Chemosphere 64 (2006) 1311–1317

CHEMOSPHERE

www.elsevier.com/locate/chemosphere

Characterization of atmospheric dry deposition particulates in Kobe, Japan

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Received 18 September 2005; received in revised form 20 December 2005; accepted 22 December 2005
Available online 8 February 2006

Abstract

The sources and character of individual metal and metalloid particles from atmospheric dry depositions in Kobe, Japan were investigated. Japan faces long-range pollutant transportation from northeastern Asia during winter and spring. Information regarding their properties and sources is useful for evaluating their affects on the environment and human health. Individual metal and metalloid particles that were collected for every 24 h on the plate, which was designed to reduce a local turbulence, were characterized for their composition, diameter, and deposition fluxes using a field emission scanning electron microscope with an energy dispersive X-ray spectrometer. Approximately 3000 metal and metalloid particles were classified into 14 types based on their composition and further classified into four groups based on their distribution patterns. They are (A) Fe–O, Fe–Ba–Sb–Cu–S–Ti–O, Fe–Zn–O, Zn–O, Ni–O, and Mn–Fe–O; (B) Cu–Zn–O and Cu–Sn–O; (C) Pb–O, Sn–Sb–O, and Ag–O; (D) Pb–Zn–Cl–Si–S–O and Bi–Cl–O. From these data, this study suggests their sources as the Asian continent (Group A), local source (Group B), multiple sources (Group C), and incineration process (Group D). This study shows (1) the sources and character of individual metal and metalloid particles from short-term atmospheric depositions in Kobe, Japan and (2) application of individual particle analysis for atmospheric depositions.

Keywords: Scanning electron microscope; Individual particle analysis; Cluster analysis; Northeast Asia

1. Introduction

Atmospheric dry deposition is one of the major sources of pollution in urban environments, soils, and lake surfaces (Nriagu and Pacyna, 1988; Holsen et al., 1993; Zufall et al., 1998). This study investigated the individual metal and metalloid particles from atmospheric dry depositions because most of them include harmful metal or metalloid elements, which have adverse effects on the environment and human health. Additionally, as many metal and metalloid particles are derived from anthropogenic sources, their compositions can be indicators of artificial sources in the environment.

Long-range atmospheric transport from the northeast Asian continent to Japan during the winter and Asian dust-storm period (spring) is compounded by the rapid industrial growth of China (Ma et al., 2001; Funasaka et al., 2003; Kim et al., 2003). Since 1965, the Japanese government has been monitoring the bulk chemical composition of atmospheric particulate matter in 16 Japanese cities using data provided by the National Air Surveillance Network (NASN) (Var et al., 2000). These data indicate that since 1974 the proportion of metals increased during the Asian dust period and winter despite the decrease in the annual average concentrations of anthropogenic elements (Var et al., 2000).

A scanning electron microscope with an attached energy dispersive X-ray spectrometer (SEM–EDS) was used to analyze the morphology, diameter, and composition of atmospheric metal and metalloid depositions. Individual particle analysis, which analyzes a large number of individual particles using a electron microscope and classifies them using statistical analyses such as the hierarchical cluster

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0045-6535/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.chemosphere.2005.12.055

analysis program (HCA) and principal component analysis (PCA), is a powerful tool to investigate a character of individual particles from the atmosphere or other environment (Casuccio et al., 1983; Post and Buseck, 1984; Anderson et al., 1988, 1992, 1996; Saucy et al., 1991; Katrinak et al., 1995; Malderen et al., 1996a,b; Piña et al., 2000; Mamane et al., 2001; Adachi and Tainosho, 2004, 2005). The main advantages of this method over bulk chemical analysis are (1) the chemical composition, morphology, and diameter of each particle can be determined and (2) it requires a very small amount of sample. The small sample size results in the investigation of distribution for daily atmospheric metal and metalloid deposition. As a result, this study can estimate their sources from multiple types of data and high-time resolution of the distributions.

This work aims at characterizing the atmospheric metal and metalloid depositions and estimating their sources in this area. Also, this study provides an example of detailed distribution of atmospheric metal and metalloid deposition using individual particle analysis.

