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An index for estimating the potential metal pollution contribution to atmospheric particulate matter from road dust in Beijing

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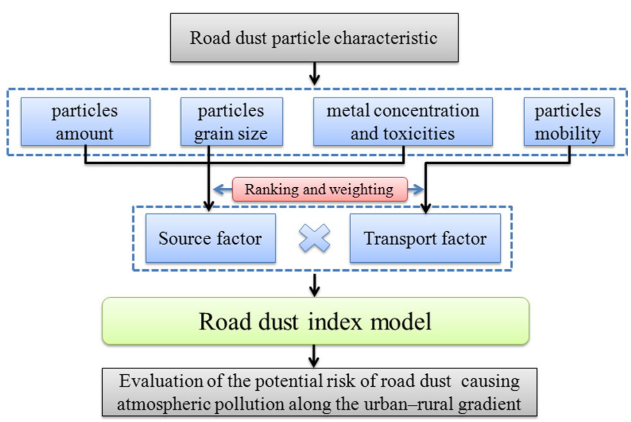
HIGHLIGHTS

- An innovative road dust index was developed.
- Road dust characteristics were ranked and weighted in the index model.
- Source and transport factors were both considered in the index model.
- The index can indicate risks of road dust causing atmospheric particulate pollution.

GRAPHICAL ABSTRACT



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ABSTRACT

The resuspension of road dust from street surfaces could be a big contributor to atmospheric particulate pollution in the rapid urbanization context in the world. However, to date what its potential contribution to the spatial pattern is little known. Here we developed an innovative index model called the road dust index ($RI_{<105\ \mu m}$) and it combines source and transport factors for road dust particles <105 μm in diameter. It could quantify and differentiate the impact of the spatial distribution of the potential risks posed by metals associated with road dust on atmospheric suspended particles. The factors were ranked and weighted based on road dust characteristics (the amounts, grain sizes, and mobilities of the road dust, and the concentrations and toxicities of metals in the road dust). We then applied the $RI_{<105\ \mu m}$ in the Beijing region to assess the spatial distribution of the potential risks posed by metals associated with road dust on atmospheric suspended particles. The results demonstrated that the road dust in urban areas has higher potential risk of metal to atmospheric particles than that in rural areas. The $RI_{<105\ \mu m}$ method offers a new and useful tool for assessing the potential risks posed by metals associated with road dust on atmospheric suspended particles and for controlling atmospheric particulate pollution caused by road dust emissions.

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Table 1
Characteristics of administrative divisions along the urban–rural gradient.

Area (no. of sampling sites)[a]	Population density (persons / km^2)[b]	Average daily traffic (vehicles / (d m))[c]	Total energy consumption (1000 t of SCE)[d]	Street cleaning method[e]	Frequency of sweeping (times/d)[f]
UCA (15)	15,000	8900	960	M	3
UVA (10)	1200	115	346	H	<0.2
CSA (58)	3000–5000	6700	960	M	3–2
RTA (41)	1500–2000	1300	346	H	2
RVA (40)	1000	105	346	H	0.3

[a] UCA = central urban area; UVA = urban village area; CSA = central suburban county area; RTA = rural town area; RVA = rural village area.
[b] Population density was estimated using data from the Beijing Municipal Bureau of Statistics.
[c] Average daily traffic was estimated using data from Beijing Transportation Research. Each value was divided by the number of lanes in the road to allow different sites to be compared.
[d] Energy consumption refers to residential consumption, including of coal, gasoline, diesel oil, liquefied petroleum gas, natural gas, heat, and electricity. Total energy consumption was estimated using data from the Beijing Municipal Bureau of Statistics. SCE means standard coal energy. SCE data were available only for the categories "urban" and "rural".
[e] M = mechanical sweeper; H = hand-swept using straw brooms. Most sites on the main roads were paved with asphalt, but a few roads in the rural areas were paved with concrete.
[f] Street cleaning methods and frequencies were determined from our own investigations.

