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Mineral Dust Environmental Impact in the Region of Pirapora and Várzea da Palma, Minas Gerais: Air, Water, Soil and Plants Pollution

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ABSTRACT: The Pirapora and Várzea da Palma steel industries (Si, Si-Fe) produce a smoke laden with mineral particles. These particles dispersed in the water, soil and plants contaminated, causing pollution and human problems. The samples were analyzed using filter XRD, ICP-OES, ICP-MS, optical microscopy, environment SEM and optical microcopy. The analysis showed that the particles are rich in Ba, Rb, As, V, Zn, Pb, Cu, Mo and Ni. The plume composition contains particles (clay, magnetite, SiO2, amorphous silicate), morphology and dimensions. The spherical particles of black smoke form a rich cluster in Fe and Si.

Keywords: dust, melting processes, Si, Si-Fe industry, contamination, human health.

1. Introduction

The Si and Si-Fe steel industries located in the Pirapora and Várzea da Palma region in central to northern Minas Gerais state, Brazil (FIG. 1 and 2). The municipality of Várzea da Palma and Pirapora located in the northern state of Minas Gerais, the two cities have a total population of 80,000 peoples, the two cities currently have two textile and seven steel industries.The climate seconds Köppem is of type AW (tropical humid), average monthly temperatures in January are around 24 ° C to 23 ° C and in the months of June and July range from 19 º C to 20 º C, the average annual rainfall is around of 1,195 mm, concentrated in the months from November to March. The area researched is regionally located in The São Francisco river hydrographic basin, more specifically in the segment high/medium – course of the river in Minas Gerais State. Geologically and geomorphologically, the basin is located in the southern Sanfranciscana Basin within the limits of the São Francisco Craton - more specifically in the Cretaceous basin of western of Minas Gerais state (SGARBI, 2001). Considering the natural landscape point of view, the area is inserted in the field of interior plains, according to the morpohclimatic division proposed. In phytogeographical classification, the investigated area is inserted in the Savannas – Cerrado/Tropical Campos/Gerais. Within the lithogeomorphic setup defined for the São Francisco river basin, a different pedological cover was developed, due to the influences of original material and landscape. We present below the main classes of land identified for the basin: Latosol Red-Yellow, charged and dystrophic clay in association with Latosol Red dark dystrophic alic, clay texture; Quartzipsamments Neosol; little humic gley dryland usually associated the sub-system Veredas; Neosol dystrophic alic and Neosol Fluvic eutrophic. Monoculture activities were extended from the 90's decade, with the introduction of commercial plantations of soybeans, corn, beans, and more recently coffee (BAGGIO, 2008).

The high temperature processes used to produce Si alloys and Fe-Si, from diverse materials cause, among other problems, the release of fine dust, which consist of parts of these compounds and their of cracking products (BORGHETTI et al., 2003, 2006, Santos et al., 2011, Horn et al., 2006, Horn et al., 2009). (BORGHETTI *et al.*, 2003, 2006, SANTOS *et al.*, 2011, HORN *et al.*, 2006, HORN *et al.*,2009).

Due to the high degree of distribution (dust, smoke), the surface-to-volume ratio and chemical activity caused by particle size and composition (FIG. 3), may cause adverse effects on human health, flora and fauna of the region.. This influence can happen following two different ways: this influence may occur by two different processes:
- dry precipitation directly on dry water bodies, flora and fauna, causing biogeochemical interactions
- through deposition of lint on the surface of soil and water, with the indirect input to biogeochemical cycles. Soil and dust samples studied in this work were collected in nearby industrial plants.

