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DISPERSION MODELING OF ATMOSPHERIC EMISSIONS OF PARTICULATE MATTER (PM_{10}) AND EVALUATION OF THE CONTRIBUTION OF DIFFERENT SOURCES OF AIR POLLUTION IN THE TOWN OF SVISHTOV, BULGARIA

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Abstract:: *This dispersion model and assessment of air pollution with particulate matter (PM_{10}) in the town of Svishtov, Bulgaria are developed in accordance with the requirements of Bulgarian legislation and the Framework Directive 96/62/EC on the assessment and control of the Atmospheric Air Quality.*
Based on an assessment of sources of air pollution in the town of Svishtov, Bulgaria are classified input data for the model including point, area and line sources of PM_{10}.
Quantitative results of modeling of the main sources of PM_{10} and background air pollution of Svishtov for 2007- 2010 confirm that local ambient pollution and emissions of PM_{10} from residential heating is a key contributor to atmospheric pollution in the city.

Key words: *Dispersion modeling, Atmospheric Air Quality (AAQ), Svishtov*

INTRODUCTION

Various local sources with different polluting potential have impact upon ambient air quality in built-up areas. Besides main air pollutants attention is paid to increased concentrations of other gases like O_3, CH_4, N_2O, CFCs etc., in regards with their influence on global climate system change and new methods for their measurement are developed [1,13]. Recently the level of PM_{10} in many urban territories in Bulgaria is high above the limit values. Increased concentrations of air pollutants lead to environmental damage and significant harmful effect upon the exposed population health. That's why improved methods for evaluating the risk of environmental degradation are applied [14,15].

The evaluation model is developed in accordance with the Clean Air Act [2], Regulation №7/1999 for the assessment and management of ambient air quality [10] and Regulation № 12/2010 [11] of Bulgarian legislation, meeting the Framework Directive 96/62/EC on the assessment and management of air quality in the European Union [6].

The main purpose of dispersion modeling of PM_{10} emissions is the assessment and management of ambient air quality of Svishtov in accordance with the Bulgarian legislation on environmental protection and the development of future measures to improve air quality, in terms of reducing dust air pollution in the area.

DISPERSION MODELING OF ATMOSPHERIC EMISSIONS OF PM_{10}. DISPERSION MODEL SELMA^{GIS}

Assessment of the impact of different sources of PM_{10} emissions on ambient air quality in the town of Svishtov is made by dispersion modeling for two periods (2007 and 2010). For this purpose was used the SELMA^{GIS} software of the German engineering office Ingenieurbüro Lohmeyer GmbH & Co. KG, Karlsruhe [8]. Modeling results are presented in accordance with Regulation № 12/2010, and meet the requirements of Section II, Annex №8 of the same by providing information on the share of modeled sources of PM_{10} in the average annual concentration of PM_{10} for the receptor points. The assessment model of pollution of Svishtov includes data for point, area and line sources and background contamination. SELMA^{GIS} includes dispersion model AUSTAL 2000 for the distribution of air pollutants, developed by the German Environment Agency [3,12]. It is a Windows-based software that works as an extension of the geographical information system (GIS) at ESRI (ArcMap).

1. Input data for dispersion modeling

Input data for dispersion modeling of PM_{10} emissions in Svishtov with SELMA^{GIS} include different data.

1.1.Meteorological data

For the purposes of this modeling are used meteorological data for the region of Svishtov provided by NIMH-BAS. In statistical terms the meteorological conditions in the atmosphere of Svishtov in the period 2007-2010 include:

- Wind speed less than 1.4 m/s in 2 % of cases of prevailing winds;
- Wind speed 2.4-3.8 m/s in 26 % of cases of prevailing winds;
- Wind speed 3.9-6.9 m/s in 17 % of cases of prevailing winds;
- Wind speed 7-10 m/s in 21 % of cases of prevailing winds.

An essential feature of the weather conditions for the period 2007 - 2010 was the absence of a well defined long-term northern, eastern and southern component in the wind direction. The prevailing components were southwest and northeast.

1.2. Emission data for point sources

Data on emissions of air pollution in Svishtov is only from industrial sources contributing to determine the air quality in terms of PM_{10} air pollution. The PM_{10} data for 2007-2010 were examined for the enterprises listed in Table 1. PM_{10} emissions from industry of Svishtov are calculated based on the records of periodic measurements (Regional Inspectorate of Environment and Waters – V. Tarnovo, Bulgarian), data from the IPPC Annual reports (Integrated Pollution Prevention and Control) of industrial plants in Svishtov and balance calculations of used fuels.

