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Carbonaceous particles in the air of the Moravian-Silesian Region, Czech Republic☆

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Summary Black carbon (BC), elemental carbon (EC) and organic carbon (OC) are emitted as primary particles from incomplete combustion from fossil fuel, industry, residential heating and biomass burning. Carbon compounds account for a large fraction of airborne particulate matter. Above-mentioned forms of carbon particles can be used for the identification of pollution sources. The following work focuses on individual emission sources in the Moravian-Silesian Region, and their portion in air pollution.

Introduction

Carbonaceous particles represent very important component of particulate matter — PM (Hidy, 2005). The substantial part (20—80%) of atmospheric fine-grained dust particles ($PM_{2.5}$) in the urban environment is formed by this carbonaceous material. In spite of their dominant percentage in PM, these carbonaceous particles are not yet quite well understood (Sillanpää et al., 2005). The carbonaceous particles originate especially during incomplete combustion of fossil fuels and biomass. They occur usually in two forms: the first one is called elemental carbon (EC), also black carbon (BC) and the second one is designated as organic carbon (OC) (Saarikoski et al., 2008). Inorganic carbon (CC) bound in carbonates is less frequent (Ozdemir et al., 2014). The term BC is used usually when optical method was used for quantitative determination of carbon concentration. On the other side, the term EC is connected with determination by thermo-optical method. The strong correlation exists between BC and EC, but these terms are not identical (Chow et al., 2010). Elemental carbon originates during incomplete combustion of coal, fuel oil, petrol, wood and other biomass (Schwarz et al., 2008). It was estimated that almost 50% of worldwide emissions of EC is formed by combustion of fossil fuels. OC represents a mixture of hundreds of organic compound, some of which are mutagenic and/or carcinogenic, e.g. some polycyclic aromatic hydrocarbons (PAH) and polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/F) (Feng et al., 2009). OC is formed in both primary and secondary sources, while EC or BC originates

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solely in the primary combustion sources. The primary OC is a product of incomplete combustion in anthropogenic or biogenic sources, whereas secondary OC can be produced by oxidation of volatile organic compounds that are present in the atmosphere during photochemical reactions (Gatari and Boman, 2003).

It is estimated that 20—80% of organic matter (OM) is derived from the primary combustion processes, the remaining part results from chemical reactions in the atmosphere and is ranked among secondary organic aerosols (Carlton et al., 2009). The value of OM is typically 1.4—1.8 times higher than measured concentrations of OC in urban environment, and up to 2.2 times higher than OC value in rural regions (Turpin and Lim, 2001). An increasing interest in emissions of BC or EC, and OC is raised not only by their negative effects on the human health, but also for their adverse impact on climate and potential to change energy balance of the Earth (Ramanathan and Carmichael, 2008). The decrease of BC emissions is therefore considered to be the possible powerful tool in the fighting against global warming (Chung et al., 2012). Black carbon and EC are dominant absorbers of the visible sun radiation in the atmosphere, and BC is therefore classed as the second largest contributor to global warming, immediately after CO_2 (Ramanathan and Carmichael, 2008).

The carbonaceous particles are formed not only at the high temperatures, but also at the low temperatures during combustion processes when the amount of the air is not sufficient. The high-temperature combustion processes produce particularly BC and EC that create the larger aggregates very fast after their origin, and represent an important absorber of the sun energy (Buseck et al., 2012). During low-temperature combustion, organic compounds of carbon are predominantly formed, and their typical effect is a dispersion of the sun radiation (Moosmüller et al., 2009).

The wide range of ratio values exists for OC and EC or BC and they can be utilized for identification of pollution sources. The value 1:1 for the average ratio OC/EC can be used for emissions sources from exhaust gases of diesel engines. The ratio OC/EC has approximate value 4:1 for combustion of biofuels, 7:1 for thermal power stations, 2:1 for industrial sources, 4:1 for domestic local combustion. Combustion of biomass has generally very high values of the OC/EC ratio in dependence on the biomass type (U.S. EPA, 2012).

