Monitoring of PM_{10} air pollution in small settlements close to opencast mines in the North-Bohemian Brown Coal Basin

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Abstract

In the past, due to air pollution, the North-Bohemian Brown Coal Basin used to belong to the famous zone called the "Black Triangle" which also covered the lower parts of Silesia and Saxony. The air pollution was for the greatest part caused by large industrial sources where its impact on the forest ecosystems gained a cross-border character. At the beginning of 1990s, after reduction measures in industry and the implementation of stricter environmental laws, the air condition started to improve rapidly. Due to extensive opencast brown coal mining and the presence of large combustion resources the area is still classed as a region with a poor air quality mainly due to increased concentrations of dust particles. In recent years the increasing effect of local combustion sources on air pollution may be seen. Nevertheless the air pollution in small settlements has not been mapped sufficiently. The article is based on the data collected from mobile measurements of air purity executed within the remit of the subgroup "emissions-immissions" of the research project "Research of physical and chemical features affected by coal mining, its use and impact on environment in the North-Western Bohemia region". The measurement was performed in the selected communities close to the opencast mines in the period 2004–2007. The aim was to evaluate the immissions status in the small settlements selected from the North-Bohemian region, to appraise the predicative value of collected results and prepare a methodology concept of mobile measurements to describe the local immission situation. This article extends the information gained from mobile measurement and the data from the stationary measuring stations and also takes into account significant sources of pollution such as coal power plants in the North-Bohemian Brown Coal Basin. The results collected during the series of measurements in the course of heating and non-heating seasons are simultaneously compared with the data regarding the manner of heating and type of the fuel used for heating in the communities.

Keywords: air pollution, immissions, emissions, local combustion furnaces, air pollution monitoring, dust particles, PM_{10}, coal opencast mining, Black Triangle.

WIT Transactions on Ecology and the Environment, Vol 123, © 2009 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/AIR090351

1 Introduction

Continuous measurement of air pollution is generally focused on residential areas with high population density. Sufficient long-term data are available from stationary measuring stations from which we can determine the air quality, predict long-term development trends and consequently design the measures to improve the air pollution condition.

The air pollution condition of small communities up to 10 thousand inhabitants where almost 46,8% of the CR population lives [3], has not been mapped yet. The work of Kotlík *et al*. is the first attempt to map this condition in the Czech Republic [5]. This work confirmed the theory that the immission pollution in small settlements is, with regard to air pollution due to suspended particles, heavy metals and polyaromatic hydrocarbons, often comparable with the pollution in cities with much higher and continuous effect of emissions from transport. High levels of solid fuels (mainly brown coal) for heating in local combustion furnaces contribute to air pollution in small communities.

The aim of this work is to map the air pollution from PM_{10} suspended particles in small communities of the North-Bohemian Brown Coal Basin. The air quality in this region, which used to be a part of the so-called Black Triangle, is distinctively affected by the presence of large combustion facilities and opencast brown coal mines. Moreover the topographic conditions of the bottom of the Krušné Hory Mountains create conditions for more frequent occurrences of inversion weather with unfavourable conditions for the dispersion of pollutants.

2 Characteristics of the region

The so called Black Triangle, which at the end of the last century reached Northern Bohemia, lower part of Silesia and Saxony, gained its name due to the extreme air pollution which affected the condition of forests and also human health. Opencast mines of the North-Bohemian Brown Coal Basin ten years ago covered an area of almost 300 square kilometres. In the period from 1860 up to now 3.85 billion tonnes of brown coal have been excavated. Coal mining required the removal of 106 communities including the royal town of Most and the emigration of 90 thousand inhabitants [4].

At the beginning of 1990s the quality of the environment started to improve partially due to the decline of industrial production and the limitation on brown coal and bunker oil consumption in large sources of air pollution. That was thanks to the implementation of direct measures to decrease emissions and also end technologies.

