Impact of Mining Activities on the Air Quality in The Village Nearby a Coal Strip Mine

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Abstract. The objective of the presented study was to estimate a share of atmospheric aerosol emitted by coal strip mine on PM10 or PM1-10, mass concentration of aerosol particles < 10 µm or 1–10 µm in aerodynamic diameter respectively, in the village situated in proximity to the mine. Parallel measurements were conducted in the mine and village situated in the northern part of the Czech Republic from the 15th to 27th November 2012. Three size fractions, consisting PM10, were sampled by a Davis rotating-drum impactor and analysed for 27 elements by Synchrotron-XRF with time resolution 1 hour. Appropriate hourly PM10 were measured by a Beta attenuation monitor in the village and calculated from 5 minute values by a nephelometer in the mine. Also, 24 hour aerosol samples for five size fractions were sampled by a personal cascade impactor sampler and viewed by scanning electron microscopy – SEM. Meteorological parameters were also recorded. Average contribution of coarse aerosol, PM1-10, to PM10 was 70% (119 ± 59 µgm-3) in the mine and 20% (12 ± 10 µgm-3) in the village. The SEM revealed solely soil particles in the mine samples but bioaerosol, ash and aggregates of ultrafine particles in the village samples. Databases of hourly elemental and mass concentrations from the two localities were analysed by EPA PMF 5.0. There were revealed following sources/average contribution to local PM10: wood burning/34%, resuspended dust/30%, coal combustion/22%, industry/11% and gypsum/3% in the village while resuspended dust/43%, coal combustion/37%, gypsum/16% and mining technologies/4% in the mine. Based on factor chemical profiles, the mine was found to contribute to PM1-10 and PM10 in the village by 6% and 20%, respectively.

1. Introduction
Atmospheric aerosol residence time differs from seconds to weeks depending on the particle aerodynamic diameter. The residence time of coarse aerosol, particles with aerodynamic diameter > 1 µm, ranges from hours to a few days and is given by equilibrium between sedimentation and turbulent mixing in the planetary boundary layer [1]. Thus, coarse particle sources significantly influence local air quality [2, 3, 4]. Recent air quality studies are needed to accurately identify and quantify the predominant anthropogenic emission sources. Such apportionments can serve as the basis to design effective strategies for reducing particulate matter (PM) concentrations. To improve the accuracy of aerosol source apportionment, size segregated aerosol measurements with high time resolution is valuable [5, 6]. There are several receptor model approaches of which factor analysis...
(FA) is the most frequently used to estimate the number and chemical profiles of the sources and their contributions to the receptor concentrations, [7, 8, 9]. Recent air quality studies use an advanced variant of the FA Positive Matrix Factorization (PMF) [10] bilinear model, where input data set are generally two dimensional of temporal variability of aerosol chemical composition and mass. PMF is powerful tool for solving receptor models with aerosol composition data highly time resolved and has been used successfully in identifying the sources of airborne particles in several recent studies (e.g. [11, 12]). The objective of the presented study was to estimate share of atmospheric aerosol emitted by mining activities on PM$_{10}$ in the village situated in proximity to a coal strip mine.

2. Material and methods

2.1. PM sampling and analysis
Measurements were conducted from the 15$^{th}$ to 27$^{th}$ November 2012 on the bottom of coal strip mine Vršany (50.48N 13.55E) and in the nearby village Čepirohy (15.48N 13.62E). The village is situated at a distance 4.8 km, SE of the mine. At both sites, three aerosol particle size fractions 1.15 – 10 μm, 0.34 – 1.15 μm and 0.15 – 0.34 μm of aerodynamic diameter were sampled by a Davis Rotating-drum Uniform-size-cut Monitor (3 DRUM, UC-Davis, USA) and analysed for 27 elements by Synchrotron – XRF with 1-hour time resolution (ALS, Lawrence Berkeley National Lab.). Also 24-hour aerosol samples for five size ranges < 0.25, 0.25 – 0.5, 0.5 – 1.0, 1.0 – 2.5, and 2.5 – 10 μm of aerodynamic diameter were sampled by a personal cascade impactor sampler – PCIS (SKC Inc., PA, USA) and analysed by scanning electron microscopy – SEM (TESCAN -Vega). Concurrently, hourly PM$_{10}$ were measured by a Beta attenuation monitor (FH 62 I-R, Thermo ESM Andersen) in the village, and 5 minute PM$_{10}$, determined by a DustTrak (DRX 8533, TSI) in the mine. Additionally, wind speed – WS and direction – WD was recorded at the mine rim in the distance of 2 km to the NW from the village site.