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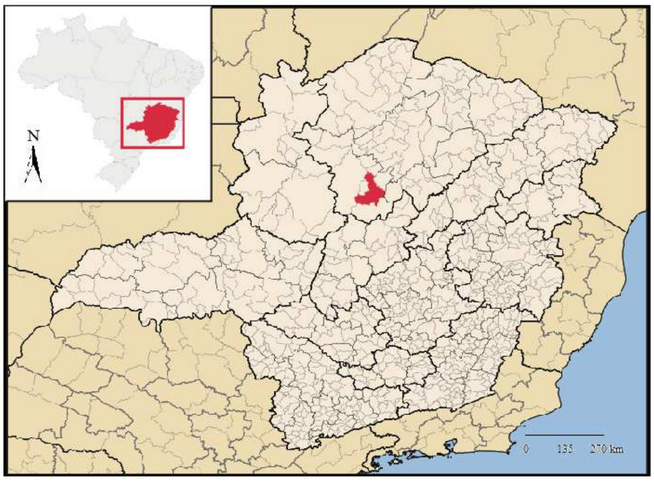

Figure 1. Location of Si and Si-Fe steel in the Pirapora and Várzea da Palma region (Minas Gerais state, Brazil) 17° 35′ 52″ S, 44° 43′ 51″ W-17.597778, -44.730833.

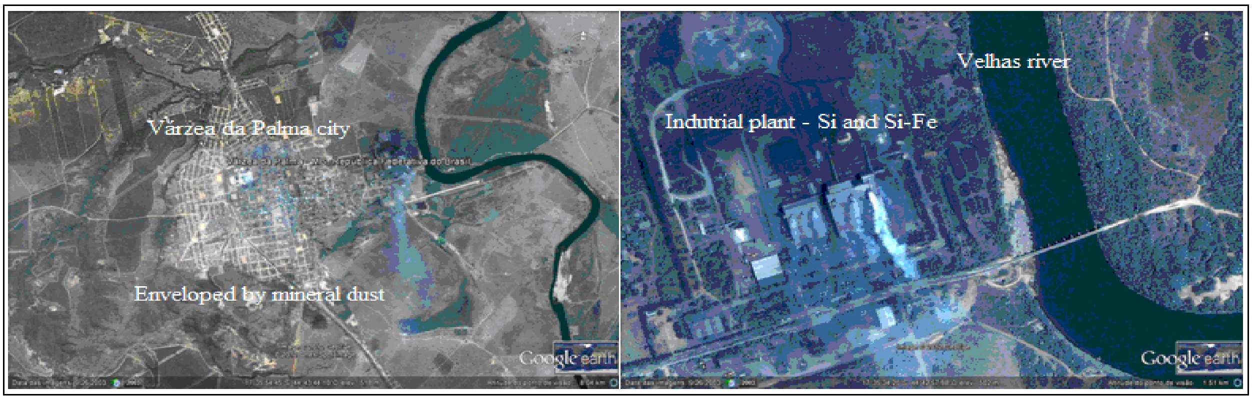

Figure 2. The orbital image shows the industrial plant and the direction of the mineral plume – N-S - 9:00 am – Várzea da Palma.

Figure 3. (a) battery of industrial furnaces, homogeneous laminar flow showing the stability of the plume photo made at 9:00 am (height of plume 4 km), (B) diffuse plume, flow, lapse below and inversion – fumigation, (C) examples of plant exposition to the smoke.

2. Materials and Methods

The raw materials used in the process are: barite, quartz crushed, mudstone, coal and wood chip to produce Si, besides, of scrap metal. (FIG. 4). Particulate matter in smoke display spherical C-compounds (μm), chromium-spinel balls (μm), irregular amorphous and crystalline SiO2-agglomerates and rare well-formed magnetite, SiO2 and Si crystals, the morphology of the particles composed of spherical minerals are spherical and irregular micro-presenting edges, grain size varies from tenths of a micrometer to <1 millimetre. Industrial process used by the foundries. The origin of the raw material explains the range of PPE's and also the composition of the particles. At all stages of the process, the release of contaminants occurs, especially in furnaces (smoke and ash) in casting processes and grinding (dust and contaminated water),together with dust particles natural air secondary reactions may occur. The plumes reach transport distances of about 50 km, influenced by the change in wind direction and temperature (turbulence).The transport directions are preferred (50% SSW NE, NW - SW N and 15% - 35% S). 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).