Table 1. The parameters of point (industrial) sources and the amount of average annual emissions of PM_{10} from them in Svishtov for 2007 and 2010

№	Emitter	Parameters of the stacks				Measured / calculated emissions PM_{10}	
						2007	2010
		H (m)	D (m)	(kg/h)	T °C	(kg/h)	(kg/h)
K1	"Central Svilosa 'PLC	150	7	2.4	120	71	103
K2S1	Svilocell Ltd, Chimney – dust cleaning. installation	8	2.25	0.5	28	0.09	0.319
K3S3	Svilocell Ltd, Chimney – Lime regeneration. furnace	22	1	6.4	73	0.36	0.82
K4S4	Svilocell Ltd, Chimney – Soda regenerating boiler	35	1.5	22.6	187	7.20	1.66
K5S18	Svilocell Ltd, Chimney – Biomass Boiler	18	0.5	28.3	147	1.00	2.055
K6	FAVO PLC Chimney - 1	10	0.5	1.7	210	0.31	0.27
K7	FAVO PLC Chimney - 2	10	0.5	1.7	210	0.31	0.27
K8	FAVO PLC Chimney - 3	10	0.5	1.7	210	0.31	0.27
K9	FAVO PLC Chimney - 4	20	1	0.4	210	0.31	0.27
K10	Sonny PLC Chimney - 1	25	1	0.7	180	0.13	0.18
K11	VINPROM PLC, Chimney - 1	22	1	0.2	190	3.07	2.90
K12	VINPROM PLC, Chimney - 2	12	0.5	0.7	230	0.004	0.004
K13	Republikakonserv PLC Chimney -1	12	0.5	4.3	240	0.36	0.20
K14	Republikakonserv PLC Chimney -2	10	0.4	6.7	240	0.36	0.20

1.3. Emission data for area sources

To determine PM_{10} emissions from burning fossil fuels in households, constructed residential areas and public sectors of the city are divided into regions of occupancy (tables 2, 3).

Table 2. Emissions from area sources (household sector) in Svishtov 2007-2010

№	Area	Average height of the emission source (m)	PM_{10} (kg/h)	
			2007	2010
1.	P1	8	0.52	0.66
2.	P2	8	1.52	1.95
3.	P3	10	1.62	2.08
4.	P4	15	2.25	2.89
5.	P5	21	2.42	3.12
6.	P6	21	1.48	1.90
7.	P7	15	2.35	3.02
8.	P8	21	1.33	1.71
9.	P9	15	1.39	1.79
10.	P10	15	1.26	1.62
11.	P11	21	1.97	2.53

Table 3. Emissions from area sources (public sector) in Svishtov 2007-2010

№	Area	Average height of the emission source (m)	PM_{10} (kg/h)	
			2007	2010
1.	P1	8	0.0031	0.0032
2.	P2	8	0.0001	0.0001
3.	P3	10	0.1329	0.1328
4.	P4	15	0.4570	0.3892
5.	P5	21	0.0214	0.0214
6.	P6	21	0.0004	0.0005
7.	P7	15	0.0001	0.0001
8.	P8	21	0.0014	0.0010
9.	P9	15	0.0088	0.0088
10.	P10	15	0.0003	0.0002
11.	P11	21	0.0031	0.0032

Estimation was made of the average gross consumption of fossil fuels by region and balance calculations of emissions of PM_{10} from households in the atmosphere of Svishtov were made under the EMEP/EEA air pollutant emission inventory guidebook, 2009 [5]. Estimated emissions of PM_{10} from the domestic sector in the regions are aggregated and defined as area sources.

1.4. Emission data for linear sources

For the modeling of emissions from transport were used census data of traffic in Svishtov for 2007-2010. For taking an inventory of PM_{10} emissions from urban transport, emission factors were used based on Handbook for Emission Factors for Road Transport [4, 7, 9]. Emission data from transport are presented on table 4.

