

KEY ELEMENTS AND GENERALLY VALID CONCLUSIONS IN THE PROGRAMS FOR MANAGEMENT OF AIR QUALITY FOR SOFIA AND PERNIK MUNICIPALITIES

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Abstract

Ambient air quality (AAQ) has been disrupted in relation to PM₁₀, PM_{2.5} and PAH indicators in the two neighboring municipalities of Pernik and Sofia. The results of the prepared Programs for management of air quality identify the main source of ambient air pollution- residential combustion, which is determining for AAQ on all three indicators under consideration. The second most important source in terms of PM₁₀ and PM_{2.5} indicators is the transport sector, for which the dust resuspended from the road surface is characteristically dominant. There has also been a high contribution of external (including cross-border) sources of PM pollution, which significantly aggravate the fight against pollution in the affected municipalities and the country as a whole.

Keywords: air pollution, particulate matter, programs for management of air quality, air quality assessment

1. INTRODUCTION

In accordance with the requirements of the Bulgarian legislation, a research team from University of Chemical Technology and Metallurgy and "Sokolovskis Environment" Ltd. prepared Programs for Management of Air Quality (PMAQ) for the territory of two neighboring municipalities: Sofia and Pernik. Typical for both municipalities are exceedances of the established average annual limit value (AALV) and permissible number of exceedances of the average daily limit value (ADLV) for particular matter (PM)₁₀ concentration, the AALV of PM_{2.5} and the AALV of polycyclic aromatic hydrocarbons (PAH) in the ambient air.

There are total of three monitoring stations (MSs) in Sofia Municipality, which measure both indicators PM₁₀ and PAH- MS "Gara Yana" (manual sample- background suburban, code BG0024A), "IAOS/ Pavlovo" (automatic- traffic urban, code BG0073A) and MS "Kopitoto" (automatic- background rural near city, with code BG0070A). PM_{2.5} is measured in MS "Hipodroma" (automatic- background urban, code BG0050A) and MS "Kopitoto".

There is one MS in Pernik Municipality, which measures simultaneously the indicators PM₁₀, PM_{2.5} and PAH - MS "Tzarkva" (manual sample- urban background, code BG0046A). Data from complex background MS "Rojen" (background for ecosystem conservation, code BG0053R) was used as a background point.

The PAH content in the air is determined by the fine particulate matter content and the analysis of the benzo(a)pyrene content in them. This does not mean that there is necessarily a high correlation between the two indicators, PM₁₀ and PAH, except when these come from the same source.

The PMAQ for Sofia Municipality has been drawn up in two stages. The first concerns PM₁₀ pollution problems, between 2015 and 2020 [1], and the second - PM_{2.5} and PAH pollution problems for the same forecast period [2].

In the period 2011-2014, exceedances of the AALV for PM₁₀-40 µg m⁻³, were measured from all MS, except MS "Kopitoto". The same regards the disturbance of the permissible number of exceedances for ADLV from 50 µg m⁻³ for PM₁₀- the thirty-sixth largest value of measured average daily concentrations (ADC) is above 50 µg m⁻³ in all urban and suburban MS. In the second stage of the Program, an analysis of the AAQ on the indicators PM_{2.5} and PAH for the period 2013-2017 was conducted.

The PMAQ of Pernik Municipality was prepared for the period 2017-2021, and the analysis of the AAQ covers the period 2013-2017. [3].

In both Programs the relevant inventories of pollution sources are made, the contributions of individual sectors to total emissions are calculated and mathematical modelling of AAQ is carried out. The contributions of individual sources to the total air pollution are presented with the help of computational program. Measures have been proposed to improve the AAQ and appropriate analyses have been carried out on the expected improvements, again through mathematical modelling.

In this work we present the main results of the analyses carried out in both PMAQs and the conclusions that can be made on the basis of the submitted data. A comparison of two different approaches was made to identify the main pollutants of ambient air in Sofia Municipality - computational from the Sofia Municipality Program [1] and laboratory analysis of the composition of PM_{10} carried out by the National Institute of Meteorology and Hydrology (NIMH) [7].

2. ANALYZES, EVALUATION METHODS AND RESULTS FROM AMBIENT AIR QUALITY MANAGEMENT PROGRAMS

2.1. Results from PMAQ for Sofia Municipality

The Program has been drawn up in two stages. The first concerns PM_{10} pollution problems between 2015 and 2020, modelling and validation of the model carried out for the reference year 2014. [1] The second addressed the problems of $PM_{2.5}$ and PAH pollution over the same forecast period. Modelling and validation of the model carried out for the reference year 2013 for PAH and 2017 for $PM_{2.5}$.

For the purposes of the Program, a detailed inventory of potential sources of emissions of fine particulate matter PM_{10} , $PM_{2.5}$ and PAH was carried out.

