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Monitoring steel bridge renovation using lead isotopic tracing

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HIGHLIGHTS

- Paint dominantly from geologically old Broken Hill Pb deposit.
- Background air particulates dominated by gasoline Pb.
- Release to atmosphere from operations detected.
- Underwater sediments have a complex history.
- Blood Pb isotopic data indicate prior exposure history to old Pb.

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ABSTRACT

Monitoring removal of lead (Pb) paint from steel structures usually involves analysis of environmental samples for total lead and determination of blood Pb levels of employees involved in the Pb paint removal. We used high precision Pb isotopic tracing for a bridge undergoing Pb paint removal to determine if Pb in the environmental and blood samples originated from the bridge paint. The paint system on the bridge consisted of an anti-corrosive red Pb primer top-coated with a Micaceous Iron Oxide (MIO) alkyd. Analysis of the red Pb primer gave uniform isotopic ratios indicative of Pb from the geologically-ancient Broken Hill mines in western New South Wales, Australia. Likewise waste abrasive material, as anticipated, had the same isotopic composition as the paint. The isotopic ratios for other samples lay on 2 separate linear arrays on a $^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ diagram, one largely defined by gasoline and the majority of the ambient air data, and the other by data for one sample each of gasoline and ambient air and underwater sediments. Isotopic ratios in background ambient air samples for the project were characteristic of leaded gasoline. Air sampling during paint removal showed a contribution of paint Pb ranging from about 20 to 40%. Isotopic ratios in the blood of 8 employees prior to the commencement of work showed that 6 of these had been previously exposed to the Broken Hill Pb possibly from earlier bridge paint removal projects. One subject appeared to have increased exposure to Pb probably from the paint renovations.

1. Introduction

Many older steel structures including steel bridges and water towers were previously coated with Pb-bearing paints, most commonly using “red-lead” (Pb_3O_4) as an anti-corrosive pigment in the primer. The environment around these structures may be contaminated with Pb from deterioration (weathering) of the paint or as a result of previous paint removal associated with maintenance of the structure over time (Howard et al., 2013; Landrigan and Todd, 1994; Landrigan et al., 1982; Lange, 2002; Lange and Thomulka, 2000; Spee and Zwennis, 1987; US EPA, 1996; Waller et al., 1994; Weiss et al., 2006). Cases have been described where animals grazing below bridges undergoing maintenance of Pb paints have been Pb poisoned and in some cases animals died. Soil and air contamination can also be of concern if there are dwellings or publicly accessed buildings (including child care centres) or

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public parks and lands in close proximity to bridges or other Pb-coated structures.

The usual method of monitoring involves analysis of total Pb in environmental samples as described in the above articles. In addition, blood samples are taken from the employees as required by relevant Work Health and Safety (WHS) regulations covering Pb work. Here we propose a novel method, not previously employed to our knowledge, using Pb isotopic tracing as a monitor for linking environmental contamination and occupational exposure of employees during Pb paint removal to the Pb present on the bridge being treated. This is one of several studies undertaken to evaluate the Pb isotopic method in monitoring contamination associated with steel bridges (e.g., Gulson et al., 2016a).

The lead isotope method has a long history of tracing sources and pathways for environmental issues and in the environmental health field. For example, Komarek et al. (2008) provided a comprehensive review of the use of lead isotopes in environmental sciences focussing on the pathways employing such materials as atmospheric aerosols, lichen, tree rings, peat, soils, and sediments from lake/stream/marine environments. They also described studies of sources such as leaded gasoline, coal, industrial activities including mining and smelting, and waste incineration. In the same year Gulson (2008) reviewed the use of lead isotopic tracing in the environmental health field, which covered such uses as tracing sources and pathways in children and adults from mining and smelting environments, in suburban environments and monitoring release of lead from the maternal skeleton during pregnancy and lactation, and use of bisphosphonates to minimize release of lead from the skeletons of more elderly subjects.

Since that time there has been a proliferation in the use of lead isotopic tracing in the environmental field, especially in China, with analyses of samples as used in the past, such as aerosols, coal and soil (e.g., Cheng and Hu, 2010). Most of the studies employed inductively coupled plasma mass spectrometry (ICP-MS) because of the relative ease of sample preparation and analysis but which provide medium quality data compared with multi-collector ICP-MS or thermal ionization mass spectrometry. In many studies using ICP-MS, interpretations are limited because of overlapping data, as shown in the final section of the current paper.

