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Large-scale distribution of elements in Chinese aerosol

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Abstract

In spite of increasing attention on Chinese aerosol, there has never been a country-wide survey of its general characteristics. This paper presents elemental data for aerosol at 23 sites in and around China, mostly drawn from the literature, and shows some of the large-scale patterns. Al, Na, and Se are used to represent the crustal, marine, and pollution components, respectively. Most of the patterns are aligned in SW–NE. Al and Na are highest to the NW and the SE, respectively, and their ratio changes rapidly near the coast. Se has a broad maximum over Central China, and the Se/Al ratio (an indicator of pollution vs. crustal aerosol) increases progressively from the NW to the SE. A simple index for simulating pollution aerosol, which uses population density, annual precipitation, and mean wind speed, adequately reproduces the large-scale pattern of pollution aerosol and shows how crustal Al in the NW gradually gives way to flyash Al toward the SE.

Keywords: Chinese aerosol; Elemental concentration; Distribution; Pollution index

1. Introduction

As China industrializes, its air pollution is becoming increasingly serious, and has moved from a regional to an international problem. According to a 1997 report by the Asian Development Bank, "Asia's environment has become so polluted and degraded that it poses a threat not just to the quality of life of its people, but also to its economic prospects (ADB, 2001). Of the world's 15 most polluted cities, 13 are in Asia (ADB, 1997)." In 1998, seven cities in China made the list of Ten Worst Polluted Cities reported by the World Health Organization (WHO). By 1999, China accounted for nine out of ten (Pei, 2002). Although dirty coal-burning power plants are still a major contributing factor, increasing automobiles are showing their effects in the atmosphere.

It is important to understand China's aerosol for various reasons. Its dust storms, which typically occur in the northern provinces during spring (Guo, Rahn, & Zhuang, 2004; Liu, Gu, An, & Fan, 1981; Sun, Zhuang, Yuan, Zhang, & Guo, 2004; Zhang et al., 2003; Zhuang, Guo, Yuan, & Zhao, 2001) as strong winds near cold fronts pass over deserts (Husar et al., 2001), affect biogeochemical cycles and the global environment. Large quantities of this dust are transported to eastern and southeastern China (Lin, 2001; Murayama et al., 2001; Zhang et al., 2000), to Korea (Chun et al., 2001; Yi, Lee, & Holsen, 2001), to Japan (Ma, Kasahara, Holler, & Kamiya, 2001; Murayama et al., 2001; Uematsu, Yoshikawa, Muraki, Arao, & Uno, 2002), and sometimes even to North America (Husar et al., 2001; Perry, Cahill, Schnell, & Harris, 1999; Tratt, Frouin, & Westphal, 2001). China's pollution aerosol which frequently exceeds national norms, is often transported along with the dust. Thus Chinese crustal and pollution aerosols are not only local problems, but also regional and global matters (Zhuang et al., 2002; Zhuang, Guo, Yuan, & Zhang, 2003).

Although China's aerosol has been measured for decades and is much better understood than before, no broad picture of its distribution has been presented. There have been few systematic observations over China, though they are almost impossible to carry out currently because of the vastness of the project. Here we try to present a first idea of the patterns of Chinese aerosol by combining the available information and presenting the results graphically. We focus on the crustal, marine, and pollution components, and use Al, Na, and Se, respectively, to represent them.

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Fig. 1. Sampling sites around China.

2. Data

We have tabulated elemental data for aerosol at 18 sites in China, which are all the aerosol data with concerned elemental concentrations we can find, and five in Japan and Korea (Fig. 1). We drew pictures of their broad-scale distributions. The sites ranged from far inland (such as Urumchi) to islands in the Pacific (such as Cheju), from nearly unpopulated areas (such as Zedang, Tibet) to heavily populated areas (such as Beijing), from sites near deserts (such as Urumchi) to coastal sites (such as Hong Kong). The elemental data came from the literature, from unpublished work of colleagues, and from our own work. We used simple arithmetic averages for the concentrations. The number of samples ranged from two for Zedang to 448 for Beijing (at some sites the number of samples is not clearly stated in the literature). The dates of sampling ranged from 1984 for Okushiri Island to 2001 for Beijing, and we averaged the data from whatever seasons we had. We did not take the seasonal variation of the aerosol concentration and composition into consideration for two reasons: for one thing, the seasonal variation is minor when considering the broad-scale distribution of the aerosol; for the other, there is not enough research work done on the seasonal variation of aerosol for the examination of the large-scale distribution of Chinese aerosol. In order to draw a broad view of the Chinese aerosol, we have to average the data we can get. Some aspects of the patterns we draw in this paper might be artifacts of the different seasons, but the basic patterns seem solid and reasonable. These samples were analyzed by instrumental neutron activation analysis (INAA), inductively coupled plasma-atomic emission spectroscopy (ICP-AES), particle-induced X-ray emission (PIXE), or X-ray fluorescence spectrometer (XRF). The data are listed in Table 1. Although the concentrations were measured by different analytical techniques, different laboratories, and spanned decades, the characteristic pattern of Chinese aerosol still can be seen.

