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Indoor metallic pollution and children exposure in a mining city

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HIGHLIGHTS

- Mining activities are an important source of environmental pollution.
- Mining pollution contaminated also indoor homes, creating a risk to population.
- Indoor dust and hair concentrations in As, Cd, Pb, Sb and Sn were correlated.
- No correlation was found for essential elements such as Cu or Zn.
- Children behavior modifies the exposure to certain elements.

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ABSTRACT

Mining industries are known for causing strong environmental contamination. In most developing countries, the management of mining wastes is not adequate, usually contaminating soil, water and air. This situation is a source of concern for human settlements located near mining centers, especially for vulnerable populations such as children. The aim of this study was to assess the correlations of the metallic concentrations between household dust and children hair, comparing these associations in two different contamination contexts: a mining district and a suburban non-mining area. We collected 113 hair samples from children between 7 and 12 years of age in elementary schools in the mining city of Oruro, Bolivia. We collected 97 indoor dust samples from their households, as well as information about the children's behavior. Analyses of hair and dust samples were conducted to measure As, Cd, Pb, Sb, Sn, Cu and Zn contents. In the mining district, there were significant correlations between non-essential metallic elements (As, Cd, Pb, Sb and Sn) in dust and hair, but not for essential elements (Cu and Zn), which remained after adjusting for children habits. Children who played with dirt had higher dust-hair correlations for Pb, Sb, and Cu ($P = 0.006$; 0.022 and 0.001 respectively) and children who put hands or toys in their mouths had higher dust-hair correlations of Cd ($P = 0.011$). On the contrary, in the suburban area, no significant correlations were found between metallic elements in dust and children hair and neither children behavior nor gender modified this lack of associations. Our results suggest that, in a context of high metallic contamination, indoor dust becomes an important exposure pathway for children, modulated by their playing behavior.

1. Introduction

Several metallic trace elements are potentially toxic for human health, such as lead, arsenic, mercury, cadmium, manganese or antimony (Hu et al., 2007; Jarup, 2003; Walker et al., 2007). As most of these elements are known to be neurotoxic, most of the epidemiological studies about metallic elements have focused on their deleterious effects for the neurological development (Grandjean and Landrigan, 2006). Children are especially vulnerable to metallic exposure because of their physiological traits and also because of their particular behavioral characteristics such as crawling, playing with dirt and sucking or chewing toys (Hubal et al., 2000; Landrigan et al., 2004).

Mining and metallurgical industries are known to have a strong impact on the environment. The exploited metals usually constitute just a portion of the mineral compounds present at most mining sites, while the remaining materials are discharged as waste. No other

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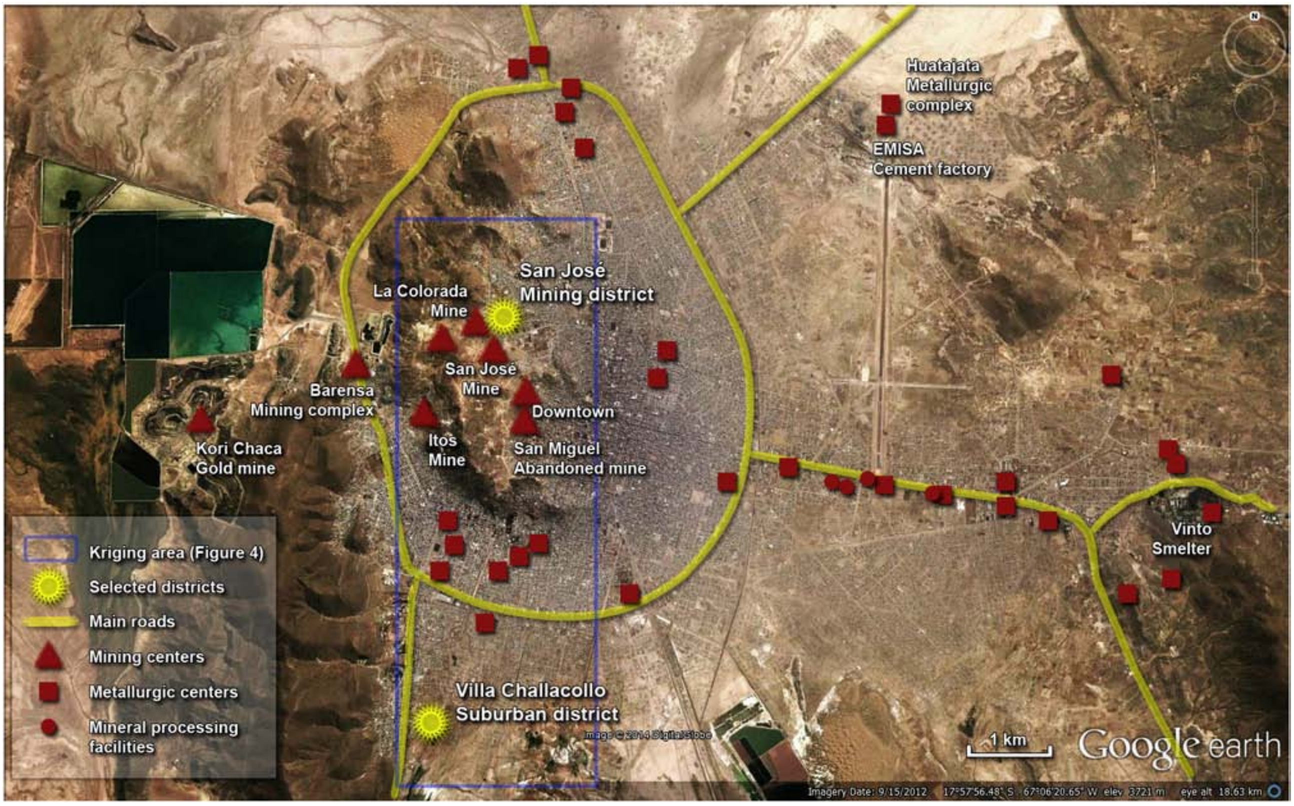

