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THE POLLUTION IMPACT ON THE WATER, SOIL AND PLANT GENERATED BY FOUNDRIES IN PIRAPORA AND VARZEÁ DA PALMA, MINAS GERAIS STATE, BRAZIL

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Abstract: The foundries in the Pirapora and Varzea da Palma produce a large smoke charged with particles. These particles disperse in the area causing water, soil and plants pollution and human health problems. The collected filter samples were analyzed using XRD, ICP-OES, ICP-MS, optical microscope, environmental SEM and microprobe. The particles from Inonibras foundry compared to Hiasa foundry are rich in Ba, Rb, As, V, Zn, Pb, Cu, Mo and Ni. The smoke contains the particles of composition (clay, magnetite, silicate, amorphous SiO_2), shapes and sizes are very various. The spherical particles of black smoke form an agglomerate rich in Fe and Si.

Keywords: dust, melting processes, Fe-Si industry, metal sources, contamination, human activities

1. INTRODUCTION

The Pirapora - Varzéa da Palma region in Central to Northern Minas Gerais State, Brazil (Fig. 1), use the processes of high temperature furnace processes in the production of metallic Si and Si-Fe leagues, starting from diversified raw materials cause, among other problems, the liberation of fine dusts which are built up by parts of these compounds and their cracked products (Borghetti et al., 2003, 2006, Santos et al., 2011, Horn et al., 2006, Horn et al., 2009).

Due to the high degree of distribution (smoke, dust), the surface-volume relation and the chemical activity caused by the particle size and its composition (Fig. 2 and 3), they may have adverse impacts on health of people and animals, the quality and quantity of agricultural products in the surrounding areas (Fig. 4) and drastic changes in the aquatic and irrigation systems. This influence can happen following two different ways:

- Direct deposition on plants and creatures causing a direct chemical interaction;
- Through the deposition on soil and water surface with the indirect entrance into the bio-cycles.

Dust and soil samples studied in this work come from the surroundings of these foundries.

2. METHODS AND MATERIALS

The raw materials used in these processes are barite, crushed vein quartz, argillite, charcoal and wood for the Si production together with scrap materials (Fig. 5).

Particulate matter in smoke display spherical C-compounds (μm), chromium-spinel balls (μm), irregular amorphous and crystalline SiO_2-agglomerates and rare well-formed magnetite, SiO_2 and Si crystals. The particle shapes are irregular to

spherical. Grain size varies from tenths of a micrometer to <1 millimetre.

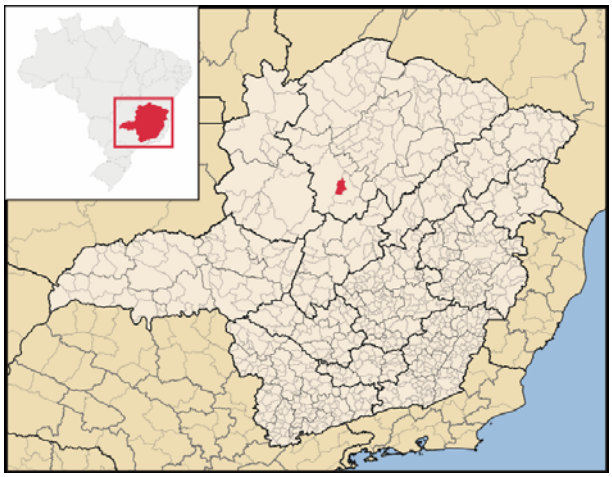

Figure 1. Location of Si and Si-Fe foundries in the Pirapora - Varzéa da Palma region (Minas Gerais state, Brazil).

Figure 2. The smaller satelite fotograph (google map) show a detailed view of Pirapora Si-plant and the smoke evolution.

Industrial process used by the foundries. The raw material explains the variety of PPE´s and nature of particles. At all stages occur liberation of contaminants, especially in the oven step (smoke, ashes), casting processes and grinding processes (dust, contaminated water).

Together with the natural air dust (clays, oxides and quartz may occur secondary reactions. The plumes show transport distances of up to 50km with changing flux conditions due to temperature (inversion) and wind direction changes. The preferential transport directions are (NE to SSW 50%, NW - SW 15% and N - S 35%).

Figure 3**.** Overview of the industrial sites with smoke plumes and indicating the principal wind direction. Up: Pirapora and down: Varzeá da Palma.

