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AIR QUALITY MANAGEMENT SYSTEM OF THE CITY OF PLOVDIV – ANNUAL ANALYSIS FOR 2013

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Abstract: Air Quality Management System of the city of Plovdiv is working operationally since 2004. The system performs several main tasks: air quality monitoring, real time dispersion modeling, analysis of the emission sectors contribution, and dispersion modeling of an accidentally released passive substance. The system has been developed step by step and its recent extensions and future development are discussed.

Analysis of the city air quality based on the system's outputs is made. The data from air quality monitoring are juxtaposed to the air quality standards. Annual and seasonal maps of the emissions and concentrations are made up from the archive of hourly maps produced by the modeling system. Some conclusions concerning contribution of different snap sectors and significance of meteorological conditions are outlined.

Key words: *air pollution management systems, dispersion modelling, air quality*

INTRODUCTION

Plovdiv is the second larges city in Bulgaria with population of about 370 000 people. Its residential area is about 110 km^2, where six small hills rise up to about 100-200m over the surrounding flat terrain. Climate of the region is characterized by often calm weather and surface temperature inversions. The Air Quality (AQ) problems in the city are mainly related to violations of the particulate matter targets. The municipality of Plovdiv (MuP) initiated creation of a local Air Quality Management System (AQMS) in 2003. Coordinator of the project is National Institute of Meteorology and Hydrology (NIMH). The main functions of the system are: 1) monitoring of the AQ and meteorological parameters; 2) dispersion modeling of the discharged emissions; 3) analysis of the contribution of different emission sectors (SNAPs); 4) simulation and forecast of the dispersion of an accidentally released pollutant. All functions are performed automatically in real time, except the last one that is conducted by the system's operator in case of an accident.

The system has been developed gradually, step by step, starting in 2004 with one AQ monitoring station and dispersion modelling of emissions from industrial sources in the city. Later on, second AQ monitoring station starts operating; other emission sectors have been taking into account; the considered pollutants have been updated several times.

DESCRIPTION OF THE SYSTEM; ILLUSTRATION OF ITS OUTPUTS

The system exchanges data between several institutions with final recipient the MuP – Fig.1. According

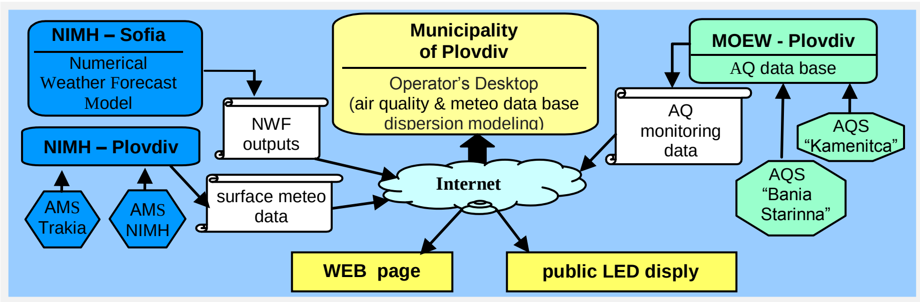


Figure 1. Structure and data flow diagram of the Plovdiv's AQMS. AQS - air quality station, AMS - automatic meteorological station, MOEW - Ministry of Environment and Waters

to the system's functions, two main part of the system can be distinguished, the monitoring system and the modeling system. System's operator has two desktops on his disposal, one for monitoring and second for modeling system (Fig.2). Contribution analysis of different emission sectors and simulation of accidentally releases are part of the modeling system.

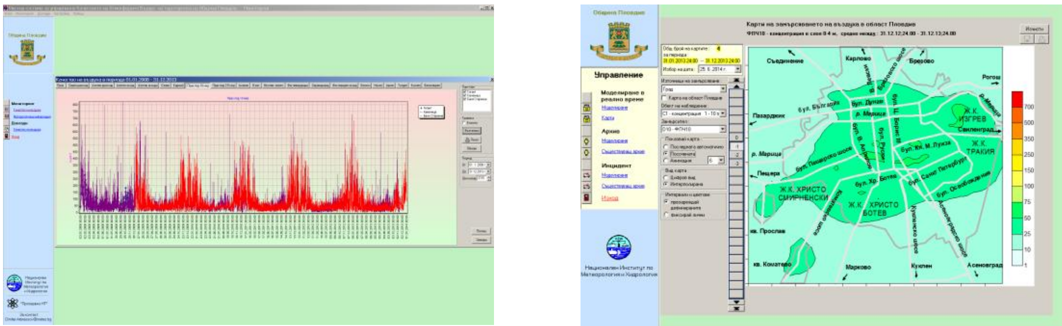


Figure 2. Monitoring system desktop and concentration of PM_{10} from 2008 to 2013 at the two measurement sites(left). Modelling system desktop and map of the annual concentration of PM_{10} for 2013 (right).

