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# Delineating the spatial extent of smelter-related atmospheric fallout using a rapid assessment technique

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ABSTRACT

The former Pasminco Cockle Creek Smelter (PCCS) at Boolaroo, New South Wales, Australia, has for many years received considerable attention in the international research literature and the community more broadly relating to legacy off-site soil metal(loid) contamination from the lead smelter operation. Smelter derived environmental Pb contamination and associated elevated childhood blood Pb concentrations have been central to these concerns. In this study, we consider the efficacy of the Lead Abatement Strategy (LAS) grid used as a management tool to delineate the extent of environment contaminant transport and deposition around the PCCS. Through *in-situ* portable X-ray fluorescence (pXRF) analysis of 150 surface soils in and outside of the LAS grid, this study demonstrates that, when compared to the Australian Health Investigation Levels (HILs), the LAS grid is a useful indicator of soil Pb concentrations around the PCCS. Soils outside of the LAS grid typically contained Pb concentrations below the Australia HIL for residential areas (HIL-A, 300 mg/kg) (median – 116 mg/kg; max – 3760 mg/kg; n = 118), with a small number of sites (n = 15) exceeding the HIL-A, mainly resulting from waste slag material. Surface soil Pb concentrations within the LAS grid exceeded the HIL-A in 38% of soils analysed (median – 182 mg/kg; max – 4170 mg/kg; n = 32). This study provides a useful application of pXRF technology that can be adopted by environmental regulators for rapid compliance assessment.

## 1. Introduction

Non-ferrous metal smelters often produce metal-rich, atmospheric emissions that contaminate nearby soils and waters, potentially leading to health exposure risks for those who live in these environments (Baker et al., 1977; Csavina et al., 2012, 2014; Landrigan et al., 1976; Taylor et al., 2014). Studies from the international literature examining ferrous and non-ferrous smelter emissions demonstrate that there is typically an enrichment of surface soil metal(loid) (hereafter referred to as metal) concentrations according to wind strength, wind direction, stack height and topography surrounding the smelter (Ettler, 2016; Félix et al., 2015; Soto-Jiménez and Flegal, 2011). In Port Pirie, South Australia, this halo extended over 65 km from the point source (Cartwright et al., 1977), while in Port Kembla, New South Wales (NSW), soil metal concentrations decreased to near background concentrations at a distance of approximately 4 km from the emission source (Martley et al., 2004). Similarly in China, surface soil metals around a lead-zinc (Pb-Zn) smelter were elevated in concentration when compared to relevant health guidelines inside the 6 km study zone (Li et al., 2015).

The former Pasminco Cockle Creek Pb-Zn smelter (PCCS) at Boolaroo, NSW, Australia, which closed in 2003 after more than 100 years of intermittent operation has resulted in significant contamination of soils and dusts around the facility (Harvey et al., 2016b). Smelter derived environmental Pb contamination in the surrounding suburbs has resulted in incidences of elevated childhood blood Pb (e.g. Dalton and Bates, 2005; Gulson et al., 2004) among other outcomes. To lower the risk of legacy Pb exposure, the Administrator for Pasminco Cockle Creek Smelter Proprietary Limited after it ceased operating and the NSW Environment Protection Authority (EPA) developed a Lead Abatement Strategy (LAS) in 2007 as a practical solution to manage smelter-derived soil Pb contamination (Zines, 2007). Following the completion of the LAS in 2013, criticism of its efficacy has come from the media and local community (e.g. Newcastle Herald, 2017) along with researchers (e.g. Harvey et al., 2016b; Morrison, 2003) due to inadequacies and inconsistencies of the approach used and its outcomes. The limitations of the LAS identified include the voluntary opt-