In all phases, the release of contaminants occurs, especially in the furnace (smoking, ashes) foundry processes and grinding processes (dust and contaminated water). The samples were submitted: the grain size, grain morphology, x-ray diffraction, optical microscopy, scanning electron microscopy and microprobe environment. The samples was opened and dissolved by acid digestion (aqua-regia) and the reading was done with an ICP-OES and ICP-MS. The physical-chemical analyzes of dust is essential to obtain information about their composition, origin etc.This shows the potential risk of smoke and its negative impact on geoenvironments involved. Research performed in the laboratory on bio-leaching of smoke particles and leaching tests indicate direct and chronic hazards by direct contact - plants dust, soil dust and soil plants. Regular collections were made from dust, over three years, and orientation measurements of wind direction and atmospheric mineral plume. For obtainment particulate material, adhesive films were used, which were implanted in locations previously selected. The samplers were exposed to air for a period of 4 weeks, and then switched, this process lasted three years. At the end of the study, samples were collected, identified, packaged and transported to the laboratory. Larger quantities of dust were collected on filters directly from the chimneys. In some places special analyzes were performed with a laser portable to obtain information particles between 5μm and 2.5μm (PM5, 2.5) and smaller than these values.

Were executed different activities with collected the samples:

- evaluation with Laser Scattering Particle size Particle Size Distribution Analyzer LA-950 Installation and count using graphics programs;
- sampling chemistry, acid digestion and by reading metals (ICP-OES and MS);
- microscopic identification, morphology and structure of dust grains made by spectrographic microscope, analysis and profiles, different dust grains for microprobe - CAMECA.

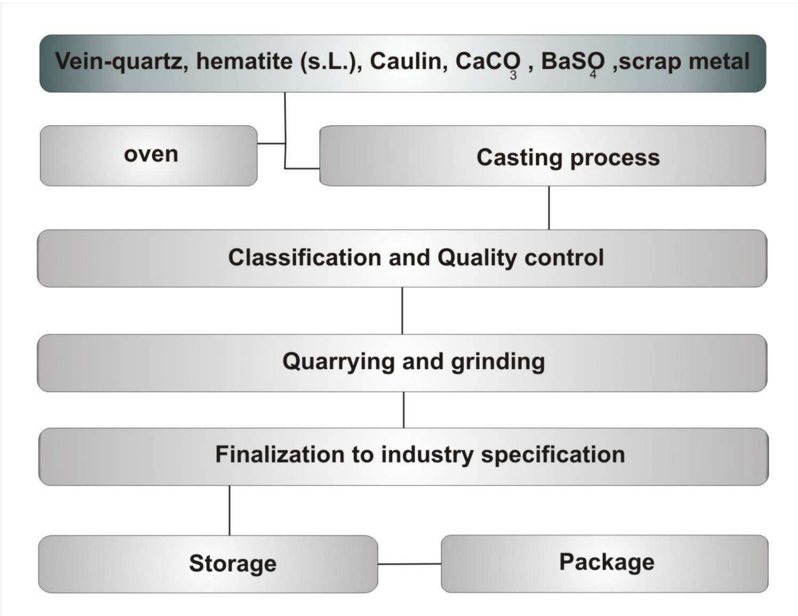

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Figure 4. Eletrotermal schematic showing the process used in foundries. The raw material (scrap metal industry) explains the wide range of PDE and the presence of hazardous particles

3. Results and discussions

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

A wide range of granulometry distribution from A high density of mesh size distribution granulometry from µm down to nm causing physical and chemical effects (GUTHRIE *et al.*, 1993, FALKOVICH *et al.*, 2001). The DRX diagrams show (FIG. 5) the different crystalline degree and mineral composition of the two samples.

