The persistence of the soil contamination by lead and Cadmium around the city of Santo Amaro da Purificação, Brazil

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ABSTRACT Several studies since 1970 have demonstrated the severity of the contamination case in Santo Amaro, Bahia. For many years, the factory installed in the city operated without any emissions control, impacting directly the local vicinity. This study evaluates the persistence of contamination of the superficial soil around the company, relating them to expected particles concentration in the air when the company was still active. In order to do this, the emissions and dispersion of particles into the atmosphere were simulated, considering the metallurgical process data and local weather and topography parameters. The results obtained were used to plot isolines of particle concentration in the air. Radial lines were drawn from the main chimney, defining sampling points at their intersections with isolines. The results showed that the past emissions still play a very important role in the soil contamination. There is a clear persistence of the lead and cadmium concentration values and, especially in areas close to the factory, they are far above the reference limits.

Introduction

During the years 1956 to 1993, intense lead metallurgic activities took place in the city of Santo Amaro da Purificação, Bahia, Brazil. These activities generated several environmental impacts that have been studied since the 1970´s (Machado et al. 2003).

Lead metallurgical debris are typically composed of Si, Ca, Fe, Zn, Pb and S oxides with traces of Cd, As, Sb, Co e Cr. Many studies evaluating the effects of the contamination on human health and the environment have been carried out in Santo Amaro showing the severity of this contamination case (Anjos, 1997, 1998, 2001, 2003; Brasil 2003; Carvalho et al., 1984, 1985, 1986, 1989, 1996, 2001; Machado et al., 2003, 2004; Silvany-Neto et al. 1985; Tavares, 1978, 1990; Tavares et al. 1989; Tavares & Carvalho 1992).

These studies demonstrate that the Santo Amaro Environmental Contamination Case can be considered as one of the most serious heavy metal contamination cases in the world.

For 34 years, the metallurgical company operated without any emissions control, having direct impacts on the immediate surroundings. In 1980, a few contamination control initiatives were taken, such as the implantation of a 90m high chimney with air filters placed at the particle emissions sources, the prohibition of the use of the lead debris for landfill purposes and the removal of all the residences within a radius of 500m of the industry. (Anjos 2003).

Although there were many sources of contamination derived from company activities, the uncontrolled air emissions, the liquid effluents poured directly into the River Subaé, the uncontrolled debris disposal and the superficial drainage water coming from the debris storage area can be cited as the main causes of pollution. Moreover, the lead debris, considered as “non dangerous” by the entrepreneur, was used by the Santo Amaro city authorities and by the population for several purposes, such as in pavements and as a landfilling material in residential courtyards and public areas (Machado et al. 2003).

After 16 years of company closure and a huge amount of papers published on the subject, there are still many persisting doubts about the residual contamination still active in the region. This study aims at evaluating how the contamination levels in the superficial soil around the company are still influenced by the previous/past atmospheric emissions. In order to do this, simulations of emissions and particle dispersions into the atmosphere were performed, considering data from the metallurgical processes, local weather and topography parameters which were then compared with the heavy metal concentrations (Pb e Cd) in the soil surrounding the former mining company.

Materials and Methods

First of all, numerical simulations of the dispersion of atmospheric emissions during the operating period of the company were performed, considering the metallurgical processes used, the topographical parameters of the region and the average local climate conditions (the weather data was obtained from weather stations located at Salvador airport). Hourly data was collected for wind direction and speed, temperature, stability, and mixing height for the rural and urban zones.

The topography was based on data acquired from SRTM Shuttle Radar Topography Mission, performed by NASA. The company operation data was obtained from work performed by The Environmental Institute of Bahia (Bahia 1992), by Anjos (1998) and by Tavares (1990). The modeling results indicated the probable concentration of the particles and sulphur oxides within the company surroundings and identified the regions where maximum concentrations occurred. For calculation purposes, it was assumed that SO_2 emissions were emitted from the 80m high chimney and that the particles were emitted via the seven smaller chimneys distributed throughout each stage of the metallurgical process. These calculations were based on the assumption that gross emissions without control occurred, which is consistent with the characteristics during the majority of the operation period of the plant.

