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GIS BASED URBAN SCALE AIR POLLUTION MODELING WITHIN A GERMAN-BULGARIAN TWINNING PROJECT

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INTRODUCTION

In the course of the enlargement of the European Union the accession countries must adapt the EU Directives. By the project “Support of Air Quality Management at Local Level (BG99EN02)” the EU supported under the management of the Bulgarian and German Ministries of Environment the analysis and the assessment of the air pollutant concentrations in Bulgaria. Aim of the project was to support the Bulgarian administrations in the implementation of the Ambient Air Quality Framework Directive and the corresponding 1st Daughter Directive. For the execution of that task, a model was needed to explain the present air pollution concentrations, to analyse the causes of these concentrations and to estimate the effects of emission reductions. It should be user friendly, being able to cope with the usual groups of air pollutant sources as streets, stacks, domestic heating etc., should be able to work on the basis of the available input data and additionally be usable to digitize and display the input and output data on the basis of maps. The German partner (Fed. Ministry of Environment) looked for such a model in Germany and finally decided to use the system SELMA^{GIS}, which was developed and is in daily operational use by Lohmeyer Consulting Engineers GmbH & Co. KG. The model was chosen also because of its special features for treatment of PM10 sources from vehicle traffic.

SOME CRITERIA FOR THE SELECTION OF THE MODEL

The selection of an operational flow and dispersion model depends on the conditions within the area under investigation, on the availability and the quality of the input data, on the experience of the user, the available financial resources and the purpose, the results are needed for.

For flow and dispersion modelling for example the following criteria have to be considered:

- What scale is considered? Is the concentration to be determined within single street canyons or is the aim to get more or less an overlook over the concentrations in a region, say in a 500m by 500m grid.
- Are there topographical features, modifying the atmospheric flow by obstacles like hills or by valley drainage flows and thus influencing the dispersion of the pollutants?
- What is the accuracy and the availability of the input data. In case there are only deficient and low quality input data, no sophisticated flow and dispersion model needs to be applied.
- What is the experience of the user? Sophisticated models are only good for experienced users.

And of course additional points have to be considered as: Is the handling of the system user friendly? Is it for example integrated into a GIS to allow easy handling and control of the input and of the results? Is it in operational use for some time and thus hopefully more or less debugged? Does it contain an acceptable handbook and is it supported by a professional hotline, not only covering the handling at the computer but also to discuss how to proceed with the task on the basis of the abilities of the model?

CONTENT OF THE MODELING SYSTEM SELMA^{GIS}

The chosen SELMA^{GIS} modelling system (System for Calculation and Representation of Air Pollutant Concentrations) is an air pollutant dispersion modeling and handling system. It is able to provide the concentrations and the statistical parameters, needed for example for the comparison to the limit values, set by Directive 1999/30/EG. For improved handling of the data SELMA^{GIS} contains digitizing and display modules, based on the Geographical Information System ArcView (V 3.2a). The system accesses under its surface the modules of the following models:

DIGIstreet, for digitalizing complex street networks incl. allocation of traffic parameters,

EMIstreet, for calculating the air pollutant emissions of these streets. It makes use of the exhaust pipe emission factors, determined for Bulgaria by RWTÜV Fahrzeug GmbH (2001). It additionally includes the PM10 emissions caused by dust re-suspension and abrasion of tires, vehicle components and the wear of the street surface as described by Düring et al. (2002),

DIGIpoint, for the creation of the receptor points,

PROKAS_V (Gaussian plume model) for the calculation of the additional street concentrations and PROKAS_B (MISKAM-based dispersion library) for calculating the additional street concentrations in built up streets,

TALBO (at that time the official German regulatory Gaussian plume model) incl. DIGItalbo, for digitalizing the parameters of point and area sources, as well as for calculation of the additional concentrations caused by emissions from these sources,

DIGIsum, for calculation of the total pollution on the basis of each individual calculated additional concentration and the background concentration. It also contains a NO/NO2 conversion module and modules to calculate the statistical parameters of the concentrations, needed for an assessment under the EU Air Quality Directives.

System requirements for SELMA^{GIS} are a Windows 98 or 2000. A Pentium III processor and a minimum of 128 RAM are recommended.

APPLICATION IN BULGARIA

a) General Information about the project

In a first step, the city of Pernik (ca. 30 km south-west of Sofia) was chosen for a pilot study. An air pollutant-monitoring program was executed for PM10, SO2, NO2 and lead. The locations were chosen to cover the influence of the major local sources from stack emissions to domestic heating and traffic as well as the local background concentration. The results led to the conclusion that the limit values for PM10 are significantly exceeded, whereas the limit values for SO2, NO2 and lead were kept in 2001. The annual mean concentrations found are higher than in Western Europe, but comparable to other hot spots in Bulgaria (e.g. Sofia) and other cities in Middle and Eastern Europe.

