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Characterization of PM_{10} fraction of road dust for polycyclic aromatic hydrocarbons (PAHs) from Anshan, China

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ABSTRACT

Nineteen road dust samples were collected during 2005 in different parts of the urban area of Anshan, Liaoning Province, China, and 11 polycyclic aromatic hydrocarbons (PAHs) species were quantitatively analyzed using GC–MS. The results indicated that the total average concentration of PAHs over the investigated sites ranged from 48.73 to 638.26 μg/g, with a mean value of 144.25 μg/g, higher than the concentrations measured in previous studies. PAHs concentrations were higher with high molecular weight homologues (4–6 rings PAHs), accounting for 83.24–96.98%, showing combustion of petroleum fuels was a potential source. Organic carbon in road dust was considered one of the important factors that influenced the concentrations of PAHs in this study, and it was found that concentrations of total PAHs were correlated with those of organic carbon in road dust. The results of diagnostic ratios analysis showed traffic emission (gasoline or diesel) was one of the most important sources of road dust PAHs. Principal component analysis (PCA) indicated that the major sources of road dust PAHs might be emission from traffic, steel industry, cooking and coal combustion.

1. Introduction

Substantial researches show the fugitive dust (or geological dust) is a major contributor to ambient particulate matter in urban areas [1–14]. Paved road dust is an important type of fugitive dust. This kind of dust is chemically similar to the primary portion of the atmospheric aerosol in many aspects, and has a dynamic relationship with atmospheric aerosol by resuspension into and redeposition from the atmosphere [15].

In China, most studies have focused on heavy metal elements contained in road dust, while the available data or relative researches on PAHs in road dusts are quite limited. On urban road surfaces, PAHs from various origins (e.g. weathered materials of road surfaces, automobile exhaust, lubricating oils, gasoline, diesel fuel, tire particles, construction materials and deposited materials) are present as road dust [16]. Moreover, some road dust PAHs will return to the atmosphere by evaporation or wind raise [17].

Liu et al. [18] collected road dust samples from central Shanghai in winter (January) and summer (August), respectively, and analyzed the 16 PAHs in the United States Environmental Protection Agency (USEPA) priority pollutants list, finding that road dust PAHs in central Shanghai mainly a mixture from traffic and coal combustion. Hassanien and Abdel-Latif [19] collected road dust samples and analyzed PAHs in 17 sites over Greater Cairo, Egypt, and concluded that vehicular traffic, industrial emissions and the incomplete combustion of open waste burning were the main sources of road dust PAHs. Furthermore, PAHs concentration in road dust was found to vary with the distance from the source of pollution [20]. Butler et al. [21] have demonstrated higher benzo(a)pyrene (BaP) concentrations in road dust near complex road interchanges than those in remote areas.

In this study, a road dust sampling campaign was conducted in Anshan, an important iron and steel city in northeastern China. The objectives of this study were (1) to determine the concentration, distribution, carcinogenic risk of road dust PAHs in the urban area of Anshan; (2) to elucidate potential sources of road dust PAHs; (3) to establish an environmental evaluation and serve as essential information for future study, such as health risk assessment.

2. Materials and methods

2.1. Study area description

Anshan is the third largest city in Liaoning province of China. Situated in the central area of the province, Anshan is about 92 km

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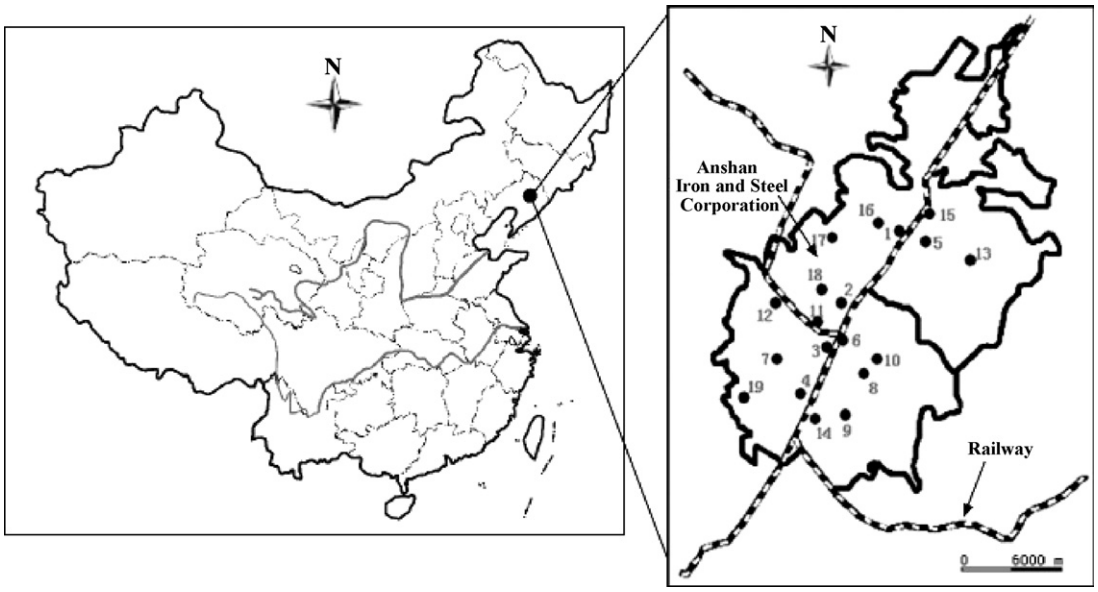