In spite of these environmental measures the region of the North-Bohemian Brown Coal Basin still belongs to the areas with deteriorated air quality, mainly due to dust particles pollution. Mainly large energy sources, vast opencast brown-coal mines, refineries and petrochemical works affect the environment pollution. In fig. 1 apart from the measurement locations, which shall be discussed in the methodology chapter, there are large stationary sources

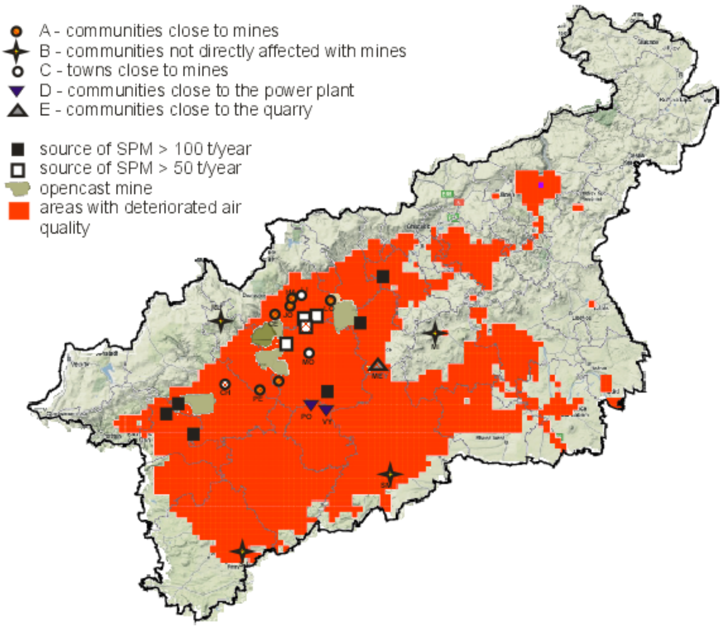

Figure 1: The area of interest with the denoted areas with deteriorated air quality, pollution sources and measurement locations.

contributing the most significantly to the emissions of suspended particulate matters denoted. We should not forget local sources such as individual heating and transport, of course. The latter sources, as opposed to the large and medium ones, show the growth of emissions due to motor transport but also insufficient legislation in the control and fines of the local combustion furnace operators.

3 Trend of PM_{10} air pollution in the North-Bohemian Brown Coal Basin

3.1 Progress of emissions from SPM and immissions of PM_{10}

In the North-Bohemian Brown Coal Basin (and also in other districts of the Czech Republic) the immission limit for the suspended particles PM_{10}, for which zero tolerance applies from 1.1.2005, has been exceeded. The level of air pollution with PM_{10} is illustrated in fig. 2. Since 2000 there has been stagnancy or even an increase in solid pollutant emissions in certain areas of the North-Bohemian Brown Coal Basin. The North-Bohemian Brown Coal Basin region is burdened with the specific emissions of solid pollutants three times more than the average in the Czech Republic.

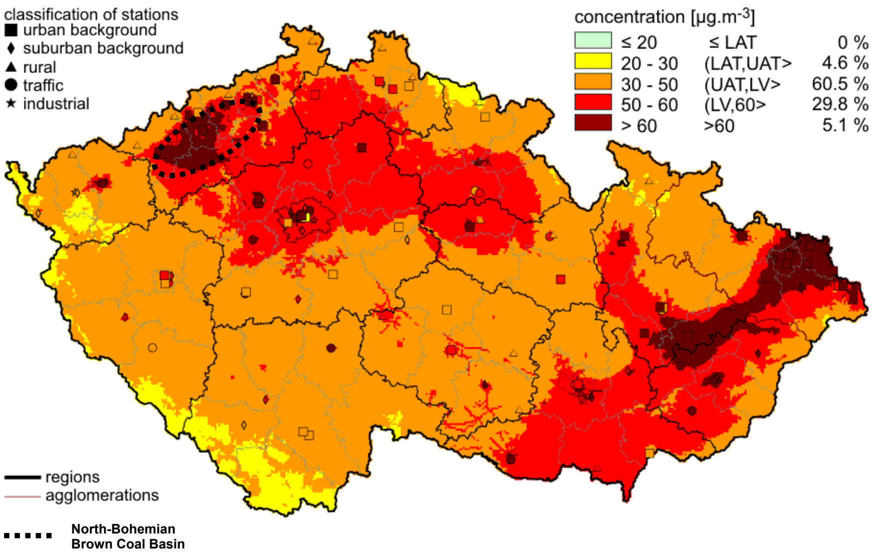

Figure 2: Field of the 36th highest 24-hour concentration of PM_{10} in the CR – year 2005. *Source: Czech Hydrometeorological Institute.*

