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Assessment of soil metal concentrations in residential and community vegetable gardens in Melbourne, Australia

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HIGHLIGHTS

- Metal concentrations were assessed in residential and community garden soils.
- Generally the only metal that exceeded regulatory guidelines was Pb.
- Soil Pb exceeded Australian guideline in 21% of residential gardens.
- Soil Pb exceeded Australian guideline in 8% of community gardens.

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ABSTRACT

Gardening and urban food production is an increasingly popular activity, which can improve physical and mental health and provide low cost nutritious food. However, the legacy of contamination from industrial and diffuse sources may have rendered surface soils in some urban gardens to have metals value in excess of recommended guidelines for agricultural production. The objective of this study was to establish the presence and spatial extent of soil metal contamination in Melbourne's residential and inner city community gardens. A secondary objective was to assess whether soil lead (Pb) concentrations in residential vegetable gardens were associated with the age of the home or the presence or absence of paint. The results indicate that most samples in residential and community gardens were generally below the Australian residential guidelines for all tested metals except Pb. Mean soil Pb concentrations exceeded the Australian HIL-A residential guideline of 300 mg/kg in 8% of 13 community garden beds and 21% of the 136 residential vegetable gardens assessed. Mean and median soil Pb concentrations for residential vegetable gardens was 204 mg/kg and 104 mg/kg (range <4–3341 mg/kg), respectively. Mean and median soil Pb concentration for community vegetable garden beds was 102 mg/kg and 38 mg/kg (range = 17–578 mg/kg), respectively. Soil Pb concentrations were higher in homes with painted exteriors ($p = 0.004$); generally increased with age of the home ($p = 0.000$); and were higher beneath the household dripline than in vegetable garden beds ($p = 0.040$). In certain circumstances, the data indicates that elevated soil Pb concentrations could present a potential health hazard in a portion of inner-city residential vegetable gardens in Melbourne.

1. Introduction

Residential and community vegetable gardening is a popular activity that has increased substantially in recent years (Kessler, 2013). Specifically, in Australia its popularity has grown markedly such that approximately 48% of homes produce some food from their garden (Wise, 2014). Gardening provides a host of benefits, including increased social cohesion (Armstrong, 2000) and improved physical and mental health (Mcbey, 1985; Wakefield et al., 2007). Food insecurity and lack of access to nutritious food has been linked with a number of health problems, and is thought to be partially responsible for the increasing obesity rates across much of the developed world (Corrigan, 2011). By improving access

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to nutritious food, residential and community gardens contribute to a healthy diet, and can help alleviate some of the emerging community health burdens.

The lack of suitable private open spaces in cities means that many urban gardens are situated in communal lots, which either due to their previous use by industrial operations, or simply due their proximity to roadways, may contain harmful contaminants (Filippelli et al., 2005; De Silva et al., 2016). As the popularity of community gardens have increased, so have concerns over the legacy of contamination at such sites with concerns of increased human exposure to contaminants, and its potential for causing a negative effect on human health (Attanayake et al., 2014; Spliethoff et al., 2016).

Metals can be emitted into urban environments from a variety of sources, including waste disposal facilities and rubbish dumps (Fujimori and Takigami, 2014; Akoto et al., 2016), industrial emissions (Harvey et al., 2017), vehicular emissions from the wear and tear of automobile tyres (Adachi and Tainosho, 2004), engine parts (Alloway, 1995) and mining and smelting operations (Galvin et al., 1993; Kachenko and Singh, 2006b; Yang and Cattle, 2015; Taylor, 2015; Taylor et al., 2014; Harvey et al., 2016). The legacy of depositions from these sources has led to ongoing contamination concerns in urban areas.

Lead (Pb) is one of the most common contaminants observed in urban soils due to its long history of use across a wide range of industrial applications, in particular it use as additions to petrol and paint. Lead additives (as tetraethyl or tetramethyl Pb) were first added to Australian petrol in 1932 to increase the octane rating of fuel and to reduce engine knocking (Kristensen, 2015). The Pb additives were used for seven decades, albeit in reducing concentrations, from the 1970s until 2002 when leaded petrol for automobile use was phased out (Kristensen, 2015). During the 70 years of leaded petrol consumption, an estimated 240,510 tonnes of Pb were emitted across Australia, with approximately 49,500 tonnes in the state of Victoria (Kristensen, 2015). Lead-based paints ranging between 1 and 50% by weight Pb have been used on many older homes in urban areas of Australia (AGDOEE, 2017). The deterioration of external lead-based paints can be a source of Pb in urban soils (Rouillon et al., 2017a).

