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Manganese and lead in dust fall accumulation in elementary schools near a ferromanganese alloy plant

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ABSTRACT

Previous studies have shown elevated airborne manganese (Mn) in villages adjacent to a Mn alloy production plant in Brazil and negative associations between biomarkers of Mn and children's cognition and behavior. Since small Mn particles may be carried for long distances, we measured manganese (Mn) and lead (Pb) dust fall accumulation in 15 elementary schools, located between 1.25 and 6.48 km from the plant in the municipality of Simões Filho, Bahia, Brazil. Passive samplers (polyethylene Petri dishes) were set in interior and exterior environments. After 30 days, the samplers' content was solubilized with diluted nitric acid and Mn and Pb levels were analyzed by electrothermal absorption spectrometry. The overall geometric mean and range of Mn and Pb accumulation in dust fall (loading rates) were 1582 µg Mn/m^2/30 days (37–37,967) and 43.2 µg Pb/m^2/30 days (2.9–210.4). A logarithmic decrease in interior and exterior Mn loading rates was observed with distance from the ferro-manganese alloy plant. Multiple regression analyses of log-transformed Mn loading rate within the schools showed a positive association with Mn levels in outdoor dust, a negative association with distance from the plant; as well, wind direction (downwind > upwind) and school location (urban > rural) entered significantly into the model. For the interior school environments, located within a 2-km radius from the plant, loading rate was, on average, 190 times higher than the Mn levels reported by Gulson et al., (2014) in daycare centers in Sydney, Australia, using a similar method. Pb loading rates were not associated with distance from the plant and were lower than the rates observed in the same daycare centers in Sydney. Our findings suggest that a significant portion of the children in this town in Brazil may be exposed to airborne Mn at concentrations that may affect their neurodevelopment.

1. Introduction

Environmental exposures to manganese (Mn) and lead (Pb) have been shown to have serious detrimental effects on neuropsychological functions, particularly in children. Although Mn is an essential micronutrient (ATSDR 2012), important for bone mineralization, energy and protein metabolism, cell metabolism regulation, and protection against oxidative stress (Keen et al., 2000), inhaled manganese bypasses homeostatic mechanisms, increasing its concentration in the brain and other organs (Aschner et al., 2007). Recent studies have demonstrated cognitive deficits and hyperactivity in children exposed to elevated airborne Mn (for review see: Sander et al., 2012; Zoni and Lucchini, 2013). Pb, on the contrary, is an ubiquitous element, considered a xenobiotic with no-known physiological role (Barbier et al., 2005). The neurotoxic properties of Pb have been known for several decades and there is growing evidence that there may not be a "safe" threshold. (Lanphear et al., 2005; Bellinger 2008; USEPA, 2013; Skerfving et al., 2015).

Both Mn and Pb are present in the air as suspended particulate matter in urban and rural areas in the $PM_{2.5}$ fraction that can be absorbed by the lungs (USEPA, 2015). Elevated airborne manganese has been reported in communities near mining and mineral processing (Cortez-Lugo et al., 2015), ferro and/or silica manganese production plants (Baldwin et al., 1999; Menezes-Filho et al., 2009; Roels et al., 2012; Lucchini et al.. 2012; Haynes et al., 2015), as well