2.2. Data analysis

The US Environmental Protection Agency version of Positive Matrix Factorization - PMF v 5.0, was applied to these data to obtain source profiles and their contributions. The below detection limit - BDL values were replaced with the value DL/2 and (5/6)*DL was used as corresponding uncertainty values [13]. The matrix of uncertainties corresponding to each species concentration in the measurement matrix was calculated according to the recommendations of Polissar et al. [13]. The data matrix was composed of the 60 minute PM$_{10}$ determined by a Beta attenuation monitor/DustTrak DRX and corresponding elemental composition for 28 elements. The final matrices had 275 rows (samples) and columns 28 (species/elements). The data matrices were analysed separately for both sites then the summed matrix analysis was conducted and results compared.

3. Results and discussions

The coarse aerosol fraction PM$_{1-10}$ formed in average 70% (119 ± 59 μgm$^{-3}$) and 20% (12 ± 10 μgm$^{-3}$) of PM$_{10}$ in the mine and in the village, respectively. At both sites the size fraction 2.5 – 10 μm dominated in the coarse fraction (54% in the mine and in the village 13%). PM$_{10}$/PM$_{1-10}$ ratio is in an agreement with the study by Pokorná et al. [14], conducted at five sampling sites situated near the large coal strip mine (45 km$^2$) situated in northern Bohemia. The SEM analysis of the PCIS stages from mine revealed soil and coal particles only with sharp edges and plate for size ranges 2.5 – 10 μm and 1 – 2.5 μm respectively.
Structure Figure 1a) and c). In the village, bioaerosol, ash and aggregates of fine particles were found along with the soil particles Figure 1b) and d). These findings are in agreement with particles observed in samples formed during the human activity in the mining region [15, 16, 17].

To estimate the PMF optimal number of sources, 2 – 5 factors were tested. The Q values, the resulting source profiles, and the scaled residuals were studied. The optimum number of factors was chosen based on the most physically reasonable result and adequate fit of the model to original data as shown by the scaled residuals. The optimal factor number was 5 for the village dataset and 4 for the mine dataset (4 factors for the combined dataset). The FPEAK parameter was used to refine the source profiles. The optimum solution was chosen to be that with FPEAK = -0.1. In the village the five resolved factor profiles were assigned as wood burning, resuspended dust, coal combustion, industry and gypsum. Combustion sources dominated during the campaign and contributed on average by 56% to PM10. Second most important source was dust resuspension with average contribution of 30% to PM10. In the mine four resolved factor profiles were assigned as resuspended dust, coal combustion, gypsum and mining technologies (abrasions and lubricants) with average contribution of 43%, 37%, 16% and 4%, respectively to PM10. The modelling results of the combined datasets agreed with the factor profiles for the mine. The difference in the results were due to the model constrains. The common factor of coarse aerosol ascribed to the mining activities was resuspended dust Figure 2, factor associated with soil components [18]. Few studies have developed a complete air quality modelling in open pit mining region [19-22]. However, the computation utilizes the emission factor to quantify the emission sources of particulate matter in open pit mining areas and do not take in the
consideration additional emission sources contributing to the air quality in the communities. Hence the receptor modelling approach could be suitable source apportionment approach.

Figure 2. Chemical profile of the resuspended dust factor resolved by the PMF

4. Conclusions
Receptor model EPA PMF v 5.0, applied to hourly resolved mass and elemental composition of PM$_{10}$, identified a common source of coarse aerosol for coal strip mine and the village nearby. The source contributed to the PM$_{10}$ concentration in the village by about 30%. Nevertheless, this factor also includes resuspended aerosol with similar chemical fingerprint as the one produced by the mining activities. Based on different time course of the factor contribution and WS and WD the contribution of mining activities in the village to PM$_{1-10}$ and PM$_{10}$ concentration is estimated to be 6% and 20%, respectively. The modelling results were supported with SEM analysis of size segregated samples. The results showed surprisingly low contribution of coal mining to PM$_{10}$ in the village but revealed significant contribution from local combustion sources.

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