Figure 4. Examples of plant exposition to the smoke. We can show the high density of particles.

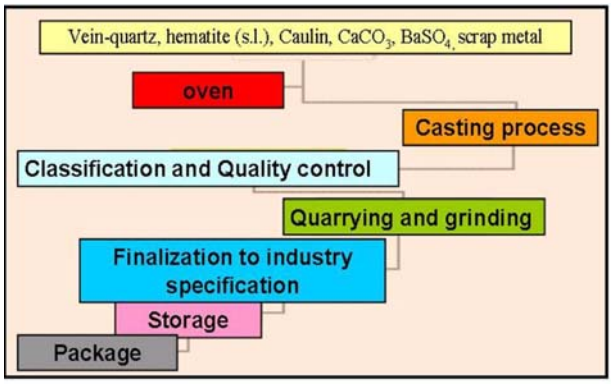

Figure 5**.** Electrothermal process used at the foundries. The raw material (scrap; industrial metallic residual) explain the variety of PDE's and dangerous particles. At all stages, liberation of contaminants occurs, especially in the oven step (smoke, ashes), casting processes and grinding processes (dust, contaminated water).

On the samples were executed grain-size measurements, XRD, optical microscope, environmental SEM and microprobe. ICP-OES and ICP-MS analyses of the primary dust composition to obtain information about mineralogical, granulometric and chemical investigations (total composition; leaching tests).

This shows the hazardous potential of the smoke and its danger for plants and soils in the concerned area. Investigation performed in the laboratory about the bio-leaching of the particulate matter in smoke and leaching tests point out direct and chronic dangers by direct plant-dust and dust-soil-plant contacts.

Were performed regular air dust samples collection over three years in varias direction and distances from the sourses (Fig. 1). The sampling substrates are collant foils which were exposed to polution over a period of 1 to 4 weeks (Figs. 6.1-2), in function of dust density and than send to laboratory.

Collection of bigger dust samples were realized directly from chimney stocking filters. In some special places were executed analyses with a portable Laser equipment to obtain informations of the very small particles particulate matter 5µm and 2.5µm (PM5, 2.5) and smaller. Were executed different activities with collected the samples:

- Granulometric evaluation with Laser Scattering Particle Size Distribution Analyzer LA-950and counting facility using graphic programs.
- Whole sample chemistry by Inductively Coupled Plasma Mass Spectrometry (ICP-MS)
- Microscopic identification of types, form and structure of dust grains by petrographic microscope, analyses in profiles over different dust grains with a CAMECA microprobe.
- Statistical study about different data.

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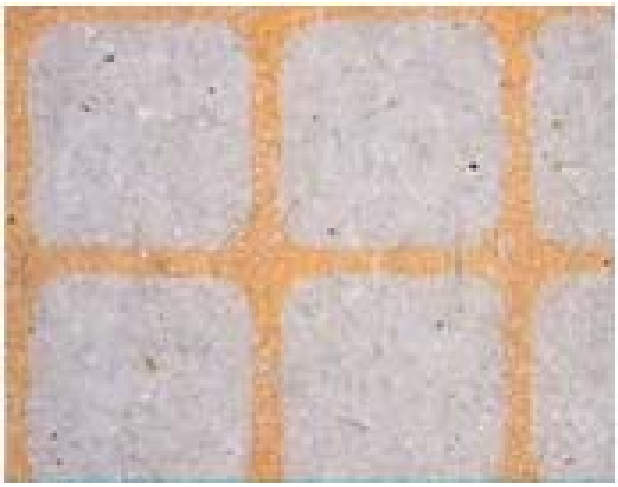

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Figure 6. This figure shows the used equipment for measuring dust distribution. 1: portable laser equipment; 2: Foil Dust collector; 3: Counting facility with a weak dust sample.

3. RESULTS AND DISCUSSIONS

We differentiate two types of smoke according to sources from. The chemical study (Table 1) of the particles show clearly that the IB Inonibras sector compared to Hiasa sector is rich in elements Ba (2236-2981ppm), Rb (44ppm), Zr (10-15ppm), As (5-7 ppm), V (36-42 ppm), Zn (96-103 ppm), Pb (17-23ppm), Cu (18-40 ppm), Mo (4-9 ppm) and Ni (5-6 ppm).

Table 1**.** Chemical composition of the two distinct dust composition obtained in direct collected powder arounding Hiasa (HI) and Inonibras (IB) plants.