The aim of this article is the determination of potential pollution sources at selected localities in the Moravian-Silesian Region utilizing information on occurrence of EC and OC in PM_{10} particles from emissions and atmospheric aerosols.

Material and methods

Concentrations of EC and OC were monitored during winter season (February) 2015 at the three selected localities of the Moravian-Silesian Region. The two localities (Ostrava-Radvanice and Trinec) are strongly influenced by industrial metallurgical activity and the third locality (Trinec-Oldrichovice) represents the area with high proportion of local heating. The concentration values of PM_{10} represent average of 24 h sampling realized by low-volume particle sampler using quartz-fibre filter (The Health Institute, Ostrava). The determination of OC and EC was performed using these filters by thermo-optical analysis at the OC/EC Analyser (Sunset Laboratory) in the laboratories of ENET Centre (Energy Units for Utilization of non Traditional Energy Sources), VSB — Technical University Ostrava. The concentrations of OC/EC were measured using the method of temperature programme EUSAAR 2 with modification of thermo-optical transmittance. In the first phase, OC is evaporated from the sample in 100% helium atmosphere up to the maximum temperature of 650 °C. In the second phase, temperature is moderately decreased to 500 °C and helium atmosphere is replaced by a mixture of 98% He and 2% O_2. The concentration of EC is then determined up to the maximum temperature of 850 °C (Sunset laboratory INC, 2005).

The sampling of particle PM_{10} from emissions sources was performed by gravimetric method according to ISO 9096/EPA/CSN EN 14385 by the company TESO Ostrava by means of isokinetic gravimetric system TESO GTE with control and evaluation system IZOMAT.

Results and discussion

Evaluation of emission sources of OC and EC was performed using material of PM obtained by sampling at ArcelorMittal Ostrava, the largest metallurgical company in the Czech Republic, producing and processing iron and steel. The concentration of EC was not determined because the filter material (glass) was not suitable for the high temperature in the second phase of thermo-optical analysis. The emissions balance of OC in PM_{10} is based on the three metallurgical processes in the ArcelorMittal enterprise: steel mill — pan furnace, blast furnaces and coke ovens. It was found that average contribution of OC in PM_{10} from these metallurgical processes is 19%. The average concentration of PM_{10} from these processes was 299.8 $\mu g/m^3$ and concentration of OC 62.7 $\mu g/m^3$. An evaluation of selected energy sources and heating plants in the Moravian-Silesian Region (including Power Plant ArcelorMittal, Power Plant Vitkovice, Heating Plant DALKIA CSA K2, K6, K12) provided the value of average OC percentage in PM_{10} 28% with range from 0.3% (Heating Plant CSA, K2) to 64.2% (Heating Plant CSA, K6) with average concentration of PM_{10} 399.2 $\mu g/m^3$ and average value of OC 29.7 $\mu g/m^3$.

During measurement of concentrations in atmosphere, the highest concentrations of PM_{10} were found at the locality Ostrava-Radvanice (63.7 $\mu g/m^3$). The concentrations of PM_{10} at Trinec (31.4 $\mu g/m^3$) and at Trinec-Oldrichovice (34.5 $\mu g/m^3$) were almost identical and they reached approximately half of value at Ostrava-Radvanice (Table 1). It is apparent from this table that concentrations of OC (20.5 $\mu g/m^3$) or EC (3.4 $\mu g/m^3$) were the highest at the mentioned locality Ostrava-Radvanice. The lowest concentrations of OC were measured at the locality Trinec-Oldrichovice (7.5 $\mu g/m^3$) and EC at Trinec (1.1 $\mu g/m^3$). From the point of view of percentage, OC dominated at the locality Trinec (35.7%) and EC at the locality Ostrava-Radvanice (4.9%).

For conversion of OC to OM, the resulting concentration of OC was multiplied by the factor 1.4 that is most often