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Particulate matter concentrations and heavy metal contamination levels in the railway transport system of Sydney, Australia

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ABSTRACT

Sampling campaign was conducted over six weeks to determine particulate matter (PM) concentrations from Sydney Trains airport line (T2) at both underground and ground levels using DustTrak. Dust samples were collected and analysed for 12 metals (Fe, Ca, Mn, Cr, Zn, Cu, Pb, Al, Co, Ni, Ba and Na) by atomic emission spectroscopy. Average underground PM_{10} and $PM_{2.5}$ concentrations from inside the trains were 2.8 and 2.5 times greater than at ground level. Similarly, PM_{10} and $PM_{2.5}$ concentrations on underground platforms were 2.7 and 2.5 times greater than ground level platforms. Average underground PM concentrations exceeded the national air quality standards for both PM_{10} (50 μg/m^3) and $PM_{2.5}$ (25 μg/m^3). Correlation analysis showed a strong to moderate association between PM concentrations at ground level and background PM concentrations (r^2 from 0.952 to 0.500). The findings suggested that underground PM concentrations were less influenced by the ambient background than at ground level. The metal concentrations decreased in the order of Fe, Cr, Ca, Al, Na, Ba, Mn, Zn, Cu, Ni, Co and Pb. The pollution index (PI) and enrichment factor (EF) values were calculated to identify the levels and sources of contamination in the underground railway microenvironments. PM was remarkably rich in Fe with a mean concentration of 73.51 mg/g and EF of 61.31, followed by Ni and Cr. These results noticeably indicated a high level of metal contamination in the underground environments, with the principal contribution from track abrasion and wear processes.

1. Introduction

Particulate matter (PM) is one of six air pollutants that have been regulated worldwide (Atkins et al., 2010). Short term and long term exposure to elevated levels of PM has been strongly associated with the development of respiratory and cardiovascular diseases as well as carcinogenic problems, as reported by the World Health Organisation (WHO, 2013). An estimate from WHO (2002) showed about 800,000 premature deaths per year were caused by short term and long term exposure to $PM_{2.5}$, highlighting the severity of the risk from PM exposure. In addition, epidemiological and toxicity studies have shown that elevated concentration of PM and their chemical compositions can cause serious respiratory problems (Epton et al., 2008; Kim et al., 2015; Liu et al., 2014); cardiovascular problems (Brook et al., 2010; Farraj et al., 2015; Lopez et al., 2006); and increase carcinogenic risks (Gray et al., 2015; Hamra et al., 2014; Lopez et al., 2006). The possible adverse effects of PM can occur directly from PM accumulation inside human bodies through ingestion, dermal contact or inhalation, and from contaminants such as heavy metals in PM (Kampa and Castanas, 2008).

As a result of ever-growing human population and traffic volumes, people in urban areas especially megacities are heavily dependent on the railway network as a vital transport mode (Song et al., 2016). Despite the fact that the time spent in travelling by

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train on the railway network is relatively short, high PM concentrations and the associated harmful chemical composition in high density population environments can cause serious health problems (Fridell et al., 2010; Karlsson et al., 2005).

There have been many studies to evaluate PM concentrations in the railway and underground networks, most of which have shown elevated levels of PM in the underground when compared with the ambient background measurements and street levels. Personal exposure levels of $PM_{2.5}$ for the commuters of the London underground rail were up to 8 times higher than three different ground level commuting modes (bicycle, bus, car) (Adams et al., 2001). Another study from Paris showed that PM_{10} and $PM_{2.5}$ concentrations in the central railway station were 5–30 times higher than those measured on streets (Raut et al., 2009). Furthermore, a study from the Los Angeles metro system showed that the average concentrations of PM_{10} and $PM_{2.5}$ were about 2 times higher in the underground platforms and the train carriages compared to the ground level light rail stations and carriages (Kam et al., 2011a). Previous railway studies reported different results in terms of PM concentrations which were justified by major factors that can significantly affect the air quality measurements such as the age of the metro network, the braking system used, the ventilation system and the availability of an air conditioning system, the frequency of the trains' passage, in addition to other operating factors (Aarnio et al., 2005; Abbasi et al., 2011; Moreno et al., 2014; Namgung et al., 2016).