- industry;
- road transport, including inner-city streets and roads with intensive traffic;
- internal combustion for heating/ residential combustion;
- construction and repair works;
- external sources.

The following figures provide aggregated results on the contribution of each source to the total emission of the pollutant concerned.

Figure 2.1-1 Specific contribution to the total PM_{10} emissions for 2014.

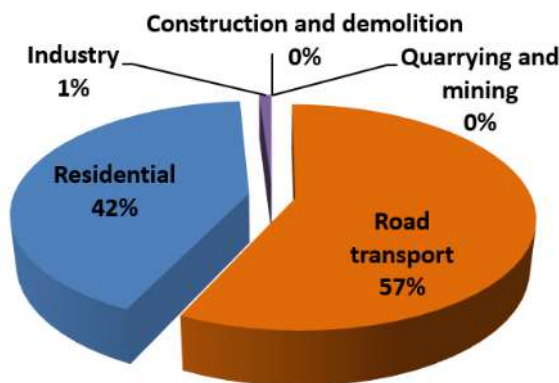


Figure 2.1-2 Specific contribution to the total PM_{2.5} emissions for 2017.

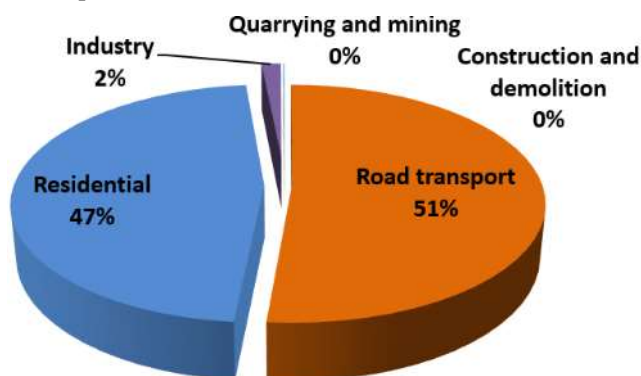


Figure 2.1-3 Specific contribution to the total PAH emissions for 2013.



Results from the figures show that for PM₁₀ and PM_{2.5} “Residential combustion” and “Transport” are close as a contribution, however “Residential combustion” achieves this “result” in about 5 months of the year, unlike transport, which operates year-round. It is also important to specify that calculated road dust resuspension from the Transport sector is more than 95 % of total PM₁₀ emissions from the sector or 54% of all emissions generated in Sofia Municipality.

It can be argued that there is one main source of PAH pollution and this is „Residential combustion“ that emits 75% of the annual emissions of PAH into the atmosphere for only 5 months of the year.

Pollution from other areas may affect the level of the regional background, which in this case is essential. Data from MS “Kopitoto” and “Rojen” are used to assess background air pollution with fine particulate matter and PAH.

Table 2.1-1-Table 2.1-3 present the measured annual average concentration (AAC) of the indicators concerned in the MS “Kopitoto” for the relevant period.

Table 2.1-1 AAC for PM₁₀ measured from MS “Kopitoto” for the period 2011-2014.

Dimension	2011	2012	2013	2014	AALV
µg/m ³	22.47	19.61	16.89	16.45	40
% of AALV	56	49	42	41	-

The background concentrations of PM₁₀ are too high, but these are also values above those measured from the background MS “Rojen”, where values are between 9 and 14 µg m⁻³ (Table 2.1-4 and Table

2.1-5) for the same period. That means either a transfer of pollutants from other regions or a specific microclimatic conditions characteristic of the mountains and the rise of pollutants at high altitudes.

Table 2.1-2 AAC for PM_{2.5} measured from MS “Kopitoto” for the period 2013-2017.

Dimension	2013	2014	2015	2016	2017	AALV
µg m ⁻³	13.17	11.44	8.89	7.58	6.54	25
% of AALV	53	46	36	30	26	-

The lasting reduction of AAC for PM_{2.5} from 13.17 to 6.54 µg m⁻³ in the period 2013 – 2017 is clearly visible here (Table 2.1-2). However, it should be noted that according to the AALV from 25 µg m⁻³ for the period considered, relatively high AAC (26÷53% of AALV) were measured from the MS “Kopitoto”.

Table 2.1-3 AAC for PAH measured from MS “Kopitoto” for the period 2013-2017.

Dimension	2013	2014	2015	2016	2017	AALV
ng m ⁻³	0.039	0.0536	0.0072	0.034	0	1
% of AALV	4	5	1	3	0	-

With regard to the pollutant PAH, background levels are characterized by extremely low values for the whole period from 2013 to 2017. It can be concluded that there is no air pollution in Sofia Municipality with PAH issued in other regions.

