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Source apportionment of PM_{10} in six cities of northern China

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Abstract

Ambient PM_{10} was sampled in six northern China cities (Urumqi, Yinchuan, Taiyuan, Anyang, Tianjin and Jinan) from December 1999 to July 2002, and analyzed for 16 chemical elements, two water-soluble ions, total carbon, and organic carbon. In addition, chemical source profiles consisting of the same particulate components were obtained from a number of naturally occurring geological sources (soil dust from exposed lands) and sources of atmospheric particulates resulting from human activities (resuspended dust, cement, coal combustion fly ash, vehicle exhaust, and secondary particles). Ambient and source data were used in a chemical mass balance (CMB) receptor model to determine the major source of PM_{10} in these six cities. Results of CMB modeling showed that the major source of ambient PM_{10} in all the cities was resuspended dust. Significant contributions from coal fly ash were also found in all six cities.

Keywords: Source apportionment; Particulate matter; Chemical mass balance; Cities of northern China

1. Introduction

Source apportionment of ambient particulate matter (PM) is conventionally attempted using receptor-oriented models such as the chemical mass balance (CMB) model, which infers source contributions by determining the best-fit combination of emission source chemical composition profiles needed to reconstruct the chemical composition of ambient samples (Watson et al., 1991, 1994).

Total suspended particulates (TSP) and PM with the aerodynamics diameter less than 10 μm (PM_{10}) are causes of heavy air pollution in China, especially in northern China (north of the Qinling mountain range and Huai River at 33°N). According to the Report on the State of the Environment in China 2000, TSP and PM_{10} were found to be the primary pollutants of China's urban areas (State Environmental Protection Administration (SEPA), 2001). In 2000, the TSP and PM_{10} concentrations of 208 cities in China (61.5% of total cities) did not meet the National Annual Mean Ambient Air Quality Standard (NAMAAQS) of People's Republic of China of 200 $\mu g\,m^{-3}$ for TSP and 100 $\mu g\,m^{-3}$ for PM_{10}, and the TSP and PM_{10} concentrations of all the six northern Chinese cities (Urumqi, Yinchuan, Taiyuan, Anyang, Tianjin and Jinan) examined in this study exceeded the NAMAAQS. A major portion of the PM pollution in northern China has been recognized as 'soot pollution' by the environmental management system, and control measures of PM pollution have been conducted aimed at soot pollution (Law of the People's

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Republic of China on the Prevention and Control of Atmospheric Pollution, 2000). Efforts have been made to reduce soot pollution in China since the 1980s, and stationary sources of large soot emission (e.g. coal burning power plants, industrial sources) have been considered the main sources of PM. From 1997 to 2002, soot emissions decreased 36.4% (from 1.265×10^7 t to 0.804×10^7 t), but PM concentrations still did not meet the NAMAAQS (State Environmental Protection Administration (SEPA), 2003). This chronic, serious particulate pollution indicates that control measures directed solely at these traditional soot pollution sources are incomplete, and suggest that other significant sources of PM contribute to the pollution. Additional analysis must be conducted to identify such sources to most efficiently decrease PM concentrations.

The source identification and apportionment of PM_{10} in urban areas of the six northern Chinese cities in this study were determined via a CMB receptor model, and adequate grounds were established for developing policies aimed at reducing emissions from non-traditional sources.

2. Experimental method

2.1. Area description

The six cities examined in this study, Urumqi (86°37′E, 42°45′N), Yinchuan (105°49′E, 37°29′N), Taiyuan (111°30′E, 37°27′N), Anyang (113°38′E, 35°12′N), Tianjin (116°43′E, 38°34′N) and Jinan (117°00′E, 36°40′N) all experience a continental monsoonal climate within a warm temperate zone, with similar characteristics of hot summer, cold winter, and windy spring. The locations of the cities are provided in Fig. 1.

Higher than average annual precipitation levels (610 mm) were observed by the China Meteorological Administration in Anyang, Tianjin and Jinan—located in the eastern part of northern China. Higher relative humidity was also observed in these three cities. As traditionally agricultural areas, these three cities provide optimal conditions for growing crops in summer and fall. During these seasons, there is little exposed land. However, during the winter and spring seasons, the area of bare land rises dramatically. Human activities such as traffic and industry are significant and widespread as a result of the population (1.05×10^6 in Anyang, 5.33×10^6 in Tianjin, and 2.6×10^6 in Jinan) and booming economy of these three cities. Sophisticated urban environmental management initiatives were implemented in these three cities as compared to western cities, and more capital was invested for environmental protection.

Fig. 1. Locations of the six cities in North China. (a, Urumqi; b, Yinchuan; c, Taiyuan; d, Anyang; e, Tianjin; f, Jinan).

Taiyuan is located in the middle of northern China, and has a lower annual average precipitation (395 mm) and relative humidity than the three eastern cities mentioned above (Anyang, Tianjin and Jinan). Exposed land is common in Taiyuan during winter and spring, and scarce in summer and fall. The rapidly developing economy of Taiyuan is largely propelled by massive coal consumption; in addition to using coal as an energy source, it is also used as raw material by a number of industries. There are a large number of coal traversing the city and surrounding vicinity of Taiyuan almost every day and plenty of road dust is created.

Urumqi and Yinchuan have lower than average annual precipitation (252 mm) and relative humidity. The proximity of these two cities to the desert limits their feasibility for growing crops. With relatively lower populations and underdeveloped economies, Urumqi and Yinchuan exhibit less significant anthropogenic impacts as compared to the eastern cities.

2.2. Ambient samples

Ambient and source samples were collected in the six cities as follows: December 1999 to September 2000 (Jinan), December 2000 to October 2001