LONG TERM EFFECT OF AIR POLLUTION NEAR TRAFFIC JUNCTIONS

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INTRODUCTION

This article presents a project concept for the investigation of traffic junctions where the most intensive exposure of people to air pollution takes place. For several years in Poland an increase in traffic and air pollution has been observed especially within the cities. There were increased emissions of nitrogen oxides, carbon oxide, particulate matter and VOC's found in the vicinity of traffic junctions. It is mainly due to the 'stop and go' nature of the traffic flow. The combination with surrounding buildings can lead to the accumulation of pollutants and the development of 'hot-spots'. Identification of the location of these zones of high pollution has become increasingly important owing to the increasing recognition of these substances as harmful to human health.

There are many examples of research on the air pollution dispersion in the street canyons (i.e. *Assimakopoulos, V.D. et al*, 2003, *Tsai, M.Y. and K.S. Chen*, 2004, *Park, S.K et al*, 2004). In many projects e.g. DAPPLE (Dispersion of Air Pollutants and their Penetration into the Local Environment 2003-2004, London), BUBBLE (Basel Urban Boundary Layer Experiment 2001-2004), Stuttgart 21 or COST CITAIR - SCIENCE AND RESEARCH FOR BETTER AIR IN EUROPEAN CITIES, an intensive research on urban atmosphere has been done. These investigations are led at most using the microscale numerical models of the atmosphere and show some general rules which govern the pollutants dispersion in built up areas. Examples of air flow microscale models are: PHOENICS (*Spalding D.*, 1981), MISKAM (*Eichhorn, J.*, 1988), MUKLIMO (*Sievers, U. and W. Zdunkowski*, 1986) or MIMO (*Ehrhard, J. et al*, 2000). However, microscale modeling covers small areas (a few square kilometers) and the characteristic time scales of a few minutes and therefore – only very short term exposure to air pollution can be analyzed. The long term effects in microscale are omitted.

This project will supplement the results of existing scientific projects with data which records the long term influence of air pollution at the microscale. Complementary approaches of monitoring data and spatial data analysis using GIS as well as regression and numerical dispersion modeling at the microscale will be used to determine the most polluted zones, which arise and persist as a result of the complex building geometries at urban intersections.

METHODOLOGY AND MEASUREMENTS

The general scheme of the project is shown in figure 1. The project is planned for two years (up to November 2006) and divided into four measurement campaigns. Two of them have been already done and the results are shown in this article. Measurements are undertaken using passive samplers and take place in Wrocław (Poland) at pl. Legionów. This traffic junction is passed by more then 30,000 cars daily. The samplers are hung in the direct neighborhood of the main streets and the crossroad, and in the backyards of the buildings as well. The passive samplers are easy to operate, cheap, light, small and do not need electricity. These features enable many measurement points to be located with few restrictions. The pollutants studied in this project are NO_x, SO_2 and VOC (Benzene, Toluene, Xylene) which are emitted by fuel burning and have a negative influence on human health. Meteorological data are obtained from British Atmospheric Data Center and from several observation points in the city of Wroclaw.

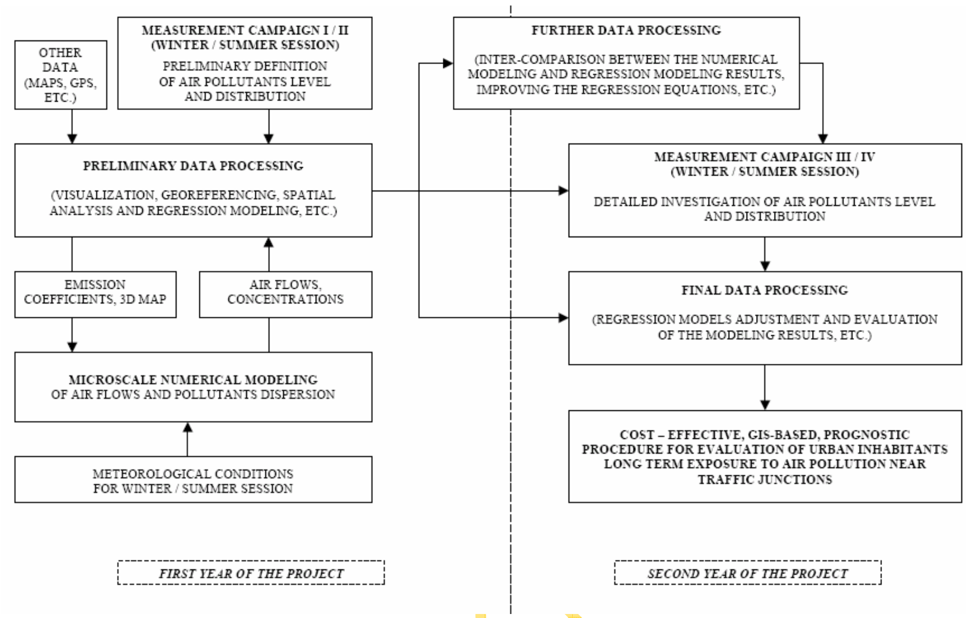

Fig. 1; The scheme of the project.

