FLY ASH CONCENTRATIONS IN PHILADELPHIA AEROSOL DETERMINED BY ELECTRON MICROSCOPY

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Abstract. In a study to differentiate between coal-fly ash and minerals in the atmosphere, samples were collected on Nuclepore filters in dichotomous samplers and analyzed by scanning electron microscopy (SEM) and energy dispersive X-ray spectrometry. The samples included ambient aerosol from two sites, resuspended soil, and emissions from coal- and oil-fired power plants in the Philadelphia area. Fly ash and minerals were identified by observing high abundances of Al, Si, K, Ca, Ti, and Fe in individual particles, and their mass concentrations were estimated from measured dimensions and an assumed density. Fly ash was distinguished from minerals by morphology. Sulfate was the major component of the fine fraction (<2.5 μm aerodynamic dia.). Crustal matter concentrations in the fine fraction estimated by SEM ranged from 40 to 300 ng m⁻³, and fly ash accounted for 7 to 62% of the crustal matter. In the coarse fraction (2.5 to 10 μm), minerals were the predominant component and ranged in concentration from 500 to 6000 ng m⁻³. Fly ash accounted for 0 to 16% of the crustal matter; the typical amount was 6%. Other less abundant coarse particles included botanical matter and industrial source emissions. Coarse fraction crustal matter estimated from x-ray fluorescence elemental data agreed well with that based on electron microscopy.

1. Introduction

Receptor models have been developed to identify emission sources that contribute to concentrations of particles in the atmosphere. The models are based on comparing the chemical compositions of ambient aerosol samples and source emissions. The chemical mass balance (CMB) type of receptor model requires that the compositions of source emissions not be collinear (Henry et al., 1984). Sources with similar chemical compositions are collinear and cannot be resolved reliably by CMB. For example, fly ash and soil particles have similar compositions within the crustal category. Both contain mainly silicates of Al and varying concentrations of Fe and Ca. It is important to be able to resolve them because the crustal component constitutes a large fraction of coarse particles in the atmosphere.

The purpose of the present study is to explore the feasibility of using scanning electron microscopy (SEM) and energy dispersive X-ray analysis (EDX) to distinguish coal- and oil-fly ash from minerals. The study is based on SEM–EDX analysis of ambient aerosol, resuspended soil, and emissions from coal- and oil-fired power plants in the Philadelphia area.

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2. Measurements

Ambient aerosol samples were collected during summer, 1982, in the Philadelphia area at three sites (Figure 1) along the line of prevailing winds (Dzubay et al., 1988). (a) The site at North Airport is northeast of downtown Philadelphia in a residential area with some light industries where fairly large areas are covered with vegetation. (b) The Camden site is at the Institute for Medical Research in Camden, New Jersey, in a residential-commercial area near industrial sources along the Delaware River. (c) The Clarksboro site is in a rural, agricultural area south of Philadelphia. A detailed description of the sampling sites is given by Core (1982). Over 50 12-hr ambient samples were collected at each site.

Sources sampled were oil- and coal-fired power plants, a municipal refuse incinerator, a refinery, an aluminum furnace, and an antimony roasting plant at locations indicated in Figure 1. Emissions from power plants were collected in a sampling train consisting of a stack probe, a dilution chamber which cooled the hot stack gases to the ambient level, and a dichotomous sampler (Olmez et al., 1986). Soil samples from several sites (see Figure 1) in the Philadelphia area were collected at depths of 0.2 to 2 cm. In the laboratory, particles larger than 300 μm were removed by a sieve, and the remaining smaller ones were resuspended in a fluidized bed aerosol generator (Batterman et al., 1987).

All source, resuspended soil, and ambient samples were collected by dichotomous samplers in two size fractions: fine (< 2.5 μm aerodynamic diameter) and coarse (2.5 to 10 μm). Parallel samples were collected on 0.3-μm pore size Nuclepore filters and 2-μm Teflon filters. Soil samples on Teflon filters were analyzed for mass by β-gauge and bulk composition by X-ray fluorescence (XRF) (Battermann et al., 1987). Ambient and source samples were analyzed for bulk composition by β-gauge, instrumental neutron activation, and XRF (Dzubay et al., 1988; Olmez et al., 1986). Individual particles on Nuclepore filters were analyzed by light microscopy (Crucher, 1985; Draftz, 1985). This approach was based on recommendations of the Quail Roost Conference (Stevens and Pace, 1984).

For SEM analyses reported here, a 4 x 4 mm segment of each filter was coated with carbon and placed on a SEM stage holder. The SEM operating conditions were 30-kV accelerating voltage, 100-μA beam, 26 ° sample tilt, and 12-mm working distance. The incident beam size was approximately 0.01 μm, but scattering and penetration caused X-rays to be emitted from a hemisphere about 1 μm in diameter. Known standards were used for SEM and EDX calibration. Each sample was scanned at low magnification to identify any non-uniform or irregular particle deposits due to sample handling. A few typical fields of view were chosen for more intensive analysis. For all particles in each field, diameters were recorded, morphologies were noted, and X-ray spectra were taken. Elements heavier than Na were detectable by EDX when their abundances exceeded about 1%. Elements lighter than Na were not detected by EDX, but if a particle was made mainly of lighter elements such as C and O in pollen or elemental carbon particles, that fact could be ascertained from the relatively low peak to background ratio and low