Analysis of PM_{10} from the air quality monitoring using INAA

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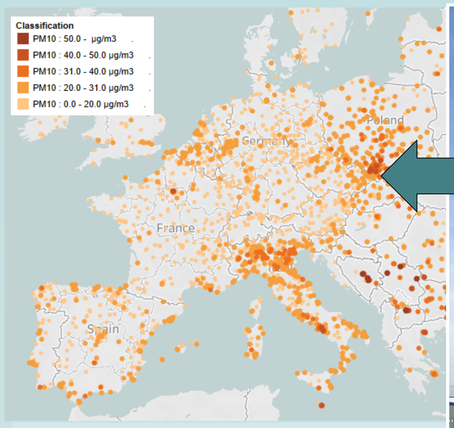
Introduction

One of the most polluted areas in Europe is the region located in the northeast part of the Czech Republic. This region is a part of the Upper Silesian Basin - a black coal basin. Suspended particles are considered to be a major air pollution problem there.[1]



The annual mean concentrations of PM_{10} in Europe, 2019[2].

The sampling was performed at the industrial area of the village Horní Suchá, at the top of an inactive mining tower (cca 86 m AGL) located in the transboundary area between the Czech and Polish Republic.

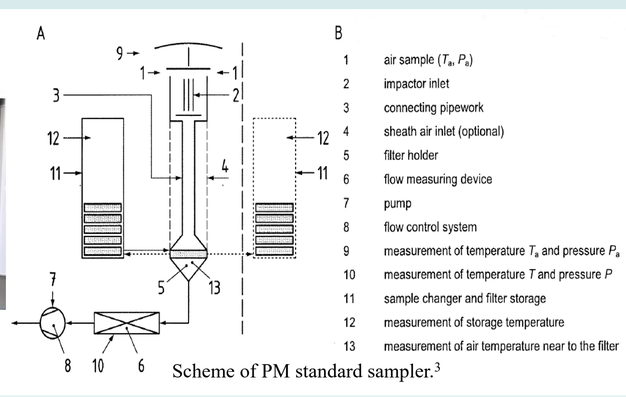
For this study samples from September (11 filters) and December (11 filters) 2019 were used.

Methodology

The sampling device, the high-volume sampler SAM Hi 30 AUTO WIND, is located at the top of the inactive mining tower, about 86 m above the ground level. The device uses a DIGITEL DPM10/30/00 PM_{10} pre-separator for airflow of 30 m^3/h. The device is equipped with a cassette where 15 glass microfibre filters (Whatman GF/A, Ø 150 mm) are stretched in filter holders.

It samples PM_{10} depending on wind conditions. Filter holders are automatically changed to the sampling position according to actually evaluated wind conditions:

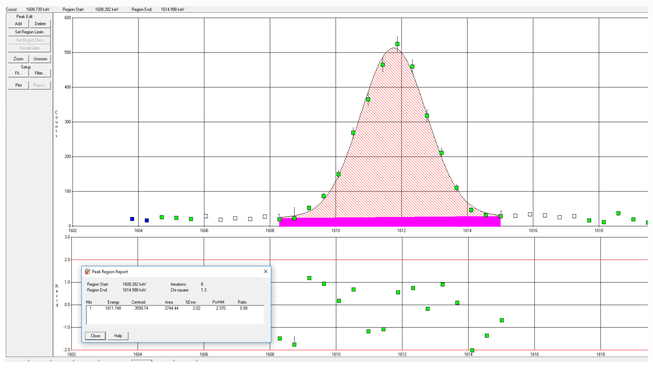
- eight basic wind directions - N, NE, E, SE, S, SW, W, NW;
- CALM - wind speed is lower than 0.2 m/s;
- INVERSION - three successive average hourly PM_{10} concentrations exceed 100 g/m^3, using 10 min data from continuous monitoring.



Scheme of PM standard sampler.[3]