Monitoring system

The information from AQ monitoring sites in the city, which are part of the National AQ monitoring network of Ministry of Environment and Waters (MOSW) is transmitted to the MuP and saved in SQL

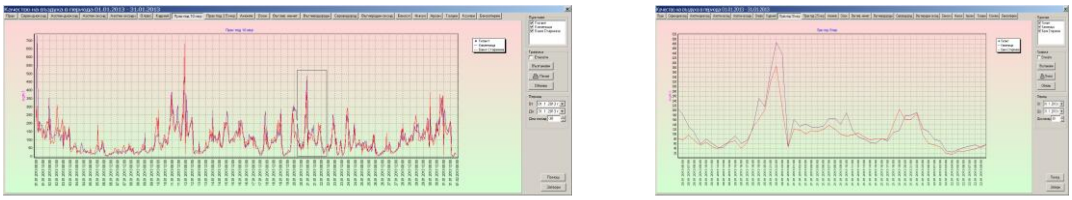
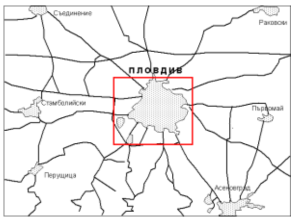


Figure 3. Concentration of PM_{10} at the two measurement sites for January 2013 (left). Zoom in the rectangle in the left panel (right).

data base. Operator can put on the screen the information he wish to analyse Figs.2-3. AQ observations are performed by an urban background AQ station where PM_{10}, $PM_{2.5}$, NO, NO_2, NO_x, O_3, NH_3, SO_2, H_2S, CO hydrocarbons, non-methane hydrocarbons and benzol are measured. Second traffic oriented station measuring PM_{10}, NO, NO_2, NO_x, SO_2, benzol, toluene, P-Xylene has been operating since 2009. Till February 2011 a total dust, NO_2 and SO_2 ware measured at three sites by manual sampling (by pumping air). The data from surface meteorological stations are also saved in the SQL database.

Modeling system

The modeling system is composed of: meteorological preprocessor, emission models, dispersion models and postprocessing analyser. The system works in two-scales (Fig.4), in real time and produces hourly maps of the pollutants' concentrations.
The meteorological preprocessor is supplied with information from an Numerical Weather Forecast (NWF) model and from local automatic meteorological stations (AMS). In the first version, the outputs at 850hPa from a NWF model of German Weather Service ware used as upper boundary conditions and AMS data as lower boundary conditions of an 1-dimensional Atmospheric Boundary Layer (ABL) model (Atanassov, D. et al., 2006). Latter on, the NIMH operational NWF model ALADIN was incorporated, corrected by the surface AMS data. Recently, a new meteorological preprocessor for optional use was developed. Surface layer parameters are determined by an modification of US EPA AIRMET model. Vertical profiles of wind and eddy diffusivity are determined according to Gryning, S.E., et al. (2007) and Kumar, P and M.Sharan (2012). This preprocessor has been used in the presented below results for year 2013.



Domain "region" :
area - 60x40km
grid cell - 2x2km,
time step of dispersion model - 90s

Domain "city" (red rectangle):
area - 11x10km
grid cell - 250x250m,
time step of dispersion model – 30s

Figure 4. Domain "region" and domain "city".

Emission sectors considered in the system do not follow exactly the SNAPs of CORINAIR. For example, the large point industrial sources in the city, i.e. the sources located into the MuP's territory are considered separately from the large point industrial sources outside the MuP's territory. This seems reasonable, as the MuP has more power to influence on the first, than on the second group of sources. Determination of the domestic emissions are based on an expert's assessment of the number of households using fossil fuels in each grid cell of the model. This valuation is periodically updated and put into the system. The emission model determines emissions on hourly basis, taking into account number of households, amount of used fuel, emission factors, air temperature, day of the week and hour of the day. Diurnal dynamics of emissions from the domestic sector is illustrated on Fig.5.

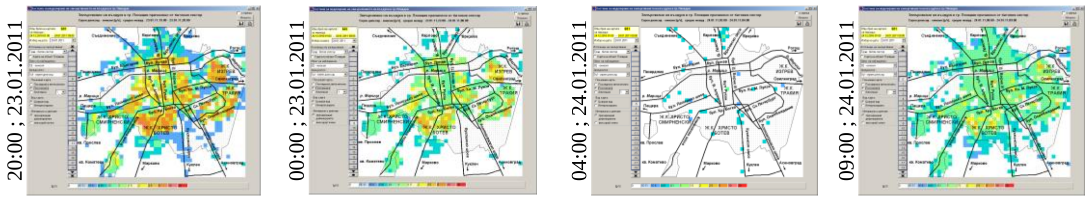


Figure 5 . Diurnal changes of emissions of SO_2 from the domestic sector, January 2011.