Soil Pb contamination in urban areas typically forms a 'bullseye' pattern, with concentrations most elevated in the older areas and decreasing towards the younger suburban areas. This pattern has been observed in New Orleans, Louisiana (Mielke et al., 2017); Indianapolis, Indiana (Filippelli et al., 2005); Sydney, Australia (Birch et al., 2011) and London, England (BGS, 2017).

1.1. Previous studies of soil metal concentrations in Melbourne's soils

There have been limited published studies attempting to quantify soil metal contamination levels in Melbourne. While some community gardens may carry out their own testing for contaminants along with councils on an *ad hoc* basis, the results are usually not made public. In order to assess the spatial distribution of Pb in surface soils of Melbourne, Laidlaw et al. (2017) collected 58 soil samples along three transects oriented across the Melbourne metropolitan area. The study included a further 56 samples collected in five Melbourne suburbs: Footscray, Altona North/Brooklyn, East Brunswick, Blackburn and Mill Park. Laidlaw et al. (2017) observed a median soil Pb concentration of 173 mg/kg (range = 32 mg/kg to 710 mg/kg) for these transect samples and a median soil Pb concentration of 69 mg/kg (range = 9 mg/kg to 1750 mg/kg) for suburb soil samples. The suburb of Footscray had the highest soil Pb concentration with a median value of 192 mg/kg (range = 40 mg/kg to 1750 mg/kg). Soil Pb concentrations were generally highest nearest the centre of the Melbourne metropolitan area and to the west of the city with lower values in the outer suburbs and to the east and north of the city centre. Soil Pb concentrations collected from transects taken from urban parks decreased with distance from roadways. A control surface soil (0–2 cm) sample collected from a rural setting located approximately 31 km northeast of the Melbourne central business district (Wittons Reserve, Waranga Park) exhibited a Pb concentration of 17 mg/kg. Mikkonen et al. (2017) assessed the background concentrations of As, Mn, Ni, Pb and Zn in soils developed on the Newer Volcanic (basalt) geology of the Melbourne metropolitan area. They observed a median and 95th percentile background soil Pb concentration of 14 and 45 mg/kg, respectively. The only other published studies regarding soil metal concentrations were those conducted by Olszowy et al. (1996, 1996) collected 80 soil samples from urban areas of Melbourne, however the locations of the soil samples were not specified. Olszowy et al. (1996) reported that 5%, 20%, 0%, and 0% of soil samples collected in older high traffic areas, older low traffic areas, newer high traffic areas and newer low traffic areas exhibited soil Pb concentrations greater than the Australian HIL-A residential guideline of 300 mg/kg, respectively. A more recent report (De Silva et al., 2016) observed that metals (including Pb) were found to be significantly accumulated in roadside soil and were related to traffic characteristics such as vehicle speed, road age and traffic density. However, there are no known published studies of soil metal concentrations in Melbourne's community and residential gardens, where there is a greater risk of exposure.

1.2. Soil lead guidelines – Australia and internationally

Regulators in Australia and internationally have established soil Pb guidelines to account for exposure to Pb in soil. Within Australia, the National Environment Protection Council (2013) has established a tiered level of soil Pb guidelines that depend on land use and risk of exposure, known as health investigations levels (HILs) (NEPC, 2013). The relevant HILs for soil Pb concentrations are 300 mg/kg for residential areas with gardens or accessible soil (HIL-A) and 600 mg/kg for public access recreation areas such as parks and play grounds (HIL-C). By contrast, some international soil Pb values are much lower. For example, the California residential soil Pb guideline is 80 mg/kg (Ca-Oehha, 2017); Canadian Council of Ministers of the Environment (CCME) soil Pb guidelines are 70 mg/kg for agricultural land and 140 mg/kg for residential or parkland (CCME, 2017); and the Norwegian soil Pb guideline for soil in day care centres, playgrounds and schools is 100 mg/kg (NPCA, 2009). In the United Kingdom, the Category 4 screening level for Pb in soil is 80 mg/kg for allotments and 200 mg/kg for residential properties with home grown produce (Defra, 2014). There is no international consensus regarding soil Pb guidelines but they are typically set a higher level than average crustal background Pb concentrations, which are in the range of 10–23 mg/kg (Callender, 2003).

1.3. Recommended soil lead level limits for growing food in gardens

Table 1 presents a list of selected recommended soil Pb concentration limits for growing food in gardens. Some of the suggestions include multiple soil Pb limits that take into consideration whether children will be participating in the gardening activity or the type of vegetables to be grown.

1.4. Objectives

The primary objective of this study was to establish the presence and prevalence of soil metal contamination in residential and