Contamination Characteristics and Assessment of Manganese, Zinc, Chrome, Lead, Copper and Nickel in Bus Station Dusts of Xifeng, Northwest China

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Abstract: The objective of this study was to investigate the concentration and spatial distribution patterns of six potentially toxic heavy metal elements (Mn, Zn, Cr, Pb, Cu and Ni) in bus station dusts in the Xifeng district of Gansu province, NW China. The contents were analyzed for Mn, Zn, Cr, Pb, Cu and Ni by using S8 TIGER Brochures wavelength dispersive X-ray fluorescence spectrometry. Geoaccumulation index (Igeo ), enrichment factor (EF), pollution index (PI) and integrated pollution index(IPI) were calculated to evaluate the heavy metal contamination level of bus station dusts. The results indicate that, in comparison with the background values of local soil, bus station dusts in Xifeng have elevated metal concentrations as a whole. The concentrations of heavy metals investigated in this paper are compared with the reported data of other cities. The results show that the arithmetic means of Mn, Zn, Cr, Pb, Cu and Ni are 440.8, 137.9, 60.0, 42.8, 33.5 and 19.8 mg kg\(^{-1}\) respectively. The mean values of Igeo reveal the order of Ni<Mn<Cr<Cu<Zn<Pb. The high Igeo and EF for Cu, Zn and Pb in bus station dusts indicate that there is a considerable Cu, Zn and Pb pollution, which mainly originate from traffic and industry activities. The Igeo and EF of Ni, Mn and Cr are low and the assessment results indicate an absence of distinct Ni, Mn and Cr pollution in bus station dusts. The assessment results of PI also support Cu, Zn and Pb in bus station dusts presented middle pollution, and IPI indicates heavy metals of bus station dusts polluted seriously.

Keywords: heavy metal; contamination assessment; X-ray fluorescence; bus station dusts

1. Introduction

Bus station dusts, particles deposited on a road, originate from the interaction of solid, liquid and gaseous materials produced from different sources (Banerjee ADK. 2003; Ferreira-Baptista and De Miguel 2005; Zhao et al. 2007; Shi et al. 2011; Lu et al. 2014a). Components and quantity of bus station dusts are environmental pollution indicators (Han et al. 2006; Al-Khashman 2007; Zheng et al. 2010). Bus station dusts receive various inputs of heavy metals from a variety of mobile or stationary sources (Ferreira-Baptista and De Miguel 2005; Ma and Singhirunnusorn 2012; Zhao and Li 2013), such as vehicular traffic, industrial plants, residential oil burning, waste incineration, construction and demolition activities and resuspension of surrounding contaminated soils (Wei and Yang 2010; Apeagyei et al. 2011; Duong and Lee 2011; Yuen et al. 2012; Rout et al. 2013; Zhu et al. 2013; Nazzal et al. 2014), and makes a significant contribution to the pollution in the urban environment, and is one of the most pervasive and important factors affecting human health (Han et al. 2006; Al-Khashman 2007; Zheng et al. 2010). Road dust plays an active role as a “sink and source” of pollutants due to enhanced levels of
Metals and other pollutants and frequent interactions of dust with the atmosphere and other mediums through resuspension and deposition of dust particles (Moreno et al. 2013). Therefore, road dust can contribute significantly to environmental pollution in urban areas and is considered an indicator of heavy metal contamination from atmospheric deposition (Zheng et al. 2010). Moreover, heavy metals in street dust are highly concerning because of their toxicity and non-degradability, as well as threat to the environment and the public health (Banerjee 2003; Wei and Yang 2010). These particles can easily enter human body through inhalation, ingestion or dermal contact (Ahmed and Ishiga 2006; Wei and Yang 2010; Shi et al. 2011) and harm urban residents health by public transportation going out, especially children. Therefore, the study of bus station dusts is important for determining the origin, distribution and level of heavy metal in urban surface environments.

Many studies on surface dust have focused on trace metal elements concentration, distribution and source identification in the last decades (Li et al. 2001; Banerjee 2003; Sezgin et al. 2003; Ahmed and Ishiga 2006; Han et al. 2006, 2008; Wei and Yang 2010; Zheng et al. 2010; Duong and Lee 2011; Shi et al. 2011; Ma and Singhirunnusorn 2012; Chen et al. 2014; Wang and Liang 2014; Wang et al. 2015; Xu et al. 2015). Elevated levels of trace metal contents are ubiquitous in urban settings as a result of a wide range of human activities, while little information is available for bus stations of cities, which were most often appear.

