Science of the Total Environment 637–638 (2018) 844–854

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

The impact of seasonal varied human activity on characteristics and sources of heavy metals in metropolitan road dusts

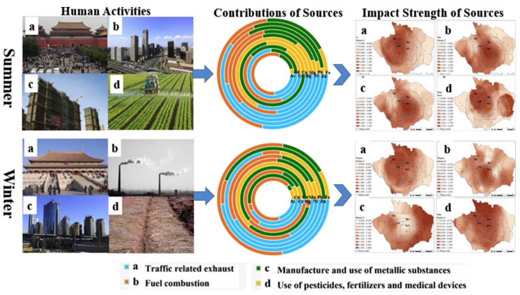
Cong Men, Ruimin Liu *, Qingrui Wang, Lijia Guo, Zhenyao Shen

State Key Laboratory of Water Environment Simulation, School of Environment, Beijing Normal University, No. 19, Xinjiekouwai Street, Beijing 100875, China

HIGHLIGHTS

- Impact of human activity on heavy metals in road dusts was studied in two seasons.
- Pollution levels and source types were similar, while source contribution varied.
- Dominant source was traffic exhaust in summer, while fuel combustion in winter.
- Source contribution and impact area changed with the variation of human activities.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 27 January 2018
Received in revised form 4 May 2018
Accepted 5 May 2018
Available online xxxx

Editor: Xinbin Feng

Keywords:
Heavy metals
Road dust
Geographic information system
Positive matrix factorization
Human activity

ABSTRACT

Due to significant human activity, road dust is becoming contaminated by heavy metals in many cities. To comprehensively investigate the variation of contamination level and sources of heavy metals in road dust, 10 heavy metals in road dust samples from Beijing, China, in both summer and winter, were evaluated by spatial analysis using geographic information system (GIS) mapping technology and the positive matrix factorization (PMF) Model. Although the concentrations of some heavy metals between summer and winter had similarities, the differences of others and spatial distributions of heavy metals between summer and winter were considerable. The mean concentrations of As, Cd, Cr, Cu, and Fe were lower in winter, while those of Hg, Mn, Ni, Pb, and Zn were higher. According to the values of the Pollution Index (*PI*) and Nemerow Integrated Pollution Index (*NIPI*), there were no obvious differences between summer and winter, but the range between different sites in winter was nearly twice that of summer. Based on the PMF model, four sources of heavy metals in the dust samples were identified. Although the types of sources were consistent, the relative contributions of each source differed between summer and winter. Non-exhaust vehicle emissions was the most important source in summer (34.47 wt%), while fuel combustion contributed the largest proportion to the total heavy metals in winter (32.40 wt%). The impact of each source also showed spatial variation different trends in summer and winter. With the alteration of seasons, intensity of human activities also changed, such as the number of tourists, energy needs for building temperature regulation, construction, and the amount of pesticides and fertilizer. That might be the reason for the variation of heavy metal concentrations and relative contribution of their sources between summer and winter.

1. Introduction

In cities, especially densely populated metropolises, the results of human activity, such as traffic exhaust, garbage, and industrial production

---

* Corresponding author.
E-mail address: liurm@bnu.edu.cn (R. Liu).

https://doi.org/10.1016/j.scitotenv.2018.05.059

activities, are extensive and considerable (Chen et al., 2017a) and can discharge various pollutants into the environment (Jiang et al., 2016). Among these pollutants, the impact of heavy metals requires special attention (Trujillo-González et al., 2016). Heavy metals are considered as priority pollutants due to their toxicity and non-degrading nature (Huang et al., 2006). Heavy metals can not only disrupt the ecological system but also threaten human health (Swietlik et al., 2015). They can reach a level of critical concentration through bioaccumulation along the food chain (Sajayan et al., 2017). Air, soil, water, and road dust in many cities worldwide suffer different levels of heavy metal contamination, mostly caused by human activities (Leopold et al., 2008; Bi et al., 2013). Therefore, it is essential to research heavy metals in cities.

Road dust is an important component in the urban ecological system. Elements in road dust are not only affected by point sources but also bound to non-point source pollution (Huang et al., 2015; Soltani et al., 2015; Samiksha et al., 2017). These are the sources and sinks of various pollutants, including heavy metals (Padoan et al., 2017). Metals produced by human activity can accumulate in road dust directly or indirectly, through absorption and atmospheric deposition (Bourliva et al., 2016). Exchange of heavy metals occurs continuously between road dust and other media, such as air, soils, and bodies of water (Franco et al., 2017). Heavy metals in road dust can enter the air through the resuspension. They can also be transported into surface water and underground water *via* rain (Liu et al., 2016). Furthermore, they could get into human bodies by inhalation of dust particles through the mouth and nose, direct ingestion of dust, and dermal absorption, which could increase risks, including carcinogenic risk (Xu et al., 2016). To protect the public from these threats of road dust, studies need to be performed on the heavy metal contamination condition of road dust.

