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Evaluating the efficacy of playground washing to reduce environmental metal exposures

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A B S T R A C T

Washing and wet mopping is often advocated as a remedial treatment to limit exposure to lead dust. Here, surface and pre- and post-play wipes were measured to ascertain dust metal exposures (arsenic, cadmium, copper, lead and zinc) following play routines at four playgrounds in the smelter city of Port Pirie, South Australia, which are washed regularly. Although post-play hand wipe metals were 55.9% (95% CI: −0.78, −0.34) lower on wash days, loadings increased ~5.1% (95% CI: 1.2, 11.7) per hour after washing. Despite washing, post-play hand lead exceeded a conservative value of 800 μg/m^2 within 24 h or sooner, with loadings increasing in proximity to the smelter. Post-play lead loadings were always >1000 μg/m^2 at the playground closest to smelter. Playground washing results in short-lived exposure reduction and effective treatment requires elimination of smelter emissions.

1. Introduction

The problem of childhood lead exposure remains a persistent problem in Australia's primary smelting and mining cities of Broken Hill, Mount Isa and Port Pirie, with the latest figures showing that 21%, 4.8% and 22.7%, respectively, of children under 5 years of age having a blood lead level above 10 μg/dL, the current (under review) Australian goal (Taylor et al., 2014b). However, the extent of exposures amongst the wider Australian population is unknown because of a lack of available population data. Nevertheless, estimates derived from USA exposure data have indicated that ~100,000 children <5 years of age may have exposures above 5 μg/dL (Taylor et al., 2012, 2014c), which corresponds to the most recent study on Australian urban children that reported 7.5% (8/107) of the cohort had a blood lead >10 μg/dL (Gulson et al., 2008).

Where exposures are well documented and the sources known, interventions, screening and advice programs are usually provided. One such case is in the city of Port Pirie in South Australia, where lead smelting has been ongoing since 1889. The effects of the smelter operations has resulted in widespread contamination of the natural and urban environment, which has been associated with persistent, but declining blood lead exposures in children over the last two decades (Maynard et al., 2006; Simon et al., 2007; Taylor, 2012; Taylor et al., 2013). Strategic interventions, lead awareness programs in the city of Port Pirie (Maynard et al., 2006; Thumbs Up for Low Levels 2015), and emission reduction efforts from the city's smelter site (Environment Protection Authority South Australia (EPASA) 2009) have contributed to the fall in blood lead levels. However, the most recent annual data show that exposures have stabilised or even by some measures increased (Taylor et al., 2014c). For example, the geometric blood lead mean for all children under 5 years of age increased from 4.5 μg/dL in 2012 to 5.0 μg/dL in 2013. The primary source of the exposures is caused by the ongoing and contemporaneous lead-in-air emissions from the smelter (Simon et al., 2007; Taylor, 2012; Taylor et al., 2014a), which result in elevated concentrations of contaminated metal rich dust being deposited on surfaces (van Alphen, 1999; Taylor et al., 2013, 2014a; Csavina et al., 2014). In addition, there is a substantial reservoir of lead-contaminated soil from accumulated emissions in Port Pirie that has the potential for re-suspension (SA Health, 2013).

The spatial extent of metal- and metalloid-rich dust (hereafter referred to as metals), including lead, was detailed in a study of playgrounds across the city of Port Pirie in 2011 (Taylor et al., 2013). This study showed that atmospheric emissions from the

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smelter were related directly to surface dust and hand metal exposures following the use of playground equipment (Taylor et al., 2013). Following this study, the Port Pirie Council and the smelter company, Nyrstar Port Pirie Limited Pty Ltd, agreed to a joint program of playground washing. Before these results were published, the playground washing intervention program was limited only to the Foreshore Playground (also known as Flinders View), which was washed twice a week on Monday and Friday mornings, with no other playgrounds washed regularly (D. Farquhar, Port Pirie Council, personal communication, 7th July 2011). Given the elevated metal loadings identified across the studied playgrounds (Taylor et al., 2013), we released the environmental data to SA Health and the Port Pirie Council ahead of publication to assist with their management of the problem. The authorities responded on August 1st, 2012 by increasing the frequency of playground cleaning to 22 washes per week across a range of different playgrounds in the city. The program was revised to include 9 playgrounds and 1 kindergarten (Supplementary Fig. S1). Following the online publication of the research on May 1st 2013 (Taylor et al., 2013), the Council and Nyrstar issued a further revision to the cleaning program on May 7th 2013. The new program increased the total number of playground wash events across the city to 49 per week covering 9 playgrounds (a total of 31 washes) and 9 child care centres, primary schools and kindergartens (a total of 18 washes) (Supplementary Fig. S2). Although the specifics of the washing techniques used on the play equipment are not provided in the cleaning schedules (Supplementary Figs. S1, S2), washing was observed at the Sports Park playground and involved scrubbing and hosing down of equipment. However, the effectiveness of the intervention strategy has not been evaluated but it warrants assessment given that other similarly impacted locations such as Broken Hill are considering equivalent regimes in response metal-rich dust contamination problems (Taylor et al., 2014b).