Xifeng, one important oil production and refining industrial district in Northwest China, has experienced a rapid urbanization and industrialization in the last two decades. The rapid growth of industry, population and vehicle exerts a heavy pressure on its urban environment. The main objective of this initial study was to determine the concentration of heavy metals in bus station dust samples collected from Xifeng district and to assess their contaminated level.

2. Materials and methods

2.1. Study area

Xifeng (35°25′55″-35°51′11″N, 107°27′42″-107°52′48″E), the busiest district of Qingyang city in Northwestern China, is situated at the southern end of the city in Loess Plateau. The district spans over 996.35 km² with the urban population of approximately 325.2 thousand in 2015. It has a typical semi-arid temperate continental monsoon climate, with an annual average temperature of 9.6°C, annual average precipitation of 465.7 mm and annual evaporation capacity of 1613.1 mm, the annual sunlight is about 2500 h. The local soil type is mainly sandy and yellow clay with a pH (H2O) 8.56. The prevailing wind direction is northwest. The urban area of Xifeng is approximately 600 km², respectively. The number of motor vehicles driven in Xifeng in 2015 was approximately 150 thousand vehicles. Xifeng has abundant gas, coal, oil and other mineral resources. It is an important industrial base of China, oil exploitation, refining and transporting are the major industries of Xifeng. The texture analysis of the soil shows that it is loam soil, composed of clayey soil 14.12%-21.20%, silty sand 36.60%-41.94% and fine sand 36.86%-49.28%. The prevailing wind direction is from northwest to southeast.

2.2. Sampling and analytical procedures

Fifty-three bus station dusts sampling sites were selected in Xifeng district, including public parks, schools, heavy and low traffic density areas, commercial areas and residential districts(Fig.1). At every sampling site, about 500 g bus station dusts composite sample was collected by sweeping using polyethylene brush and tray from five to eight points of road/pavement edges during the dry season in
April 2016. All collected bus station dusts samples were stored in the sealed polyethylene bags, labeled and then transported to the laboratory.

All the samples were air-dried in the laboratory for 2 weeks, and then sieved through a 2 mm mesh nylon sieve to remove large stones, crop and grass debris before halving. One half was stored, the other one was then ground-with agate mortar and pestle-carefully homogenized and sieved through 0.074 mm (200 mesh) were ground further in a grinding miller. After reduction by repeated quartering, the sample was analyzed as outlined below.

All procedures of handling were carried out without contact with metals, to avoid potential cross-contamination of the samples. Weigh 5.0g of milled bus station dusts sample and 2.0g of boric acid and place in the mold, and press into a 32-mm diameter small briquette under 31.5t pressure, and the briquettes were stored in a desiccator. Therefore, the concentrations of Mn, Zn, Pb, Cr, Cu and Ni in bus station dusts samples were directly measured by wavelength dispersive X-ray fluorescence spectrometry (S8 TIGER Brochures, XRF), the relative proportions of dust were determined according to methods (dos Anjos et al. 2000; Staloki et al. 2004; Huang and li, 2007; Lu et al. 2009a, 2009b). Meanwhile, a series of soil and rock standards were used to calibrate the application. These were the GSS- and GSD-series geochemical reference materials (Institute of Geophysical and Geochemical Prospecting, PR China). The analytical precision, measured as relative standard deviation, was routinely between 2% and 4%, and never higher than 6%. Accuracy of analyses was checked using standard and duplicate samples. The quality control gave good precision (S.D. <4%) for all samples.

2.3. Contamination assessment methods

A number of calculation methods have been put forward for quantifying the degree of metal enrichment or pollution in soils and dusts(Gonzalez-Macias et al. 2006; Gagneten et al. 2007; Gemici and Tarcan, 2007; Gonzalez-Macias et al. 2007; Hu et al. 2011; Han et al. 2014; Li et al. 2015). In the study, geoaccumulation index (I$_{geo}$), enrichment factor (EF), pollution index (PI) and integrated pollution index (IPI) were calculated to assess the heavy metal contamination level in the bus station dusts.

