<5	224	8.36	2.02	3.66	11.9	30.4	29.5	<9	12.7	<0.1
	Mar/04	6.92	19.2	125.0	495	<5	126	8.97	1.74	3.60	9.53	27.8	38.6	<9	11.5	35.0
	May/04	6.42	18.6	123.0	532	<5	68.0	9.39	1.84	3.75	6.79	7.41	57.3	<9	14.6	26.2
	Jul/04	5.93	18.4	126.5	408	<5	17.0	9.47	1.85	3.90	6.30	<4	68.0	<9	33.6	25.6
	Sep/04	6.56	18.6	122.7	388	<5	<5	9.93	1.74	3.97	6.06	11.5	71.1	<9	25.9	25.6
	Nov/04	6.87	19.1	127.1	397	<5	27.0	9.44	2.03	3.37	10.7	25.3	30.2	<9	11.3	42.4

do not form a regional water table, assuming a local expression in valleys and depressions. On the other hand, they are very important in the recharge of the subjacent-fissured rocks, because they act as a catchment for rainwater throughout the permeable (or semi-permeable) surface, reducing losses by runoff, minimizing evaporation and contributing to the underground storage in the basin.

Aquifers in Itabiritic rocks This aquifer system is represented by the Itabira Group, divided into the Cauê and Gandarela Formations and composed of chemical sediments. These rocks occur north of Ouro Preto city and the Veloso ridge. The Cauê Formation is constituted by finely-laminated itabirite, composed of alternating bands of granular quartz and iron ore (hematite, magnetite and martite), and dolomitic itabirite, where quartz is usually substituted for dolomite (Carvalho 1994). From the hydrogeologic point of view, this formation plays an important role, due to its good porosity and permeability, thick network of fractures, micro-fractures and foliation planes, conferring characteristics for a granular or granular-fractured aquifer. The thickness of the Cauê Itabirite can reach 200 m in the study area, according to available information and sections (Dorr 1969). The Gandarela Formation is composed of dolomitic and calcitic layers with marble, dolomitic phyllite and dolomitic iron formations.

Fractured medium

These are local, discontinuous, free and semi-confined aquifers, restricted to joints and fractures, being covered by deposits and undivided Tertiary-Quaternary detrital covers. The groundwater circulation takes place in a network of fractures, joints, diaclases and discontinuities associated with weathering mantles, constituting a free aquifer system where the topography is the main factor responsible for water circulation. The superficial drainage network and rainwater are the major contributors for the aquifer recharge, being more efficient in areas where the structural control of the drainage is by means of fractures, allowing a continuous recharge.

Aquifers in schistose rocks

These are represented by the Nova Lima Group and Fecho do Funil, Barreiro and Sabará Formations. The Fecho do Funil Formation is composed of dolomitic phyllite, phyllite, and impure dolomite. The Barreiro Formation is dominantly constituted by phyllite and graphitic phyllite. The Sabará Formation is composed of mica- and chlorite-schists with greywacke and sub-greywacke intercalations. A basal conglomerate with rounded pebbles and blocks of granite and dolomite with a phyllite or chlorite-schist matrix is reported in the area.

The Nova Lima Group, cropping out north of Ouro Preto, presents a great diversity of rock types, of which the most conspicuous are: chlorite-phyllite and schist, quartz-chlorite and quartz-chlorite-sericite phyllite, and sericitic schist and quartzite.

Aquifers in quartzitic rocks

These aquifers are represented by rock formations predominantly constituted by quartzites, encompassing the Moeda and Cercadinho Formations of the Minas Supergroup and the Itacolomi Group. The Moeda Formation constitutes the basal unit of the Minas Supergroup and is separated from the Rio das Velhas Supergroup by an angular and erosional unconformity. It is in normal contact with the Upper Batatal Formation (Dorr 1969). A coarse-grained (quartzite, conglomerate and phyllite) and a fine-grained (phyllite) facies, both essentially quartz-rich, constitute the Moeda Formation. The Cercadinho Formation is formed by ferruginous quartzite, quartzite and phyllite. The Itacolomi Group is constituted predominantly by conglomeratic quartzite with conglomerate lenses.

Materials and methods

From the various superficial and groundwater catchments that supply the Ouro Preto city population, 17 sampling points (SP) were chosen for this study. Samples of the natural superficial and groundwater were collected throughout 2004, in six sampling campaigns, i.e. January, March, May, July, September and November. In each collecting point, in situ measurements of pH, Eh, temperature, total dissolved solids and electric conductivity were taken.

Two samples of filtered water were collected by means of a 0.45 μm cellulose acetate membrane (Milipore®), acidulated with 0.2% HNO_3 P.A., kept under refrigeration at 4°C, for cation analysis by ICP-OES. Other non-filtered water samples, acidulated with 0.2% HCl were collected for the analysis of As speciation and analyzed immediately after sampling. Since the time interval between sampling and analysis of the As speciation is fundamental, the maximum interval between both procedures was 6 h (Borba 2002).