INITIALLY RESULTS AND DISCUSSION

The preliminary data processing containing buildings heights evaluation, vector and raster maps creation, sampling points location, georeferencing, 3D visualization and animation using prepared rasters and satellite data was undertaken using GIS software (TNTmips, Microimages, Inc.). Spatial data about the area and samplers locations were obtained from existing digital maps and verified using GPS measurements. The computational domain was constructed, keeping some distance away from the inlet and the lateral boundaries, to achieve a stable internal boundary-layer (required for numerical modeling). The model area extends 600 m in the N-S (y-axis) and 740 m in the W-E (x-axis). The planned grid cells are a mesh width of 5 x 5 meters although for other purposes (like i.e. regression modeling or interpolation) a smaller mesh width was considered (1 x 1 meter).

The first two campaigns (for winter and for summer) provided data about the averages of pollutant concentrations in the investigated area during measurement period (about 30 days). There were 26 sampling points over the traffic junction (see figure 2). The information gained from the first two campaigns is used for three main aims:

1. preliminary definition of pollutants levels and dispersion,
2. the recognition of the probable relationships between pollutants concentrations and specified features of the investigated area (using linear regression method),
3. the estimation of the emission coefficients (for the numerical modeling of dispersion).

As an outcome from the preliminary analysis a GIS-spatial data base has been created in which the results from first two measurements campaigns were included. The GIS was then the basis for the spatial analysis of pollutants distribution using minimum curvature interpolation method to accomplish the first aim. An inverse distance method was chosen as an initialization procedure which fits a smooth surface to the input elevation values. Finally, iterations of the algorithm adjusted output raster cell values and a smooth, uniformly representative surface was produced. The results of the interpolation confirmed that the concentrations of air pollutants in the microscale are not homogenously spatially distributed. The most clearly view of street and buildings scheme reflections are given by NO_2 distribution (see figure 2). Similar effects showed the distributions of VOC's concentrations.

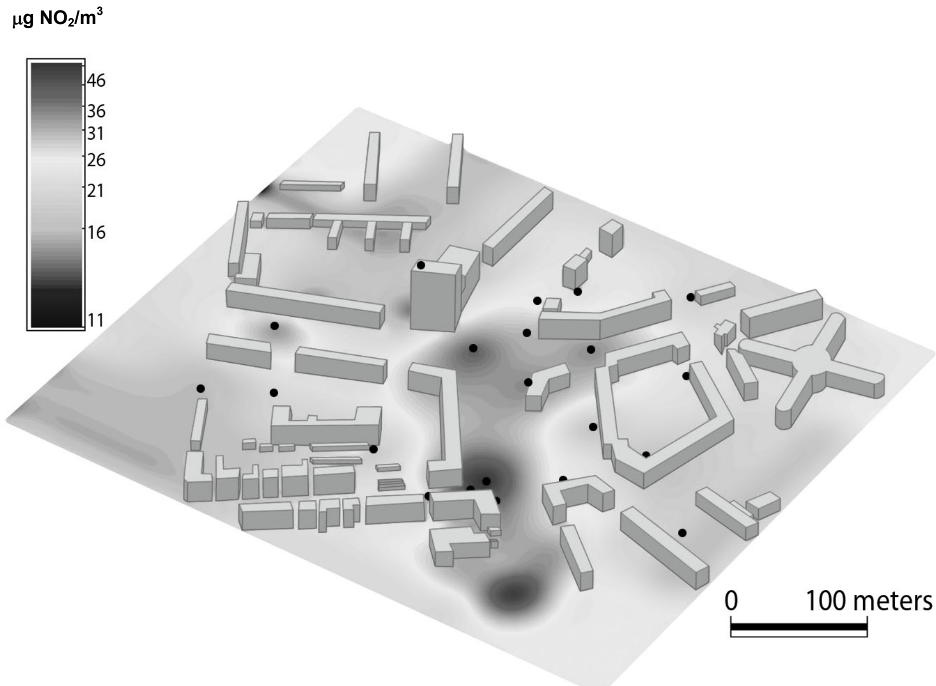

Fig. 2; Perspective view of the sampling site (from South-East) and results of interpolation of nitrogen dioxide for summer measurements campaign. The dots mark the places for the passive sampling.

The preliminary data processing is being continued using created GIS to construct a 'built up-area-features' map which will enable to investigate their impact on air pollutants concentrations. The considered features are taken from the known general rules which govern the pollutants dispersion in built up areas. These are mainly the geometry of the buildings and streets as well as meteorological conditions (wind rose for analyzed period). The first approaches to the 'built up – area – features' map are shown in figure 3.

FUTURE PROSPECTS AND CONCLUSIONS

The next step of the GIS-based data processing will be detailed regression analysis. It will give information about relationships between pollutants concentrations and specified features of the investigated traffic junction. Similar but more general study has been done by *Park, S.K. et al* (2004). As a result of this project stage a linear multiple regression model for each studied air pollutant will be established. The equations will then be used to modeling of air pollutants dispersion in the analyzed periods and the results will be verified against chosen few measurement points which will not have been taken into consideration by regression analysis. The regression equations will be also used for modeling according to the annual wind rose given for Wroclaw to obtain a more general view of possible locations of the most polluted zones.