The amorphous SiO2 rich smoke has a more homogeneous distribution than the “black” Fe3O4 and SiO2 rich smoke. FIG. 6 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. A wide variety of grain composition and textures can be seen in FIG. 7 and 8. The granulometry 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 SiO2, Al2O3 and Fe-oxides rich particles.

There is a large variety in shape, size and composition. Particles (100 nm one) are represented:

1. clay material together with amorphous SiO2;
2. agglomerate of SiO2 particles together with C-compounds;
3. irregular particle compounds by SiO2, clay, barite and Fe-oxides;
4. fine particles of principal amorphous SiO2 from white smoke;
5. principally amorphous SiO2 from dark smoke, together with very small magnetite particles;
6. Si and Si-C steel, particles together with other C-compounds;
7. crystalline Magnetite and silicate particles;
8. smaller agglomerate of SiO2, Si, clay and C-compounds;
9. Si-Al plates with smaller aggregated SiO2 balls;
10. irregular sphere of smaller SiO2 (more amorphous and less crystal particles), C-Si-Al-Fe-compounds; barite and clay crystals.

Table 1. Chemical composition of the powder obtained in two distinct dust collected directly from Liasa (LI) 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	<0.1	0.4	0.4	<0.1
Nb	0.2	1.2	0.9	<0.1
Rb	3.6	43.6	44.3	1
Sn	<0.1	4	12	1
Sr	14.2	<0.1	<0.1	0.5
Th	<0.1	0.2	0.2	0.2
V	49	42	33	8
W	<0.1	0.7	0.6	0.5
Zr	2.1	9.5	15.2	0.1
Y	<0.1	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	<0.1	0.5	0.7	0.3
Sm	<0.1	0.09	0.12	0.05
Eu	<0.1	0.02	0.02	0.02
Gd	<0.1	0.06	0.17	0.05
Tb	<0.1	0.01	0.02	0.01
Dy	<0.1	0.14	0.14	0.05
Ho	<0.1	0.02	0.03	0.02
Er	0.06	0.07	0.10	0.03
Yb	<0.1	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	<0.1	5.4	7.1	0.5
Cd	<0.1	0.2	0.2	0.1
Sb	0.2	1.2	1.3	0.1
Bi	<0.1	0.5	0.6	0.1

Source: Elaborated by authors.