To control the contamination more effectively, information on the sources and distribution of heavy metals in road dust is necessary. Receptor models were widely used in determining the source proportions (Li and Zhang, 2011; Tian et al., 2017). Compared with diffusion models, receptor models do not need information about emission conditions, weather and topography, and transportation processes, which contribute to the wide application of receptor models (Taiwo et al., 2014; Singh et al., 2017). Among receptor models, positive matrix factorization (PMF) has been applied in increasingly more studies regarding source proportions in recent years (Jiang et al., 2016; Haji et al., 2016). PMF has the distinct advantage of being able to accommodate data that is missing or below detection limit (Yu et al., 2015). PMF can identify a number of factors, source profiles, and the amount of mass contributed by each factor for each individual sample and the residual of each species in each sample (Norris et al., 2014; Wang et al., 2015). Based on the PMF Model, combined with geographic information system (GIS) mapping, the contribution of each source on heavy metal concentration in road dust can also be analyzed, and the range and impact of areas influenced by human activity can be determined (Yu et al., 2016).

The types and impact of human activity may vary in different seasons as a result of different climate characteristics, such as temperature, rainfall, and humidity (Norouzi et al., 2017; Nuel et al., 2018). The concentrations and sources of pollutants would probably change with the seasons (Yu et al., 2016; Khidkhan et al., 2017). The contributions of biomass burning and biogenic-dominated, secondary organic aerosols to the particulate matter peak in winter (Li et al., 2017a). The results of many studies showed that the examined values in summer and winter represented the highest and lowest extremes, respectively, out of the four seasons (Sivakumar, 2016; Li et al., 2017a; Norouzi et al., 2017). However, most studies of heavy metals in road dust were carried out using samples taken during one season; few take seasonal variation into consideration (Murakami et al., 2007; Watanabe et al., 2013). Therefore, an analysis investigating the effect of different seasons would be significant for more representative and convictive conclusions (Shirokova et al., 2013; Farraj et al., 2015).

The human activities varied between different seasons, while few studies focused on the variation of impact strength of sources influenced by human activities in different seasons. Because of the variation of types and impact of human activities, conclusions on characteristics of heavy metals such as concentrations and impact strength of sources based on one season are not convictive enough. Based on the heavy metal sample data in road dust in Beijing in June and December 2016, the main objectives of the present study were to 1) compare the differences in characteristics and sources of heavy metals in road dust between summer and winter and 2) analyze the influence of human activity on the characteristics and sources of heavy metals in road dust in different seasons.

2. Materials and methods

2.1. Study area

Beijing (115.7°–117.4° E, 39.4°–41.6° N) is one of the largest cities in China (Fig. 1). It is in a warm temperate and semi-humid continental monsoon climatic zone (Li et al., 2016a). The four seasons are distinctive in Beijing, and summer and winter have the longest durations (Beijing statistical Bureau, 2016). The summers have high temperatures and rainy weather, while the winters are cold and dry. The production and lifestyles of citizens change with the alternating contrast of summer and winter. There were nearly 22 million residents in Beijing in 2015, and 80% of these people lived in the urbanized area. Moreover, in recent years, over 200 million tourists per year came to Beijing (Beijing statistical Bureau, 2016). This large number of people consumed much energy and produced a large amount of waste, intensifying the pollution. The metallic pollution in air particle matters has been hazardous at times (Chen et al., 2017a). The non-carcinogenic risk caused by heavy metals in road dust was close to the threshold value for children (Tang et al., 2012).

2.2. Sampling

The road dust samples were collected in June and December 2016. Thirty-six sites were picked in each season (Fig. 1). In each site, >100 g samples were collected from no less than five sub-sites. Sampling methods and procedures were all kept concordant between these two sampling periods. Samplings were conducted at hardened ground, which was dried for at least seven days (Tang et al., 2016). Plastic brushes and dustpans were used for collecting. Samples collected at each site were stored in self-sealing polyethylene bags and transferred to the laboratory as soon as possible (Yu et al., 2017). The samples were air-dried for 15 days and then sieved with a 1000-μm nylon sieve to remove all debris, including hair and leaves. Subsequently, parts of the sieved dust samples were stored at 4 °C before analysis.

Ten typical metals that showed high pollution potential in related studies were chosen for measurement. These were arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), zinc (Zn), and iron (Fe) (Kefeni and Okonkwo, 2013; Coufalík et al., 2014). To measure the concentration of metals, two 0.50 g aliquots from each sample were selected for analysis. One of the aliquots was designated for the detection of Cd, Cr, Cu, Mn, Ni, Pb, Zn, and Fe. It was placed in a Teflon crucible (50 ml) and dissolved with HCl (5 ml), HNO_3 (5 ml), HF (5 ml), and $HClO_4$ (3 ml). An electric hot plate was used for heating. 50% (*v:v*) HNO_3 (5 ml). The extracted sample was moved to a volumetric flask and diluted to 50 ml. The other one was used for the detection of As and Hg. It was placed in a Teflon crucible (50 ml). A little distilled water and mixture of HCl and HNO_3 (1:3 in volume) (20 ml) were added in turn. The sample was then heated on an electric hot plate. HNO_3 (0.5 ml) and distilled water (20 ml) was added after cooling the treated sample. Then, the sample was heated for 2 min. After cooling, the extracted sample was moved to a volumetric flask and diluted to 50 ml. Cd, Cu, Ni, Pb, and