Sector	HI	IB1	IB2	LD
Ba	3	2235	2981	1
Co	0.6	13	18	0.2
Cs	0.2	1.6	1.7	0.1
Ga	2.6	5.8	8.7	0.5
Hf	<	0.4	0.4	0.1
Nb	0.2	1.2	0.9	0.1
Rb	3.6	43.6	44.3	1
Sn	<	4	12	1
Sr	14.2	<	<	0.5
Th	<	0.2	0.2	0.2
V	49	42	33	8
W	<	0.7	0.6	0.5
Zr	2.1	9.5	15.2	0.1
Y	<	0.3	0.7	0.1
La	0.3	1.6	2.5	0.1
Ce	0.6	19	41	0.1
Pr	0.02	0.15	0.33	0.02
Nd	<	0.5	0.7	0.3
Sm	<	0.09	0.12	0.05
Eu	<	0.02	0.02	0.02
Gd	<	0.06	0.17	0.05
Tb	<	0.01	0.02	0.01
Dy	<	0.14	0.14	0.05
Ho	<	0.02	0.03	0.02
Er	0.06	0.07	0.10	0.03
Yb	<	0.12	0.12	0.05
Mo	0.2	9.4	4.1	0.1
Cu	2.8	18.2	40.3	0.1
Pb	3.1	17.0	22.6	0.1
Zn	391	130	96	1
Ni	1	5.9	4.6	0.1
As	<	5.4	7.1	0.5
Cd	<	0.2	0.2	0.1
Sb	0.2	1.2	1.3	0.1
Bi	<	0.5	0.6	0.1

A wide range of granulometric distribution from µm down to nm (Fig. 7) causing physical and chemical effects (Guthrie et al., 1993, Falkovich et al., 2001). The DRX diagrams show (Fig. 8) the different cristallinity degree and mineral composition of the two samples.

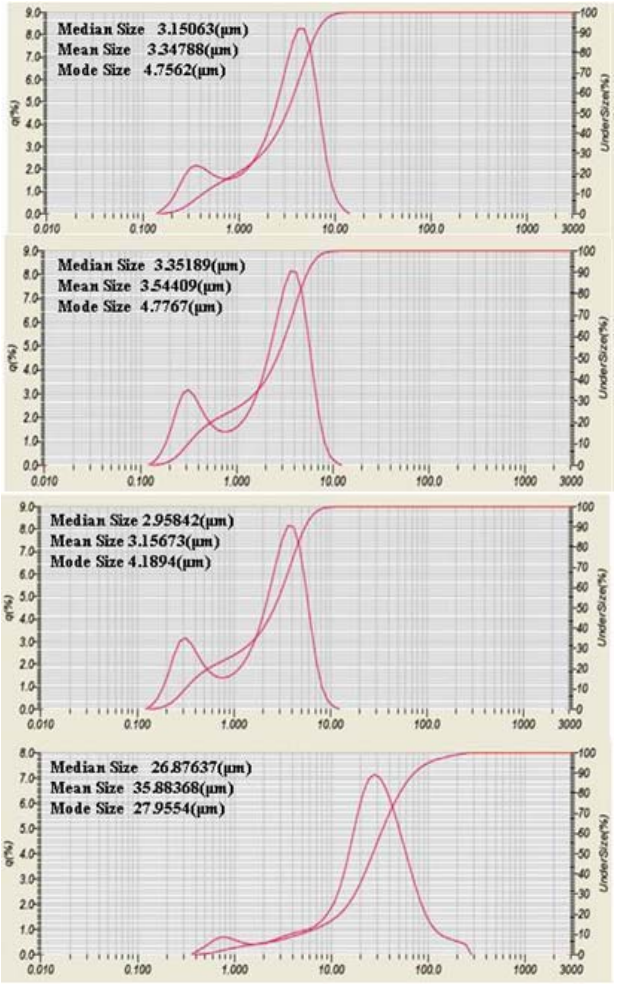


Figure 7**.** Grain size distribution of the two smokes types with basic statistical distribution data. The up and down 1, 2, 3 and 4.

The amorphous SiO_2 rich smoke has a more homogeneous distribution than the "black" Fe_3O_4 and SiO_2 rich smoke. Figure 8 represents DRX diagrams of the two dust type, showing a clear correlation between distance from source and particle distribution in size, quantity and composition (relation between industrial and surface related particles).