3.2 Contribution of source groups on air pollution PM_{10}

Local combustion furnaces contribute to air pollution with the suspended particles PM_{10} in the Czech Republic for the most part (pursuant to the Czech legislation the sources which belong to the category of small sources of pollution denoted as REZZO 3). The contribution of these sources has been increasing since the 1990s. It is mainly caused by the inhabitants reverting to the cheaper type of heating with solid fuels mainly to brown coal. The conditions of combustion in local combustion furnaces do not enable them to achieve the efficient burning and cleaning of flue gases as in the industrial sources. Moreover there is often waste combustion. In the Czech Republic local combustion furnaces contribute to air pollution with suspended particles from 38%, to the pollution with polyaromatic hydrocarbons even from 66% [11]. The other new member states of EU show similar contribution while the contribution of the local combustion furnaces of the original member states is lower [1].

3.3 Progress of brown coal mining and overburden disposal

The presence of opencast mines has a negative impact on air pollution with dust particles in the North-Bohemian Brown Coal Basin. Dust nuisance is caused by lots of processes related to coal mining. The sources of dust nuisance in the opencast mines can be classified as passive (temporary coal disposal site, eroded slopes and dumps) and active sources of emissions (coal preparation plants, excavators, conveyor belts and other mining facilities) [6]. Most dust nuisance comes from the overburden disposal. That is because of the higher volume of overburden rock involved compared to coal mining but also different consistency of both materials. We should not forget the geological characteristics of overburden [7]. Coal and overburden mining progress in the North-Bohemian Brown Coal Basin is shown in fig. 3. In the monitored period 2004 – 2007 the annual coal and overburden exploitation was ca on the same level – 38 million tonnes of coal and 115 million m^3 of overburden.

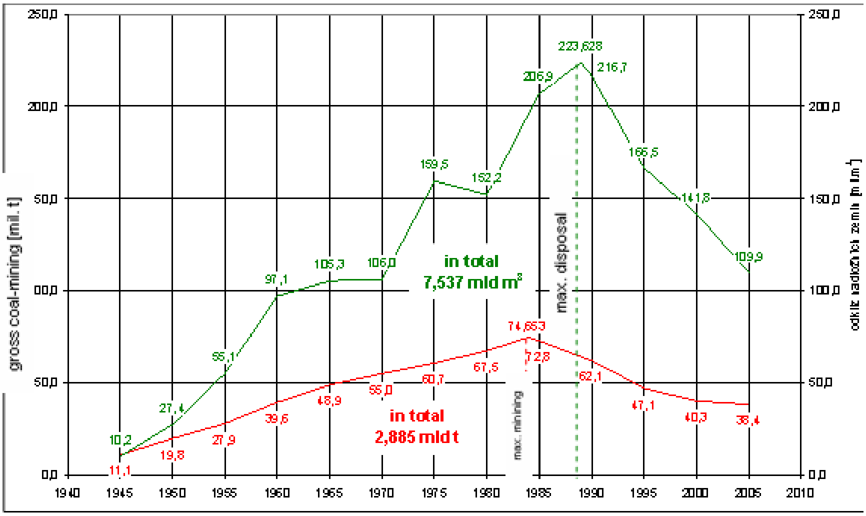

Figure 3: Progress of brown coal mining and overburden rocks disposal in the North-Bohemian Brown Coal Basin. *Source: Chytka, Valášek, 2009.*

4 Methodology

4.1 Groups qualification

Mobile measurement focused on the immission condition monitoring in the small settlements of the North-Bohemian Brown Coal Basin was performed in the series in the years 2004–2007 at 10 measuring locations. Data from 8 measuring locations were used for this work complemented with the data from the same number of measuring locations where continuous measurement within the network of automated immission monitoring of the Czech Hydrometeorological Institute is provided [10].

The locations were divided according to the distance from the opencast mine, the type of development and contribution of large combustion sources on pollution with PM_{10} [9] into five categories – see table 1. Then the contribution of solid fuels on heating in local combustion furnaces was found out at the communities [8]. It is a percentage of number of people using coal or wood for heating. The data do not relate to the total number of inhabitants but only that group of inhabitants which does not use central heating.

