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# Chemical mass balance source apportionment of TSP in a lignite-burning area of Western Macedonia, Greece

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**Abstract**

Total suspended particle mass concentrations (TSP) were determined in the Kozani-Ptolemais-Florina basin (western Macedonia, Greece), an area with intensive lignite burning for power generation. The study was conducted over a 1-year period (November 2000–November 2001) at 10 receptor sites located at variable distances from the power plants. Ambient TSP samples were analyzed for 27 major, minor and trace elements. Particulate emissions were also collected from a variety of sources including fly ash, lignite dust, automobile traffic, domestic heating, and open-air burning of agricultural biomass and refuse, and analyzed for the same chemical components. Ambient and source chemical profiles were used for source identification and apportionment of TSP by employing a chemical mass balance (CMB) receptor model. Diesel burning in vehicular traffic and in the power plants for generator start up was found to be the major contributor to ambient TSP levels at all 10 sites. Other sources with significant contributions were domestic coal burning, vegetative burning (wood combustion and agricultural burns) and refuse open-air burning. Fly ash escaping the electrostatic precipitators of the power plants was a minor contributor to ambient TSP.


*Keywords:* Atmospheric particulate matter; Chemical mass balance; Fly ash; Power generation; Receptor models; Source profiles; Trace elements

## 1. Introduction

Source apportionment of the airborne particulate matter (PM) is frequently attempted by using receptor-oriented models. Receptor models infer contributions from different source types using multivariate measurements taken at one or more receptor locations. On the other hand, source-oriented models estimate concentrations at a receptor by combining source emission rates with meteorological measurements. True receptor models are not statistical black boxes. They are based on the same scientific principles as source models, but they are explanatory rather than predictive. Source and receptor models are complementary rather than competitive, and both types can and should be used in air quality source assessment (Watson et al., 2002a).

Among the various receptor models, the well established chemical mass balance model (CMB) and has been widely used to develop pollution control strategies. The CMB model infers source contributions by determining the best-fit combination of emission source chemical composition profiles needed to reconstruct the chemical composition of ambient samples (Watson et al., 1991, 1994a). Species abundances and the receptor concentrations, with appropriate uncertainty estimates,

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serve as input data. The output consists of the amount contributed by each source type represented by a profile to the total mass and each chemical species. The CMB model requirements and assumptions can be found in a number of relevant publications (Hopke, 1991; Watson et al., 2002a).

Hundreds of source profiles have been compiled for use in the CMB modeling representing emissions from fugitive dust (e.g. paved and unpaved road dust, soil dust, storage pile dust, etc.), motor vehicle exhaust, vegetative burning, marine aerosol, industrial emissions, and other aerosol sources (Watson et al., 1994b, 2001; Chen et al., 2001; Watson and Chow, 2001; Vega et al., 2001; Samara et al., 2003; Chow et al., 2004). Major and trace elements, ionic components (sulfate, ammonium, nitrate salts), and carbon species (organic/elemental) are sufficient to account for most of the particle mass in both ambient PM and source emissions. Elements, in particular, are good fitting species in the CMB modeling due to their chemical stability (i.e. they are not subjected to transformations during transport from source to receptor).

The major objective of the present study was to quantify source contributions to ambient concentrations of PM in the Kozani-Ptolemais-Florina basin, western Macedonia (Greece), an area characterized by intensive lignite burning for electricity generation. The area has suffered in the past (Tassiou et al., 1985) from high ambient levels of total suspended particles (TSP) and heavy metals though electrostatic filters were used in the power plants. In recent years, most power plants are equipped with electrostatic precipitators with high retention efficiency (>99.9%), however, considerable amounts of fine fly ash particles may be emitted to the atmosphere because of the high rate of coal consumption. In addition to direct emissions from stacks, coal use also results in fugitive dust from mining, and disposal of non-combustible ash or pollution control residues remaining after combustion.

Chemical composition profiles containing 27 elemental components were created for ambient TSP from 10 receptor sites located at different distances from the power plants and particulate emissions from major stationary, fugitive and mobile sources within the area. A CMB receptor model was employed to determine contributions to ambient TSP levels at the receptor sites for the cold and the warm period of the year.

## 2. Experimental

### 2.1. Area description

The proven geological lignite reserves in Kozani-Ptolemais-Florina basin are 4.3 billion tons, representing the $\frac{2}{3}$ of the total lignite reserves in Greece (Kolovos et al., 2002). Four thermal power stations (PS1–PS4, Fig. 1) are located in this basin producing more than 70% of the country's power requirements. About 64 Mt of lignite, produced by open-cast mining in four mines, are annually used in the power plants leading to an annual fly ash production of nearly 13 Mt (Georgakopoulos et al., 2002). The major amount of the fly ash arrested by the electrostatic filters is stockpiled in open areas before land filling in mine sites or dispose off in specific mounds. Suspension of the finest fly ash fraction (typically of particles with diameters up to 60 μm) might, therefore, cause atmospheric pollution in addition to direct emissions escaping the electrostatic filters (Arditsoglou et al., 2004).

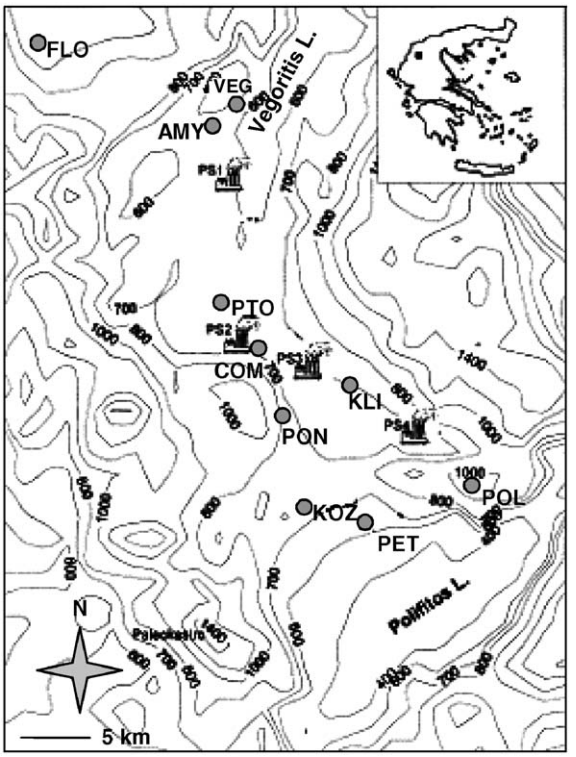


Fig. 1. Map of the studied area. *Receptor sites*: Florina (FLO), Vegoritis (VEG), Amynteon (AMY), Ptolemais (PTO), Community (COM), Klitos (KLI), Pontokomi (PON), Kozani (KOZ), Polymylos (POL), Petrana (PET); *Power stations*: PS1–PS4. (Map source: Triantafyllou, 2001).

Distilled oil (approximately 200,000 t $yr^{-1}$) is the main fuel utilized for residential heating in the basin. Wood burning occurs to unknown extend in wood stoves, fire places, and barbeques. Around 30,000 t $yr^{-1}$ of diesel oil is used in semi-trucks, that constitute the major vehicular type in agricultural sites, and in buses and taxis in the urban sites. Another 27,000 t $yr^{-1}$ is used in the four power stations for generator start up. The proportion of catalytic to non-catalytic gasoline-fueled