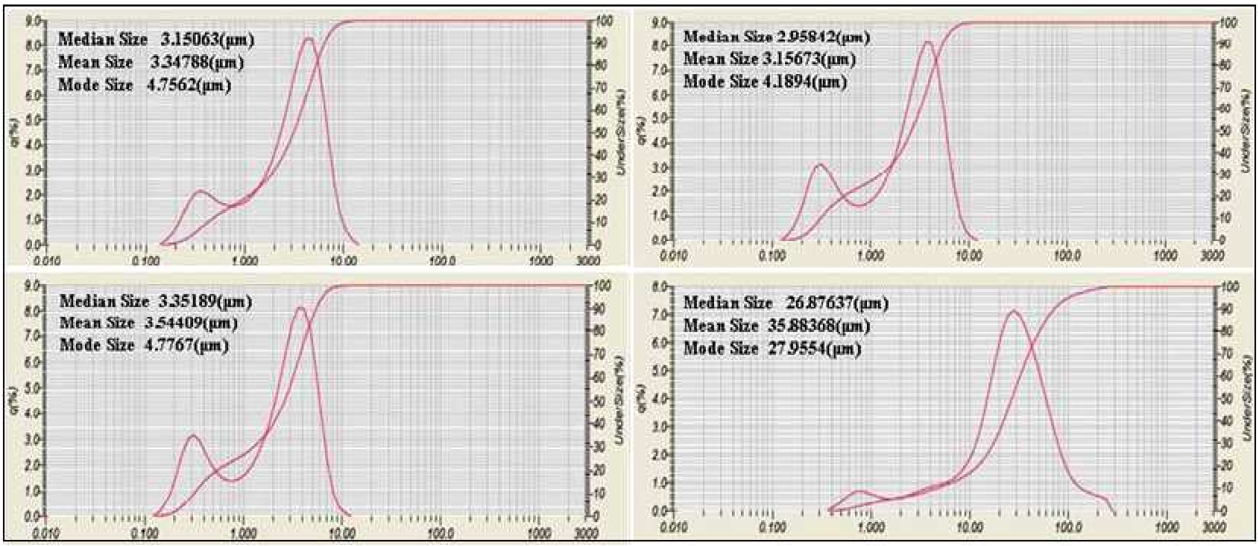

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Figure 5. Grain size distribution of the two smokes types with basic statistical distribution data. The up and down 1, 2, 3 and 4.

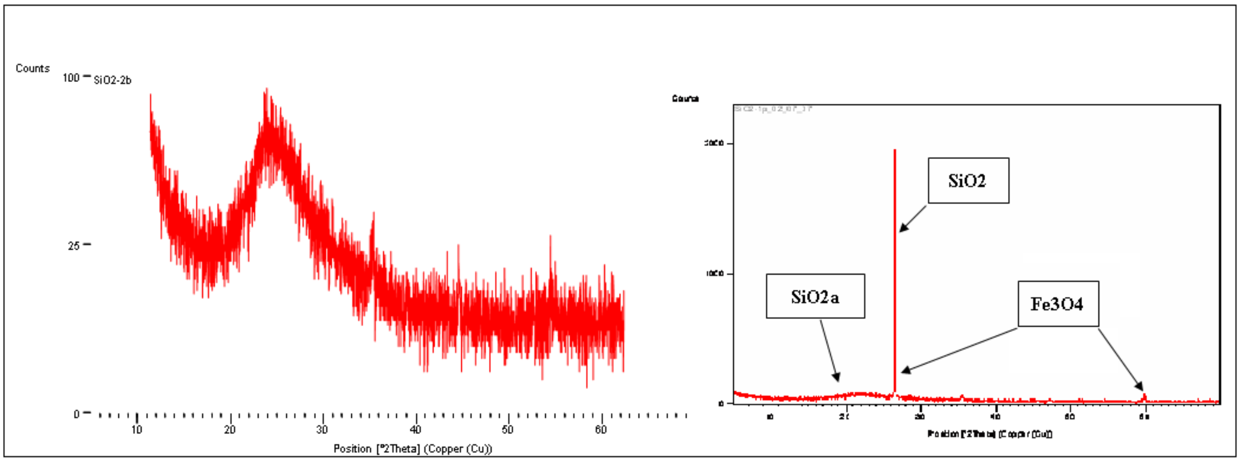

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Figure 6. DRX diagrams of the two dust types from Liasa and Inonibras sector.

4. Conclusion

The industrial plants of Si and Fe-Si located in Palma and Lowland Pirapora produce intense smoke particles loaded with minerals. The precipitation and dispersion of particles in water, soil and plants, create pollution and human health problems (skin, lungs, eyes or allergic reactions) being the main cause, the direct and indirect contact with atmospheric dust mineral.The particles generated by smelting plant Inonibras compared with Liasa casting are rich in Ba, Rb, As, V, Zn, Pb, Cu, Mo and Ni. The smoke composition contains particles (clay, magnetite, SiO2, amorphous silicate), shapes and sizes, are very different.

The spherical particles of black smoke form a rich cluster in Fe and Si was noted negative environmental impacts, environmental systems, flora and fauna and human health due to the high concentration of these particles in the air.