As the source operating conditions vary with the changing seasons of the year and also different climate and dispersal conditions, the results were classified not only from the total overview and the view of time trend development but also with respect to the seasons. The evaluation results were divided into three groups corresponding the following periods:

- *Heating period (ca from 15. 10. to 15. 3.)* – mainly with increased output of the all category sources operations from small sources (local combustion furnaces) to large sources (heating plants, power plants). Climate and dispersion conditions often burden the pollutants dispersion.
- *Non-heating period (ca from 15. 5. to 15. 9.)* – with prevailing low output of large and medium size sources and also small sources mainly local combustion furnaces. Climate and dispersion conditions, (qualified only to a certain limit), creation of poor dispersion conditions. Higher summer temperatures can contribute to the increase of dust nuisance from opencast mines, construction sites and increased secondary dust nuisance.
- *Transition period (ca from 15. 9. to 15. 10. and from 15. 3. to 15. 5.)* – with varying output of large and medium and also small sources. Climate and dispersion conditions causing frequent occurrence of temperature inversions and fog thereby worsening the conditions for pollutants dispersion.

4.2 Mobile measurement

The measurement of suspended particles was performed with a continuous β-dust-meter FH 62 I R with heated probes and pre-separator of particles bigger than 10 μm PM_{10} and ESM Eberline. The draw-offs of dust for indicative definition of metals in the air were executed (Ni, Be, Cd, As, Hg and Pb). Other basic pollutants were also monitored. This article is focused on the dust particles PM_{10} and selected heavy metals.

Meteorological unit THIES was used for measuring wind speed and direction, the temperature of air, relative air humidity and barometric pressure. The metering device was located in the measuring vehicle Mercedes 711D.

Table 1: Review of measuring locations.

Community	Estate character	Distance from M, D/ P * in km	No. of measurements 2004 - 2007	No. of people using solid fuels for heating	Contribution of power plants on PM_{10} immissions in % (average – 2004 – 2006)
A - Communities close to mines					
Ce	community	< 1/ > 5	105	274	9 - 17
St	community	< 1/ > 5	41	93	23 - 32
Pe	community	< 5/ < 10	37	8	23 – 32
Lo	community	< 2/ < 10	continuous	1081	8 - 15
Jo	estate housing	< 5/ > 5	20	N	9 - 17
Ha	estate housing	< 5/ <10	22	N	9 - 17
B - Communities non-affected directly with mines					
Mi	community	> 20/ > 10	34	283	20 -28
Ru	- **	> 5/ < 15	continuous	-	32 - 40
Sm	community	> 30/ >30	continuous	55	10 - 18
Sj	community	> 20/ < 25	continuous	0	10 - 18
C – Towns close to mines					
Mo	town	< 5/ < 5	35	290	13 - 27
Ch	town	< 5/ < 10	continuous	555	27 - 35
Li	town	< 5/ < 10	continuous	584	10 - 18
D – Communities close to power plants					
Bl	community	< 10/ < 5	continuous	23	30 - 38
Vy	community	> 10/ < 5	continuous	146	30 - 38
E – Community close to quarry					
Me	community	< 1***/ > 10	34	253	32 - 40

Legend: * M – opencast brown coal mine, D – mine dump, P – power plant; ** - measuring locations places in the mountains out of the urban area, *** - distance from the quarry, N - non-detected

4.3 Basic data files

Data files with short-term 3-minute values were collected from mobile measurements at the measuring locations. These short-term values were analysed for each measuring location and converted into the following output qualities:

- average concentrations from the single measurements
- average concentration from the whole block of measurements
- average concentration in the periods selected according to the operating regime of energy sources (heating, transition and non-heating periods)
- direction characteristics (concentration rosette) - average concentrations from the selected ranges of wind direction in the appraised period
- climate characteristics - average concentrations by the selected range of climate conditions in the appraisal period.

From the files of daily values for the classified periods an arithmetic mean, standard deviation and the number of values, median or geometric average, or quantile corresponding the allowed number of surplus a year according to the specification of the immission limit were calculated or analyzed.