In terms of the chemical composition, studies have found that PM in the railway environments was highly enriched with different heavy metals specifically Fe, Cr, Cu, Mn and Ni (Aarnio et al., 2005; Perrino et al., 2015; Salma et al., 2009; Querol et al., 2012). These metals are generally produced by the friction, wear and abrasion processes for the wheels, rail lines and the break system.

Sydney as the capital city of NSW with a large population of more than 5 million people has different transport modes to cope with the needs of its residents. Due to the fact that it covers a wide urban area, the major transport mode used in Sydney is the private car followed by buses and trains (Bureau of Transport Statistics, 2015). So now, major research focus on PM has been on private cars, buses and tunnels, only a limited number of studies have been conducted on PM from Sydney transport systems (Knibbs et al., 2009; Knibbs and Morawska, 2011). To the best of our knowledge, no detailed study to evaluate Sydney railway microenvironments in terms of PM concentrations and associated metal contamination levels has been produced to date. Currently, the patronage of Sydney train is about 328 million customer journeys are taken annually in Sydney trains network; this number is expected to increase annually to meet the increasing demand of the population in Sydney (Bureau of Transport Statistics, 2015). Therefore, with such a significant number of journeys by urban population in Sydney, it is important to assess the PM contamination and its associated metal contaminants in the Sydney railway system and their potential impact on human health.

The aim of this study was therefore to evaluate PM and metal contamination from the Sydney railway system. The specific objectives were to measure PM_{10} and $PM_{2.5}$ levels at both underground and ground level platforms and inside train carriages, to assess the concentrations and potential sources of selected metals in the underground platforms.

2. Experimental methodology

2.1. Sampling sites

For PM concentration assessment, the Sydney Airport Line (T2), shown in Fig. 1, was sampled during 6-weeks sampling period

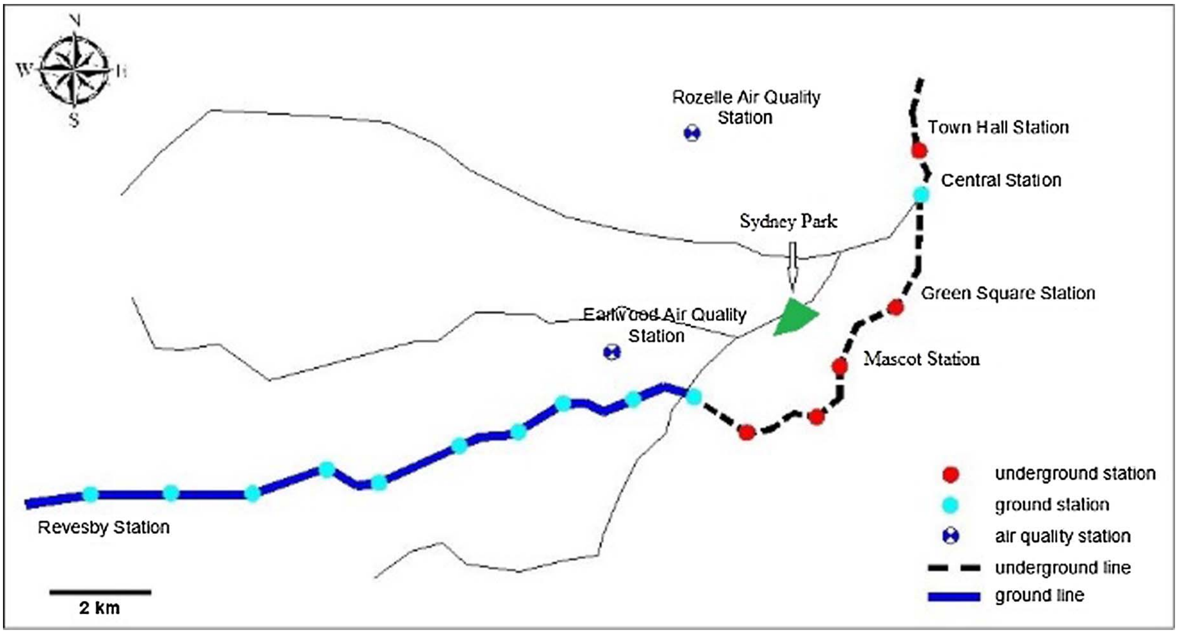

Fig. 1. Map indicating the sampled railway line (T2), underground and ground level platforms, and nearby background air quality monitoring stations monitored by NSW OEH. Also shown is Sydney Park as background where particles were sampled for metal analysis.