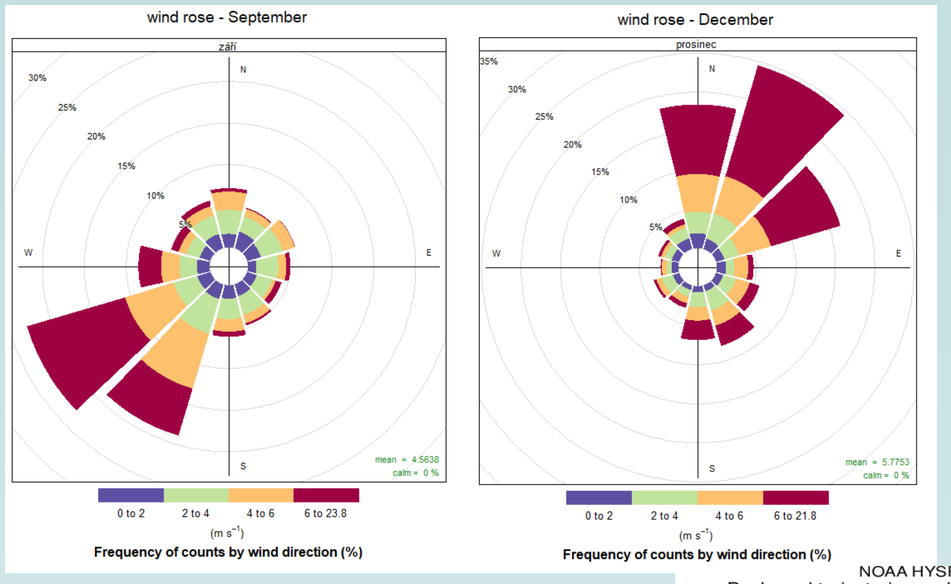
Filters were checked, stabilized (at 20°C ±1°C and 50 ±5% RH for more than 48 h) and weighed (Analytical balance Sartorius MC 210P) before use, in the weighing room of the Czech Hydrometeorological Institute. The mass of each filter was approximately 0,9 g. Filters were then loaded into filter holders and were inserted into the filter cassette in the sampler. Sampled filters were weighed, folded into halves and four circles from each were punched into 16 mm diameter (one sample consists of eight layers of the filter.) For cutting a special automatic punching head from stainless steel, Teflon, and synthetic rubber (finish surface) was used. Prepared samples and blanks were packed into a foil and sent to the Frank laboratory of neutron physics at JINR.

Mass of each unpacked sample (approximately 0.065 g) was recorded by Vibra AF 225DRCE. Samples and standards were packed into aluminium capsules for irradiation. Neutron activation analysis was used for the determination of collected elements. Irradiation was carried out on the channel nr. 3 installed at the IBR-2 pulsed nuclear reactor. Samples and standards were repacked into clean plastic containers 4-5 days after the end of the irradiation. Immediately after repacking, the first measurements of gamma-ray spectra by HPGe detector begun. The second gamma-ray spectrometry measurement was started 22 days after the end of the irradiation. For the measurement Canberra HPGe detector was used. Spectra were processed in Canberra Genie-2000 program and mass fractions were calculated by CalcCon program created at FLNP JINR.

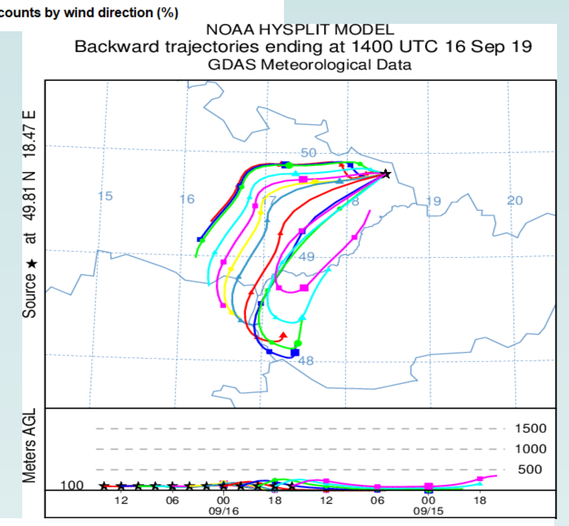


Outputs

The wind direction characteristic for the given area is demonstrated in wind roses below, this airflow is caused by the orographic influence of the Moravian Gate. From the southwest, the wind flows at high speed and is associated with cyclone type of weather. In contrast, the northeast wind is associated with an anticyclone situation and is often accompanied by worse dispersion conditions, especially during the cold period of the year.