The direction contributions were classified only from the files with 3-minute values where we can expect close dependency between the measured concentrations and wind direction.

5 Measurement results and their evaluation

The results of PM_{10} concentration measurements in the settlement groups monitored are illustrated in fig. 4. Based on these it is obvious that the highest concentrations are seen in the E group, the community closest to the quarry (< 1 km), where also the highest contribution of pollution from the power plants was found and also the highest contribution of solid fuels to the heating in local combustion furnaces (86%). The second highest PM_{10} concentration was found in group A – communities close to the opencast brown coal mines with the exception of non-heating period when higher concentration was found in group D – communities close to the power plant. The communities far from the mines displayed the lowest PM_{10} concentration in all the periods whereas the contribution of power plants on PM_{10} pollution was about the same for both the groups.

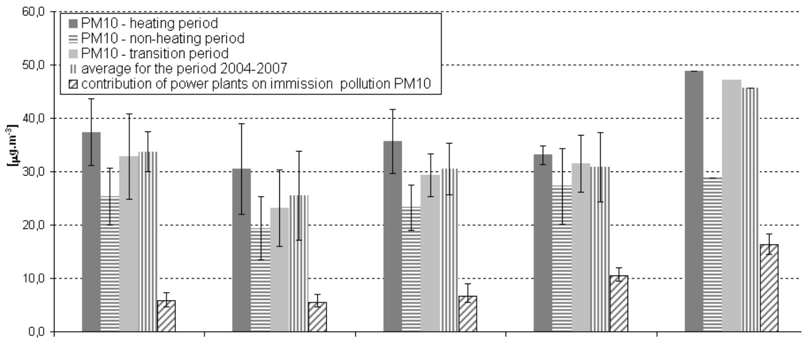

Figure 4: Average concentration of PM_{10} in the settlements monitored.

It is also obvious from the results that the values have a significantly seasonal character with the highest PM_{10} values in the heating period and increased values in the transition period. The ratio of PM_{10} values in the heating and non-heating periods was greatly different in some groups. The E group displayed the most distinctive difference where the values in the heating period reached 169% of values found in the non-heating period. Compared to the group D, only 121% growth of values was found in the heating period.

The results from the small settlements were compared where we managed to find out the details of the fuel types used for heating in local combustion furnaces. It is clear from fig. 5 that for the small settlements from groups B, D and E (communities unaffected directly by opencast mines, communities close to the power plants and quarry) we can state that heating using solid fuels impacts PM_{10} pollution in these communities during the heating and transition period which corresponds with the work of Kotlík *et al.* [5]. Solid fuel combustion in local combustion furnaces, of course, contributes to the pollution and in the communities close to the opencast mines, but in the monitored group the PM_{10} values did not reflect this relationship. The contribution of large stationary sources and opencast mines is significantly reflected and also variable characteristics of wind direction due to the topographic conditions at the bottom of the Krušné Hory mountains.

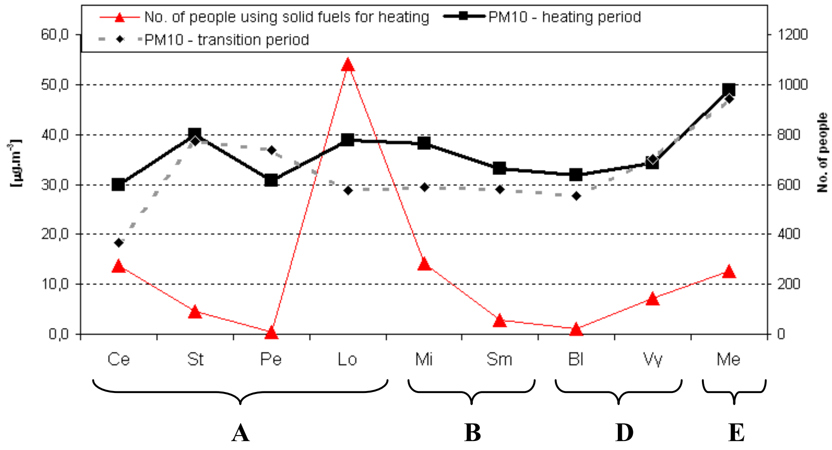

Figure 5: Comparison of PM_{10} concentrations in heating and transition periods related to solid fuel heating.