2. Material and methods

2.1. Sampling

Sample collecting equipment was placed on the roof of a five-storey building of the Faculty of Human Development at the Kobe University campus (34.44°N, 135.14°E). The university is located in the city of Kobe, which has a population of 1.5 million (Fig. 1). The building is situated at an altitude of 200 m at the foot of Mount Rokko (elevation 931 m), with no significant local source of atmospheric pollutants or large roads within a radius of 500 m. A steel plant and coal-fired power plant are located near the seacoast, 3 km southeast of the sampling area.

Samples were collected every 24 h starting at 14:00 (local time) from December 9 to 18, 2003 except during one short rain event (December 11, 10:00–24:00) (Table 1). During the sampling period, the average wind velocity was 1.4 m s^{-1}, the temperature ranged from 0 to 18.2 °C, and the average relative humidity was 63% (36–96%).

Samples were collected using a double-sided carbon tape (2 cm × 3 cm) adhered to a smooth glass plate that was attached to a clean stainless plate with a sharp leading edge ($<10°$). This arrangement was similar to that used in earlier studies (Noll et al., 1988; Kim et al., 2000; Yang et al., 2004). The sampling plate was mounted on a wind vane and pointed in the direction of the wind to reduce the edge effect caused by local turbulence (Vawda et al., 1990). Noll et al. (1988) showed that this sampling method reproduce the same weight at 95% confidence level for 34 duplicate plates. The deposited samples could be directly observed without any additional treatment other than carbon coating. Thus, it was possible to count the actual

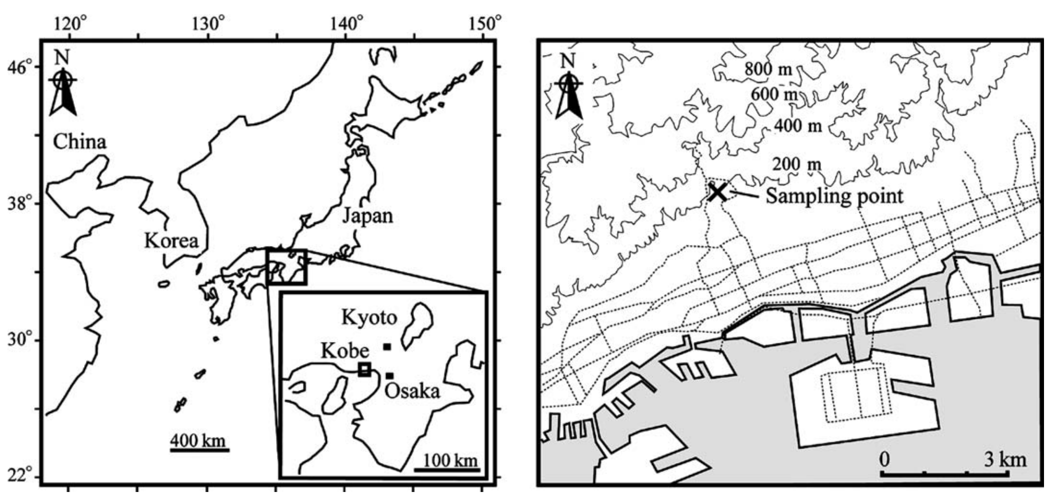

Fig. 1. Sampling map for this study. Samples were collected at Kobe City, Japan.

Table 1
Metal and metalloid particle deposition flux and sampling times for each sampling day

Sampling day	1	2	3	4	5	6	7	8	9	10
Date	12/9–10	12/10–11	12/12	12/12–13	12/13–14	12/14–15	12/15–16	12/16–17	12/17–18	12/18–19
Effective sampling area (mm^2)	92.8	66.0	119.1	70.2	15.3	58.2	102.4	137.0	11.2	23.4
Particle number	301	301	300	300	304	303	301	300	307	306
Hour	24	20	14	24	24	24	24	24	24	24
Flux (mm^{-2} day^{-1})	3.2	5.4	4.3	4.2	19.5	5.1	2.9	2.2	27.0	12.9