The dispersion model that operates in the two domains is PolTran - a combination of an Eulerian advection scheme and numerical calculation of the turbulent diffusion (Atanassov, D., 2003). Pollutants considered by the current version of the modeling system are: PM_{10}, $PM_{2.5}$, NO_2, SO_2, benzo(a)piren (BaP). The system calculates separately dispersion from: the domestic heating in the city, the industrial

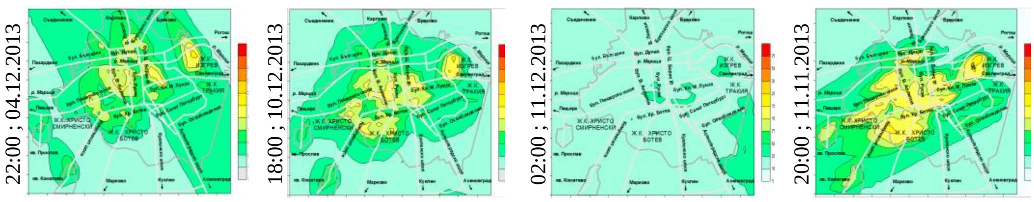


Figure 6. PM_{10} concentration at some moments of December 2013, jointly caused by the industrial sources outside the city, by the industrial sources in the city, by the domestic heating and by the background concentration.

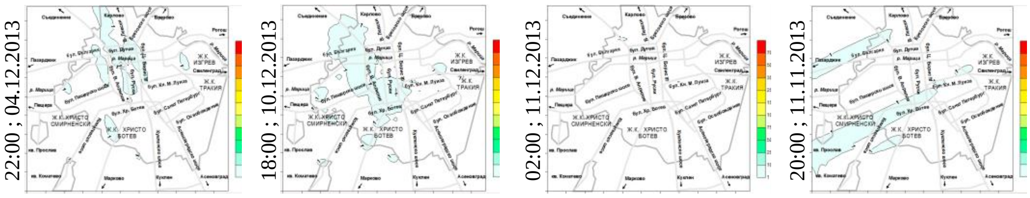


Figure 7. Contribution of the industrial sources in the city to the PM_{10} concentration at same moments of December 2013, that are shown on Fig.6.

sources in the city (Fig.7), and from the industrial sources outside the city, in the domain "region". The postprocessing analyser calculates the map of total concentrations caused by the all sectors (Fig.6) as well as the map of the sector's contribution (Fig.8).

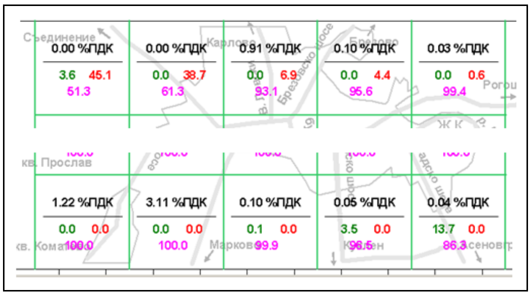


Figure 8 . The map of SO_2 pollution as part of the AQ limit value (black), contribution of the industrial sources outside outside the city (green), industrial sources in the city(read), and the domestic heating in the city (violet) at 22:00 on 23.01.2011. Only the the northern and southern part of the city are shown of the figure.

Modeling of accidental releases should be run by the operator, who has to set some basic specifications for the release. This option is available in the two domains and allows forecast up to 3 days ahead. If any additional details for the release become available latter on, the run can be repeated again. Fig.9 shows some characteristic moments of an accident that has happened in 2008.

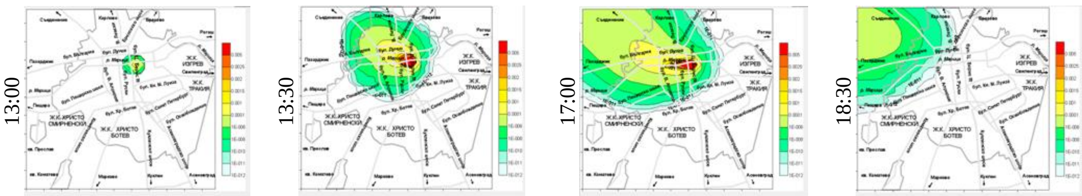


Figure 9. Air pollution during the fire in the "Water Palace", happened between 12:30 and 17:00 on 03.07.2008г.