For completeness of the analysis in Table 2.1-4 and Table 2.1-5, data from Quarterly bulletins of the Executive Environment Agency (EEA) have been used- measured annual concentrations for PM₁₀ and PM_{2.5} in MS “Rožen” for the same period [6]. Comparing the reported results in both background MS- “Kopitoto” and “Rožen” could be accepted with a sufficient degree of confidence that 55÷65% and 60÷80% from the measured concentrations of PM₁₀ and PM_{2.5} in MS “Kopitoto” are as a result of external for Sofia area sources.

A comparison of the results in both background MS shows that the actions of local authorities to implement effective measures for AAQ improvement are significantly aggravated by the inability to influence PM pollutants from external sources.

Table 2.1-4 AAC for PM₁₀ measured from MS “Rožen” for the period 2011-2014.

Dimension	2011	2012	2013	2014	AALV
µg m ⁻³	14.35	11.03	9.28	10.47	40
% of PIN	36	28	23	26	-

Table 2.1-5 AAC for PM_{2.5} measured in MS “Rožen” for the period 2013-2017.

Dimension	2013	2014	2015	2016	2017	AALV
µg m ⁻³	5.415	6.01	4.54	4.54	4.77	25
% of normal	22	24	18	18	19	-

The analysis of the relief between the neighboring municipalities shows that the transmission of air pollutants between Pernik and Sofia is not only possible, but also very likely. Figure 2.1-4 represents the valley between Sofia and Pernik, respectively from the site of Vladaya and Knyazhevo.

Figure 2.1-4 Relief of the earth's surface in the area of Vladaya village (left) and in the area of Knyazhevo (right).



Based on the inventory of pollution sources, a comprehensive assessment of the prevalence of emissions from different types of sources has been carried out across the municipality. For the purposes of the study, the BREEZE AERMOD/ISC package of the American company Trinity Consultants Inc. was used for working with Windows operating system.

For the model, 73 industrial emission sources, 32 area sources and 53 linear sources of road emissions, 40 area sources of residential combustion emissions, 23 area sources of emissions from construction and 3 area sources of emissions from landfills, quarries, storage, etc. were used.

The analysis of the results obtained is systematized in Table 2.1 6-Table 2.1 9. “Residential combustion” is the most significant pollutant source in Sofia Municipality. For the limited period (5 months in the year) in which this source is active, more than 25% of AALV for PM_{10} and $PM_{2.5}$ are achieved, over 50% of ADLV for PM_{10} and over 90% of AALV for PAH are achieved.

The results obtained in Table 2.1 6 show that average 33% of the total estimated PM_{10} concentrations in these MS result from “Road/ Transport” sector, followed by Residential combustion with 30% average contribution. “Road/ Transport” sector includes road dust resuspension, with 31% average contribution and fuel combustion in car engines and tires and brakes with 2% average contribution. Similar results were obtained in NIMH work [7]. In both works, “Road/ Transport” sector with road dust resuspension is reported as the most significant source of total PM_{10} air pollution, followed by Residential combustion.

In the course of the analyses above, external sources of pollution significantly contribute to the calculated AAC of PM_{10} and $PM_{2.5}$ and ADC of PM_{10} . As shown in the tables below (Table 2.1 6-Table 2.1 8) contribution of the background (including external sources) to total pollution, reaches nearly 50% for PM_{10} and 22% for $PM_{2.5}$.

“Landfills and quarries” sector has a negligible contribution to the total pollution of ambient air on the territory of Sofia Municipality.

Table 2.1-6 Contributions of individual source groups to AAC of PM₁₀ in Sofia.

	MS "Gara Yana"	MS "IAOS/ Pavlovo"
Residential combustion	39%	25%
Transport	12%	53%
Background/External Sources	49%	22%

Table 2.1-7 Contributions of individual source groups to the maximum ADC of PM₁₀ in Sofia.

	MS "Gara Yana"	MS "IAOS/ Pavlovo"
Residential combustion	79%	57%
Transport	11%	38%
Background/External Sources	10%	5%

Table 2.1-8 Contributions of individual source groups to AAC of PM_{2.5} in Sofia.

	MS "Hipodruma"
Residential combustion	27
Transport	50
Background/External Sources	22

Table 2.1-9 Contributions of individual source groups to AAC of PAH in Sofia.

	MS "Gara Yana"
Residential combustion	>90%
Transport	<10%
Background/External Sources	-

Relevant measures for improving the AAQ have been proposed on the basis of the results obtained for the contributions of individual pollution sources. The measures that are most important are aimed at the Residential combustion and Road/Transport sectors.

