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Source apportionment of size resolved particulate matter at a European air pollution hot spot

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HIGHLIGHTS

- Fugitive and coal-combusting sources dominated during the temperature inversion.
- Metallurgy industry prevailed during the post-smog period.
- Analysis of particles sampled by an airship helped to interpret PMF factors.
- Small-scale $PM_{2.5}$ network confirms representativeness of the PMF model.

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ABSTRACT

Positive Matrix Factorization—PMF was applied to hourly resolved elemental composition of fine ($PM_{0.15–1.15}$) and coarse ($PM_{1.15–10}$) aerosol particles to apportion their sources in the airshed of residential district, Ostrava—Radvanice and Bartovice in winter 2012. Multiple-site measurement by $PM_{2.5}$ monitors complements the source apportionment. As there were no statistical significant differences amongst the monitors, the source apportionment derived for the central site data is expected to apply to whole residential district. The apportioned sources of the fine aerosol particles were coal combustion (58.6%), sinter production-hot phase (22.9%), traffic (15%), raw iron production (3.5%), and desulfurization slag processing (<0.5%) whilst road dust (47.3%), sinter production—cold phase (27.7%), coal combustion (16.8%), and raw iron production (8.2%) were resolved being sources of the coarse aerosol particles. The shape and elemental composition of size-segregated aerosol airborne-sampled by an airship aloft presumed air pollution sources helped to interpret the PMF solution.

1. Introduction

Despite the imposition of European Union limit values for particulate matter (PM), frequent exeedances of the limit for PM_{10} concentrations have been observed widely across Western Europe, particularly in Switzerland, Belgium, Germany, Italy, Norway and the Czech Republic (Harrison et al., 2008). To develop effective emission control strategies, receptor models have proven to be a useful tool to apportion PM sources (Watson et al., 2002; Viana et al., 2008; Belis et al., 2013). The size distribution and chemical composition of the emitted PM are source dependent (Dodd et al., 1991). Therefore, to improve the accuracy of aerosol source apportionment, size segregated aerosol measurements with high time resolution are valuable (Zhou et al., 2004; Han et al., 2005; Ogulei et al., 2005; Peré-Trepart et al., 2007; Bernardoni et al., 2011; Richard et al., 2011). Positive Matrix Factorization (PMF) developed by Paatero (1997) is a powerful method to apportion the sources of ambient PM at the receptor site.

The first Czech receptor modelling study was conducted by Pinto et al. (1998) using data from the Teplice air quality-monitoring programme of 1992. More recent PMF analyses have been performed on particle size distributions recorded in Prague (Thimmaiah et al., 2009), polycyclic aromatic hydrocarbons measured at a background station Košetice (Dvorska et al., 2012) and $PM_{1–10}$ sampled in a village situated in an industrial region of northern Bohemia (Pokorná et al., 2013).

The Moravian–Silesian Region with it principal city, Ostrava, is one of the most polluted regions not only in the Czech Republic (CR), but in Europe as shown by long term observations (Houthuijs et al., 2001; CENIA, 2012). Ostrava with a population of 312 000 (3rd in CR) and an urban area of 214 km^2 (2nd in CR) has historically been affected

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by the exploitation and use of the high quality black coal deposits and extensive heavy industry development which lead to high air pollution. Presently, many of the heavy industries are being closed or transformed. However, the collection of steel industry and coke plants has caused some of the worst air quality in the EU with an health impact to human population, particularly to children (Dostal et al., 2013; Sram et al., 2013). In 2012 the daily EU PM_{10} limit was exceeded at 50 stations in Czech Republic, of which 74% were in the Moravian-Silesian Region. The exceedances were most commonly recorded at Ostrava—Radvanice ZU station (GPS: 49°48′ 25.403″N, 18°20′20.897″E, http://portal.chmi.cz/files/portal/docs/uoco/web_generator/locality/pollution_locality/loc_TORE_GB.html) situated in residential district of Ostrava—Radvanice and Bartovice (116 days). The annual EU PM_{10} limit was exceeded at 15 stations in the Czech Republic and all of them were located in Moravian–Silesian Region. Additionally, the annual average of PM_{10}-bond benzo(a)pyrene-B[a]P in Ostrava—Radvanice and Bartovice was almost eleven times higher than annual EU limit (1 ng m^{-3}, 2004/107/EC) (CHMI, 2012). Such high B[a]P of particle-bond concentrations induce remarkable genotoxic effect which increases with particle mass and vary with aerosol particle sizes (Topinka et al., 2010). The dominant source of B[a]P, or polycyclic aromatic hydrocarbons in general, is an incomplete fuel combustion more frequent during cold period of year when there are also less favourable conditions for pollutant dispersal. Therefore, the study was conducted in winter period.

