Atmósfera 29(3), 221-234 (2016)
doi: 10.20937/ATM.2016.29.03.04

Determining heavy metal contamination of road dust in Delhi, India

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Received: February 2, 2016; accepted: May 3, 2016

RESUMEN

La contaminación del aire es considerada como uno de los mayores desafíos ambientales debido a sus efectos sobre los ecosistemas y la salud humana. En este estudio se investigan los niveles de concentración y las fuentes de la contaminación por metales pesados en muestras de polvo de caminos recolectadas en varios sitios que incluyen áreas con cuatro actividades diferentes en Delhi, India: industriales, carreteras, residenciales y de uso mixto. El contenido de metales en polvo de caminos se analizó mediante espectroscopia de emisión atómica por plasma de acoplamiento inductivo. Los resultados muestran altos niveles de concentración de Ni, Cr y Pb en áreas industriales. Los coeficientes de correlación de Pearson acoplados con análisis de componentes principales revelaron que el CD, el Cr, el Ni y el Pb están vinculados con fuentes industriales en tanto que el Zn y el Cu proceden principalmente del tráfico vehicular. La contaminación en polvo de caminos se valoró a través de varios métodos: grado de contaminación, índice ecológico e índice de contaminación. El análisis de los factores de contaminación reveló que las muestras de polvo de caminos estaban contaminadas de manera considerable con Zn y Pb. Los índices de potencial ecológico indicaron la presencia de contaminación significativa por Cd y moderada por Pb en el polvo de camino, en tanto que la contaminación por Cr, Cu, Ni y Zn fue baja. El índice de contaminación de la mayoría de los metales fue mayor a 1, lo cual revela un deterioro en la calidad del polvo de caminos en Delhi a causa de las emisiones antrópicas. El grado de contaminación, el índice de potencia ecológico y el índice integrado de contaminación indican que el polvo de caminos en áreas industriales, de carreteras y de uso mixto exhiben alta contaminación por metales pesados. El polvo del camino también está contaminado de manera significativa. Evaluaciones realizadas por diversos métodos indicaron que todas las técnicas son importantes para valorar la calidad ambiental.

ABSTRACT

Air pollution has been considered one of the major environmental challenges because of its effect on ecosystems and human health. The concentration levels and sources of heavy metals contamination were studied in road dust samples collected from various locations including four different activity areas: industrial, highways, residential and mixed use in Delhi, India. Metal content in road dust was analyzed by inductively coupled plasma atomic emission spectroscopy. The results showed high concentration levels of Ni, Cr and Pb in industrial areas. Pearson's correlations coupled with principal component analysis revealed that Cd, Cr, Ni and Pb are associated with industrial sources whereas Zn and Cu are mainly contributed by vehicular traffic. Road dust contamination was assessed by various methods: degree of contamination, potential ecological index and pollution index. Contamination factor analysis showed that road dust samples are significantly contaminated by Zn and Pb. The potential ecological indices indicated high contamination of Cd and moderate contamination of Pb in road dust, but low contamination of Cr, Cu, Ni and Zn. The pollution index of most of the metals was higher than 1, indicating deterioration of road dust quality of Delhi city due to anthropogenic emissions. The degree of contamination, the potential ecological index and the integrated pollution index reveal that road dust from industrial, mixed use and highway areas are highly contaminated by heavy metals. The road dust from the residential area is also contaminated considerably. Evaluations by various methods indicated that all assessment methods are important for environmental quality evaluation.

Keywords: Correlation analysis, ecological risk index, pollution index, principal component analysis, toxic elements.

1. Introduction

Due to accelerated industrialization and urbanization, nearly half of the population in the world now lives in urban agglomerations. These intensive activities resulted in increasing quantities of contaminants into the urban environment. Consequently, a variety of environmental problems have cropped up and toxic metal pollution has become a major issue, especially in urban air, soils and road dust (Bilos *et al.*, 2001; Madrid *et al.*, 2002; Han *et al.*, 2006). Road dust is a complex mixture of particles and may contain various components like organics, heavy metals, other inorganics, mould spores, animal dander, pollen, pollen fragments etc., which can possibly get resuspended due to movement of vehicles and wind, resulting in an important source of atmospheric air pollution. It was observed that the particles and associated metals, particularly with fine dust, remain suspended in air longer under certain meteorological conditions. Road dust, an important environmental indicator of metal contamination from atmospheric deposition, receives varying inputs of anthropogenic metals from various stationary and mobile sources such as vehicular traffic, industrial activities, power plants, residential fossil fuel burning, waste incineration, construction and demolition activities, and resuspension of contaminated soil (Bilos *et al.*, 2001; Charlesworth *et al.*, 2003; Bhanarkar *et al.*, 2005, 2008; Gupta *et al.*, 2012). Road dust, therefore, is a significant contributor of pollution in the urban environment. The adverse effects of poor environmental conditions on human health are most evident in urban environments, particularly in developing countries where urbanization, industrialization and rapid population growth are taking place on an unprecedented scale (Duzgoren-Aydin, 2007).

Toxic metals in urban areas are a subject of great concern, due to their non-biodegradable nature and long residence time. The prolonged presence of the contaminants in the urban environment, particularly in road dust, and their close proximity to the human population significantly increase the exposure of the urban population to metals via inhalation, ingestion, and dermal contact (Mielke *et al.*, 1998; Abrahams, 2002). Metals can accumulate in fatty tissues, affecting the functions of organs and disrupting the nervous system or the endocrinal system (Waisberg *et al.*, 2003; Duzgoren-Aydin, 2007) and some metals could cause mutagenic, teratogenic and carcinogenic effects in living beings (Lienesch *et al.*, 2000; Cook *et al.*, 2005).

Although several studies on metal pollution in road dust have been carried out in developed countries (de Miguel *et al.*, 1997; Arslan, 2001; Rasmussen *et al.*, 2001; Charlesworth *et al.*, 2003; Sezgin *et al.*, 2003; Tokalioglu and Karta, 2006; Shi *et al.*, 2008; Amato *et al.*, 2009), very little information is available on this topic in developing countries. Only few studies on quantification and distribution of metals in road dust have been conducted recently in Indian cities (Chatterjee and Banerjee, 1999; Banerjee, 2003; Rawat *et al.*, 2009; Rajaram *et al.*, 2014).

Considering the above, the main objectives of this study include: (1) determination of heavy metals concentration in road dust in various urban environments of Delhi, (2) identification of the possible sources of metals in road dust through statistical analysis and (3) assessment of the metal contamination in urban road dust by various methods.

2. Materials and methods

2.1 Study area

Delhi, the capital of India, is a major center of international and domestic activities in the Asian subcontinent. It is spread over a 1483 km^2 area with a population of about 16.7 millions (GOI, 2011). Rapid urbanization and industrialization of the city resulted in growth of vehicular population in the city. There has been an exponential growth in vehicular fleet, which increased from 3.05 million in 1998-1999 to 6.3 million in 2008-2009, thereby registering an overall annual compound growth rate of 7.52%. Delhi has about 85 private cars per 1000 inhabitants (Government of NCT Delhi, 2010). The total distance traveled by all categories of vehicles in the city is estimated to be about 79.2 million km. Out of the above, two-wheelers and four-wheelers (car/van) account for a major share of 42.7% and 38% respectively. Three-wheelers and local buses account for about 11.8% and 3.6% of vehicular fleet in Delhi respectively, whereas the share of light commercial