1. Introduction

At present, air quality degradation due to ambient particulate matter has become an environmental issue of public health concern in most metropolitan areas in China (Chen et al., 2012; Huang et al., 2014). It is well known that the resuspension of road dust particles from urban street surfaces is an important source of atmospheric particulate pollution (Amato et al., 2009b; Martuzevicius et al., 2011). Previous studies indicated that road dust particles, with diameters of less than 100 μm, can easily be resuspended by passing traffic or the wind, and that some of the particles can subsequently be redeposited on roads (Rogge et al., 1993; Zhao et al., 2014b). Road dust particles have been found to be an important contributor to PM_{10} and $PM_{2.5}$, respectively (Amato et al., 2009a; Bukowiecki et al., 2010; Karanasiou et al., 2011; Kuhns et al., 2001).

Furthermore, rapid urban population growth and industrialization in China produce large quantities of particulate matter and contribute to the particulate-bound pollutant contents of road dust (Zhao et al., 2011). The emission magnitudes between urban and rural areas could be different. However, there is still no method to assess the spatial distribution of the potential risks posed by metals associated with road dust particles. A variety of road dust particle emission models, such as AP-42 (US-EPA, 2011), PMF (Bukowiecki et al., 2010; Karanasiou et al., 2011) and TRAKER (Etyemezian et al., 2003; Kuhns et al., 2001), have been developed in recent years to quantify the resuspension of road dust to become suspended particles in the atmosphere, yet these studies are mostly from the perspective of air particles. It is difficult to use such models to assess the risk of road dust particles becoming atmospheric particulate matter because the models require measurement of many parameters (e.g., very detailed traffic condition parameters).

There is a clear need to design a new method for simplicity and ease of use to identify the potential risk of road dust becoming atmospheric particulate matter. Furthermore, little information is available on spatial and temporal variations in potential emission sources, and on the mechanisms through which road dust particles are resuspended. Thus, the present study aims to 1) investigate the spatial pattern of road dust particle characteristics (e.g., the amount, grain size, mobility, and metal concentrations) along an urban–rural gradient; 2) develop an innovative index model combining the source and transport factor with consideration of the road dust characteristics; and 3) to quantify and differentiate the impact of the spatial distribution of the potential risks posed by metals associated with road dust on atmospheric suspended particles.

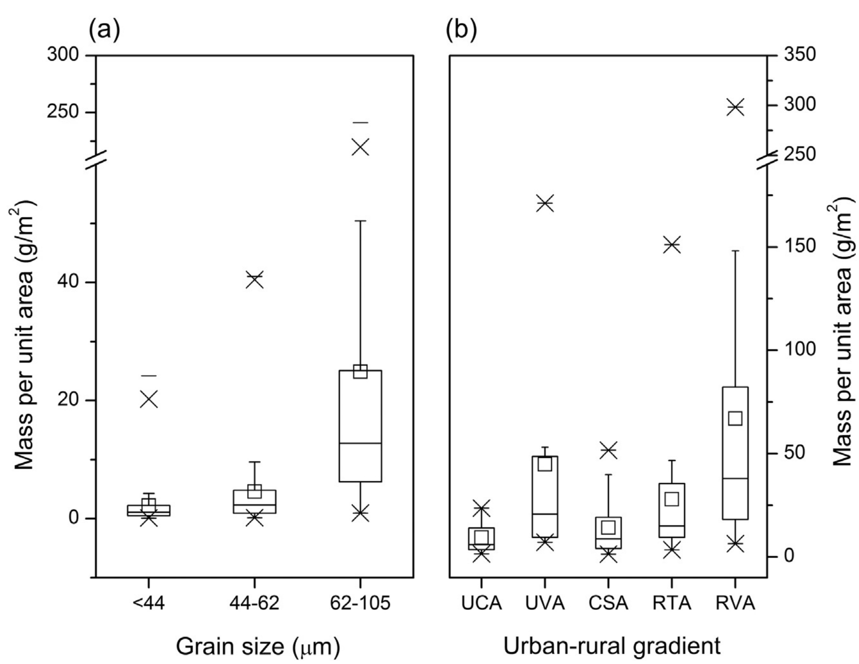

Fig. 1. Box plots of masses of road-deposited sediment per unit area along the urban–rural gradient in Beijing. (a) Masses of different grain sizes per unit area in all samples and (b) urban–rural gradient in total mass of particles per unit area. UCA = central urban area, UVA = urban village area, CSA = central suburban county area, RTA = rural town area, and RVA = rural village area.