Distribution of PDE´s in soil surface is determined by industrial production peaks, rainfall quantity, and sunshine intensity and by various wind directions (Fig. 9).

A wide variety of grain composition and textures can be seen in figures 10-11. The granulometric variety permits a wide range of physical and chemical activities from macroscopic to submicroscopic scale. An important factor is the substrate function of this amorphous SiO_2, Al_2O_3 and Fe-oxides rich particles.

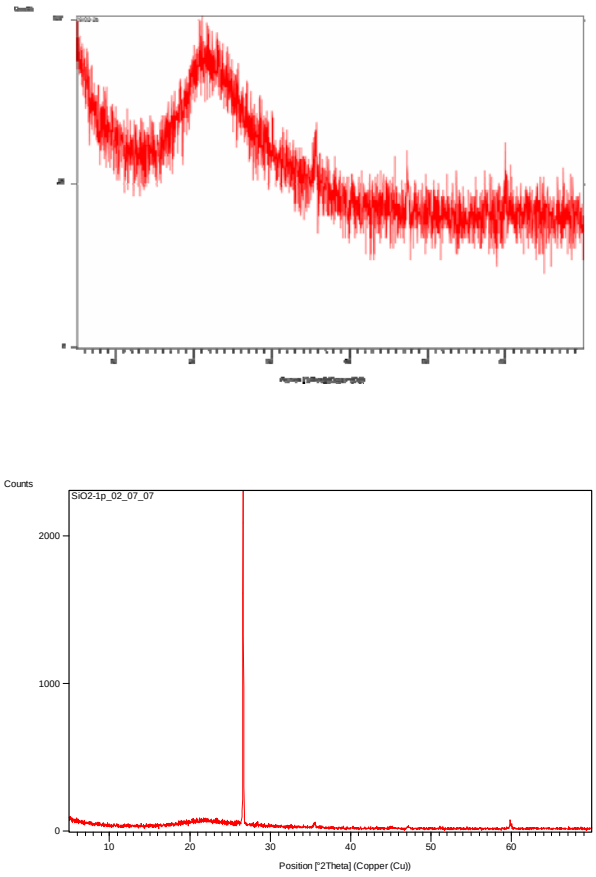


Figure 8. DRX diagrams of the two dust types from Hiasa and Inonibras sector.

It exist a great variety in size, form and composition. The Particles (from nm to 100 µm) are represented:

1. Clay material together with amorphous SiO_2;
2. Agglomerate of SiO_2 particles together with C-compounds;
3. Irregular particle compounds by SiO_2, clay, barite and Fe-oxides;
4. Fine particles of principal amorphous SiO_2 from white smoke;
5. Principally amorphous SiO_2 from dark smoke, together with very small magnetite particles;
6. Founded Si and Si-C particles together with other C-compounds;
7. Crystalline Magnetite and silicate particles;
8. Smaller agglomerate of SiO_2, Si, clay and C-compounds;
9. Si-Al plates with smaller aggregated SiO_2 balls;
10. Irregular sphere of smaller SiO_2 (more amorphous and less crystal particles), C-Si-Al-Fe-compounds; barite and clay crystals.

4. CONCLUSION

The foundries in the Varzea da Palma region produce a large smoke charged with particles. These particles disperse in the area causing water, soil and plants pollution and human health problems (skin, lung, eyes or allergic reactions is function of the smoke impact over the town- or countryside). The particles from Inonibras foundry compared to Hiasa foundry are rich in Ba, Rb, As, V, Zn, Pb, Cu, Mo and Ni. The smoke contains the particles of composition (clay, magnetite, silicate, amorphous SiO_2), shapes and sizes are very various.

