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METALLURGICAL SOURCE-CONTRIBUTION ANALYSIS OF PM_{10} ANNUAL AVERAGE CONCENTRATION: A DISPERSION MODELING APPROACH IN MORAVIAN-SILESIAN REGION

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The goal of the article is to present analysis of metallurgical industry contribution to annual average PM_{10} concentrations in Moravian-Silesian based on means of the air pollution modelling in accord with the Czech reference methodology SYMOS´97.

Key words: air quality, modelling, metallurgy, impact, pollution source

INTRODUCTION

The particulate matter (PM_{10}) air pollution is in the Czech Republic a significant problem, mainly in the highly industrialized Moravian-Silesian Region and Ostrava city. According to the Statistical Environmental Yearbook of the Czech Republic 2011 the region recorded the highest values for pollution by the PM_{10} fraction.

The pollution situation in this region is complicated due to a long term tradition of heavy industry, dense population and geomorphological condition which correspond to particular meteorology.

Facilities of ArcelorMittal Ostrava (coke plant, blast furnaces, tandem furnaces, medium section rolling mill, heavy section rolling mill, wire-rod mill), OKK Koksovny (coke plant), Evraz Vítkovice Steel (steel plant, rolling mills), Třinecké železárny (coke plant, blast furnaces, steel plant), ŽDB Bohumín (foundry, wireworks) reside in the densely populated valley at the area of about 100 km^2.

Regional PM_{10} emission balance shows that industrial sources form an important part of the emission load [1], Figure 1.

Assessment of metallurgical emissions comprises the diversity of sources and so carries considerable inaccuracies. It is assumed that in addition to the inventory emissions there may also be some fugitive emissions from different technological systems. Regarding the morphological characteristics of PM_{10} emissions a large proportion of finer fractions (up to the nanoparticles) is assumed. Regarding the chemical characteristics a wide range of chemicals that can be dangerous to humans and ecosystems (heavy metals, PAHs, modified alkaline composites [2]) is assumed.

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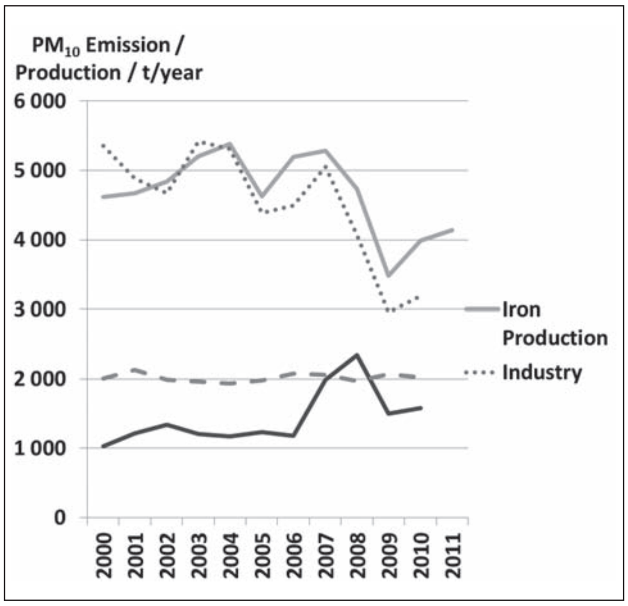

Figure 1 PM_{10} Emission and Iron Production in Moravian Sialesian Region [1]

METHODS

Origin of the pollution can be determined by different ways. The first of these is the measurement, when comparing the emission sources fingerprint (granulometry, morphology, chemical composition), with pollution monitoring values. In addition, the meteorological parameters (especially wind velocity and direction) are evaluated. A simpler method is a receptor modelling, which uses only the analysis of pollution monitoring close to sources. Evaluation can be done using applications of various models, including neural networks, which are otherwise used for process control [3].

Instruments are complex dynamic models that require high computing power and difficult to obtain data, such as the heat flux [4].

Another method is using the statistic modelling. To manage air quality in the region and apply effective remedies, a detail analysis of emission – pollution relation was made. The data for the first approximation were valuable year 2006, which was the year of the legislation change when generally remedies started then the impact of remedies which was made up to now and which are in progress was made. This analysis was based on air pollution dispersion modelling. The authors have developed their own modelling system ADMoSS to process detailed modelling in vast areas with a huge amount of sources which has been already used to work out many similar studies and analysis and serve to local governments as a decision support tool. This system was already used for the Ostrava city, the Opava city, the Plzeň city and many others. It is run for the Air Quality Management System in the Olomouc City, in the project Clean Air for the Moravian Gate, in the international project AIR SILESIA (CZ.3.22/1.2.00/00/09.01610).