Fig. 1. (a) Locations of Anshan (b) the general study area and road dust sampling sites.

south of Shenyang, the province's capital. Anshan is on the boundary between the Mountains of eastern Liaoning and the plains of the west. Steel manufacture, metallurgy, mining, and chemical engineering are its dominant industries, all of which are high energy consumers and high pollution emitters. Due to the rapid growth of industrial production, building activities, population and traffic density, the air quality has been deteriorating during recent years [22].

Fig. 1 illustrated the detailed location of Anshan (N40°27′–41°34′, E122°10′–123°13′): the city lies in the central area of Liaoning Province with Qianshan Mountain in the east. It has 1.45 million residents in its 624 km^2 areas. The prevailing wind directions in Anshan are south in summer, and north in winter. Temperature inversion occurs frequently during the wintertime.

As shown in Fig. 1, Anshan Iron and Steel Corporation is located in the northwestern part of the city and has an area of 29 km^2, nearly a quarter of the urban area. It is one of the largest iron–steel enterprises of China, including power generation, mining, beneficiating, sinterablity, coking, iron-smelting, steel-making, steel-rolling, etc., with the iron and steel producing ability of 12 million tons per year. Meanwhile, the corporation emitted large amount of air pollutant and industrial dusts, with yearly emissions of 2.4×10^5 tons of coal combustion fly ash and 6.8×10^5 tons of industrial dusts in 2005 [22].

2.2. Sampling

Paved road dust samples were collected from the 19 sampling areas chosen across the urban area of Anshan as shown in Fig. 1 in August, 2005. All sampling sites were selected to represent different functional area. Classification of sites was shown in Table 1. Sites 16, 17 and 18 were set in the area of Anshan Iron and Steel Corporation, representing highly industrialized area of Anshan. Except these three sites, all sites were located close to the main stem or intersection. Sites 1, 2, 3, 5, 6, 11, 12 and 15 were located close to Anshan Iron and Steel Corporation, and 3, 7, 8, 13, 14, 15 were in residential area with high density population. All 19 samples were swept from representative portions of major paved road surfaces with a plastic brush and dustpan.

Each dust 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 screen to remove hair, fibers and other larger particles. Then the sieved samples were suspended in a resuspension chamber [23–25] and sampled through PM_{10} inlets onto quartz-fiber filters. Filters were weighed both before and after sampling by a sensitive microbalance (Mettler M5). The balance sensitivity was ±0.010 mg.

2.3. Polycyclic aromatic hydrocarbons analysis

2.3.1. Sample analysis

For PAHs analysis, the filters were extracted ultrasonically with dichloromethane, concentrated using a rotary evaporator, purified with a silica gel cleanup technique, reconcentrated by rotary evaporation, and finally condensed to exactly 1 mL under a gentle nitrogen stream in 60 °C water bath. The extracts were transferred into two ampoule bottles and stored in refrigerator until GC/MS analysis [26].

A gas chromatography coupled to mass spectrometry (trace 2000 GC–MS, Thermo Finnigan, USA) was used for determining

Table 1
Locations and character of sites over the urban area of Anshan.

ID	Site name	Functional zone
1	Lishan Bridge	Industrial zone
2	Labor Union	Mixed zone[a]
3	Old Man Center	Residential zone
4	Jiefang Road Bridge	Mixed zone
5	Lishan culture center	Mixed zone
6	City square	Mixed zone
7	Qianlonghu community	Residential zone
8	Environmental monitoring center	Residential zone
9	Traffic management agency	Mixed zone
10	February 19th Park	Mixed zone
11	South gate of Anshan Iron and Steel Corporation	Industrial zone
12	Tiexi Government	Mixed zone
13	High School of Anshan Iron and Steel Corporation	Residential zone
14	Zhangda Square	Residential zone
15	Tuanjie Primary School	Residential zone
16	Steel-making section	Industrial zone
17	Sinterability section	Industrial zone
18	Iron-making section	Industrial zone
19	Xingsheng Road developing area	Mixed zone

[a] Mixed zone: industrial and residential mixed zone.