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Identification of lead sources in residential environments: Sydney Australia

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ABSTRACT

Interior and exterior dust, soil and paint were analysed at five brick urban Sydney homes over 15 months to evaluate temporal variations and discriminate sources of lead (Pb) exposure. Exterior dust gauge Pb loading rates (μg/m^2/28 days), interior vacuum dust Pb concentrations (mg/kg) and interior petri-dish Pb loading rates (μg/m^2/28 days), were correlated positively with soil Pb concentrations. Exterior dust gauge Pb loading rates and interior vacuum dust Pb concentrations peaked in the summer. Lead isotope and Pb speciation (XAS) were analysed in soil and vacuum dust samples from three of the five houses that had elevated Pb concentrations. Results show that the source of interior dust lead was primarily from soil in two of the three houses and from soil and Pb paint in the third home. IEUBK child blood Pb modelling predicts that children's blood Pb levels could exceed 5 μg/dL in two of the five houses.

1. Introduction

In many urban inner-city areas in the United States, there is an epidemic of childhood PbB poisoning (Gould, 2009). It has been estimated that 24.5%, or 9.6 million US children have a PbB in the 2–10 μg/dL range, a level which will cause sub-clinical signs (Gould, 2009). The United States Centers for Disease Control and Prevention (CDC) estimates that in the United States approximately 535,000 children aged 1–5 years had BLLs ≥5 μg/dL (CDC, 2013). These exposures are quite variably geographical with some locations more significantly affected. For example, in New Orleans children currently have a PbB prevalence (>5 μg/dL) of 29.6% (Mielke et al., 2013) and Detroit children (aged 0–10 years) have a PbB prevalence of 33% (>5 μg/dL) (Zahran et al., 2013). In 2012, the United States CDC Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP, 2012) recommended the adoption of a children's PbB reference level of 5 μg/dL. While the PbB prevalence has been assessed in the United States, in Australia childhood PbB surveillance are not collected and reported systematically so spatial and temporal distributions are unknown. The last national PbB testing occurred in 1995, when 1575 children were tested (Donovan, 1996). The arithmetic mean PbB level was 5.72 ± 3.13 μg/dL. Currently, PbB testing programs are focussed on Australia's Pb mining and smelting towns: Broken Hill, Mount Isa and Port Pirie (Taylor et al., 2011). Similar to the United States, there is no federal government program for testing or remediation of diffuse non-point source urban soil Pb contamination, although the extent of these sources is increasingly better understood, particularly in urban neighbourhoods (Olszowy et al., 1995; Birch et al., 2011; Laidlaw and Taylor, 2011).

The premise of this study is derived from Laidlaw and Taylor's (2011) review of multiple Australian soil Pb and dust Pb studies that concluded soils and interior dust in many older Sydney suburbs are likely to have been contaminated from industrial and domestic Pb sources. In support of this contention, is the work by Birch et al. (2011) who mapped soil Pb concentrations in the Sydney basin and observed widespread soil Pb contamination with highest concentrations located in the inner parts of eastern, northern and western Sydney.

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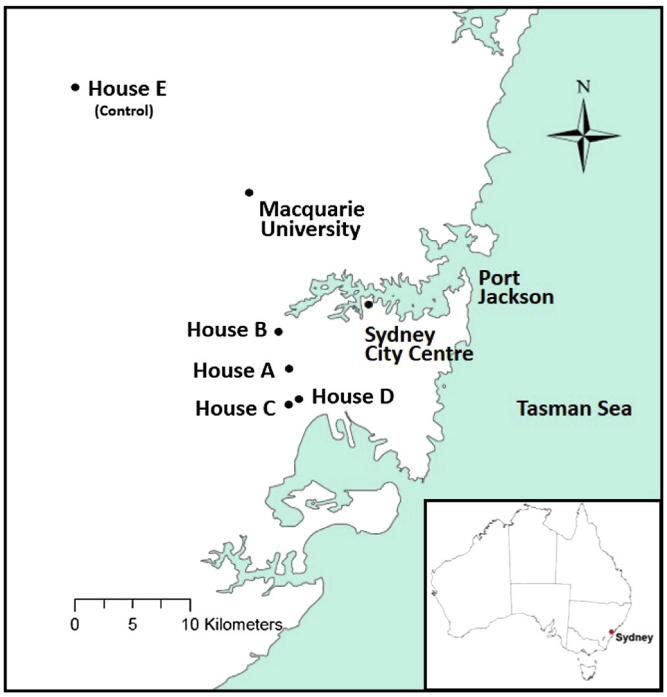

Fig. 1. Site locations of houses sampled in the study. This figure displays the locations of the houses that participated in this study.

This study examines sources of residential Pb and its temporal cycling in 5 brick homes over a 15 month period during 2010–2012 in Australia's largest urban city, Sydney (population 4.61 million; Australian Bureau of Statistics (ABS), 2012). The principal aim of the study was to determine the predominant source(s) of Pb inside typical western Sydney brick homes. Brick homes were selected to avoid the potential confounding effect of exterior lead paint that was used in older homes. Given that the study involved the collection of longitudinal environmental data, it was also possible to evaluate the seasonal variation in exterior and interior Pb quantities.

2. Methods and approach

2.1. House selection

The criteria for the four principal study houses located in the older inner west of Sydney was that each house was greater than 50 years old and was constructed of unpainted bricks. The four houses were built between 1900 and 1918. The houses were selected from three inner west Sydney suburbs: Arnfield (2), Marrickville and Haberfield (Fig. 1). A fifth brick house, approximately 30 years old was also sampled as a reference site. This property was located in an area of low-density bushland in the suburb of Glenhaven, 28 km northwest of Sydney city centre (Fig. 1). The owners of each home gave their consent to environmental sampling.