Results obtained from the numerical simulation were interpolated and presented in the form of isolines representing air particle concentrations, as shown in Figure 01.

A total of five isolines representing concentrations of 100, 80, 60, 40, and 20 $\mu g/m^3$, were determined within a radius of 4,5 km from the main chimney. A sixth contour line was projected at a distance of 1 km from the 20 $\mu g/m^3$ isoline and was adopted as a boundary line, beyond which, the influence of the past emissions can be neglected. The total study area, covered by the sixth contour line, is about 7500 hectares in size and corresponds to nearly 16% of the total area of Santo Amaro City.

Eight radial axis were plotted every 45 °, using the factory chimney as the center point. The first axis was intentionally positioned over the urban area of Santo Amaro. The intersections of the radial axis with the concentration isolines defined the location of the 48 sampling points used in this work.

These points were geo-referenced to enable the field sample campaign be performed, using GPS. Superficial soil samples (up to 20 cm) were then collected at these 48 points in order to determine the Pb and Cd metal concentration values.

Superficial soil samples were analyzed using AAS Atomic Absorption Spectrometry.

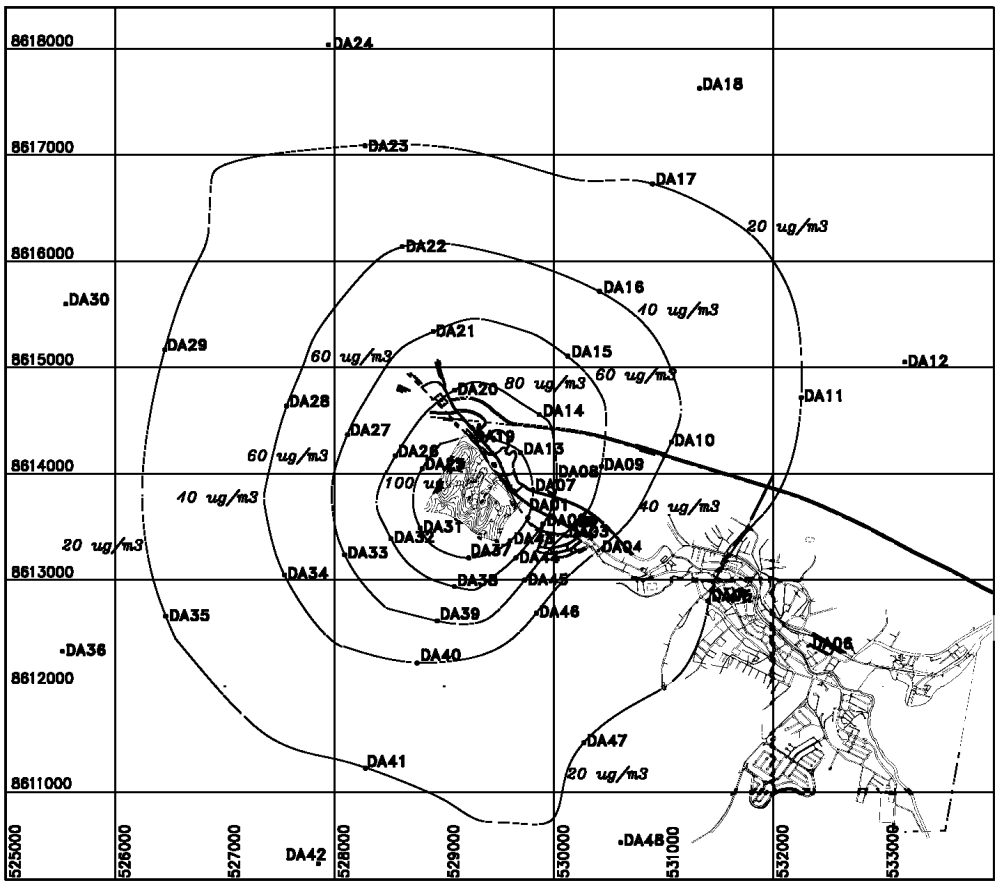

Fig. 01 Map of the city of Santo Amaro showing the soil sampling points and the isolines of particle concentrations of air.