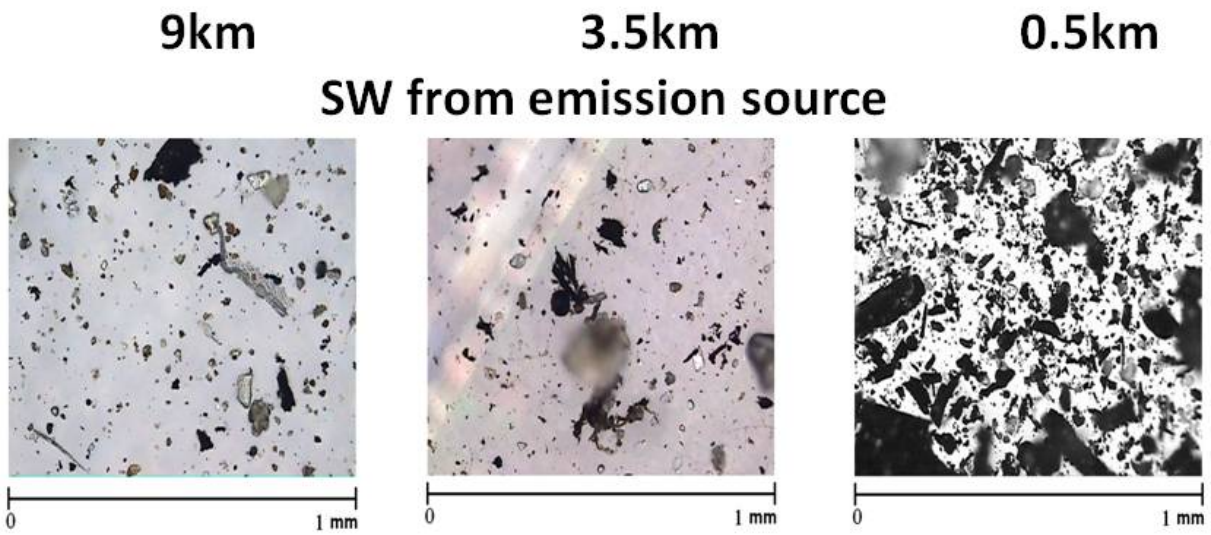


Figure 9. The distribution correlated with distance from the source. The smoke from Pirapora foundry crossing the São Francisco River from right to left in this figure, the density of particle decrease.