To assess the emission – pollution dependence the ADMoSS system is used. The system utilizes GIS software to prepare all necessary input data for modelling, divide modelling task into a number of simpler ones, and run the modelling tasks on a parallel supercomputer cluster. It also manages calculations, does data management and result post processing. The final results are presented in a form of GIS created cartographic outputs.

This modelling was performed in accordance with the Czech reference methodology SYMOS'97 [5]. This methodology is based on the application of the statistical theory of turbulent diffusion formulated by Sutton. It is a Gaussian long-term model. Meteorological data enter the model after processing of real meteorological observations as a weather-type classification, which is determined by the range of wind speeds and the average vertical temperature gradient in the mixing layer. The annual average data on the sources and annual average meteorological data is used. The result is so the annual average concentration of pollutants.

Results of modelling are adjusted in accordance with the pollution monitoring data. The output of the system is a realistic characterization of the pollution distribution which allows analysis of influence of different pollution sources on the air quality.

Analysis comprises a number of basic steps. First of all there is the processing of input data, contenting the relevant data about air pollution sources then the modelling and analysis are run.

INPUT DATA PROCESSING

Industrial air pollution sources data are procured from the Register of Emissions and Air Pollution Sources (REAPS). This national database is kept systematically since 1980 and operated by the Czech Hydrometeorological Institute (CHMI).

From these databases are procured emission characteristic and technical parameters of stationary industrial sources. This data contains also technological description of sources.

Information about emission data sources from REAPS databases does not content the sufficient spatial specification. To run this system these sources are exactly localized and kept in form of point layer of ESRI shapefile. The shapefile contains emission characteristics and technical parameters of each source which are subsequently used as input modelling data.

Non-industrial air pollution sources can be divided to local heating systems and road traffic. Local heating system is an energetic source appointed for local heating of housing room (houses, apartments etc.). It is important emission source group because of its huge amount, localization in housing development, relatively low chimneys, heat outputs, fuel quality etc. Local heating system keepers have no incumbency to submit a sort and a consumption of fuels. Official data source about local heating systems is information from Population and Housing Census (PHC) of Czech statistical office (CZSO). The most up to date PHC is from 2001, so it is necessary to actualized them according to local questionnaires.

Because of the importance of local heating systems our institute has developed a special methodology to analyse their distribution in a development and to represent them by the network of planar sources. Local heating systems are for the modelling represented by the regular network of planar sources with 100 m cell size. Then emissions are allocated to such represented planar sources. Local heating systems emission calculation is processed in accordance with methodology of Czech Hydrometeorological Institute which is based on the heat inventory [6].

The road traffic is also one of the important sources. To specify emissions of this category of air pollution sources is difficult. It is based on traffic structure and frequency data assessment. The traffic structure and frequency data are procured from the Road Traffic Census which is operated by Road and Motorway Directorate of the Czech Republic. The road traffic is represented by network of linear sources which copy the road network. The parts of lines represent air pollution sources. The optimal length of parts was tested and was set up to 50 m.

Road traffic emissions depend on technical parameters of vehicle, on type of fuel, on type and state of road, on ride mode, on traffic frequency etc. Road traffic emissions are defined in according to emission factors. Emission factors values are procured from MEFA program, v. 06 (ATEM, DINPROJEKT, VSCHT Prague). This way calculated emissions are allocated to the linear sources network and are subsequently used as modelling input data.

MODELLING AND ANALYSIS

The next step after input data processing is detailed air pollution modelling. For detailed modelling apart from exactly localized air pollution sources data, the dense network of calculating points (receptors) is necessary.

For modelling the area of the Moravian Silesian region is divided by the graticule with 1 500 m cell size. For large air pollution sources which impact by their emission vast areas, the receptor graticule with 100 m cell size is used. For lower sources with closer impact (medium-sized sources, local heating systems and road traffic) the special compounded graticule is used. Such graticule consists of two parts. The first one is the 2 500 m buffer of medium-sized sources, respectively 1 500 m buffer of local heating system and road traffic. These buffers consist of the 100 m receptor graticules. The second one contains the rest of modelled area and consists of the 1 500 m receptor graticule. By this way it is possible to obtain detailed pollution data in areas where they sharply fluctuate and in the same time control the pollution in the whole area.

By means of GIS modelling task are divide into a number of simpler ones according to the described graticule and run at the parallel supercomputer cluster. Results are presented in the form of GIS created cartographic outputs.

Modelling is followed by the modelling results assessment and analysis. The participation of industrial sources, primary and secondary metallurgy is assessed. Then the preponderance of these groups of sources is analysed. Each analysis is run in GIS.