Table 4. Emission data from linear sources, Svishtov 2007-2010

№	Name of the road section	Average speed (km/h)		Workload of stretch of road per day (Motor Vehicles/24 h)		Proportion of heavy vehicles> 3.5 t (%)	
		2007	2010	2007	2010	2007	2010
1	Otets Paisius	39	38	2589	2354	19	17
2	Danube	36	37	3025	2750	19	17
3	Prof. D.Barov	35	36	3025	2750	19	17
4	33rd Regiment Svishtov	36	36	7103	6457	19	17
5	Kliment Ohridski	25	26	2589	2354	1	1
6	P. R.Slaveykov	26	25	2589	2354	1	1
7	Dr. Chernev	25	26	2589	2354	1	1
8	Aleko Konstantinov	26	25	6050	5500	10	4
9	Tsar Osvoboditel	25	25	8506	7733	10	5
10	Exarch Antim 1	33	32	4731	4301	1	1
11	Vasil Levski	34	33	7248	6589	1	1
12	Petar Angelov	34	32	7248	6589	1	1
13	Patriarch Evtimii	39	38	8506	7733	11	10
14	Gregory Nachovich	26	25	1464	1331	1	1
15	Hadji Dimitar	27	28	1464	1331	1	1
16	Chiriac Tsankov	24	25	1573	1430	1	0.5
17	Iskar	24	25	1573	1430	1	1
18	Lulin	25	25	1815	1650	1	1
19	Nikola Petkov	27	26	3618	3289	3	3
20	Hristaki Pavlovich	26	26	3618	3289	3	3
21	Nove	24	25	1573	1430	1	1
22	Third March	27	26	3364	3058	1	1
23	Students	25	26	1694	1540	1	1
24	Black Peak	29	30	1815	1650	1	1
25	Tsvetan Radoslavov	27	28	2553	2321	19	17
26	Tsanko Tserkovski	28	29	2009	1826	19	17

RESULTS OF MODELING

Modeling process includes the following steps:

1. Preparation of a digital map of the area

Initially through ArcMap is introduced digital map of the town of Svishtov, georeferenced to WGS 1984 - UTM coordinates.

2.Selection of receptor network and receptor (monitoring) points

Receptor network includes multiple fixed points on the digital map, which SELMA^{GIS} calculate concentrations of PM_{10}. For the purpose of modeling is chosen network of receptor points with parameter 6000/4500 m (total 2,640 units receptor points). For each receptor point SELMA^{GIS} allows visualization of the calculated concentrations. Thus, the calculated concentration of PM_{10} determines air pollution within a radius of 100 meters. The choice of the number and location of the receptor (monitoring) points in the model which will determine air pollution can be fixed without restriction on the map. In this model, one monitoring point is selected initialized as a receptor point (RT1061). The location was chosen as close as possible to the monitoring station (MS) equipped with an automatic differential optical absorption spectroscopy (DOAS - OPSIS) in Svishtov. This allows for comparison of the calculated modeling results and PM_{10} concentration measured by MS (DOAS – OPSIS) Svishtov.

3.Entering data for the sources

Three types of sources are modeled - point, area and line. The necessary parameters of emission streams for each type of source are entered using dBase files. All necessary input data is prepared in advance as described above.

4. Calculation

Calculation of emissions of PM_{10} is done with the included modular SELMA^{GIS} dispersion model – AUSTAL 2000 [3], formal model of the German Federal Environment Agency. This is the mathematical three dimensional Lagrangian dispersion model for assessment of air pollutants from various emission sources. In this case, three types of sources AUSTAL 2000 calculated the average annual concentration of PM_{10} dispersion in the town of Svishtov.

5. Accounting for background contamination

Background concentration of PM_{10} can not be calculated from the dispersion model therefore input data for the model are set. In this modeling assessment of the local background level of PM_{10} characteristic of Svishtov region for the period 2007-2010 is made. The average background concentration set in the model is 23 $\mu g/m^3$ which was defined by the method of objective evaluation and extrapolation of the measured concentrations of PM_{10} PM (DOAS - OPSIS) in Svishtov for the period 2007-2010 year.

6. Visualisation of Results

Modeling results are saved in a*. DBF format. Visualisation of the same is done by the module SELMA Visualisation directly into ArcMap as (*. shp) files. The results of the modeling of PM_{10} from all sources in Svishtov are presented in fig. 1 (for 2007 year) and fig 2. (for 2010 year).