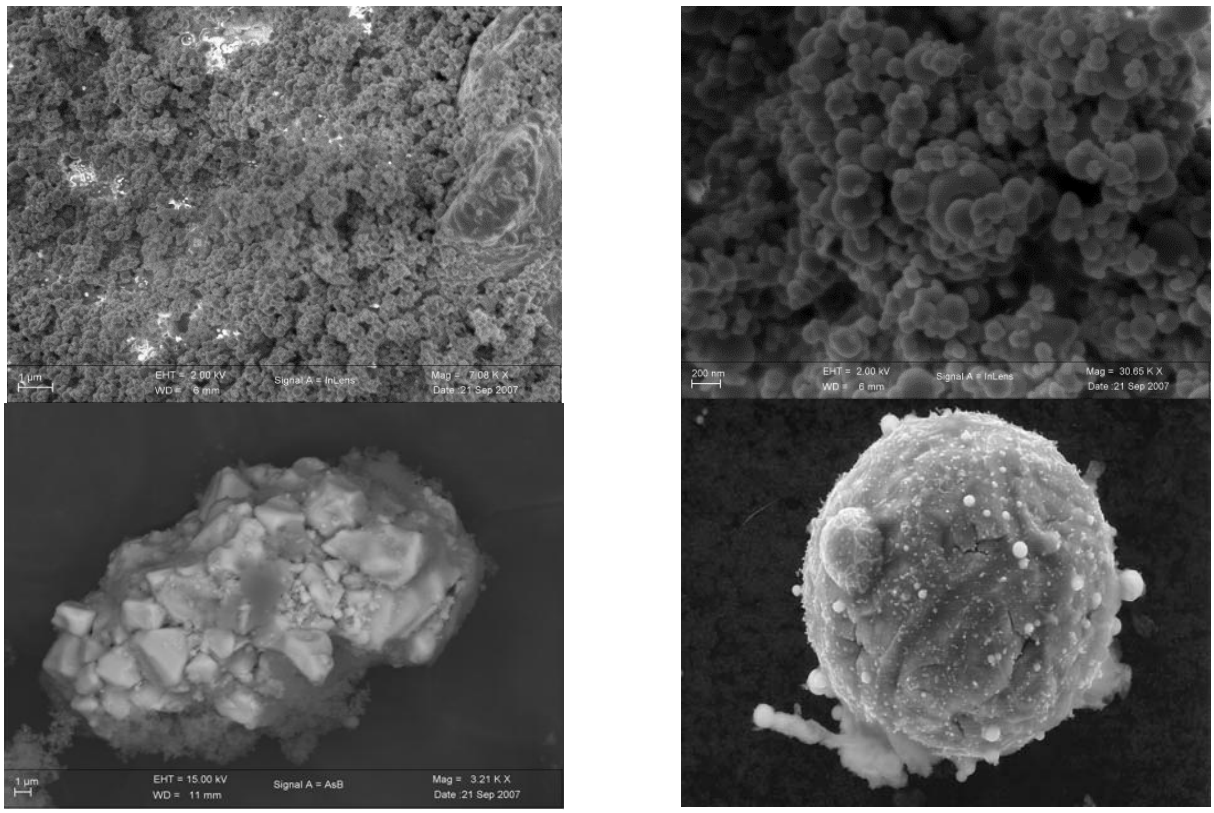
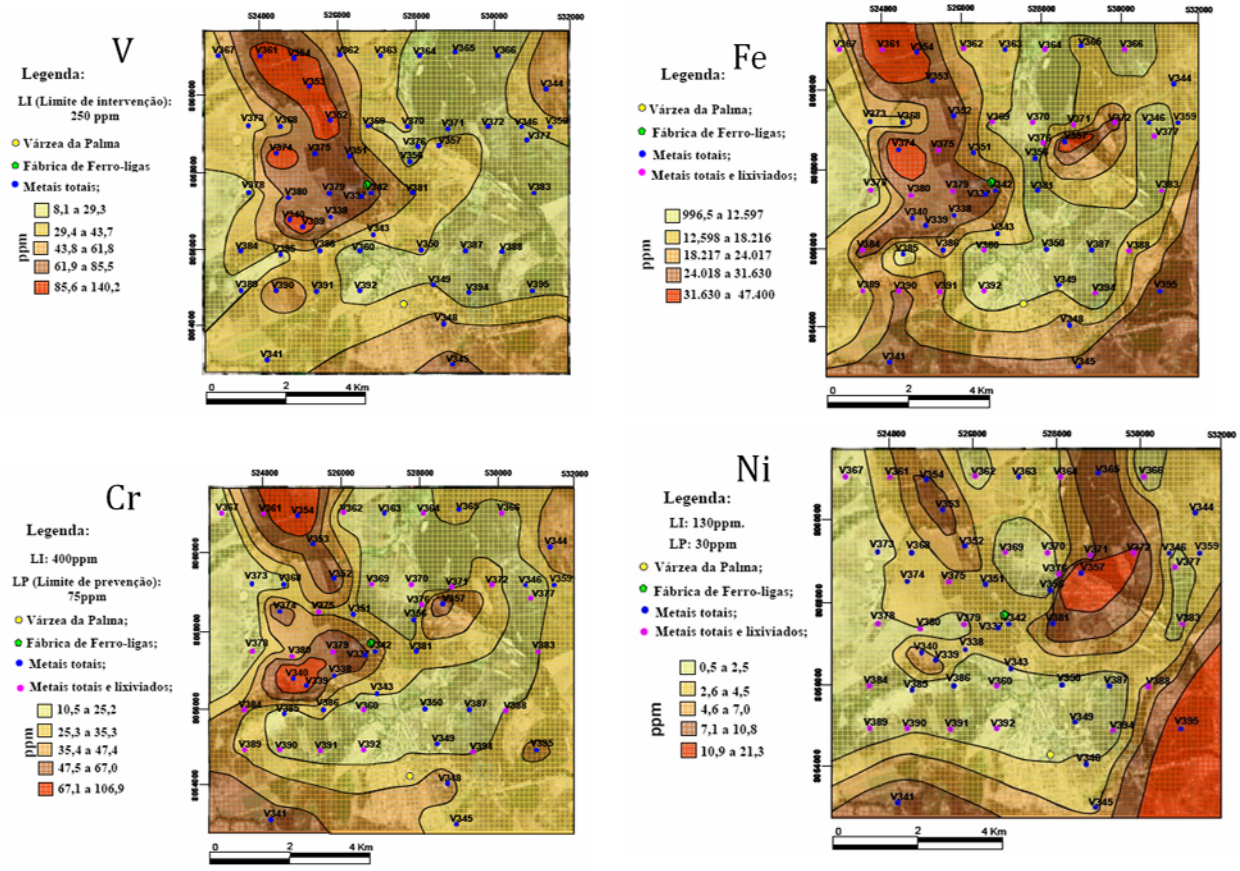


Figure 10**.** The clear smoke particles (left) and the black smoke particles (right). The spherical particle is typical of coal smoke.