$I_{geo}$ was originally used with bottom sediments in Ref. (Müller, 1969). It is computed by the following equation: $I_{geo} = \log_2 \frac{C_x}{1.5B_x}$

where $C_x$ is the measured concentration of the element x and $B_x$ is the geochemical background value of the element. In the study, $B_x$ is the background content of the element x in Chinese soil(CNEMC, 1990). The constant 1.5 is introduced to minimize the effect of possible variations in the background values which may be attributed to lithologic variations in the sediments. The following classifications is given for geoaccumulation index(Müller, 1969): unpolluted ($I_{geo} < 0$), unpolluted to moderately polluted
(0 ≤ Igeo < 1), moderately polluted (1 ≤ Igeo < 2), moderately to strongly polluted (2 ≤ Igeo < 3), strongly polluted (3 ≤ Igeo < 4), strongly to extremely polluted (4 ≤ Igeo < 5), and extremely polluted (Igeo ≥ 5).

Enrichment factor (EF) of an element in the studied samples was based on the standardization of a measured element against a reference element. A reference element is often the one characterized by low occurrence variability, such as the most commonly used elements: Al, Fe, K, Si, Sr, Ti, etc. (Tasdemir and Kural 2005; Turner and Simmonds 2006; Hao et al. 2007; Kartal et al. 2006; Meza-Figueroa et al. 2007; Mandal and Sengupta 2003; Cao et al. 2011). The EF calculation is expressed below as

\[ EF = \left( \frac{C_x}{C_{ref}} \right)_{sample} / \left( \frac{C_x}{C_{ref}} \right)_{background} \]

where \( C_x \) is the concentration of the element of interest and \( C_{ref} \) is the concentration of reference element for normalization. In this study, Al was selected as the reference material. EF values less than 5.0 are not considered significant, because such small enrichments may arise from differences in the composition of local soil material and reference soil used in EF calculations (Kartal et al. 2006).

However, there is no accepted pollution ranking system or categorization of degree of pollution on the enrichment ratio and/or factor methodology. Five contamination categories are recognized on the basis of the enrichment factor: states deficiency to minimal enrichment (EF < 2), moderate enrichment (2 ≤ EF < 5), significant enrichment (5 ≤ EF < 20), very high enrichment (20 ≤ EF < 40) and extremely high enrichment (EF ≥ 40) (Han et al. 2006; Kartal et al. 2006; Lu et al. 2010; 2014a and b).

Pollution index and integrated pollution index are also commonly used to assess the environment quality (Chen et al. 2005). The PI was defined as the ratio of element concentration in the study to the background content of the corresponding element of Chinese soil (CNEMC, 1990). The pollution index obtained by the following equation: \[ PI = \frac{C_x}{B_x} \]

The PI of each element was calculated and classified as either ≤ 1 = low pollution, 1 < PI ≤ 3 = middle pollution, or > 3 = high.

The integrated pollution index (IPI) of the six heavy metals is obtained by the following equation:

\[ IPI = \sqrt{\frac{P^2_{mean} + P^2_{max}}{2}} \]

where \( P_{mean} \) and \( P_{max} \) are the mean value and max value of the pollution index (PI) of 6 kinds of metals. IPI ≤ 1 indicates that dusts are low pollution, 1 < IPI ≤ 2 illustrates that dusts are middle pollution, IPI > 2 illustrates that dusts are high pollution (Chen et al. 2001).