The analysis of the reasons of exceedance for PM10 based on the measurement data alone did not provide clear conclusions. But with the help of the dispersion modeling an estimation of the share of the different emission sources and the regional background concentration for the local ambient air quality situation was possible.

b) Some aspects of the calculations

The dispersion calculation was done including the emissions of traffic on the main roads, domestic heating, stack and fugitive emissions from industrial plants and dust emissions from local ash and waste deposits.

For use for the emission modeling, traffic counts were executed and for the dispersion calculation meteorological measurements were done. The domestic heating emission factors were derived from factors used in Germany and other countries (see Bibliography) and taking into account the special characteristics of the fuel used locally. The emission factors of the dust emissions from area sources like ash and waste deposits were derived from factors and formulas published by US-EPA (AP 42) and VDI guidelines 3790, 2&3.

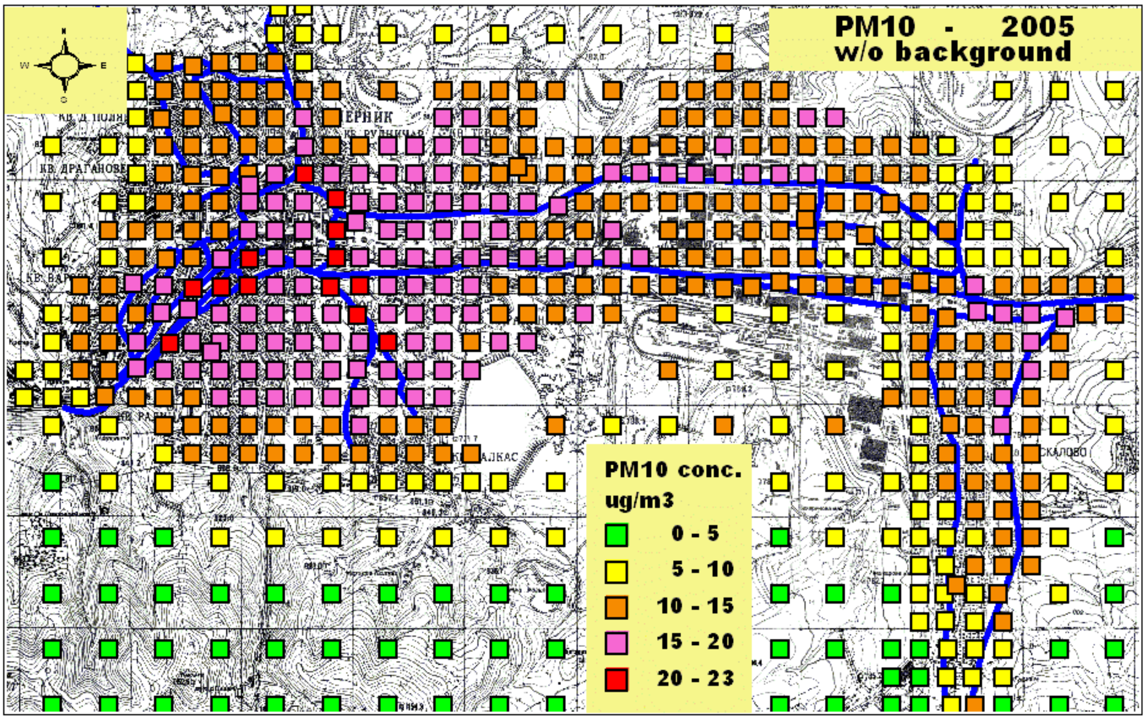
The calculations were done for a fixed 250 m x 250 m grid in the inhabited area of the city and increased to a 500 m x 500 m grid in the vicinity plus all locations of the field measurements. The calculation was done for the contributions of the different sources, additionally the total concentration as sum of these contributions plus the regional background concentration was determined. For comparison of the results of the modelling and the monitoring see Moldenhauer et al. (2002).

c) Example of the results

Fig. 1 displays the calculated annual mean concentrations of PM10, resulting from the Pernic local sources. They increase versus the centre of the city, several areas with concentrations larger 20 µg/m³ (red squares) are displayed. It can be seen, that in this case they are all close to the major roads.

Fig. 2 gives one of the results of the calculations, used for the systematic search for the origin of the concentrations. The share of the different source groups can be detected.

Fig. 1: PM10 in 2005. Annual mean concentrations resulting from local sources, i.e without regional background concentration.