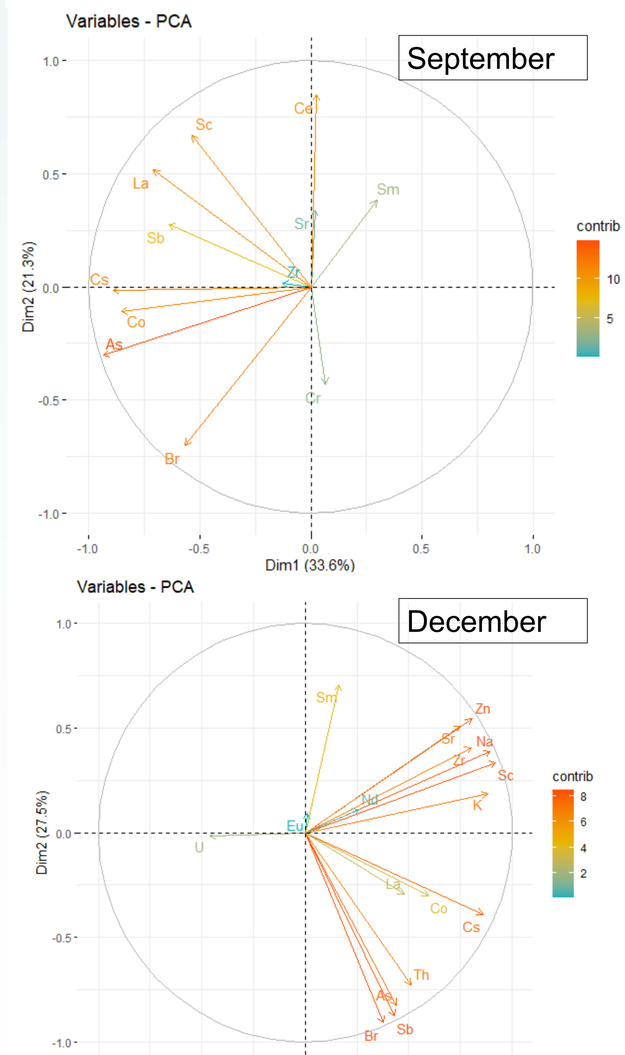


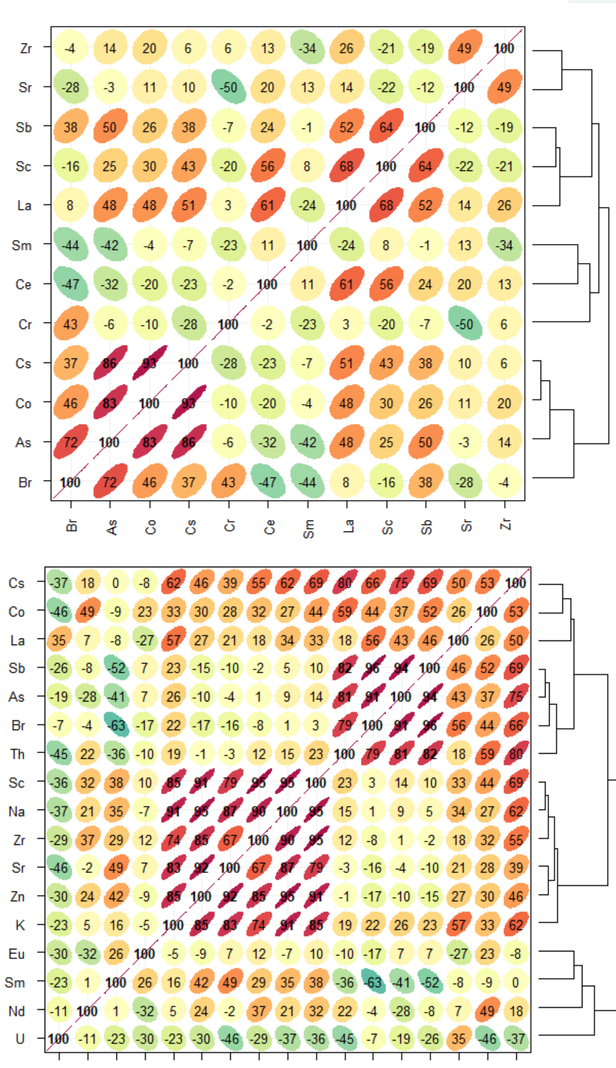
Back trajectories of air masses were performed, for period when contamination was collected on filter for inversion. In the southwestern direction from the place of monitoring a lot of industrial sources is located: steel processing (Liberty Ostrava), coking plants (OKK Koksovny), generation plants (Tameh, ČEZ Energetické služby), power station (Veolia Energie), foundry (Vítkovice slévárny) and others. Each of them produced more than 2 tones of PM_{10} in 2019.



For PCA and correlation analysis were used elements Sc, Cr, Co, As, Br, Sr, Zr, Sb, Cs, La, Ce, Sm, determined by NAA from September filters. 70,9% of the variation is explained by the first 3 principal components. The highest positive correlation is depicted between elements Br, As, Co, Cs and Sb, Sc, La, (Ce). These groups of elements are also positively correlated to each other. And all of the elements contribute to 1st or 2nd PC. To the 3rd PC contribute the most Zr and Sr. According to the wind rose the pollution originated most likely from the metallurgic complex (steel processing, coking plant, metal foundry, generation plant in the south-west direction).

For PCA and correlation analysis were used elements Na, K, Sc, Co, Zn, As, Br, Sr, Zr, Sb, Cs, La, Nd, Sm, Eu, Th, U, determined by NAA from December filters. Elements were according to the PCA divided into three main components which together retain 77,9% of the variation. A high positive correlation is depicted between the elements Sb, As, Br, Th (contribute to the 2nd PC) and Sc, Na, Zr, Sr, Zn, K (contribute to the 1st PC). A positive correlation is observed also for Cs, Co, La (contribute to the 3rd PC) According to the wind rose the pollution came from the north/north-east direction and originated most likely at coal industry, local heating (a large cluster of local heating plants in N). This pollution is connected to the transboundary transfer from the Poland.





References

1. Hůnová, I. (2020, February 20). Ambient Air Quality in the Czech Republic: Past and Present. Atmosphere, p. 2014.
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3. EN 12341. Ambient air - Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2,5}$ mass concentration of suspended particulate matter,2014.