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# Characterization of $PM_{10}$ source profiles for fugitive dust in Fushun-a city famous for coal

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ABSTRACT

A total of 120 fugitive dust samples were collected to acquire chemical source profiles of $PM_{10}$ in Fushun including 27 soil dust samples, 32 road dust samples, 19 construction dust samples, 13 coal storage pile samples, 2 cement production samples, 13 coal-fired power plant fly ash samples, 5 fly ash samples from iron smelt plant and 9 samples from industrial raw material and production piles. The samples were classified as 20 subtypes. The dust samples were dried, sieved, resuspended and sampled through a $PM_{10}$ inlet onto filters, and then chemically analyzed. Inductively coupled plasma-atomic emission spectrometry, ion chromatograph and thermal/optical reflectance methods were adopted for analyzing twenty elements including Na, Mg, Al, Si, S, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Pb and Hg and nine ions including $Na^+$, $NH_4^+$, $K^+$, $Mg^{2+}$, $Ca^{2+}$, $F^-$, $Cl^-$, $NO_3^-$ and $SO_4^{2-}$ as well as OC and EC, respectively.

The chemical compositions were compared for 20 subtypes. Si and Ca were the most abundant elements in all the fugitive dust profiles. Enrichment factors of elements in fly ashes compared to raw coal were calculated with Fe as reference element. The highest enriched elements were Ni, Cu, Zn and Pb. Significant difference existed among $PM_{10}$ profiles with the coefficient of divergence values ranging from 0.28 to 0.78. Profiles were compared with others. Si exhibited lower content in this study for soil and road dust while EC and Cr showed much higher content compared to others indicating the influence of coal mining and industries activities in Fushun. This was validated by source signatures analysis which indicated almost all the fugitive dust were relative to coal and may also be influenced by metallurgy. The ratios of Mn/V, V/Ni, Zn/Pb and Zn/Cd were calculated for source identification. Elemental ratios may vary widely even for the same source types with different processing courses. Chemical profiles of fugitive dust should be established based on characteristic sources for a specific region and updated timely.



## 1. Introduction

Source identification and quantification of atmospheric particulate matter (PM) have now become increasingly important and widespread issues to develop pollution control strategies (Khan et al., 2010). This work was frequently attempted by using receptor models among which chemical mass balance (CMB) model has been well established and widely used (Watson et al., 2002; Samara, 2005; Tony et al., 2005; Khan et al., 2010; Kong et al., 2010). It required information about the chemical characteristics of the sources that were likely to affect pollutant concentrations at a receptor (Watson et al., 2001; Gupta et al., 2007).

Until now, many of the CMB source apportionment studies were conducted based on source profiles from literatures with local profiles not available (Tony et al., 2005; Rizzo and Scheff, 2007; Chuersuwan et al., 2008; Lee et al., 2008; Mugica et al., 2009; Stone et al., 2010; Yin et al., 2010) which may substantially bias source contribution estimates (Samara, 2005). Though chemical compositions of several sources were identified in data base of USEPA (SPECIATE) and former studies (Watson and Chow, 2001; Watson et al., 2001; Chow et al., 2003; Ho et al., 2003; Chow et al., 2004; Zhao et al., 2006; Bi et al., 2007; Cao et al., 2008), it was recommended to characterize the PM sources locally for source apportionment studies with respect to the diversity in geographical locations, fuel type, combustion and emission control technologies

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as well as variation along with time (Watson and Chow, 2001; Yatkin and Bayram, 2008).

Fugitive dust is originated from paved or unpaved roads, bare ground site, agricultural tilling, construction, storage piles, etc (Watson et al., 2002; Chow et al., 2003; Ho et al., 2003; Samara et al., 2003; Samara, 2005). It has been identified to be a major contributor to $PM_{10}$ (particles with aerodynamic diameters less than 10 μm) and an important contributor to $PM_{2.5}$ (particles with aerodynamic diameters less than 2.5 μm) in many urban areas in China (Ho et al., 2003; Bi et al., 2007). Former studies for fugitive dust have been focused mainly on paved or unpaved road dust (Watson et al., 2001; Chow et al., 2003; Ho et al., 2003; Chow et al., 2004), soil dust (Watson and Chow, 2001; Chow et al., 2003; Ho et al., 2003; Chow et al., 2004; Bi et al., 2007; Cao et al., 2008) and cement (Ho et al., 2003). While $PM_{10}$ source profiles for construction dust, for fly ashes from sinter, kiln stoves, shaft furnace and electric cooker for metal smelt, for dust from industrial raw materials and production storage piles are still limited. More researches are needed to characterize source emissions and assemble source databases.

Fushun, named as "the capital of coal", holds abundant mine resources with total reserves as 6.0 billion tons including 0.75 billion tons of coal (http://www.lgy.cn/fushun/3.htm). Coal usage can also raise fugitive dust emission from mining, stockpiling and carrying of non-combustible ash or pollution control residues remaining after combustion (Samara, 2005). There is limited information on source emissions, however, especially the chemical compositions in $PM_{10}$ size fraction for conducting source apportionment and putting forward effective air pollution control strategies in Fushun.