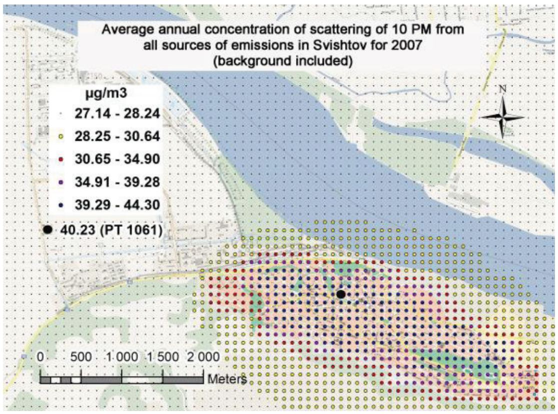

Fig. 1. The results of the modeling of PM_{10} AACs from all sources in 2007

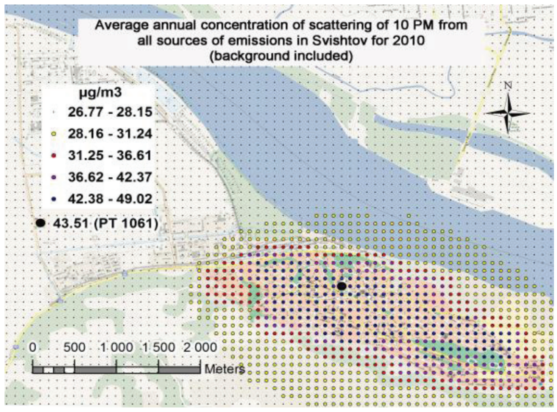

Fig. 2. The results of the modeling of PM_{10} AACs from all sources in 2010

7. Evaluation of modeling results

Tables 5 and 6 show the calculated from the model average annual concentrations of PM_{10} at receptor point (RT 1061), near the monitoring station (DOAS - OPSIS) Svishtov.

Table 5. Involvement of different sources and background in the formation of AACs of PM_{10} at receptor point (RT1061) – 2007

Source	AACs of PM_{10} Defined at receptor point(RT1061) $\mu g/m^3$	Contribution of different sources in AACs modeled value	
		(no) background concentration %	(with) background concentration %
Point sources (Industry)	0.33	1.10	0.82
Point sources (Central Sviloza - AD)	0.10	0.33	0.25
Linear Sources (Transport)	1.33	4.45	3.31
Area sources (household sector)	13.13	44.93	32.64
Area sources (public sector)	2.34	7.83	5.82
Background contamination*	23	-	25.70
TOTAL SOURCES	40.23	100.00	100.00

Dispersion modeling allows a quantitative assessment of immission air pollution in Svishtov with PM_{10}. Comparison of these results allows estimation of the contribution of each source of pollution (point, line, area,background) to total PM_{10} pollution of air in Svishtov for 2007 and 2010.

Table 6. Involvement of different sources and background in the formation of AACs of PM_{10} at receptor point (RT1061) – 2010

Source	AACs of PM_{10} Defined in Section receptor (RT1061) $\mu g/m^3$	Contribution of different sources to AACs modeled value	
		(no) background concentration %	(with) background concentration %
Point sources (Industry)	0.26	0.95	0.60
Point sources (Central Sviloza - AD)	0.14	0.51	0.32
Linear Sources (Transport)	1.26	4.60	2.90
Area sources (household sector)	16.85	61.47	38.73
Area sources (public sector)	2.00	7.30	4.60
Background contamination*	23	-	37.00
TOTAL SOURCES	43.51	100.00	100.00

Quantitative results of modeling the major sources and background PM_{10} in ambient air of Svishtov for 2007 showed that PM_{10} emissions from domestic heating and local pollution with resuspended dust have the greatest contribution to the levels of air pollution in city by 32 % and 31 % (fig.3, fig.4). Quantitative results of modeling the major sources of emissions of PM_{10} in ambient air of Svishtov for 2010, confirms that PM_{10} emissions from domestic heating and background contamination is a key contributor to the pollution levels in the atmosphere in the city.

