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Comparison of sources of submicron particle number concentrations measured at two sites in Rochester, NY

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ABSTRACT

Sources contributing to the submicron particles (100–470 nm) measured between January 2002 and December 2007 at two different New York State Department of Environmental Conservation (NYS DEC) sites in Rochester, NY were identified and apportioned using a bilinear receptor model, positive matrix factorization (PMF). Measurements of aerosol size distributions and number concentrations for particles in the size range of 10–500 nm have been made since December 2001 to date in Rochester. The measurements are being made using a scanning mobility particle sizer (SMPS) consisting of a DMA and a CPC (TSI models 3071 and 3010, respectively). From December 2001 to March 2004, particle measurements were made at the NYS DEC site in downtown Rochester, but it was moved to the eastside of Rochester in May 2004. Each measurement period was divided into three seasons i.e., winter (December, January, and February), summer (June, July, and August), and the transitional periods (March, April, May, September, October, and November) so as to avoid experimental uncertainty resulting from too large season-to-season variability in ambient temperature and solar photon intensity that would lead to unstable/non-stationary size distributions. Therefore, the seasons were analyzed independently for possible sources. Ten sources were identified at both sites and these include traffic, nucleation, residential/commercial heating, industrial emissions, secondary nitrate, ozone- rich secondary aerosol, secondary sulfate, regionally transported aerosol, and a mixed source of nucleation and traffic. These results show that the measured total outdoor particle number concentrations in Rochester generally vary with similar temporal patterns, suggesting that the central monitoring site data can be used to estimate outdoor exposure in other parts of the city.

1. Introduction

Recently, research has linked exposure to elevated concentrations of particulate matter (PM) to increased rates of cardiovascular and respiratory illness, hospitalization, and pre-mature mortality e.g. (Samet et al., 2000; Dockery 2001; Ibald-Mulli et al., 2001; Pope et al., 2002; Schwartz et al., 2003; von Klot et al., 2005). Although it is not clear whether it is mass, number, or even surface area of particles that is the most important determinant of health consequences, some toxicological studies have indicated that the size of airborne PM is an important factor in generating health effects (Utell and Frampton, 2000). For example, ultrafine particles (UFP or PM<0.1 μm) are associated with greater toxicity on a per-mass basis than larger particles (Donaldson et al., 1998b; Oberdorster et al., 2002; Li et al., 2003; Xia et al., 2004; Nel et al., 2006). The mechanisms by which PM induces health effects are still unclear. PM does not only affect human health, but it also affects visibility and impacts climate. Therefore, to precisely assess the effects of PM on visibility, climate, and human health, it is imperative to understand the formation, size distributions, transformation, transport, and removal mechanisms of UFP together with the identification of the main sources contributing to these particles.

UFP size distributions and number concentrations in urban atmospheres have been measured at different locations in the United States, (e.g., Woo et al., 2001; Stanier et al., 2004b; Tolocka et al., 2004; Jeong et al., 2004, 2006; Park et al., 2005; Shi et al., 2007) and Europe e.g. (Wichmann et al., 2000; Ruuskanen et al., 2001; Charron and Harrison, 2005). Furthermore, many source apportionment studies have been conducted, using positive matrix factorization (PMF) to identify and apportion the sources of fine and ultrafine particles in urban areas, e.g. (Ramadan et al., 2000; Polissar et al., 2001a, b; Lee et al., 2002; Kim et al., 2003; Hwang and Hopke, 2006). However, only limited studies have utilized size distribution to identify and apportion the sources of fine and ultrafine particles. Some of the

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studies that have employed PMF to apportion the sources of fine and ultrafine particles based on their size distributions include Kim et al. (2004), Zhou et al. (2004, 2005a,b), Ogulei et al. (2006a, 2007a,b).

In this study, the bilinear receptor model, Positive Matrix Factorization (PMF) was utilized to elucidate the sources of sub-0.5 µm particles measured at two sampling sites in Rochester, NY. The measured gaseous species and meteorological variables were also utilized in the identification of the suspected sources. The identification of sources of UFP and sub-0.5 µm particles is important because it can help explain the sources responsible for the observed health effects involving these particles. Currently, little information on source profiles of particle size distributions is available since most studies on source apportionment are based on particle composition measurements. Therefore, source apportionment studies based on particle size distribution are necessary to adequately address the contributions from the ultrafine and sub-0.5 µm particles.

The present study utilized PMF to identify and apportion the sources of sub-micron particles in Rochester, NY. Particle size distribution measurements were made sequentially at two different sites. These results are relevant in identifying and apportioning the sources that are responsible for the observed particle concentrations. Furthermore, this information is useful in demonstrating the similarity in source characteristics that were identified from the different site measurements.

2. Description of the sampling sites and data sets

Measurement of the number concentrations of particles in the size range of 10–500 nm were made sequentially at two New York State Department of Environmental Conservation (NYS DEC) sites in Rochester, NY from December 2001 to December 2007. From December 2001 to March 2004, particle measurements were conducted at the NYS DEC monitoring site surrounded by an inner loop road within 0.5 miles of downtown Rochester, NY (latitude 43°09′40″ N, longitude 77°36′12″ W). It was located approximately 50 m from major roads, and sampling was performed on the roof of the central fire station, about 10 m in height. From May 2004 to December 2007, measurements were conducted at the new NYS DEC primary site (latitude 43°09′56″ N, longitude 77°33′15″ W) on the eastside of Rochester, NY. The sampling site is close to two major roads (I-490 and I-590) as well as NY route 96, a major route carrying traffic traveling to and from downtown Rochester.