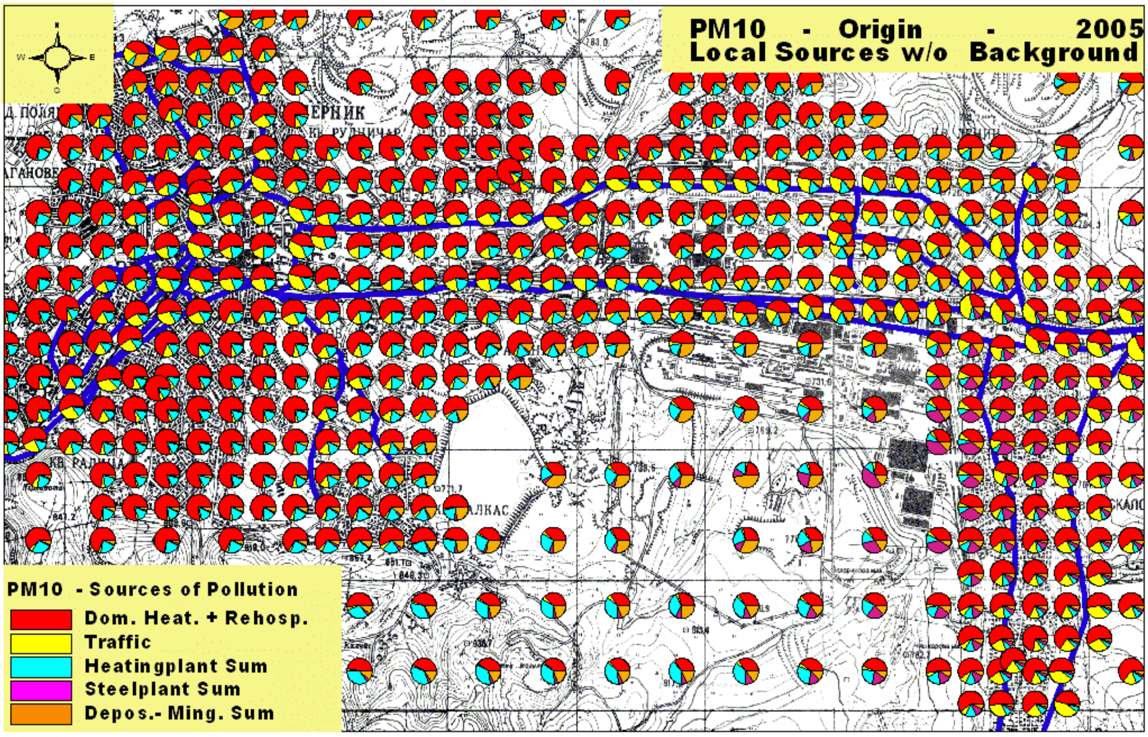


d) Conclusions for Pernik

With the help of the dispersion modeling a detailed analysis of the share of the different sources and the regional background concentration for the local ambient air quality was possible. Additionally the modeling showed that the concentrations of SO2 and NO2 are in a range where exceedances of the limit values cannot be excluded for sure. At the monitoring sites there were no exceedances, but as only one site covers the required measurement period of one year for these pollutants it can not be ruled out that this monitoring might not have taken place at the location where the highest concentrations occur.

The ambient air quality (AAQ) for NO2 is mostly influenced by the road emissions. The highest values were found near streets with high traffic volume and a high share of heavy-duty vehicles. The AAQ situation for SO2 is strongly influenced by domestic heating and by emissions of the local district heating plant (DHP). The concentrations for lead are dominated by traffic emissions (leaded fuel) and emissions of the local steel plant.

Fig. 2: PM10 in 2005. Origin of pollution from local sources. Annual mean. Without regional background concentration.



The AAQ situation for PM10 is most complex and determined by several sources in the city as well as by the regional background concentration. All these sources contribute to the exceedance of the limit values. The highest contribution for the locally caused PM10 concentrations seems to be due to domestic heating. The DHP, the steel work, the vehicle traffic and the erosion from dusty areas including ash deposits also contribute significantly to the PM10 concentration, but to a different degree in the different areas of the city.

Another main result of the modeling was the conclusion that a high regional background concentration of PM10 significantly contributes to the PM10 concentrations in Pernik. This regional background concentration is in the magnitude of 30 to 35 µg/m^3 (annual mean) thus already close to the limit value. Therefore, actions for reducing the local PM10 emissions are very important, but will probably not be sufficient to reach the limit values.

FUTURE PROSPECTS

The twinning project ended in September 2002. It helped to improve the knowledge about the levels of the air pollutant concentrations and their causes. The Bulgarian authorities plan to go on with the implementation of an air quality management system, aiming on the development of emission reduction strategies.

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