Environmental Impact Assessment of the Coal Yard and Ambient Pollution

M. Kucbel[1], H. Raclavská[1], J. Růžičková[1], M. Šafář[1], B. Švédová[1], D. Juchelková[2], K. Slamová[1]

[1] Centre ENET, VŠB – Technical University of Ostrava, Moravian-Silesian Region, 708 00, Czechia
[2] Department of Electronics, VŠB – Technical University of Ostrava, Moravian-Silesian Region, 708 00, Czechia
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Presenting author email: marek.kucbel@vsb.cz

Introduction

The changes in the concentrations of particulate matter PM_{10} and black carbon (BC) or coal particles with a height in several profiles (ground measurements = 1 m, 30 m, and 60 m from the ground surface) were observed above the coal storage site itself and in the surrounding area of about 6.5 km^2. For the identification of coal particles, a relationship was used between geochemical markers that characterise the presence of coal and the concentrations of black carbon (BC) measured in situ by the MicroAeth device located on the UAV (Unmanned Air Vehicle).

The storage of coal in the open-air area leads to the spread of coal dust particles over a wide area during dry periods of the year, especially at higher wind speeds (Cheng et al., 2021). The main sources of air pollution during coal storage operations generally include the loading and unloading of coal, wind erosion from coal deposits, and coal particle resuspension (Rojano et al., 2016). Particle distribution is influenced by the height of the coal deposit, particle size and the petrographic type of coal (Kurniawan et al., 2021), moisture in the surface layer of the deposit (Techarat and Tontiwachwuthikul, 2019) as well as the operation on unpaved surfaces and the maintenance of local roads (Rojano et al., 2016). Approximately 30% of coal particle emissions from wind erosion come from wind movement around the coal yard, 40% from the operation itself at the landfill (loading and unloading coal), and 30% from the operation of trucks in the area of the coal yard (Kurniawan et al., 2021).

Atmospheric dust particles (PM) can be characterised as a diverse mixture of elemental carbon (EC) or black carbon (BC), organic carbon (OC), and inorganic particles: sulphates (SO_4^{2-}), nitrates (NO^{3-}), ammonium ions (NH_4^+), mineral dust, heavy metals, and other trace elements (Zhang et al., 2020). Black carbon particles (BC) are a significant part of carbon aerosols, which are the product of the imperfect combustion of fossil fuels and biomass from local heating, transport, industrial sources, power plants, etc. (Wyche et al., 2020). In urban European air, BC contributes to 5-15% of PM mass concentrations (Cavalli et al., 2016).

When monitoring air pollution, UAVs (Unmanned Air Vehicles) provide immediate results. It is a relatively non-demanding, cheap, and very effective method compared to conventional, very expensive air pollution monitoring. This method also allows sampling in both horizontal and vertical directions (Bieber et al., 2020). On the other hand, the disadvantage of these systems is limited flight time due to battery capacity, legislative restrictions on flying in certain areas, the influence of turbulent swirls, and the concentration range of individual sensors for detecting air pollutants (Cárdenas et al., 2018).

Material and methods

A UAV was used to monitor the vertical distribution of dust particles and coal particles: A DJI Matrix 600 Pro hexacopter (DJI, Shenzhen, China) with dimensions of 1,668 mm (rotor diameter) × 727 mm (height).

The elevation profile was obtained by measuring PM_{10} dust particles with Fidas Frog (Palas, Germany) and BC Aethalometer MicroAeth/MA2000 (Aethlab, USA) at the height of 1 m (ground measurement), 30 m and 60 m above the surface. In order to minimise the effect of air turbulence caused by rotor activity, a Tygon® Teflon sampling hose with a length of 1,500 mm is used for measurements on both instruments. Meteorological parameters were measured with the EFWS 2900 digital weather station (Eurochron). Identification of coal particles is based on BC particle concentration results, which have been recalculated using a factor determined from coal particle analysis using the Thermal Desorption Method with Gas Chromatography and Mass Spectrometry (TD-GC/MS).

Figure 1. The location of measurement sites in the topographical map.

The measurements were carried out at eight locations (Table 1) during the period from May to October 2022. Overall, 13 measurements were carried out in similar meteorological conditions (temperature, relative air humidity, pressure, and wind speed). Individual measurements did not show a clear trend. The analysis at one height took three minutes (12 data/min).