Fig. 6 compares the concentration rosettes of PM_{10} found at the selected stations during the heating, non-heating and transition periods. Also here a significant seasonality of the measured values is conspicuous not only with respect to different concentration levels but also in relation to various shape of rosette. It is obvious from the concentration rosettes that in summer and winter other sources dominate air pollution. This group is more apparent at the community from group B, so the community is here non-affected with the mine and the community from group E, close to a small quarry. Both these communities are also typical with a high number of people using solid fuels for heating.

Since 2000 the complaints from citizens about air pollution were also monitored. These were accepted through a free hot line of the Environmental Centre Most which has been working as an information centre about environment in the Euroregion Krušnohoří-Erzgebirge. Most of the complaints related to the increased emissions from local combustion furnaces mainly from small settlements. The callers often pointed out illegal waste combustion in the local combustion furnaces which has been, for the time being, very difficult to prosecute. Since 2000 ca. 8000 questions were asked of which ca 80% related to the air quality which proves that the citizens of the North-Bohemian Brown Coal Basin considered the problem of air pollution a priority.

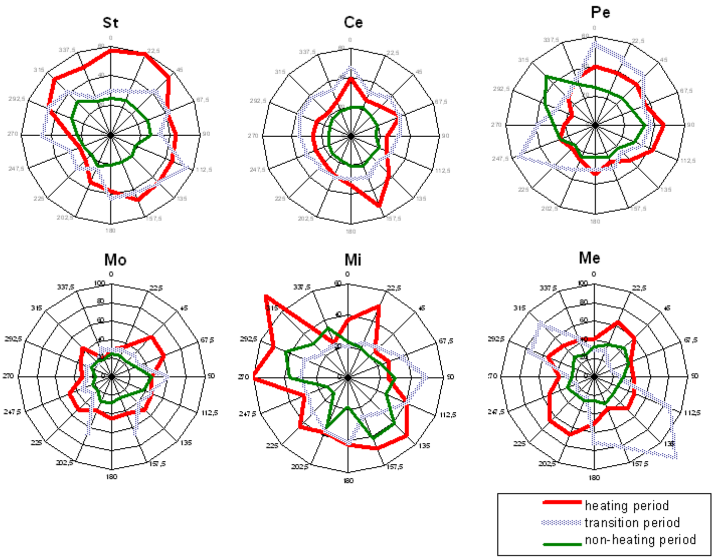

Figure 6: Comparison of directional characteristics PM_{10} in the periods.

6 Conclusion

Statistical analyses of PM_{10} concentrations in the North-Bohemian Brown Coal Basin gathered in the period 2004 – 2007 shows that in the winter (heating) period there is a significant increase in the concentration of substances generated or released in the combustion processes. It is a consequence of significantly more intense operation of energy sources and usually more frequent occurrences of poor dispersion conditions. Local combustion furnaces for solid fuels are proved markedly poor for small settlements on the local scale. In the case of villages situated close to opencast mines it is more problematic to define the exact contribution of the pollution sources. In the case of small settlements not exposed to the effect of opencast mines, significantly larger inter-season variations in PM_{10} values are noted. The results also warn of significant PM_{10} pollution in communities close to a smaller quarry.

The results of this work also led to the conclusion related to the methodology of stratified measurement. That cannot be, in the sense of standard procedure, generally used for all cases, defined mainly in such an exposed region as North-Western Bohemia. Therefore a stratified measurement methodology was proposed for an additional measurements of the results gained from the measurement networks of Brown Coal Research Institute situated at the edges of municipal development in the surroundings of opencast mines. The stratified measurement will be focused on the evaluation of immission situation from the perspective of suspended particles PM_{10} concentrations at the places located a maximum of ca 2 km from the stationary locations, i.e. in the area where continuously measured local meteorological data from the measurement network are valid.

Acknowledgements

This article was prepared within the works on the state task of the Ministry of Education, Youth and Physical Education of the Czech Republic “Research of physical and chemical features affected by coal mining, its use and impact on environment in the North-Western Bohemia region”.

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