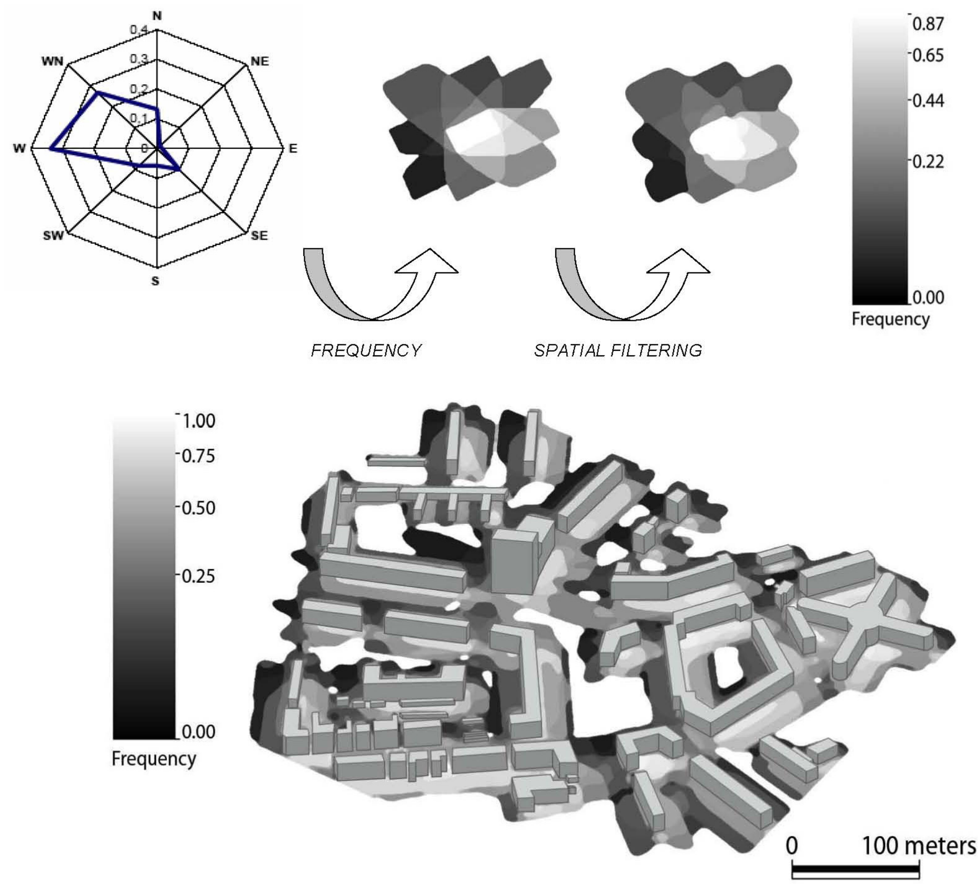

Fig. 3; A wind rose for the summer measurement period and the consequent 'wind rose feature'. Top: an example for one building. 'Shadows' are in the leeward sides of the building with frequency taken from the wind rose. Bottom: the whole area.

The third aim of the already conducted measurement campaigns is to estimate emission coefficients for numerical modeling of air pollutants dispersion. It is assumed that the main air pollutants will be from traffic emission sources. The pollutants plumes are thus emitted with low velocity from the ground level and quite quickly adopt features from the surrounding air. *Park, S.K. et al* (2004) have given an equation which implies the ratio between the residual rate of the air pollutant and the vehicle emission rate within a street canyon. We have undertaken passive measurements directly near the emission sources and we will try to use it to parameterize the microscale model MIMO for real emission conditions. The MIMO is a 3D, numerical model, developed in the Institute of Technical Thermodynamics at Karlsruhe University, for simulating microscale wind flow and dispersion of pollutants in built-up areas. It solves the Reynolds averaged conservation equations for mass, momentum, energy and other scalar quantities such as the humidity or the concentration of pollutants. Numerical modeling will be done for the atmosphere conditions which occur during the measurement period (separately for night and day) and the results will be averaged. According to the fact that the deposition and the chemistry will not be taken into consideration, the dispersion of the air pollutants will give a general but three-dimensional information about possible location of the most polluted zones. These data can be used for qualitative inter-comparison to the results of regression modeling, for improving the regression equation (adding new features) and for better understanding of the impact of the 'built up-area-features' in the investigated traffic junction.

In the second year of the project we will concentrate on:

1. the verification of the recognized previously relationships between pollutants concentrations and 'built up-area-features',
2. the evaluation of the elaborated models,
3. the formalization of the prognostic procedure.

These will be the aims of the next two measurement campaigns (for winter and for summer). They will take place in 2006 with approximately twice more passive samplers than in the first year. The passive sampling net will be planned according to the modeling results with particular concentration on the polluted zones identified during previous measurements and modeling approaches.

The final result we expect to obtain is a new, cost-effective, GIS-based, prognostic procedure which can provide reliable results for evaluation of urban inhabitants exposure to air pollution near traffic junctions and thus is an effective tool for urban management.

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