Fig. 1. Overview of the study area, showing the districts sampled, the main mining and mineral processing facilities, and the area covered by the Kriging interpolation depicted on Fig. 4.

industry generates such an amount of solid waste (Ayres and Ayres, 2002). Due to geochemical processes, the compounds present in the tailings and mining waste are potentially the origin of persistent sources of metallic pollution for water resources, air, and soil (Ayres and Ayres, 2002; Schwarzenbach et al., 2010).

Soil pollution by metallic trace elements has been studied in many different contexts (Bjerre et al., 1993; Han et al., 2002; Markus and McBratney, 2001; Mielke et al., 1999; Senesi et al., 1999). It is common to observe that the intensity of the contamination is proportional to the distance to the pollution sources (Meyer et al., 1999b; Qu et al., 2012; Zota et al., 2011). Moreover, it has been demonstrated that metallic pollution can also reach indoor environments (e.g., households), increasing the risk of non-occupational exposure (Fontúrbel et al., 2011; Glorennec et al., 2012; Meyer et al., 1999a; Thornton et al., 1990; Zota et al., 2011).

In developed countries, mining waste is often adequately managed. However, the situation is different in some mining sites located in developing countries. When resources are limited and the implementation of the laws and regulations is not very effective, tailings and waste piles remain exposed and subject to wind erosion and leaching processes, becoming a certain source of pollution and may even be used as bulk-fill in improvised construction projects (Yáñez et al., 2002). Furthermore, it is not rare to find settlements and even towns in direct contact with mining pits, waste piles, ponds and artisanal smelters (e.g., Schaider et al., 2007; van Geen et al., 2012).

A clear example of this situation is the city of Oruro (17.97°S–67.10°W), a major Andean mining city in the Bolivian plateau at ~3700 m above sea level. With a current population of approximately 250,000 inhabitants (INE, 2001), this city has been historically dedicated to mining, metallurgical and metal trading activities for centuries. Like many other Andean cities, Oruro is cold and arid, with long dry seasons – usually from April to November – and strong winds, which contribute to making it a dusty city. Besides, even though it is in an urban context, many roads are still unpaved and most mining tailings are uncovered.

Previous studies have shown the presence of metallic trace elements in Oruro (Goix et al., 2011), particularly inside the households (Fontúrbel et al., 2011) of the mining and metallurgical districts, where the contamination largely exceeds the United States Environmental Protection Agency (US EPA) recommendations for residential

Table 1
Median concentrations of trace elements measured at mining ($N = 56$) and suburban ($N = 41$) districts. Percentiles 5% and 95% are shown in parentheses.

Element	Dust samples (ppm)		Hair samples (μg/g of hair)	
	Mining	Suburban	Mining	Suburban
As	88.60 (18.54–469.51)	40.61 (32.50–58.21)	0.89 (0.10–3.19)	0.38 (0.12–1.52)
Cd	10.40 (5.10–38.15)	5.78 (4.80–8.99)	0.14 (0.00–1.65)	0.08 (0.03–0.26)
Pb	560.60 (87.86–5198.00)	103.65 (57.95–742.78)	13.26 (3.36–65.36)	1.88 (0.56–8.01)
Sb	108.70 (27.08–2770.28)	33.96 (23.47–84.31)	0.37 (0.00–4.11)	0.09 (0.05–0.19)
Sn	63.40 (25.96–309.12)	32.17 (19.85–61.57)	0.19 (0.06–0.66)	0.09 (0.04–0.17)
Cu	80.15 (31.70–325.50)	49.18 (25.86–175.18)	10.73 (3.61–39.96)	8.02 (4.59–10.83)
Zu	414.54 (167.80–1705.50)	199.75 (142.00–442.64)	118.97 (37.44–350.70)	122.52 (40.80–187.35)