Results and Discussion

For each isoline, the results were analyzed taking into account the average lead and cadmium concentrations obtained in the superficial soil samples, as shown in Figure 2. In this figure, the dashed lines include all the experimental results and the solid line excludes the DA 01-06 axis, which passes through the urban area of Santo Amaro.

As it can be seen in the Figure 2 there is a clear correlation between the concentration values in the superficial soil and the values obtained from the atmospheric dispersion simulation, indicating that past air emissions still play an important role in the contamination of the studied area.

It can also be observed that the exclusion of the axis that passes through the urban area causes a considerable decrease in the average concentration values obtained in field. This is probably due to the presence of the debris disposed in the urban area. The authors believe that due to the circulation of vehicles and people in these locations and the regular works of excavation, transportation and re-compaction of superficial soil performed by the city authorities and population, there is a considerable amount of dust with high levels of lead and cadmium that is deposited on the surface soil, increasing the concentration values in the urban zone. Another important aspect to be considered is that the lead debris are classified as a Class I residue according to the NBR 10004, NBR 10005 and NBR 10006 (Brazilian Standards).

According to Anjos (2001) and Machado et al. (2003), it is clear that this material liberates a significant quantity of lead into the environment due to the leaching of rainwater.

Table 1 summarizes the lead concentration values obtained and compares them with the reference values established by CETESB (2005). It can be observed that 43 sampling points presented lead concentration values above the quality limit, 16 were found to be above intervention limits for agricultural use, 11 were above the intervention limits for residential use and 4 of the collected samples were even above the limits for industrial use.

The soil cadmium concentrations also presented worrying results: 39 samples showed values above the quality limit, 28 were above the intervention limit for agricultural use and 7 presented values above the intervention limit for residential use (see table 2).

The results published in this work are coherent with other results published in the technical literature. According to CCME (1996) *apud* Cunha (2003), studies presented by the National Contaminant Sites Remediation Program showed that: (1) the concentration values of lead in residential superficial soils within a radius of approximately 2 km from the refineries, presented lead concentration levels varying between 53 and 5200 mg/kg; and (2) in areas where industrial activities and/or where refining had ceased, the superficial soil in residential areas, gardens or parks close to the refinery plants, remained contaminated and (3) the lead levels decreased as the distance from the refinery increased.

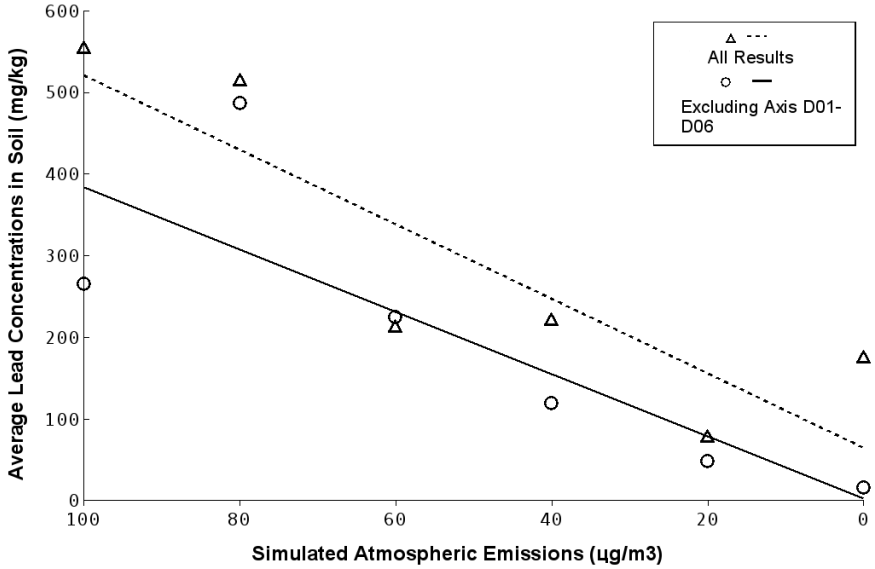

Fig. 2 Average Lead Concentrations in soil as a function of the simulated concentrations of the Atmospheric Emissions from the company