2. Methods

2.1. Details of the Ryde Bridge and proposed work and monitoring schedules

The Ryde Bridge in western Sydney [New South Wales (NSW)], officially opened in 1935, is an 11 span bridge of riveted steel compound girder construction, with Spans 4, 5 and 6 being the truss spans, the refurbishment of which was the scope of the work contract. Span 5 was formerly a lift span and, although no longer serviceable, the lift towers had been retained because of their heritage value and were included in the works. The old Ryde Bridge across the Parramatta River carries three lanes of traffic (Concord Road) in the northbound direction (Fig. 1 Supplementary files). A newer parallel bridge carries three southbound lanes. Estimated maximum traffic volume was of the order of 50,000 vehicles per day at the time of refurbishment. In order to facilitate the repainting works, especially the control of emissions, for all but the latter stages of the contract, the old bridge was closed and all traffic was diverted to the new structure.

The contract for the repainting of the steel truss spans in the early 1990's has special significance with respect to the development of current national guidelines for the management of Pb-coated structures. The specification and accompanying guidelines for this project, which were prepared by an overseas consultant to the then Roads and Traffic Authority of NSW (RTA), [now Roads and Maritime Services (RMS)], were the source of much of the information subsequently detailed in the Standards Australia document, AS 4361.1—1995 "*Guide to lead paint management Part 1: Industrial applications*".

A previous contract to repaint the Ryde Bridge steelwork in the late 1980's had been stopped as a result of unacceptable emissions produced which impacted adversely on the construction of the adjoining new structure. Wet abrasive blasting techniques had been employed for the removal of the Pb paint but the access and containment systems had proved inadequate to satisfactorily control the waste water and blast debris that was produced. A contract for the repainting of the steel truss spans of the Shoalhaven River Bridge (Southbound) in southern NSW, also in the late 1980's, was similarly cancelled as a result of unacceptable emissions.

These contracts highlighted a gap between the typical work practices of the time and the much more rigorous approach to emission control that was required to address the greater public awareness of environmental matters at the time and in particular, increasing community concerns related to exposure to Pb.

The work involved the complete removal of the original aged Pb paint by abrasive blast cleaning and the application of a modern epoxy coating system providing long term corrosion protection of the steelwork. Whereas wet abrasive blasting techniques were used for the earlier unsuccessful contract, dry abrasive blast cleaning was specified for the latter contract. The contract required the use of full containment, ventilation and dust extraction equipment to control emissions to the environment and to reduce dust levels within the containment to acceptable levels for worker safety.

Most significantly, the Ryde Bridge repainting contract included emission limits that had not been previously specified and there were concerns that the emission levels specified were too onerous given the nature of the work. Leaded gasoline was still in use at the time. Assessing the effectiveness of the emission control measures employed would require some measure of the respective proportions of Pb in environmental and blood samples that originated from bridge paint versus that from gasoline, hence the employment of the Pb isotopic tracing method.

The NSW RTA arranged for environmental monitoring to be carried out during the contract works by an independent private consultant as a means of determining environmental compliance by the contractor, using standard environmental analysis procedures. Employee blood monitoring was conducted by the contractor under their regulatory WHS requirements.

2.2. Paint sampling

Representative samples of paint were removed from several locations on the bridge using a stainless steel blade which was cleaned between each sampling site, ensuring all layers of the paint system down to the substrate were included. Paint layers were prepared as polished epoxy blocks, examined by reflected light microscopy and scanning electron microscopy (SEM). Lower layers were orange, brown or red in colour consisting of Pb oxide and these were handpicked from the sample for Pb content and Pb isotopic analysis. Two samples of the outer grey layer, 'touch-up paint', consisting of Pb-Zn-O were separated. Total Pb digestion of paint samples employed refluxing 1:1 nitric acid/hydrogen peroxide mixture for 2 h followed by dilution to 100 g with MilliQ de-ionised water at CSIRO laboratories, North Ryde NSW. Samples were also analysed in an alternative laboratory using microwave-assisted digestion with nitric acid/hydrofluoric acid. At CSIRO, total lead concentrations were measured by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) and the alternate laboratory by Flame Atomic Absorption Spectroscopy (AAS).