3. Results and discussion

3.1. Heavy metal concentration in bus station dusts

The descriptive statistic results of heavy metal concentrations investigated in bus stations samples, as well as background values of Chinese soils (CNEMC, 1990), are listed in Table 1. Table 1 shows that the arithmetic means of Mn, Zn, Cr, Pb, Cu and Ni are 442.8, 144.2, 61.0, 44.9, 34.6 and 22.2 mg kg\(^{-1}\), respectively. The mean concentrations of Cr in dust samples collected from bus station of Xifeng is close to the background values of Chinese soil. Table 1 shows the concentrations of Mn and Ni in bus station dusts of Xifeng are lower than the background values of Chinese soils, and the concentrations of Zn, Pb and Cu in bus station dusts of Xifeng are higher than the background values of Chinese soils. The
geometric means of all studied metals are approximately equal to their arithmetic means, which are 440.8, 137.9, 60.0, 42.8, 33.5 and 19.8 mg kg\(^{-1}\), respectively for Mn, Zn, Cr, Pb, Cu and Ni. These are especially true for Zn, Pb and Cu, which are 2.36, 2.43 and 1.69 times the background values of Chinese soil, respectively. The maximums of Mn, Zn, Cr, Pb, Cu and Ni have been found in the sample from heavy traffic site, such as nursery schools, primary schools, secondary schools, housing estates and city center apartments blocks and bus stops, while their minimums were detected in dust sample from bus stations of the city edge, such as residential site with less traffic density. The source of Ni, Pb and Zn in bus station dusts was indicated by research as tyre abrasion, the corrosion of metallic parts of cars, lubricants and industrial and incinerator emissions (Al-Khashman 2004; Arslan 2001; Jiries et al. 2001; Lu et al. 2010; 2014a and b). The values of the mean concentration of heavy metals in dust from bus stations of Xifeng divided by the corresponding background values of Chinese soil decrease in the order Mn>Zn>Cr>Pb>Cu>Ni. Small standard deviations and variation coefficients (SD/mean) were found for all heavy metals in bus stations dust, except for Ni. It may be concluded the sources of these heavy metals in bus station dusts of Xifeng mainly originated from anthropogenic activities (e.g. oil refining and coal combustion) and automotive emissions. Concentrations of Mn in all dust samples were found to be in the range of 354.6-549.4 mg kg\(^{-1}\) which are lower than Mn background value of Chinese soils (553 mg kg\(^{-1}\)), this shows Mn in bus station dusts mainly originated from natural source.

<table>
<thead>
<tr>
<th>Element</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>S.D.</th>
<th>GM</th>
<th>Median</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Reference value (CNEMC, 1990)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn</td>
<td>354.6</td>
<td>549.4</td>
<td>442.8</td>
<td>41.7</td>
<td>440.8</td>
<td>444.5</td>
<td>0.1</td>
<td>0.6</td>
<td>553.0</td>
</tr>
<tr>
<td>Zn</td>
<td>64.7</td>
<td>343.2</td>
<td>144.2</td>
<td>45.8</td>
<td>137.9</td>
<td>135.5</td>
<td>1.7</td>
<td>5.8</td>
<td>61.0</td>
</tr>
<tr>
<td>Cr</td>
<td>36.7</td>
<td>95.2</td>
<td>61.0</td>
<td>11.0</td>
<td>60.0</td>
<td>61.8</td>
<td>0.5</td>
<td>1.4</td>
<td>61.8</td>
</tr>
<tr>
<td>Pb</td>
<td>20.1</td>
<td>96.2</td>
<td>44.9</td>
<td>15.6</td>
<td>42.8</td>
<td>39.8</td>
<td>1.7</td>
<td>2.9</td>
<td>18.5</td>
</tr>
<tr>
<td>Cu</td>
<td>17.8</td>
<td>58.8</td>
<td>34.6</td>
<td>8.7</td>
<td>33.5</td>
<td>34.2</td>
<td>0.3</td>
<td>0.0</td>
<td>20.5</td>
</tr>
<tr>
<td>Ni</td>
<td>12.7</td>
<td>151.3</td>
<td>22.2</td>
<td>19.1</td>
<td>19.8</td>
<td>18.6</td>
<td>6.3</td>
<td>42.3</td>
<td>29.0</td>
</tr>
</tbody>
</table>

Table 1 shows Zn, Pb and Ni the skewness values of heavy metals are higher than unit which means all the elements skew towards the lower concentrations, as can also be confirmed by the fact that the median concentrations of these metals are lower than their mean concentrations, except for Zn, Mn and Cr. So, the geometric and arithmetic means of all heavy metals investigated present more probable content data.

It is a common practice to compare mean concentrations of heavy metals in bus stations dusts in different urban environments (De Miguel et al. 1997; Charlesworth 2003; Duzgoren-Aydin et al. 2006; Lu et al. 2009b; Li et al. 2012; Xu et al. 2015), although there are no universally accepted sampling and analytical procedures for geochemical studies of urban deposits. In table 2, concentrations of heavy metals measured in bus station dusts of Xifeng are compared with data reported for other cities streets dusts (Xu et al. 2004; Guo et al. 2005; Han et al. 2006; Gao et al. 2007; Shi et al. 2008; Lu et al. 2009a; Wei et al. 2009; Zhang and Wang 2009; Li et al. 2012; Shi et al. 2013; Han et al. 2014, 2016; Liu et al. 2014; Wang et al. 2014; Zhao et al. 2016).