TABLE 1- Comparison of lead concentrations in soil with CETESB legislation (CESTESB 2005)

CETESB Threshold values of Pb (mg/kg)		N° of Points above limit	Percentage of points above limit (%)
Quality	17	43 points	89,58
Prevention	72	33 points	68,75
Rural Intervention	180	16 points	33,33
Urban Intervention	300	11 points	22,92
Industrial Intervention	900	4 points	8,33

TABLE 2- Comparison of Cadmium concentrations in soil with CETESB legislation (CETESB 2005)

CETESB Threshold values of Cd (mg/kg)		N° of Points above limit	Percentage of points above limit (%)
Quality	<0,5	39 points	81,25
Prevention	1,3	37 points	77,08
Rural Intervention	3	28 points	58,33
Urban Intervention	8	7 points	14,58
Industrial Intervention	20	0 point	0

Figure 3 compares the results obtained in this study to other results published by different authors (Anjos 1998, Brasil 2003, Costa 2001 and Machado et al., 2003). Although data is scattered, the average results presented in this paper lie within the middle range of other results performed in the area, indicating the persistence of the contamination levels.

Conclusions

After more than 16 years of closure of the metallurgic company in Santo Amaro, Bahia, Brazil, the remaining contamination results derived from previous/past atmospheric emissions are still a matter of concern.

This scenario is extremely worrying, especially if the residential and agricultural use of land near the company grounds is considered.
The heavy metal contamination values in the superficial soil are dependent on air particle concentration values obtained using the atmospheric dispersion simulation.

Attention should be paid to the high levels of contamination detected along the axis that runs through the urban area, probably related to the use of the industrial waste as a landfill material.

Acknowledgments
The authors wish to thank CEPED/UNEB and GEOAMB/UFBA, partners of the project and the Center for Higher Education (CAPES/MEC) and the Foundation for Research Support of the State of Bahia (FAPESB) for their financial support towards the project.

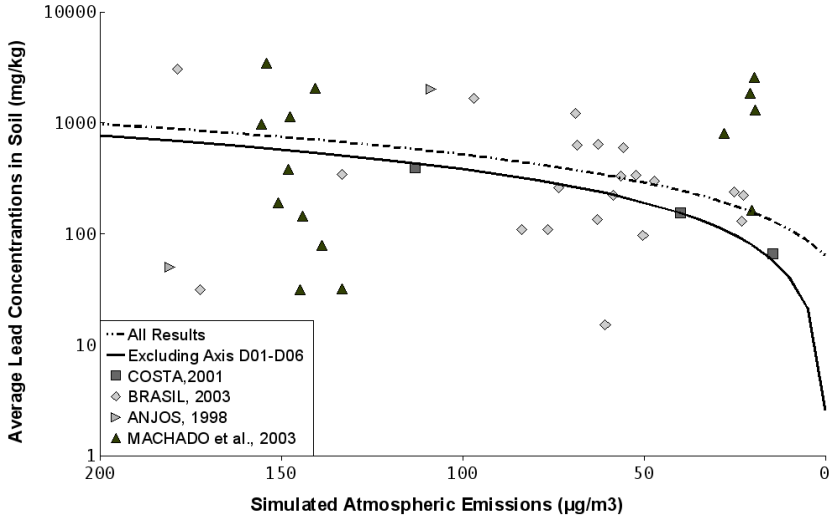

Fig. 3 Results obtained in this study compared to other results published by different authors (Anjos 1998, Brasil 2003, Costa 2001 and Machado et al. 2003)

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