Table 1
Characteristics of aerosols at the sites

Site	Al (ng/m^3)	Na (ng/m^3)	Se (ng/m^3)	Zn (ng/m^3)	Sampling dates	Reference
Zedang	2.9E+04	3.9E+03	3.7E+00	5.1E+01	January 1998	Yang, Li, and Zhu (2001)
Urumchi	1.5E+04	3.5E+03	2.0E+00	2.5E+02	October 1990 and October 1991	Hashimoto, Sekine, Kim, Chen, and Yang (1994)
Lanzhou	2.7E+04	4.8E+03	8.8E+00	6.6E+02	October 1990 and October 1991	Hashimoto et al. (1994)
Baotou	2.5E+04	3.3E+03	5.7E+00	3.9E+03	October 1990 and October 1991	Hashimoto et al. (1994)
Xi'an	3.2E+04	8.4E+03	3.2E+01	3.9E+03	July–August 1997 and January 1998	Xie, Huang, Li, and Li (1999)
Chengdu	2.7E+04	4.0E+03	1.1E+01	1.1E+03	October 1990 and October 1991	Hashimoto et al. (1994)
Chongqing	1.2E+04	4.0E+03	2.7E+01	8.0E+02	September 1986	Zhao and Rahn (personal communication)
Jinghong	4.6E+03	8.1E+02	9.2E+00	7.4E+01	November 1997	Yang et al. (2001)
Beijing	1.0E+04	1.6E+03	8.1E+00	7.1E+02	September 2000–Junuary 2001	This study
Tianjin	9.7E+03	2.3E+03	8.7E+00	9.1E+02	September 1983	Zhao and Rahn (personal communication)
Qingdao	3.1E+03	2.7E+03	2.1E+00	1.4E+02	May 1989	Gao, Arimoto, Duce, Lee, and Zhou (1992)
Zhuzhou	1.4E+03	2.1E+02	4.1E+00	2.8E+02	Auguat–September 1987	Maenhaut (personal communication)
Lechang	1.0E+03	4.7E+02	1.4E+00	7.1E+01	August, 1987	Maenhaut (personal communication)
Guangzhou	5.4E+03	9.0E+02	8.4E+00	4.6E+02	August–September 1987	Maenhaut (personal communication)
Lin'an	3.8E+03	1.4E+03	7.0E+00	2.1E+02	August–November 1991 and February–June 1994	Yang et al. (1995)
Hong Kong	1.2E+03	6.0E+03	3.0E+00	6.8E+01	September 1991–April 1994	Arimoto PEM-West (2007)
Kenting	3.1E+02	6.9E+03	9.7E−01	2.1E+01	September–October 1991 and February–March 1994	Arimoto PEM-West (2007)
Yellow Sea	1.5E+03	2.5E+03	1.7E+00	4.2E+01	April 1989	Gao et al. (1992)
Seoul	1.4E+03	6.2E+02	1.3E+01	4.1E+02	May 1986–March 1989	Hashimoto, Kim, Otoshi, and Sekine (1991)
Mallipo	1.3E+03	2.6E+03	2.1E+00	6.4E+01	May 1989	Gao et al. (1992)
Okushiri Island	4.7E+02	1.2E+04	2.8E−01	2.1E+01	November 1984–May 1985	Rahn, Lowenthal, and Harris (1989)
Cheju	1.3E+03	1.2E+04	2.2E+00	4.6E+01	September 1991–March 1994	Arimoto PEM-West (2007)
Okinawa	7.4E+02	9.7E+03	1.0E+00	1.9E+01	September 1991–March 1994	Arimoto PEM-West (2007)