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Sources of ambient fine particulate matter at two community sites in Detroit, Michigan

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Abstract

Detroit, Michigan is a non-attainment area of the annual $PM_{2.5}$ (particles $\leqslant 2.5\,\mu m$ in diameter) National Ambient Air Quality Standard (NAAQS), and contains a host of local pollution contributors including high diesel traffic from a nearby international border crossing. A source apportionment analysis was conducted using $PM_{2.5}$ data collected from 1999 to 2002 by the Community Action Against Asthma (CAAA) project in Detroit, Michigan. CAAA used a community-based participatory research approach to identify and address the environmental triggers for asthma among children residing in southwest and east Detroit. The data used for the study included 24-h measurements of $PM_{2.5}$ mass, elemental and organic carbon, and a suite of trace element species, along with hourly measurements of $PM_{2.5}$ mass and black carbon. Positive matrix factorization (PMF2) was used to quantitatively apportion the sources of ambient $PM_{2.5}$ at each of two Detroit community sites. Results showed that southwest Detroit $PM_{2.5}$ levels can be apportioned to seven source categories: secondary sulfate/coal combustion, gasoline vehicles, diesel vehicles, refinery/oil combustion, iron–steel manufacturing/waste incineration, automotive electroplating, and sewage sludge incineration that includes crustal material from runoff. The PMF2 model apportioned the east Detroit $PM_{2.5}$ data into five source categories: secondary sulfate/coal combustion, motor vehicles/combustion, refinery/oil combustion, iron–steel manufacturing/waste incineration, and automotive electroplating. For both locations, approximately over 60% of the $PM_{2.5}$ mass was attributed to secondary sulfate/coal combustion sources, approximately 30% to vehicular sources, and 1–5% to local industrial sources. The unexplained mass accounted for $<2\%$ of the measured $PM_{2.5}$ mass. This study illustrates that regional secondary sulfate/coal combustion and local motor vehicle emissions alone are enough for this mid-western US city to be in non-attainment for the annual $PM_{2.5}$ NAAQS.

Keywords: Receptor modeling; Positive matrix factorization; $PM_{2.5}$; Trace elements

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1. Introduction

A large number of studies of the health effects of $PM_{2.5}$ (particles $\leqslant 2.5\,\mu m$ in diameter) have shown a correlation between elevated levels of ambient aerosol and an array of adverse health outcomes, including decreased lung function, exacerbation of asthma, cardiovascular disease and premature death (Gold et al., 1999; Harrison and Yin, 2000; Lippmann et al., 2000; Pope et al., 2006). The US Environmental Protection Agency (US EPA) promulgated new National Ambient Air Quality Standards (NAAQS) for fine particulate matter (Federal Register, 1997), and designated areas as being in non-attainment beginning in 2004. The US EPA designated over 200 areas across the US including the Detroit metropolitan area as being in non-attainment of the new NAAQS for $PM_{2.5}$. Studies have shown that children with asthma in Detroit disproportionately experience decreased lung function and adverse respiratory symptoms as a result of exposure to $PM_{2.5}$ (Keeler et al., 2002; Lewis et al., 2005).

Studies that focus on quantifying the contribution from different sources to ambient fine particle levels are needed to establish effective emissions reduction strategies and to relate adverse health effects to specific apportioned source categories. In order to identify sources, multivariate receptor modeling can be applied to the observed PM composition data. Among the multivariate receptor models used for aerosol source identification, positive matrix factorization (PMF2) is a relatively new technique developed by Paatero and Tapper (1994) and Paatero (1997). PMF2 has been used successfully to assess contributions from ambient $PM_{2.5}$ sources in numerous studies (Lee et al., 2002; Kim et al., 2003; Gao et al., 2006; Hopke et al., 2006). The objective of the current study was to apportion and compare the sources of ambient $PM_{2.5}$ to which children with asthma are exposed in two Detroit communities.

Air quality sampling was conducted in neighborhoods in east and southwest Detroit. East Detroit is predominantly African American (97%) and contains a major interstate highway and several manufacturing plants. Southwest Detroit is the part of the city where the largest percentage of Latinos reside (approximately 60% Latino, 16% African American, and 20% White) and has historically contained most of the industrial facilities of Detroit (US Census Bureau, 2006). Nearby southwest Detroit emission sources include iron/steel manufacturing, coke ovens, chemical plants, refineries, sewage sludge incineration, and coal-fired utilities located in and around Zug Island, an industrial complex along the Detroit River (Fig. 1). In addition, southwest Detroit experiences heavy car and truck traffic because of both the presence of two major interstates and the entrance/exit of the Ambassador Bridge, the international border crossing that connects Detroit, Michigan to Windsor, Canada. The Michigan Department of Transportation (2000) reported the Ambassador Bridge as the busiest international border crossing within the United States with an average daily traffic volume of 100,000 vehicles day^{-1} from major interstates around the bridge. A seven-county area in southeast

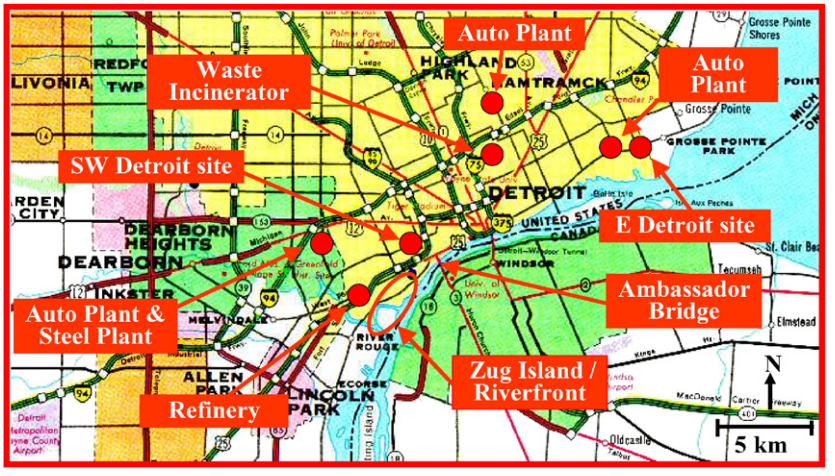

Fig. 1. Map of Detroit, Michigan, illustrating air-monitoring sites and nearby PM emission sources.