The mean concentration of Mn in bus station dusts sampled in Xifeng (this work) is similar to those sampled in Inner Mongolia B., higher than those sampled in Xining, and lower than those sampled in Baoji, Baotou, Bayan Obo, China B., Hangzhou, Urumqi and Xi’an. The mean concentration table 2 of Zn in bus station dusts of Xifeng is low compared with several cites in the world except for Baotou, China B., Inner Mongolia B., Xining. The mean concentration of Cr in bus station dusts sampled
in Xifeng is similar to those sampled in Changchun, higher than those sampled in China B., Hangzhou, Inner Mongolia B. and Urumqi, and lower than those sampled in Baoji, Baotou, Bayan Obo, Nanjing, Shanghai, Xi’an, Xianyang and Xining. The mean concentration of Pb for bus station dusts in Xifeng (this work) is lower than other compared cites except for China B. and Inner Mongolia B.. The Cu concentration in bus station dusts of Xifeng is similar to Bayan Obo, while lower than other cities except for Baotou, China B. and Inner Mongolia B.. On the other hand, the mean concentration of Ni in bus station dusts of Xifeng (this work) is similar to Baotou, Changchun, China B. and Xining, while lower than other cites except for Inner Mongolia B. (Table 2). In general, each city has its own characteristics combination of elemental compositions, and the observed similarities as well as variations may not reflect actual natural and anthropogenic diversities among the different urban settings. Therefore, there is an immediate need to establish a standard procedure to represent and analyze urban samples (Duzgoren-Aydin et al. 2006; Lu et al. 2009b; Li et al. 2012; Xu et al. 2015).

Table 2 A comparison of the heavy metal concentrations (mg kg\(^{-1}\)) in street dusts of Xifeng and other selected cities

<table>
<thead>
<tr>
<th>District</th>
<th>Mn</th>
<th>Zn</th>
<th>Cr</th>
<th>Pb</th>
<th>Cu</th>
<th>Ni</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baoji</td>
<td>804.2</td>
<td>715.3</td>
<td>126.7</td>
<td>433.2</td>
<td>123.1</td>
<td>48.8</td>
<td>Lu et al.2009a</td>
</tr>
<tr>
<td>Baotou</td>
<td>548.2</td>
<td>85.9</td>
<td>182.1</td>
<td>58.2</td>
<td>29.1</td>
<td>21.2</td>
<td>Han et al.2014, 2016</td>
</tr>
<tr>
<td>Bayan Obo</td>
<td>3407.3</td>
<td>299.3</td>
<td>141.2</td>
<td>183.9</td>
<td>36.3</td>
<td>31.2</td>
<td>Wang et al.2014</td>
</tr>
<tr>
<td>China B.</td>
<td>482.0</td>
<td>67.7</td>
<td>53.9</td>
<td>23.6</td>
<td>20.0</td>
<td>23.4</td>
<td>Xu et al.2004</td>
</tr>
<tr>
<td>Changchun</td>
<td>-</td>
<td>170.8</td>
<td>60.3</td>
<td>70.8</td>
<td>43.5</td>
<td>23.1</td>
<td>Guo et al.2005</td>
</tr>
<tr>
<td>Guiyang</td>
<td>-</td>
<td>243</td>
<td>-</td>
<td>79.5</td>
<td>66.1</td>
<td>38.9</td>
<td>Li et al.2012</td>
</tr>
<tr>
<td>Hangzhou</td>
<td>509.5</td>
<td>321.4</td>
<td>51.2</td>
<td>202.1</td>
<td>116.0</td>
<td>25.8</td>
<td>Zhang and Wang, 2009</td>
</tr>
<tr>
<td>Inner Mongolia B.</td>
<td>434.3</td>
<td>47.5</td>
<td>35.7</td>
<td>13.5</td>
<td>12.7</td>
<td>16.6</td>
<td>Xu et al.2004</td>
</tr>
<tr>
<td>Nanjing</td>
<td>786.0</td>
<td>307.0</td>
<td>139.0</td>
<td>113.0</td>
<td>238.0</td>
<td>47.0</td>
<td>Gao et al.2007</td>
</tr>
<tr>
<td>Shanghai</td>
<td>-</td>
<td>733.8</td>
<td>159.3</td>
<td>294.9</td>
<td>196.8</td>
<td>83.9</td>
<td>Shi et al.2008</td>
</tr>
<tr>
<td>Urumqi</td>
<td>926.0</td>
<td>294.4</td>
<td>54.2</td>
<td>53.5</td>
<td>94.5</td>
<td>43.2</td>
<td>Wei et al.2009</td>
</tr>
<tr>
<td>Xi’an</td>
<td>687</td>
<td>421.4</td>
<td>167.2</td>
<td>230.5</td>
<td>94.9</td>
<td>-</td>
<td>Han et al.2006</td>
</tr>
<tr>
<td>Xianyang</td>
<td>-</td>
<td>375.3</td>
<td>135.6</td>
<td>77.3</td>
<td>132.1</td>
<td>69.5</td>
<td>Shi et al.2013</td>
</tr>
<tr>
<td>Xining</td>
<td>409.1</td>
<td>108.6</td>
<td>573.0</td>
<td>52.7</td>
<td>40.6</td>
<td>22.6</td>
<td>Zhao et al.2016</td>
</tr>
<tr>
<td>Xifeng</td>
<td>441.3</td>
<td>144.8</td>
<td>60.7</td>
<td>45.1</td>
<td>34.5</td>
<td>22.3</td>
<td>This work</td>
</tr>
</tbody>
</table>