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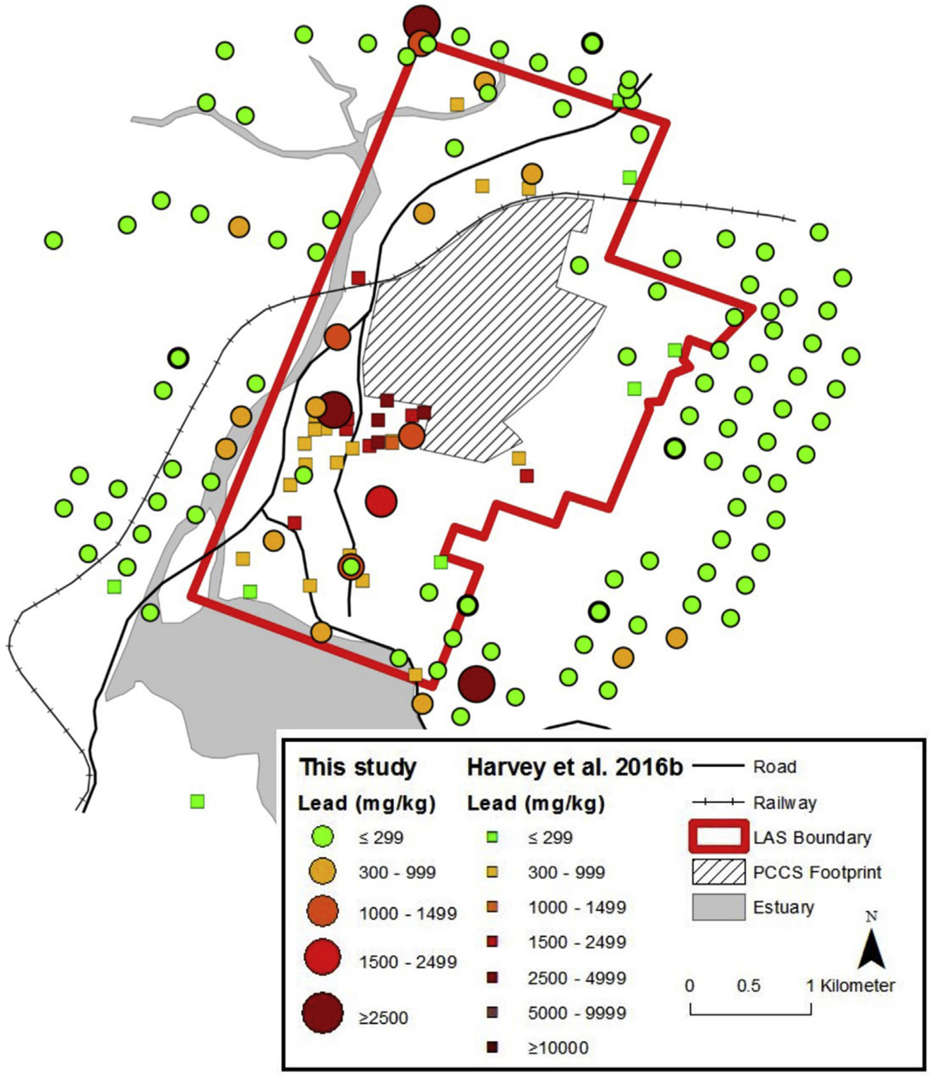


**Fig. 1.** Distribution and concentration of soil samples surrounding the PCCS site. Data from Harvey et al. (2016b) are included to supplement this assessment. Notably, the majority of soils outside of the LAS grid boundary contained soil Pb concentrations ≤299 mg/kg.

in approach for the assessment of residential properties (40% of eligible properties did not receive abatement), the exclusion of metal-rich slag materials (originating from the PCCS) from abatement, the thickness of the soil capping used and the depth of soil sampling (Harvey et al., 2016b, Morrison, 2003, LEWG, 2016). Further, concerns have been raised about the LAS 'grid' which encompasses the former PCCS and was used to delineate the perceived spatial extent of environmental contamination arising from the smelter operation (Newcastle Herald, 2014, Fig. 1).

The origins of this grid are unclear, however, there is speculation that it was derived from a combination of historic soil metal concentration data, child and pet blood Pb data and expected atmospheric fall-out patterns due to local topography (Galvin et al., 1992, 1993; Harvey et al., 2016b; Morrison and Gulson, 2007). During the operation of the PCCS, Galvin et al. (1992) considered the spatial extent of atmospheric fallout from the smelter and it was determined that soil Pb concentrations decreased with distance from the smelter to approximately 1200 m in the north-south direction, where soil metal concentrations became relatively consistent. Recent research has mainly focussed on characterising soil contamination within the grid, pre- and post-cessation of smelting, and the human health impacts associated with that contamination (Galvin et al., 1992; Gulson et al., 2004; Harvey et al., 2016b; Morrison, 2003; Morrison and Gulson, 2007; Morrison et al., 2016; Ouw and Bisby, 1976; Willmore et al., 2006). A study by Huang and Gulson (2002) considered soils and moses up to 4 km from the PCCS and used selenium (Se) concentrations to demonstrate that the PCCS was a primary source of soil contaminants in the area. Another study by Kim et al. (2009) considered a small number of non-systematic soil samples in- and outside of the LAS boundary (n = 13) and found the potential for health-related impacts from soil exposure. More recently in 2014, the Lead Expert Working Group (LEWG) was established by the NSW EPA to evaluate the effectiveness of the LAS and other associated remediation activities surrounding the PCCS. The LEWG reached the following key finding, among others:

> "The sampling methods used to establish the LAS area and assess the degree of soil lead contamination were not consistent with best practice and therefore cast a degree of uncertainty over the relevance of this area for ongoing management." (LEWG, 2016)

Regardless of the origin of the grid to date and doubts about its relevance, there has been no systematic evaluation of soil Pb concentrations outside of the LAS grid, and subsequently no knowledge exists about the potential hazard and exposure risks related to those soils. The objective of this new work is to assess surface soils outside of the LAS grid to establish (a) the extent and human health hazard associated with the presence of Pb contamination; (b) to determine the