Intervention programs in lead contaminated environments typically involve advice to wet wipe and mop in order to reduce the hazard associated with the build-up of lead dusts (and other metals) in domestic environments (e.g. Living Safely with Lead, 2014; New South Wales Government 2014; Thumbs Up for Low Levels 2015). However, a Cochrane review of household interventions for preventing domestic lead exposure in children, including the removal of dust, demonstrated such approaches were not effective in reducing blood lead levels in children (Yeoh et al., 2012).

Lead in dust on surfaces in home environments at levels much lower than the typical intervention levels pose a measurable risk factor for elevated blood lead levels in children (Dixon et al., 2009). Data modelling predicted floor dust lead at concentrations as low as 12 $\mu g/ft^2$ (129 $\mu g/m^2$) would result in 4.6% of children living in USA homes constructed before 1978 (the era when the use of lead in paint was prevalent) to have a blood lead $\geq$ 10 μg/dL, with 27% to have a blood lead $\geq$ 5 μg/dL (geometric mean 3.9 μg/dL) (Dixon et al., 2009). Given that the US Centers for Disease Control and Prevention have moved to using $\geq$5 μg/dL as the reference level for children's blood lead and Australia appears to be moving to the same value for investigating environmental sources of exposure (NHMRC, 2014a,b), it is imperative that effective and evidence-based abatement and risk reduction strategies are promulgated (Taylor et al., 2014c).

Therefore, the purpose of this study was to evaluate the efficacy of the Port Pirie playground cleaning regime to reduce environmental metal exposure risks to children. Such information is useful for other similarly impacted locations where substantial regulatory effort and cost is invested in reducing potential exposures from contemporary metal-rich dust depositions.

2. Methods and approach

2.1. Field sampling

Field sampling was carried out in accordance with established methods (Taylor et al., 2013). The four Port Pirie playgrounds sampled in the previous study, Foreshore playground, Memorial Park playground, Sports Park playground and Woodward Park playground were sampled again each morning for a 5-day period between 20th July and 24th July 2013 (Fig. 1). The distances of the playgrounds from the smelter are: Foreshore Playground (1.0 km); Memorial Park Playground (1.2 km); Sports Park Playground (2.4 km); Woodward Park Playground (3.0 km) (Fig. 1). Images of each of the playgrounds showing the playground equipment and surrounds are provided in Fig. S2a–d of the Supplementary in Taylor et al. (2013).

Given that we wanted to evaluate the efficacy of washing as a remedial treatment, playgrounds that were subject to a morning wash according to the published schedule (Supplementary Fig. S2), were re-sampled in the afternoon approximately 6 h after the initial morning sample. These data were also used to investigate the dimension of washing for reducing playground surface contamination (Table 1).

Two playground surface dust wipe samples were also collected following the methods described in ASTM E1728-10 (ASTM, 2010) at each playground at the time of hand wipe sampling ($n = 58$). The playground surface wipe sampling approach detailed in ASTM (2010) is, for all intents and purposes, identical to that detailed in Australia's guide to lead paint management, AS 4361.2–1998 (Standards Australia, 1998). The areas wiped were measured to enable surface wipe metal values to be transformed to $\mu g/m^2$. As in the previous study, sites were selected to be close to, but away from the playgrounds, and unlikely to be interfered with during normal play routines or affected by the washing routines undertaken by Council or Nyrstar. The same researcher (L. Kristensen, as per Taylor et al., 2013) undertook the 20 min of child simulated play on the facilities from which we were able to obtain 29 paired samples of pre- and post-play hand wipes over the five-day study period. Hand contact was limited to the equipment and deliberately excluded contact with the ground surface around the playgrounds. The anterior (palmar) hand surface area of the play participant was calculated using the DuBois and DuBois (1916) method and metal concentrations transformed to $\mu g/m^2$ for pre- and post-play wipes.

2.2. Laboratory analyses

All wipe samples were tested for arsenic, cadmium, copper, lead and zinc at the National Measurement Institute, Sydney. Samples were digested in sterile polypropylene tubes using a mixture of 3 mL concentrated nitric acid and 1 mL hydrochloric acid (analytical reagent grade) on a digestion block at 110 °C for 90 min. A further 10 mL of Milli-Q was added to the samples prior to an additional 30 min digestion at 110 °C (Evans, 2013). Element concentrations were determined using a Varian Vista Pro ICP-OES and PerkinElmer Elan DRC II ICP-MS. Reagent blanks, dust wipe blanks, matrix spiking and reference materials AGAL-10 (Hawkesbury River Sediment) and AGAL-12 (Biosoil) were analysed concurrently for quality assurance. Reagent blanks were all below laboratory limit of reporting (LOR) as were the wipe blanks for arsenic (0.2 μg/wipe) and cadmium (0.05 μg/wipe). The wipe blanks returned an average copper concentration of 0.67 μg/wipe, lead concentration of 0.03 μg/wipe and zinc concentration of 20.85 μg/wipe. Field blanks collected at each playground were below LOR for arsenic and cadmium and with average values of 0.84 μg/wipe for copper, 25.44 μg/wipe for zinc and 0.11 μg/wipe for lead (0.07 μg/wipe for Memorial Park, Sports Park and Woodward Park and 0.23 μg/wipe