RESULTS

According to the modelling results the annual limit value for PM_{10} (40 μg·m^{-3}) was exceeded at the majority of populated areas of the region. For concentration distribution field see Figure 2.

The highest concentrations were achieved in areas of large settlements where effects of industry, high traffic and local heating are combined. It concerns the city of Ostrava, Opava, Bohumín, Karvina, Trinec, Frydek – Mistek, Studénka. Maximum value occurs in the city of Ostrava, Bohumín and Třinec where the concentration exceeds 60 μg.m^{-3} and also where the facilities of primary metallurgy (Ostrava and Třinec) and secondary metallurgy (Bohumín) are situated.

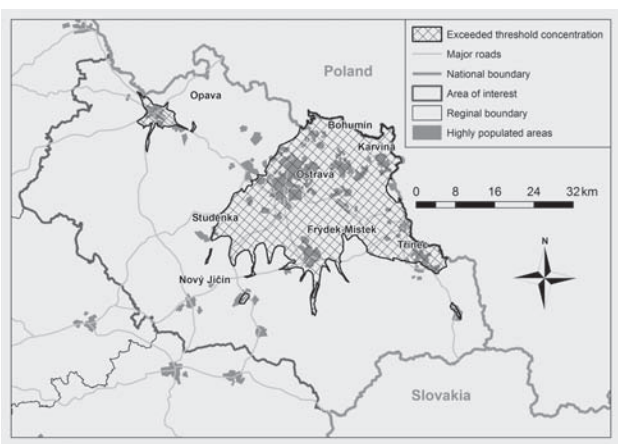

Figure 2 Map composition of annual average PM_{10} concentration (area with exceeded limit 40 μg·m^{-3})

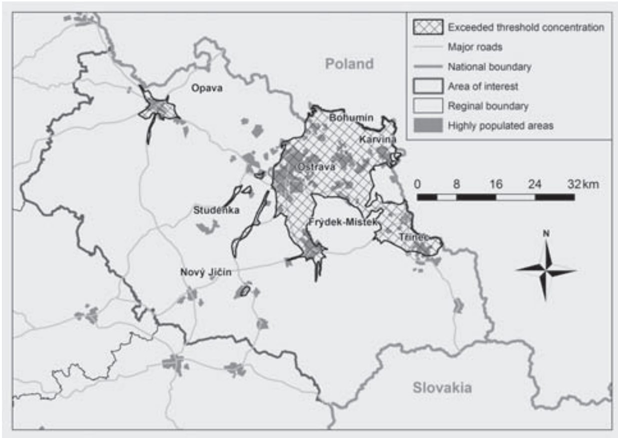

Figure 3 Map composition of annual average PM_{10} concentration (area with exceeded limit 40 μg.m^{-3}) including remedies

The modelling of contribution of metallurgy facilities to pollution situation shows that this group of sources by itself is able to cause excess of the annual PM_{10} limit value in areas close to ArcelorMittal Ostrava (coke plant, blast furnaces, tandem furnaces), OKK Koksovny (coke plants), EVRAZ VÍTKOVICE STEEL (steel plant, rolling mills), Třinecké železárny (coke plant, blast furnaces, steel plant). In accord with modelling result the contribution of metallurgy facilities to the pollution situation was locally quite important. This fact confirms the analysis of preponderance of this group of pollution sources which shows where metallurgy sources dominate the other groups of pollution sources (the rest of industry together with local heating systems and transport).

The application of the remedies at the metallurgical facilities up to now and projected to 2015 would change the situation but according to the model the annual average PM_{10} concentration would be still exceeded at some important part of populated areas of the region. For concentration distribution field see Figure 3.

CONCLUSION

The results of air quality analysis indicated that the industrial sources and especially metallurgical industry effected in 2006 the pollution situation in the important way. Together with adverse meteorological conditions it causes locally concentration levels exceeding limits and contributes to increment of particulate matter background in the major part of modelled area.

The analysis of the situation in 2006 indicates that the air quality improvement in the region to the level corresponding to the annual limit value is implicated also by further reduction of industrial sources emissions as was also concluded in other studies [7].

To improve the air quality in the region to the level corresponding to the annual limit value is necessary in accord with modelling to reduce industrial sources emissions. But also other remedies concerning the local heating systems and the transport are demanded.

Nowadays condition of the metallurgical facilities in the region has improved. A lot of them has been or will be modernize, substituted or arranged and has accepted more strict emission standards. But it does not concern all of them and it is necessary to continue this positive trend. The metallurgy has in the region a long term tradition and to have modern, top-of-the-range technologies in not only the question of environmental impact.

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Note: I. Pavlíková responsible for English translation, Ostrava, the Republic Czech