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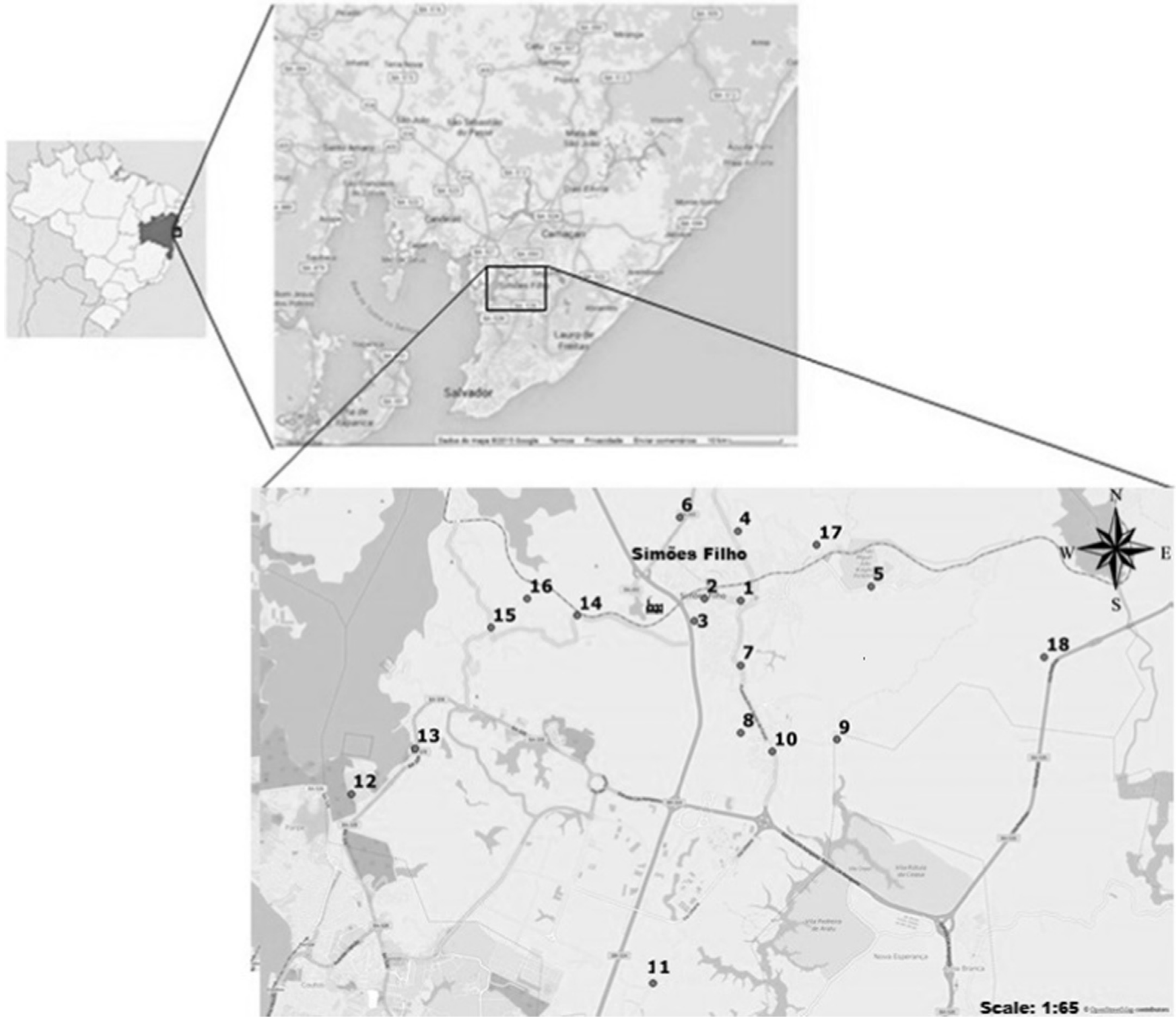

Fig. 1. Study area showing the municipality of Simões Filho, the manganese processing plant and the selected elementary schools Schools numbered 5, 11 and 18 were excluded following visit.

in communities living near roadways where methylcyclopentadienyl manganese tricarbonyl (MMT) is or was used as a gasoline additive (Röllin et al., 2005; Zayed 2001).

Elevated hair and/or blood Mn have been reported in communities exposed to environmental airborne Mn from different anthropogenic activities, including mining and mineral processing (Torres-Agustin et al., 2013), ferro-alloy production (Mergler et al.. 1999; Lucchini et al., 2007; Menezes-Filho et al.. 2009; Viana et al., 2014) and aerial spraying of mancozeb fungicide (Mora et al., 2014). Blood Pb concentrations have decreased since the phase-out of leaded gasoline (Lanphear et al.., 1998), however, blood Pb levels near roads with intense traffic remain higher than areas with little or no traffic due to deterioration of car parts, brakes friction and soil resuspension (Hjortenkrans et al., 2006). Communities living near certain including smelting industries and mining processing, solid waste burning, welding, pottery glazing and cigarette smokers present higher biomarkers of Pb than the general population (Lanphear et al., 2005; Menezes-Filho et al., 2012). Small children, especially toddlers, are more likely to be exposed to metal-laden dust due to hand-to-mouth or object-to-mouth contact. They may also absorb more airborne metals since their respiration and metabolic rates are higher than adults (WHO 2011).

Airborne and settled dusts constitute good surrogates of air pollution and reflect the potential risk of exposure of the general population to organic and inorganic pollutants. Several methods of dust sample collection have been described. Surface brushing (Mohmand et al., 2015), aerosol concentration measurements with the GRIMM device (Alam, 2015) and vacuuming (Gunier et al., 2014) are some of the most used methods. Generally, analyte concentration and/or loading are expressed. Gravimetric analysis (expressed as concentration (μg of metal/g of dust) requires time consuming and complex sampling procedures. Dust contamination, expressed as loading or the amount of contaminant per area unit (ie. square meter), is a much simpler method and can be more informative when expressed as loading rate (the amount of contaminant per unit of area in certain period of time (day, month, etc). For the latter, passive samplers are used, including cone-shaped samplers with microfiber filters (Wong et al., 2003), coated