2.2. Study design

The sampling period was undertaken between November 2010 and January 2012 (15 months). At each house, exterior atmospheric Pb loading rates were measured monthly using passive sampling dust gauges in the rear garden at each home. Interior vacuum Pb in the <75 μm fraction were analysed monthly and attic and interior petri-dish Pb loading rates were measured quarterly. Soil Pb concentrations (<75 μm fraction) were measured in surface soil samples (0–2 cm) collected adjacent to the roadway in front of each house, within 1 m from the front of each house and in the middle of each back yard. In addition, one soil sample was collected at a depth of 50 cm in the middle of each back yard. Using the three inner west homes with the highest total soil Pb concentrations (Houses A, C and D), Pb isotopic composition analysis of selected environmental samples was undertaken using quadrupole Inductively Coupled Mass Spectrometry (ICP-MS). These samples consisted of front yard surface (0–2 cm) and sub-surface (50 cm) soils (<75 μm fraction); a vacuum dust sample (<75 μm fraction); and an indoor paint chip sample from the surface identified previously to have the highest Pb concentration. Finally, Pb speciation of vacuum dust and surface soil (0–2 cm) samples were determined from the same three houses (Houses A, C and D) using X-Ray Absorption Spectroscopy (XAS) at the Australian Synchrotron facility in Melbourne, Australia.

2.3. Sieving

Soil and vacuum dust samples were sieved using a 75 μm mesh prior to analyses. Sieves were rinsed in a tap water/Alconox™ solution followed by rinsing with type II deionised water (American Society of Testing Materials (ASTM) standard) and then dried at 85° C before and after use. Soil and dust samples selected for XAS analysis were milled to <20 μm with a Retsch MM301 tungsten carbide milling machine in order to mitigate sample thickness effects that could otherwise distort the spectra. The mills were cleaned with fine silica sand followed by Alconox wash and type II deionised water rinse.

2.4. Soil and vacuum samples

Each surface soil sample was a composite of three samples collected approximately 1 m apart using a plastic hand trowel that was cleaned with deionised water and dried between sample locations. Samples were collected and stored in metal-free plastic bags prior to sieving.

Monthly interior vacuum dust samples (1 sample per location per month) were collected from each house over the study period, all of which used High Efficiency Particulate Air (HEPA) vacuum cleaners. Four of the vacuum cleaners (Houses A, C, D and E) were bag-less and one contained a vacuum bag (House B). The entire content of each vacuum sample was placed in a large, resealable metal-free plastic bag. Sieved (<75 μm) soil and vacuum samples were analysed for total extractable Pb concentrations using United States Environmental Protection Agency (USEPA) SW-846-6010 (USEPA, 2013b) method by the ALS Laboratory Group in Sydney, Australia.

2.5. Dust gauge samples

Exterior dust gauges were placed in the rear garden areas of each house in a location where they would not be disturbed. The dust gauge consisted of a 150 mm diameter glass funnel which was inserted into a 2.75 L glass bottle secured in a plastic bucket affixed to a ~2 m high tripod (Australian Standard 3580.10.1-2003; Standards Australia, 2003). Dust gauge bottles were replaced monthly over the study period (1 sample per location per month). Ten ml of copper sulphate solution was inserted into each bottle to prevent algal growth. Dust gauge samples were analysed for total Pb concentrations measured using NexION 300D ICP-MS by the ALS Laboratory Group in Sydney. Total extractable Pb concentration was analysed using USEPA Method SW-846-6020 (USEPA, 2013b).

2.6. Petri-Dish samples

Petri-dish(es) (150 mm or 85 mm diameter) were placed in the attic of each house and on the main living area of each house at approximately 2 m above the floor to collect settled airborne interior dust. The polycarbonate petri-dishes were purchased in an air-tight plastic and were pre-sterilised. Petri-dishes were replaced on a quarterly basis during the study (five quarters over the study period). The main living area petri-dish was placed in the baby's bedroom in house D, and in the living room/family room of houses A, C, B and E. Each petri-dish sample was analysed for the mass of Pb using ICP-MS by the ALS Laboratory Group in Sydney. Samples were digested using a concentration of 7 M nitric acid and 6 M hydrochloric acid according to the method described in Wlodarczyk et al. (1997). Interior and attic petri-dish lead dust loading rate samples were collected quarterly (1 sample per location every three months).

2.7. Paint chip analysis

Paint chip samples were collected from the interior paint inside each house using new disposable razor-blades. Samples were stored in metal free plastic freezer bags prior to analysis for total Pb concentration. Paint chips with the highest concentration in houses A, C and D were analysed for their Pb isotopic composition.

2.8. Pb isotopic composition analysis

Total Pb paint concentrations and Pb isotopes in soil (sieved < 75 μm), vacuum dust (sieved < 75 μm) and Pb paint were analysed using a quadrupole Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) at the ChemCentre in Bentley, Western Australia. In addition, several paint samples used for initial screening were also analysed for total Pb concentrations at ALS Laboratories. Soil and dust particles (sieved < 75 μm) were digested after drying overnight. Analysis was performed using mixed high purity redistilled acid (nitric/hydrochloric) microwave assisted acid digestion (USEPA 3051A modification). Paint samples were digested with strong reflux with nitric acid as per the Association of Official Agricultural Chemists (AOAC) method 974.02 (AOAC, 2013). Sample digests were filtered and volumed in 18 MOhm water before determination of total Pb content by ICP-AES. Samples measured for their Pb isotopic composition were diluted within a concentration range of 10–