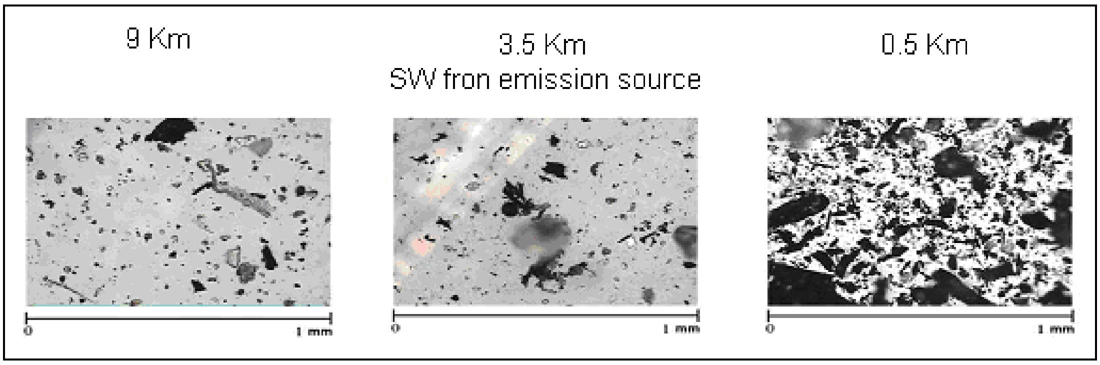

Figure 7. Microphotographs of atmospheric mineral particles, the distribution correlated with distance from the source. The smoke from Pirapora foundry crossing the São Francisco river, from right to left in this figure, the density of particle decrease.

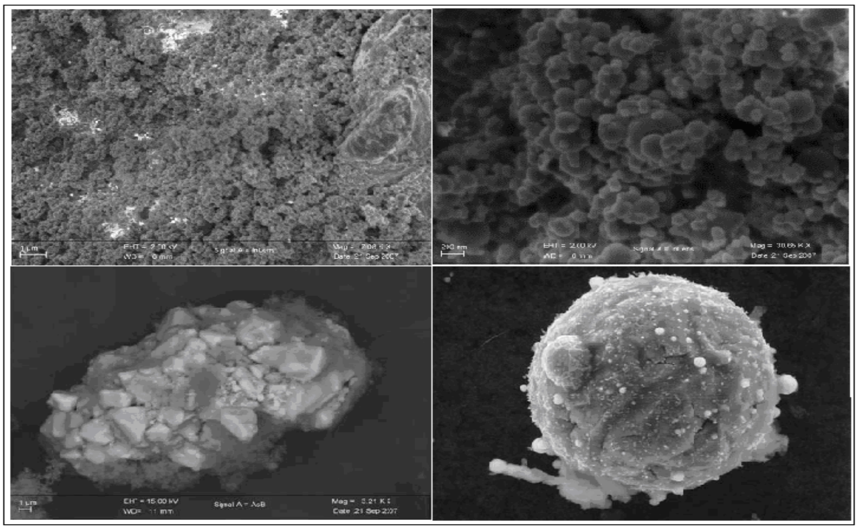

Figure 8. The clear smoke particles (left) and the black smoke particles (right). The spherical particle is typical of coal smoke.

