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Environmental contamination in an Australian mining community and potential influences on early childhood health and behavioural outcomes

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Abstract

Arsenic, cadmium and lead in aerosols, dusts and surface soils from Australia's oldest continuous lead mining town of Broken Hill were compared to standardised national childhood developmental (year 1) and education performance measures (years 3,5,7,9). Contaminants close to mining operations were elevated with maximum lead levels in soil: 8900 mg/kg; dust wipe: 86,061 μg/m^2; dust deposition: 2950 μg/m^2/day; aerosols: 0.707 μg/m^3. The proportion of children from Broken Hill central, the area with the highest environmental contamination, presented with vulnerabilities in two or more developmental areas at 2.6 times the national average. Compared with other school catchments of Broken Hill, children in years 3 and 5 from the most contaminated school catchment returned consistently the lowest educational scores. By contrast, children living and attending schools associated with lower environmental contamination levels recorded higher school scores and lower developmental vulnerabilities. Similar results were identified in Australia's two other major lead mining and smelting cities of Port

Pirie and Mount Isa.

Graphical abstract

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Introduction

The metalliferous mining history of Australia dates to the 1840s, when lead (Pb) and silver was discovered in Glen Osmond, South Australia (Drew, 2011). The minerals resource industry continues to play an important role in the Australian economy, contributing approximately 10% to gross domestic product (Roarty, 2010). Environmental contamination arising from mining and smelting operations is a worldwide concern (Nriagu, 1994, Malm, 1998, Ghose and Majee, 2000, Mighall et al., 2002, Zhang et al., 2012, Hang and Kim Oanh, 2014). In Australia, environments have been severely contaminated with metals (e.g. arsenic (As), cadmium (Cd), copper (Cu), Pb and zinc (Zn)) from ore mining and processing (e.g. Cartwright et al., 1976, van Alphen, 1999, Morrison and Gulson, 2007, Taylor et al., 2014a, Taylor et al., 2014b).

The effects of environmental exposures on children's health have been reported widely outside Australia (Schwartz et al., 1986, Lanphear et al., 1998, Selevan et al., 2003, O'Bryant et al., 2011, Ciesielski et al., 2013). However, in Australia, there has been a relative paucity of research examining the impacts from mining and smelting emissions on educational and behavioural outcomes in children. The available research has focused largely on impacts of environmental Pb contamination at Port Pirie (McMichael et al., 1988, Baghurst et al., 1992, Tong et al., 1996, Burns et al., 1999). Earl et al. (2015) examined the effect of Pb on children's cognitive abilities in both Port Pirie and Broken Hill using a small cohort of 106 children with a mean age of 7.96 years. Therefore, an opportunity exists to utilize existing national education and development measures to evaluate possible linkages between environmental toxic metal exposures (e.g. As, Cd and Pb) and childhood outcomes (Australian Curriculum Assessment and Reporting Authority (ACARA), 2008, Australian Early Development Census (AEDC), 2013). Although less well studied than Pb, several studies have shown As and Cd exposure in children and adults can also result in neurocognitive impairment (Calderon et al., 2001, Wright et al., 2006, O'Bryant et al., 2011, Ciesielski et al., 2013).

Broken Hill, Australia, contains the world's largest silver-lead-zinc mineral deposit and has been mined since the discovery of ore in 1883 (Solomon, 1988). Lead poisoning in Broken Hill was reported as early as 1893 (Thompson et al., 1893). Previous studies about environmental contamination were conducted between the 1990s and early 2000 (e.g. Gulson et al., 1994). Systematic investigation of childhood blood lead levels commenced in 1991, thereafter a general decrease in childhood blood lead levels has been recorded (Lesjak et al., 2013). However, since 2010 the proportion of children over the recently withdrawn national guideline of 10μg/dL increased from 12.6% (2010), 13% (2011) to 21% (2012 and 2013) (Lesjak et al., 2013, New South Wales (NSW) Government, 2014). The recent rises in the percentage of children exceeding 10μg/dL may be due in part, to greater participation in annual blood lead monitoring programs following efforts to increase sample size by NSW Health. The recent increase in Broken Hill childhood blood lead levels stimulated further environmental contamination studies and attention from the New South Wales (NSW) Government in regard to persistent problem of elevated blood lead in children (Taylor et al., 2014b, Kristensen et al., 2015, Kristensen and Taylor, Humphries, 2015).

This research was undertaken in the context of recent rises in childhood blood lead levels in Broken Hill and the newly revised Australian blood lead intervention level of 5μg/dL (NHMRC, 2015). The study applies an ecological approach to assess the spatial relationship between the potential risk of harm from environmental neurotoxic metal and metalloid hazards (As, Cd and Pb) and children's behavioural and educational performance.

Section snippets

Sampling and materials

Surface soil samples (0–2 cm) were collected from a total of 57 sites across the city covering six primary school catchments (SC) (Fig. 1). School catchments are used to guide parents to which primary school is appropriate for their home address. However, it is not an absolute guide as a small number of children attend schools in other catchments. Soil samples collected from school catchments and public spaces, were sieved to <2 mm using stainless steel sieves before analysis. From the 57 sites …

Lead in airborne particulates

According to the National Pollutant Inventory (NPI), estimated atmospheric Pb emissions between 2012 and 2013 (26,000 kg) from Perilya Limited rank it third in Australia and first in NSW (NPI, 2014a). From May 2012 to May 2014, lead in air measured as TSP Pb recorded at Licence point 12 (LP12) displayed consistently higher values between the months October to January, for both years (Supplementary Fig. S6). These months returned a maximum of 0.707 $\mu g/m^3$ and an average of 0.487 $\mu g/m^3$ compared to …

Conclusions and study limitations

There are some limitations to the study's research findings in addition to those associated with ecological research of this nature. The NAPLAN data is limited to school level. While students from each school are drawn predominantly from their corresponding catchments (~95%), there is some variance, which was not able to be accounted for. In addition, the measures of exposure from environmental contaminants are not based on individual exposures but are derived from neighbourhood samples.…

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