- Not available.

3.2. Assessment results of the heavy metal contamination in bus station dusts

The calculated results of \(I_{geo}\) of heavy metals in Xifeng bus station dusts are presented in Fig. 1. The \(I_{geo}\) of Mn ranges from -1.21 to -0.59 with a mean value of -0.92, -0.49 to 1.91 with a mean value of 0.66 for Zn, -1.32 to 0.04 with a mean value of -0.60 for Cr, -0.47 to 1.79 with a mean value of 0.7 for Pb, -0.78 to 0.93 with a mean value of 0.18 for Cu and -1.78 to 1.8 with a mean value of -0.97 for Ni. The mean values of \(I_{geo}\) increase in the order of Ni<Mn<Cr<Cu<Zn<Pb. The mean \(I_{geo}\) of Cr, Mn and Ni less than 0 indicating that Cr, Mn and Ni are unpolluted, the mean \(I_{geo}\) of Cu, Pb and Zn less than 1 indicating that Cu, Pb and Zn are unpolluted to moderately polluted, nevertheless, 66.0% \(I_{geo}\) of Cu, 79.2% \(I_{geo}\) of Pb, 77.4% \(I_{geo}\) of Zn and 1.9% \(I_{geo}\) of Cr and Ni, between 0 and 1 indicate unpolluted to moderately polluted, 18.9% \(I_{geo}\) of Pb, 13.2% \(I_{geo}\) of Zn and 1.9% \(I_{geo}\) of Ni between 1 and 2 indicate moderately
polluted.

Fig. 1. Box-plot of Igeo for heavy metals in bus station dusts of Xifeng.

Fig. 2. Box-plot of EF for heavy metals in bus station dusts of Xifeng.

Enrichment factors of heavy metals were calculated for each bus station dusts sample relative to the background value of the elements in Chinese soil (CNEMC, 1990), choosing Al as the reference element. The EF of Mn, Zn, Cr, Pb, Cu and Ni is in the range of 0.847-1.558, 1.667-6.961, 1.023-2.485, 1.873-7.915, 1.482-4.611 and 0.754-7.207 with an average of 1.215, 3.549, 1.497, 3.618, 2.567 and 1.147, respectively (Fig. 2).