Hourly $PM_{2.5}$ mass, SO_2, CO concentrations; wind speed and wind direction, ambient temperature and relative humidity (RH) were also measured at the above mentioned sites throughout the study period, i.e. December 2001 to December 2007. Before May 2004, O_3 was measured at the old NYS DEC site on the east side of Rochester, and from May 2004 to date, all of the measurements were made at the new NYS DEC eastside site together with the rest of the air pollutants. The locations of the sampling sites are shown in Fig. 1.

Size distribution measurements were made using a scanning mobility particle sizer (SMPS, TSI Inc.) system consisting of an electrostatic classifier (TSI model 3071), with an impactor having an orifice size of 0.0457 cm, a ^{85}Kr aerosol neutralizer (TSI model 3077), and a continuous flow condensation particle counter (CPC; TSI model 3010). The ambient aerosol was drawn from a 50 mm diameter standard ambient air monitoring sampling manifold. The SMPS was operated at a sheath air flow ratio of 10:1 (sheath and sample air flow rates were 5 and 0.5 L min^{-1}, respectively, with the SMPS's inlet located about 2 m from the main inlet. The CPC inlet and sample flow rates were maintained at 1 L min^{-1}. The size range bounds were 10.4 nm (lower) and 0.542 µm (upper) leading to measurement of mid-point particle sizes ranging from 11.1 nm to 0.47 µm (32 channels per decade) at a total scan-up time of 5 min per sample. Routine maintenance such as calibrating the flow rates was being performed once a week to ensure that the system was functioning properly. Furthermore, the quality of the SMPS measurements was ensured throughout the study using laboratory aerosols; several side-by-side measurements were made comparing results with another similar SMPS system.

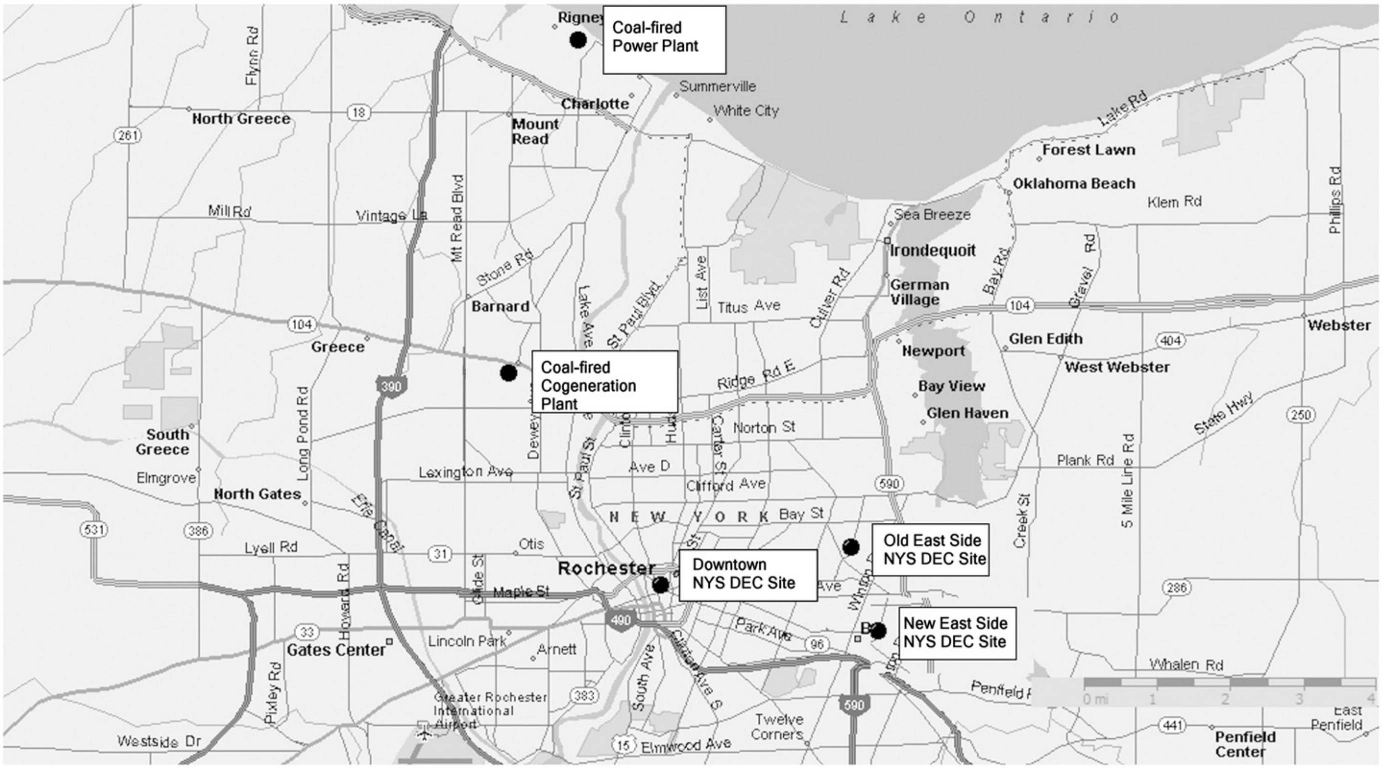

Fig. 1. Location of the sampling sites in Rochester, NY.