The analysis method for As speciation was by square wave voltammetry The experiments were carried out using a Metrohm polarograph, model 757 VA Computrace, equipped with a working el dropping mercury electrode, a

reference electrode Ag/AgCl/KCl 3 mol L^{-1} and an auxiliary platinum electrode.

The reagents used were all of P.A. purity (Merck). The conductivity of the ultrapurified water used was of the order of 0.05 μS. The standard solutions of 5–500 μg L^{-1} in As(III) and 2.5–150 μg L^{-1} in As(V) were obtained from a storage solution containing 1,000 mg L^{-1} of the respective species. The support medium was HCl 1 mol L^{-1} and 45 mg L^{-1} Cu(II) for As (III) or 400 mg L^{-1} Cu(II) for As(V). Since As(V) is not polarographically active, it was reduced (before each measurement) to As(III) by adding 500 μL of a 0.032 mol L^{-1} sodium thiosulfate solution to 25 mL of the standard solution or natural sample, as suggested by Ferreira and Barros (2002). The room temperature was kept around 22°C.

Each measurement was carried out three times, using potential stripping from –0.50 to –0.90 volts, with square wave pulses. Before each stripping, a stage of superficial deposition of an As compound, which effectively is the electroactive species, was performed according to Li and Smart (1996). This stage lasted for 3 min, under agitation. After each deposition stage followed a rest time (equilibrium time), and the potential stripping was carried out without the agitation.

Results and discussions

Arsenic was detected only in four localities (Fig. 1a), As(V) was found in concentrations varying between 9 and 224 μg L^{-1} while As(III) was not detected in any of the water samples analyzed. Samples that yielded As concentrations unsuitable for human consumption corresponded to sampling points P1 (Mina do Chiquinho), P2 (Chafariz – Rua do Barão), P3 (Piedade-Tassara) and P4 (Biquinha da Rua Santa Rita—Mina Velha).

The direct and close relation between the pluviometric regime and As(V) concentration values observed in these four points, is shown in Fig. 2. In all these points, the curves that represent rainfall indexes (2a) and As(V) concentration values (2b) show the same trend, i.e., in periods of higher rainfall, from December to March, higher As(V) concentration values are found in the waters analyzed. On the other hand, from June to September (acute period of dryness), the lowest values of As(V) concentration were found and at points P1 and P3, no As was detected. For all points where As(V) was detected, the maximum and minimum As contents coincided with the maximum and minimum rainfall indexes. The leaching process is demonstrated by the presence of Na, K, Ca, Mg, Al, Ba and Sr in the water, probably associated to the weathering of minerals.

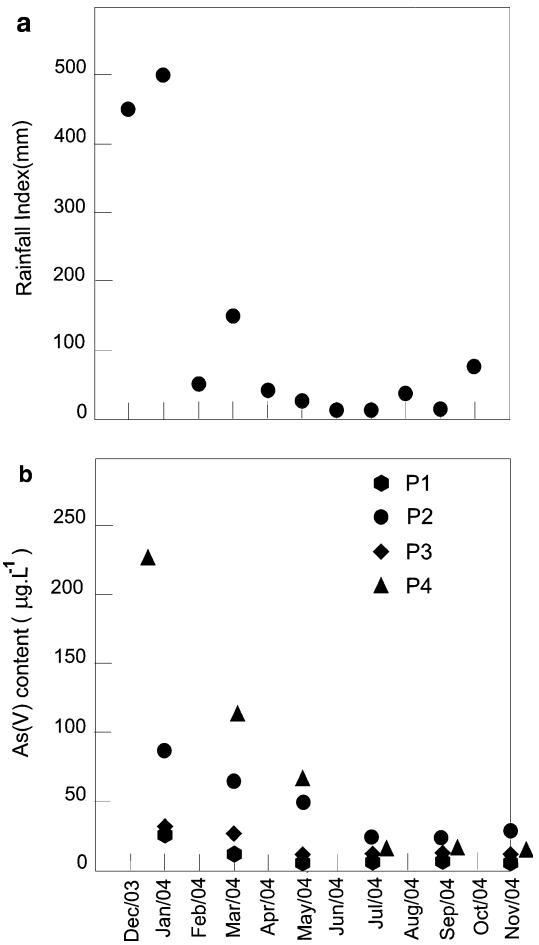

Fig. 2 **a** Graphic representation of the rainfall index of Ouro Preto, and **b** As(V)content in the waters, covering the period from December 2003 and November 2004

Two hydrogeochemical conditions can lead to variations in the quality of the waters (Rose et al. 1991): (1) lowering of water levels after the rainy season initializes oxidation processes in the aquifer systems and (2) in the rainy periods, the salts formed in the oxidation zones during the dry period are dissolved and transported.