The mean EF of Pb, Cu and Zn exceeds 2, while the mean EF of Cr, Mn and Ni is lower than 2. The maximum EF of Ni, Zn and Pb are higher than 5, which shows that Ni, Zn and Pb in bus station dusts mainly originate from anthropogenic sources (Liu et al. 2003). It seems, as a consequence, that EF can
also be an effective tool to distinguish a natural origin from anthropogenic sources in the study. The order of mean EF values is Ni<Mn<Cr<Cu<Zn<Pb, which can also be seen as the increasing order of their overall contamination degrees of bus station dusts in Xifeng. EF of Ni, Mn and Cr have 96.2%, 100% and 94.3% less than 2, respectively, revealing the lack of enrichment with Ni, Mn and Cr as a whole, while only 1.9% and 5.7% EF of Ni and Cr sample belongs to moderate enrichment. EF of Cu, Zn and Pb have 83.0%, 92.4% and 84.9% in 2-5, respectively, indicates Cu, Zn and Pb of bus station dusts are mainly moderate enrichment. while 3.8% and 13.2% EF of Zn and Pb sample more than 5, with mean EF 3.681 and 3.549, indicating significant enrichment. The analytical results of EF of heavy metals are same as the analytical results of Igeo.

The PIs, calculated according to the background concentration of heavy metals in Chinese soil, vary greatly across the different metals (Fig. 3). Ni and Mn exhibit lower values, ranging from 0.44 to 5.22 and from 0.64 to 0.99, respectively. For Ni and Mn, the mean PI are 0.76 and 0.80, only three samples Ni are classified as middle PI and one sample Ni is classified as high PI and all of the samples Mn have low-level PIs, indicating that the concentration of Ni and Mn in the bus station dusts samples are comparable with the background concentration of Chinese soil and there are low pollution of Ni and Mn in Xifeng bus station dusts samples. The mean PI for Cu, Zn and Pb are 1.69, 2.36 and 2.40, and only one sample Cu is classified as low PI, and seven samples Zn and nine samples Pb are classified as high PI, indicating middle to high Cu, Zn and Pb pollution of bus station dusts in Xifeng.

![Fig. 3. Box-plot of PI and IPI for heavy metals in bus station dusts of Xifeng.](image)

The PIs of Cr is middle since 26 samples are classified as low PI (PI≤1) and 27 samples are classified as middle PI (1<PI≤3), ranging from 0.59 to 1.54, with mean value of 0.99 for Cr. These data indicate that Cr of bus station dusts presented low to middle pollution in Xifeng. The IPIs of bus station dusts samples vary from 0.10 to 4.32 with an average of 2.12, indicating that all samples studied presented heavy metal high pollution.
4. Conclusion

The concentrations of heavy metal Ni, Mn, Cr, Cu, Zn and Pb and their contamination level in bus station dusts collected from Xifeng, Northwest of China have been studied in the work. The concentration of Mn, Zn, Cr, Pb, Cu and Ni in bus station dusts ranges from 354.6 to 549.4, 64.7 to 343.2, 36.7 to 95.2, 20.1 to 96.2, 17.8 to 58.8 and 12.7 to 151.3 mg kg$^{-1}$, with an arithmetic mean of 442.8, 144.2, 61.0, 44.9, 34.6 and 22.2 mg kg$^{-1}$, respectively. The concentrations of heavy metals investigated in the work are compared with the reported data of other cities streets dusts and with the background values of elements in Chinese soil. The results indicate that bus station dusts in Xifeng have elevated metal concentrations as a whole.

The calculated results of I$_{geo}$ and EF of heavy metals reveal the order of I$_{geo}$ and EF are Ni<Mn<Cr<Cu<Zn<Pb. The high I$_{geo}$ and EF for Cu, Zn and Pb in bus station dusts indicate that there is a considerable Cu, Zn and Pb pollution, which mainly originate from traffic and industry activities (such as oil refining and boiler emissions). The I$_{geo}$ and EF of Ni, Mn and Cr are low and the assessment results indicate an absence of distinct Ni, Mn and Cr pollution in bus station dusts. The assessment results of PI also support Cu, Zn and Pb in bus station dusts present middle pollution, and IPI indicates heavy metals of bus station dusts polluted highly. These findings indicate that more attention should be paid to heavy metal contamination of bus station dusts in Xifeng, especially Pb.

Acknowledgments

The research was supported by the National Natural Science Foundation of China through Grant 41271510, the Fundamental Research Funds for the Central University GK201601009, the Longdong University PhD candidate scientific research fund LDXY151230. We thank Ma Ge, Yun Jiang, Yun Pujun et al. for their help with the experiments. Opinions in the paper do not constitute an endorsement or approval by the funding agencies and only reflect the personal views of the authors.

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