The objective of the presented study is to apportion sources of $PM_{0.15-1.15}$ and $PM_{1.15-10}$ at residential district of Ostrava—Radvanice and Bartovice in the Czech Republic during January and February 2012.

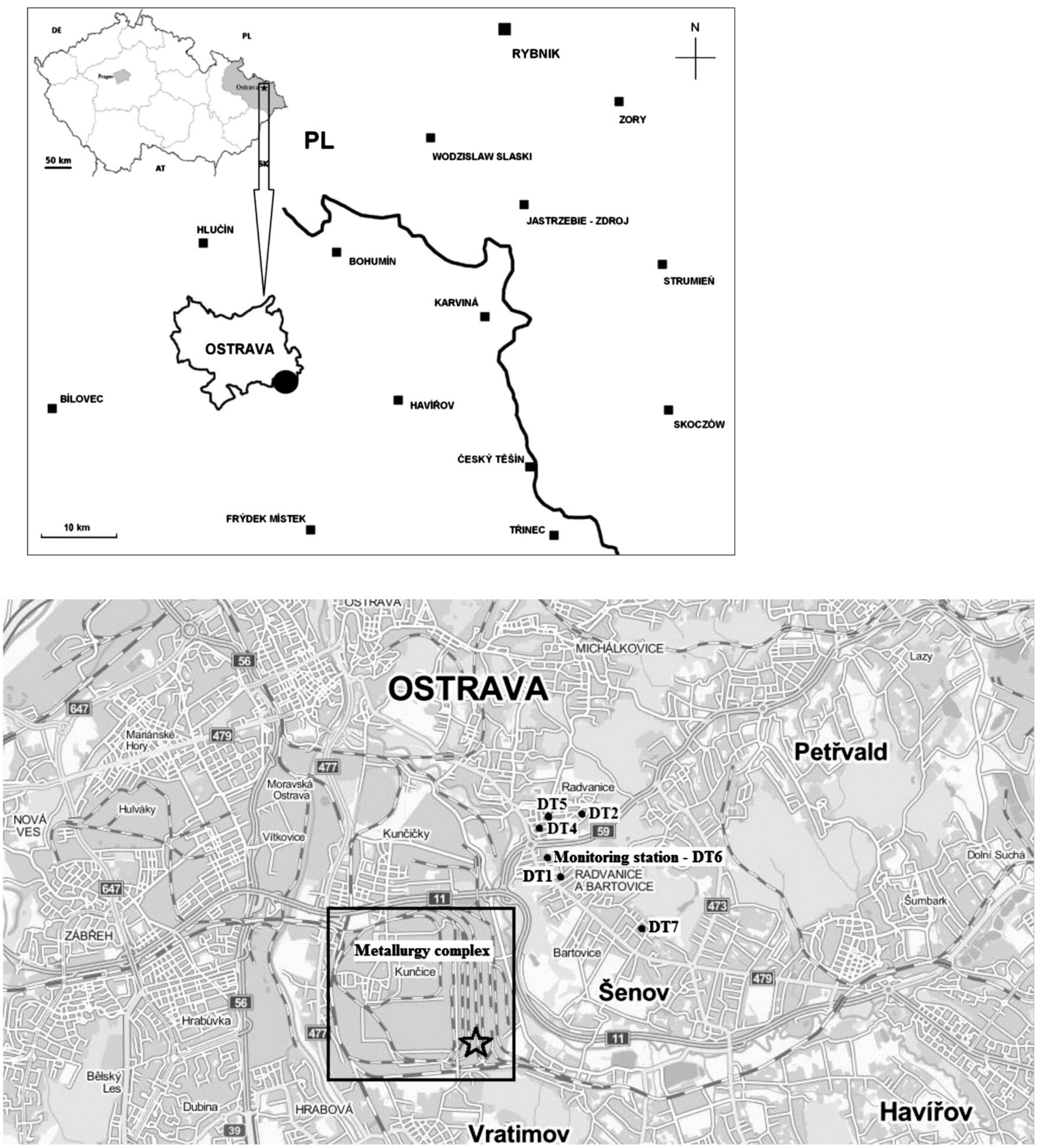

Fig. 1. Outline map of Czech Republic, the city of Ostrava and detailed map of the district Ostrava—Radvanice and Bartovice with location of the monitoring station, the $PM_{2.5}$ monitoring network sites, highlighting the metallurgy complex and marked with a star position of the airship during the sampling sequence.