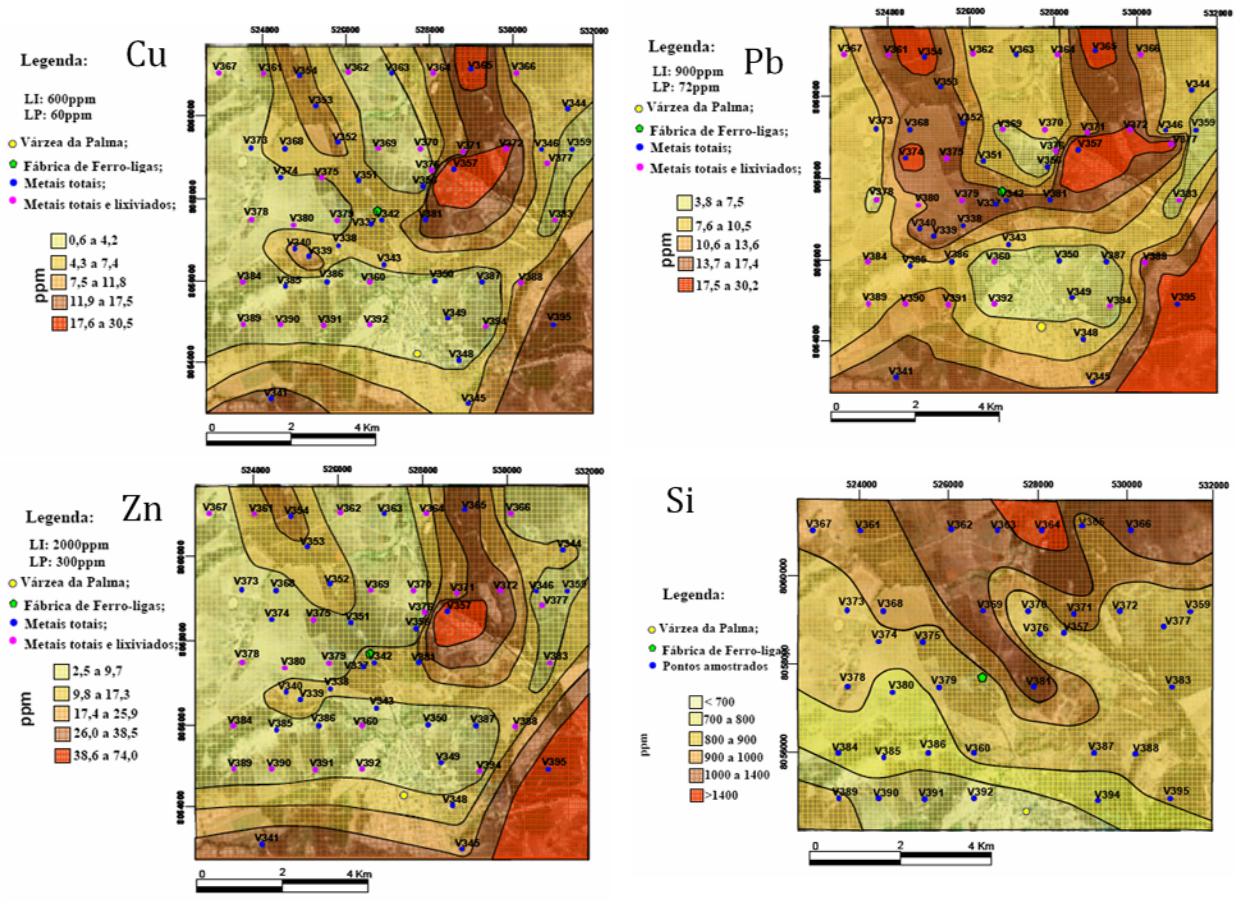


Figure 11. Correlation between selected element concentration in soil, distance and climate factors for the foundry in Várzea da Palma area. There is clearly a higher metal concentration is soil surfaces with direct smoke deposition, especially in ~SW and ~NE directions.

The spherical particles of black smoke form an agglomerate rich in Fe and Si. There is a very strong healthy and visual impact due to the high particle concentration in the air.

5. Agreements

IGC-UFMG gave logistic and FUNDO FUNDEP financial support. Analyses were executed at the NGqA of IGC-UFMG, laboratories of the Universities of Rouen and Marne-la-Vallée, both at France. The granulometric investigations were done by HORIBA, São Paulo, Brazil.

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