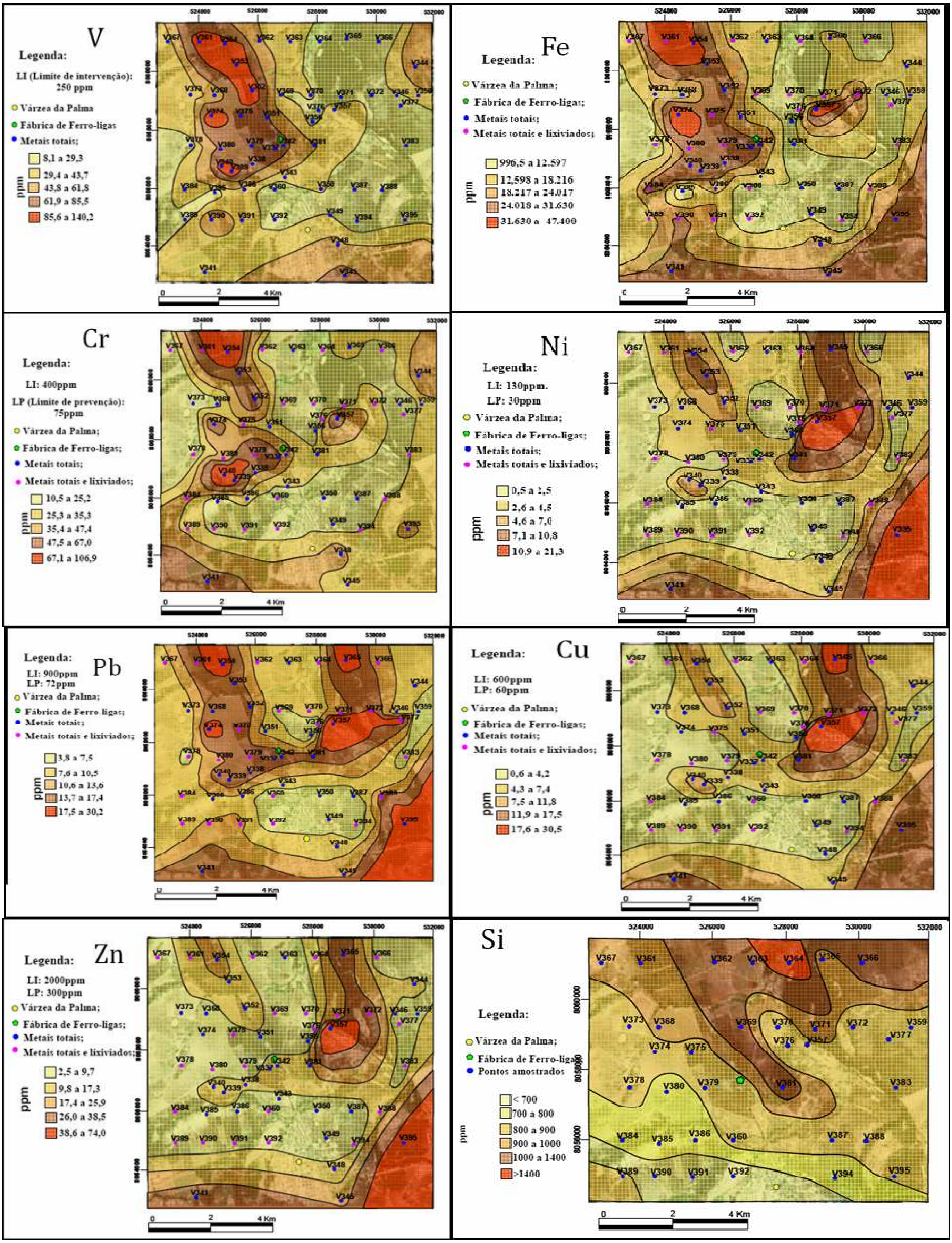

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Figure 9. Correlation between selected element concentration in soil, distance and climate factors for the foundry in Várzea da Palma area. There is clearly a higher metal concentration is soil surfaces with direct smoke deposition, especially in ~SW and ~NE directions.

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Agreements

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Poeira mineral e impacto ambiental na região de Pirapora e Várzea da Palma, Minas Gerais: contaminação do ar, da água, do solo e das plantas.

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Resumo As indústrias siderúrgicas de Pirapora e Várzea da Palma produzem uma fumaça carregada com partículas minerais. Estas partículas dispersas na área cotaminam a água, o solo e as plantas, causando poluição e problemas de saúde humana. As amostras coletadas foram analisadas usando filtro DRX, ICP-OES, ICP-MS, microscópio óptico, ambiental SEM e microssonda. A análise mostrou que as particulas são ricas em Ba, Rb, As, V, Zn, Pb, Cu, Mo e Ni. A pluma contém partículas de composição (argila, magnetite, SiO2, silicato amorfo), morfologia e dimensões variadas. As partículas esféricas de fumaça negra formam um aglomerado rico em Fe e Si.

Palavras-chave poeira, processos metálicos, industrias Si, Si-Fe, contaminação, saúde humana.

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