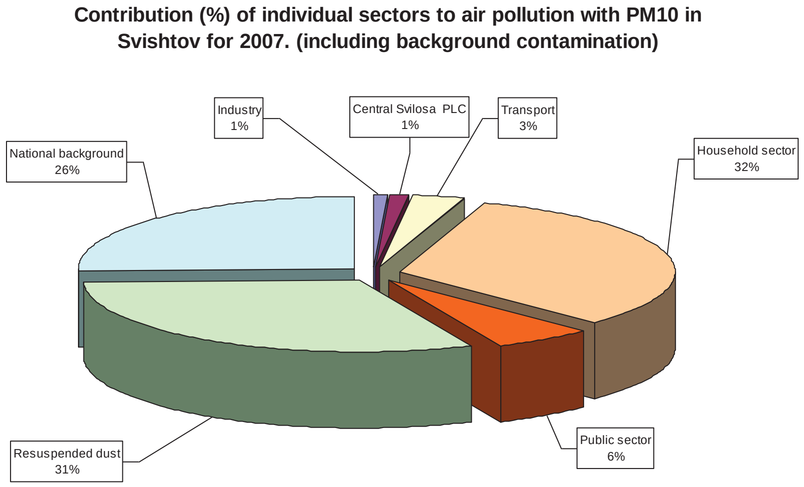

Figure 3. Percentage of sources of PM_{10} pollution 2007 (with background)

UNCERTAINTY OF MODELING RESULTS.

Comparison of the calculated results of the dispersion modeling with SELMA^{GIS} and measured annual average concentrations of PM_{10} PS DOAS - Svishtov for 2007 - 2010 is made at receptor points as close as possible to the point of monitoring (MS-AIS) of Svishtov.

Pursuant to the requirements of Section I, Table. 16, Annex № 8 of Regulation № 12/2010 of the results of the dispersion modeling of PM_{10} a legally required data quality is set which is not more than 50 % uncertainty for the average values. The uncertainty for modeling is calculated as the difference of the measured and calculated level of PM_{10} monitoring stations for the period compared to an average annual rate - 40 µg/m^3 for PM_{10} (table 7).

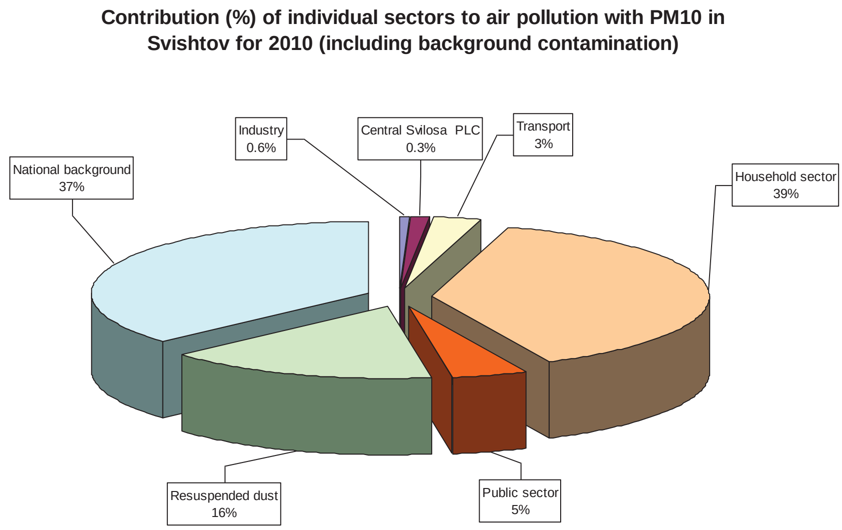

Figure 4. Percentage of sources of PM_{10} pollution 2007 (with background)

Table 7.Uncertainty of the results of PM_{10} dispersion modeling

Year	Estimated average annual concentration SELMA^{GIS}		Measured average annual concentration	Uncertainty in % compared to average annual rate = 40 µg/m^3
	receptor point	µg/m^3	µg/m^3	%
2007	PT1061	40.23	45	11.9
2010	PT1061	43.51	47.6	10.2

The uncertainty of the modeling results for 2007 and 2010 was calculated based on measurements in MS-DOAS Svishtov, where uncertainty is achieved amounted respectively to 11.9 % and 10.2 % compared to SGN = 40µg/m^3.

Estimated uncertainty of the results of dispersion modeling of PM_{10} for 2007 and 2010 is consistent with the statutory requirements for their quality and can be considered representative and reliable.

The modeling of annual average concentrations of PM_{10} in Svishtov (2007 - 2010) meet the statutory requirement for uncertainty and show the expected trend of the contribution of various pollution sources to the total PM_{10} air pollution.

CONCLUSIONS:

Modeling results show that:

-Background local pollution and PM_{10} emissions from domestic heating have the largest contribution to the air pollution of Svishtov with PM_{10} for 2007-2010;

-The contribution of point and linear sources of PM_{10} air pollution of Svishtov is below 10 %.

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