In addition to the climatic conditions and operating concomitantly, the trajectory of the rainfall, both by superficial runoff and infiltrated waters, finds, in the geomorphology and in the abrupt relief of the area (Fig. 1b), the proper conditions for rapid flows, enabling interactions between water and rock, causing dissolution and transport of higher quantities of substances and elements.

The existing aquifer systems also contribute significantly to the dissolution and liberation of As to the environment. Phyllites and ferruginous quatzites, Cercadinho Formation rocks (fractured aquifer), and mainly the Cauê Formation itabirites and dolomitic itabirites, Gandarela Formation dolomitic phyllites and dolomitic iron formations, schistose rocks (granular-fractured aquifer) present

good porosity and permeability conditions, a dense network of fractures, micro-fractures and foliation planes. In these formations, which correspond to the points where As was detected in groundwater, oxidized sulfide minerals and secondary minerals are exposed in the surface.

The oxidation of sulfide mineral bodies starts with the reduction of water inflow at the end of the rainy period, extending throughout the dry period, producing a considerable amount of soluble salts. These first reactions occur mainly in the recharge areas of the groundwater and slopes, where the weathering processes in the non-saturated zone, rich in free O_2, cause the oxidation of sulfide minerals, in special arsenopyrite. The arsenopyrite oxidation reaction, according to Plumlee (1999) is

$$\mathrm{FeAsS} + 3.25\mathrm{O_2} + 1.5\mathrm{H_2O} \rightarrow \mathrm{Fe^{2+}} + 2\mathrm{H^+} + \mathrm{HAsO_4^{2-}} + \mathrm{SO_4^{2-}}.$$

Under these acid conditions, As is highly mobile (Mok et al. 1988), being released from the mineralized rocks by means of inorganic or biotic processes (Nordstron and Southam 1997). Bacterial oxidation of arsenopyrite is 2.5 times more intense than abiotic oxidation, due to the transformation of Fe^{2+} in Fe^{3+} by catalyzing processes.

In experiments involving the inorganic and biotic oxidation of arsenopyrite, Richardson and Vaughan (1989), Nesbitt et al. (1995), and McGuire et al. (2001) observed the formation of a superficial oxidized layer, where As(III) and As(V) oxyanions, iron and sulfur arsenate and Fe^{3+} oxides were found. From these As oxyanions, arsenic acid—H_3AsO_4 and its deprotonated species ($H_2AsO_4^-$, $HAsO_4^{2-}$, AsO_4^{3-}), and arsenious acid—H_3AsO_3 and its deprotonated species ($H_2AsO_3^-$, $HAsO_3^{2-}$, AsO_3^{3-}) originate. From the oxidation of arsenopyrite, it is possible that most of the arsenate comes from scorodite ($FeAsO_4.H_2O$), a secondary mineral formed by weathering, according to Alpers et al. (1994). Borba (2002) attributes the presence of As in the groundwater, some Ouro Preto mines and in the Passagem de Mariana mine, to this mineral and to its incongruent dissolution, due to the pH increase. In the Zimapám Valley in Mexico, Armienta et al. (2001) report groundwater contamination by As resulting from the oxidation of arsenopyrite and dissolution of the scorodite present in sulfide mineralizations hosted by carbonaceous rocks.

Conclusions

The method used allows a quick quantification of the inorganic species As(III) and As(V) in natural waters at a relatively low cost and with high sensitivity. Contents above 5 μg L^{-1} can be easily determined, covering an ample range of concentrations. The answers for real sample analyses are perfectly similar to those of the standards, with no detrimental interference from the matrices.

A characteristic of the areas in which groundwater presents a high As content in relation to the permitted human consumption values, is the degree of spatial variability of As concentrations (Smedley et al. 2001). Thus, to predict the As concentration in a spring, well or mine from the results found in the neighboring springs or wells may be difficult or impossible. Aquifers contaminated by As may be restricted to certain environments, show an erratic spatial behavior and seem to be the exception rather than the rule.

The variations in As concentrations in the study area groundwater, during a year-long period, are seasonal. In the dry season, the lowering of the water level in the aquifers favors oxidation of sulfide minerals. In the rainy season, these minerals will dissolve, mobilizing and leaching As (Banks et al. 1997, Freeze and Cherry 1979) to the environment, increasing As concentrations in the groundwater, at the same time that the original concentrations are diluted. The As concentration values found in the water samples are representative of the time of sampling and the season, varying to higher or lower values along time.

Due to the presence of As in groundwater used by the population of some neighborhoods of Ouro Preto city, measures must be taken by the municipal agencies responsible for the water supply. An effective and efficient water supply system must contemplate the identification and characterization of contaminated areas, an inventory of all water catchments, and the preparation of a control system that includes a constant monitoring plan of these waters.

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