SOME RESULTS FOR 2013

Typically for a real time systems, the outputs of the MuP's system are generally on hourly basis. Some monthly maps for 2013 are presented on Fig.10 and Fig.11. The role of the meteorological conditions for violation of the AQ standard is an important question in AQ management. An analysis designed to bring

Figure 10. Mean monthly concentration of PM_{10} for January, April and December 2013, jointly caused by the background concentration, by the industrial sources in and outside the city and by the domestic heating.

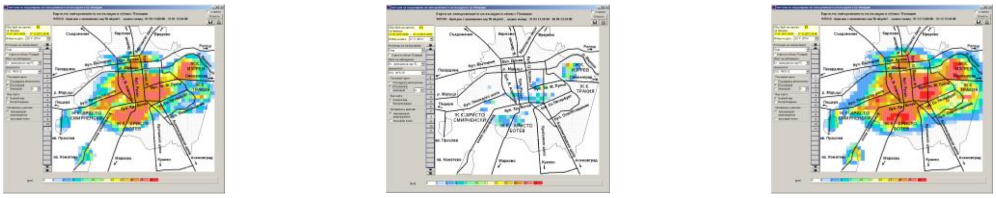


Figure 11. Number of days in January, April and December 2013, when the daily threshold of 50 µg/m^3 for PM_{10} has been exceeded as result of the background concentration, the domestic heating and the industrial sources in and outside the city.

light on this question has been done with respect to the violations of the daily threshold of 50 µg/m^3 for PM_{10} concentration. Pasquill stability class has been determined for the all 8760 hours of year 2013. The mean for the day and night stratification is defined as number of hours with unstable stratification minus number of hours with stable stratification. This 'daily mean' stratification and the averaged for the day and night wind speed are juxtaposed to the daily PM_{10} concentrations. The result for the first 20 days of December is illustrated on Fig.12 and statistics for the year 2013 is presented in Table 1.

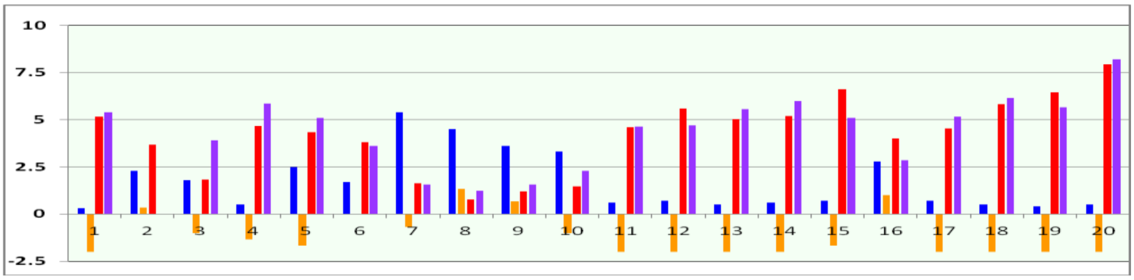


Figure 12. Meteorological conditions and PM_{10} concentrations for 1-20 December of 2013. Daily mean concentrations of PM_{10} at AQS "Bania Starinna"(red) and "Kamenitca"(violet), re-scaled by division to 20 (the daily threshold of PM_{10} on the figure is 2.5); "stratification" (orange); wind speed (blue).

Table 1. Number of days in 2013 when the daily threshold of 50 µg/m^3 for PM_{10} have been exceeded. Distribution according to wind speed and stratification.

	wind speed, m/s			**stratification***			**total for**
	> 2	1-2	calm (<1)	unstable (>0)	neutral (=0)	stable(<0)	**2013**
Kamenitca	15	34	124	69	20	84	173
	8.7%	19.7%	71.7%	39.9%	11.6%	48.6%	100%
Bania Starinna	12	19	112	33	18	92	143
	8.4%	21.7%	78.3%	23.1%	12.6%	64.3%	100%

*stratification = number of hours for the day with unstable stratification - number of hours with stable stratification

CONCLUSION

The contribution of the industry to the PM air pollution of the city of Plovdiv is not significant. The challenge for improving the AQ in the city are domestic heating, and, probably, the traffic, which is not considered in the system at this stage. Problems that can not be solved by the municipality authorities are the high value of the background concentrations and the meteorological conditions. Potential of the atmosphere to disperse the discharged pollutants in the region of Plovdiv turns to be too low. Prevailing part of AQ standard violations for PM_{10} happened in condition of calm weather (71-78% of the cases) and in stable stratification (49-64% of the cases). The AQ management system of the city of Plovdiv supplies authorities with valuable information. Some important extensions of the system are necessary, first of all to take traffic sector into account and to give forecasting abilities to the system.

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