This is the first study on chemical source profiles of fugitive dust emitters in this city. A total of 120 set of resuspension data for geological material, road dust, construction dust, dust from coal storage piles (raw coal and washed coal), coal combustion fly ash from boilers and sinter, kiln stoves, shaft furnace, electric cooker for iron smelt, dust from industrial raw materials and production storage piles (magnesium, cement and fire-resistant material production, iron powder and coke) were obtained. The objective was to develop fugitive dust profiles that could be used for receptor modeling. And also we expected the data in this study could update global PM chemical source profiles database.

## 2. Methodology

### 2.1. Study area

Fushun (123°39′–125°28′ E, 41°41′–42°38′ N) is located in the eastern mountainous area of Liaoning Province with an urban area of 713.6 $km^2$ and approximately 20,000 inhabitants per $km^2$. The climate of this area is mainly dominated by continental monsoon climate with distinct seasonal variation. Annual average precipitation is 760–790 mm and average temperature is 5–7 °C. Petrochemical, coal mining, cement production, iron and steel manufacture, electric power, ceramics and non-ferrous metal smelting are its major industrial particle emitting sources.

As listed in Table 1, 27 soil dust samples, 32 road dust samples, 19 construction dust samples, 13 coal storage pile samples, 2 cement production samples, 13 fly ash samples from coal-fired power plants, 5 fly ash samples from iron smelt plants and 9 samples from industrial raw material and production piles were obtained. Fig. 1 showed the sampling locations of fugitive dust in Fushun.

### 2.2. Sample collection and pre-treatment

For each type of dust, samples were all collected in about one week in the same season in 06/2007–11/2007. Dust samples were collected using a plastic dustpan and brush for about 1 kg and then transferred into coded self-sealing polyethylene bags for transport to laboratory. Care was taken to reduce the disturbance of fine particles. Any obvious extraneous matters were not collected. Each brush was used once only before giving a thorough cleaning. Coordinates of the sample locations were recorded with a GPS.

**Table 1**
Source sampling characteristic of fugitive dust in Fushun.

| Abbr. | Source types | Descriptions | Mnemonic | Num. |
|---|---|---|---|---|
| SD | Soil dust | Surface layer soils around the city | SDSS | 25 |
| | | Soil dust from solid waste disposal plants | SDWD | 2 |
| RD | Road dust | Dust from the city's main streets | RDCS | 30 |
| | | Dust from cement plants street | RDCP | 2 |
| CD | Construction dust | Dust collected at building sites | CDBS | 19 |
| CS | Coal storage pile dust | Raw coal storage piles | RCS | 12 |
| | | A clean coal storage pile | CCS | 1 |
| CP | Cement | Cement production | CP | 2 |
| FA | Coal fly ash | Ash collected by pollution control devices in coal-fired power plants | FAPC | 13 |
| FI | Fly ash from iron smelt plant | Ash collected by pollution control devices from an electric cooker | FAEC | 1 |
| | | Ash collected by pollution control devices from a shaft furnace | FASF | 1 |
| | | Ash collected by pollution control devices from a sinter | FAS | 1 |
| | | Ash collected by pollution control devices from kiln stoves | FAKS | 2 |
| ISP | Industrial storage pile dust | Raw material storage pile for magnesium manufacture | RSMM | 1 |
| | | Production storage pile for magnesium manufacture | PSMM | 1 |
| | | White lime storage pile for cement production | WSCP | 2 |
| | | Calcium oxide storage pile for cement production | CSCP | 2 |
| | | Fire-resistant material storage pile | FMS | 1 |
| | | Iron powder storage pile | IPS | 1 |
| | | Coke storage pile | CS | 1 |
| Total | | | | 120 |

Samples were pre-treated using resuspension method to collect particles with diameter less than 10 μm (Chow et al., 1994; Kong et al., 2011b). Each sample was weighed after being dried in the vacuum freeze dryer to remove the moisture. After drying, the samples were sieved through a 160-mesh Tyler screen to remove fibers and other larger particles (Han et al., 2009; Kong et al., 2011a, 2011b). About 0.5 g sieved material was placed in a 250 mL side-arm vacuum flask sealed with a rubber stopper. Air puffs into the flask introduced dust into a chamber and sampled through $PM_{10}$ inlets with a flow rate of 20 L/min for about 1 min onto polypropylene and quartz-fiber filters. At last, 1.35–50.5 mg deposits were obtained on filters with diameter of 47 mm. Prior to sampling, polypropylene and quartz-fiber filters were calcined at 60 °C for 0.5 h and 800 °C for 2 h to remove any organic compounds that may be present on the filters, respectively. After sampling, the filters were removed from the inlets, folded in half and wrapped in a laminar-flow clean hood until use (Kong et al., 2011a).

Filters were equilibrated in a relative humidity (35% ± 1%) and temperature (22.0 °C ± 1 °C) controlled environment for 48 h before gravimetric analysis to minimize particle volatilization and aerosol liquid water bias. Filters were exposed to a low-level