The sampled area of the PKP Cargo Karviná Barbora coal depot is located in the area of the Barbora logistics and distribution centre, Karviná–Doly cadastral area, Moravian-Silesian Region, Czech Republic. The area is situated in a locality strongly affected by mining activities between Karviná and Havířov in the Ostrava-Karviná coal basin (Figure 1). In the immediate vicinity of this locality, a heating plant, administrative buildings, small production facilities, and sale of aggregates are located. The nearest residential built-up area is located about 600 m from the coal depot. The emission situation of the locality is influenced by significant sources of pollution in the agglomeration in the winter period by the long-distance transmission of emissions from Poland, locally by small sources (home heating in the winter period).

Results and discussion

At the PKP Cargo site, Karviná Barbora, conditions of very mild currents prevail with wind speeds of 0-5 m/s. The annual average wind rose for the Barbora coal yard showed that the southwest, southeast, and east wind directions dominated. The average air temperature, regardless of the elevation at which the measurements were made, was 23.7 ± 3.0 °C; the wind speed was 0.59 ± 0.41 m/s, and the relative air humidity was 41.45 ± 9.56 %.

It was found that at the height of 1 m and 30 m, coal particles cannot be considered relevant for the connection to the coal depot but are also affected by the activity of the surrounding sources. Only at the height of 60 m the origin of coal particles can be clearly associated with the coal depot and are thus distinguishable from other pollutants. The average concentration of PM_{10} at the height of 1 m above the ground reached 28.16 ± 17.59 μg/m^3. At the height of 30 m, 29.49 ± 18.27 μg/m^3 was measured, and at 60 m, 28.14 ± 17.79 μg/m^3. The average amount of coal particles at the height of 60 m was 220.56 ± 15.35 ng/m^3 with a range of values from 189.58 to 240.67 ng/m^3. At the height of 30 m, the concentrations of coal particles ranged from 217.04 to 249.61 ng/m^3 with an average value of 231.23 ± 10.52 ng/m^3. The highest amounts of coal particles were found at the height of 1 m, between 202.00 and 257.37 ng/m^3, with an average value of 233.73 ± 16.49 ng/m^3. Correlation analysis showed that only at the height of 60 m above the ground, the concentrations of dust particles show a significant inverse proportion with the concentrations of coal particles (r = -0.78). It can, therefore, be concluded that dust particles and coal particles come from different sources.

Table 1. GPS coordinates of individual locations and average concentrations of PM_{10} and coal particles at different elevations above the terrain surface.

	GPS_Lat	GPS_Lon	PM_{10} (μg/m^3)			Coal particles (ng/m^3)		
			1 m	30 m	60 m	1 m	30 m	60 m
1	49.824085	18.483913	31.48±16.91	25.91±9.96	23.88±9.73	236.52±86.83	217.04±66.04	240.67±66.30
2	49.832466	18.491069	24.93±14.56	25.56±14.47	22.97±9.81	239.26±87.68	222.99±81.53	224.18±73.88
3	49.830391	18.478053	32.76±23.78	29.42±21.73	26.40±18.06	234.95±78.79	238.59±80.10	224.00±71.64
4	49.829307	18.470752	25.51±16.44	28.05±17.34	26.68±17.73	246.79±99.47	237.21±75.61	228.37±84.23
5	49.824724	18.472962	32.68±20.99	34.33±22.21	29.99±20.12	257.37±122.12	249.61±118.04	230.56±118.94
6	49.813482	18.468511	30.70±18.43	39.87±26.35	42.27±33.23	202.00±42.62	222.47±49.83	189.58±43.65
7	49.820870	18.494456	29.90±17.42	30.68±20.98	30.62±19.20	229.71±84.80	230.74±66.57	213.85±72.75
8	49.835078	18.501574	21.42±12.22	22.05±13.14	22.32±14.48	223.25±101.71	231.18±98.71	213.23±106.05

Conclusions

The average percentage of coal particles in PM_{10} at 60 m above the ground level is 0.80 ± 0.18 %. The highest average concentration of coal particles at 60 m is 240.67 ng/m^3, which is higher than the background value by approximately 9%. The storage of coal in the open air does not contribute to the aggravation of the pollutant load in the vicinity of the coal yard. The maximum coal particle pollution from the coal depot ranges from 500 to 1000 m. Information on the area and spatial distribution of coal particles in PM_{10} can be used to set concentration limits that will be safe in terms of the maximum environmental load range.

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