The Program carried out forecast mathematical models and assessed the expected improvement of the AAQ. On the basis of the results obtained, the following main conclusions have been drawn:

- as a result of the implementation of the measures envisaged to reduce PM₁₀ emissions, and according to the model assessment of the prevalence of this pollutant in the ground atmospheric layer, PM₁₀ concentrations are expected to be below the AALV by 2020 and meet the requirements of the regulatory framework and with regard to the ADLV, both at the MS and on the territory of Sofia Municipality.
- after implementation of the measures the AAQ with regard to PM_{2.5} will be significantly improved and the AALV will be achieved;
- a problem for Sofia Municipality is the transfer of fine particulate matter from sources external to the municipality;

- the AAQ in terms of PAH will be significantly improved, but additional efforts are needed in order to achieve the AALV throughout the field of study– especially economic incentives for replacing the combustion base for heating;
- a major problem for Sofia Municipality, and for the whole country remains the burning of wood, coal and heating oil.

2.2. Results from PMAQ for Pernik Municipality

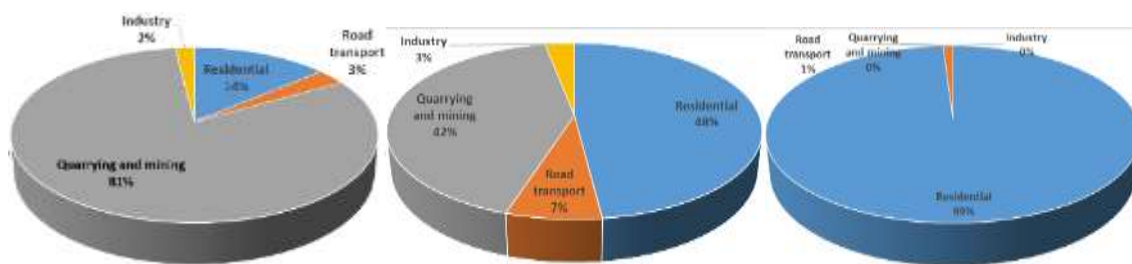
The Program for management of air quality for Pernik Municipality 2017 -2021 was prepared in 2018 and approved in 2019.

Detailed inventory of potential sources of emissions of PM₁₀, PM_{2.5} and PAH was carried out in the Program, as followed:

- industry;
- road transport;
- internal combustion for heating/ residential combustion;
- landfills, quarries, waste repositories, etc.;
- external sources.

The following figures provide generalized results on the contribution of each source to the total emission of the pollutants concerned.

Figure 2.2-1 Sector-specific contribution to the total issue, %, PM₁₀ (left), PM_{2.5} (middle) and PAH (right) for 2017.



Results from the figures show that for PM₁₀ and PM_{2.5}, the main source of emissions is the open spaces, landfills, quarries, repositories, etc. Residential combustion is the second most important sector emitting 14% of total PM₁₀ emissions and 42% of total PM_{2.5} emissions. The transport sector is the third largest sector emitting 3 and 7% of total PM₁₀ and PM_{2.5} emissions. The industry ranks last by source of PM₁₀ and PM_{2.5} emissions.

It can be argued that PAH has one main source of pollution which is the „Residential combustion“– for 5 months only, this sector emits 99% of the annual emissions of PAH into the atmosphere.

Similarly, in this Municipality the pollution from other regions can affect the level of the regional background, as in Sofia. Data from MS “Rozhen” were used to assess the background air pollution with PM and PAH.

Based on the inventory of pollution sources, a comprehensive assessment of the prevalence of emissions from different types of sources has been carried out in the territory of a municipality. For the purposes of the study, the same product- BREEZE AERMOD/ISC package of the American company Trinity Consultants Inc. was used.

For the model, 14 organized industrial emission sources, 3 area sources and 6 linear sources of Road/Transport emissions, 50 area sources of Residential combustion emissions and 6 area sources of emissions from landfills, quarries, waste repositories were used.

The analysis of the results obtained shows (Table 2.2-1) that the main contributors to air pollution with PM₁₀ and PM_{2.5} in the area of MS "Tzarkva" are two sectors: Residential combustion and existing, landfills and mines.

The transport and industry sectors make a negligible contribution to the total air pollution on the territory of Pernik Municipality.

Domestic combustion is the only significant source of PAH pollution, contributing up to 99% of the estimated AAC.

Table 2.2-1 Contributions of individual source groups to AAC of PM₁₀ in Pernik Municipality.

Source	Contribution to			
	AAC of PM ₁₀	ADC of PM ₁₀	AAC of PM _{2.5}	AAC of PAH
Residential combustion	33%	52%	51%	99%
Transport	7%	4%	8%	<1%
Landfills and mines	27%	35%	7%	-
External sources	33%	9%	34%	-

The Program includes technical, regulatory, economic and information/educational measures that target all significant sources of ambient air pollution in the municipality. According to the results in Table 2.2-1 the most important measures include reclamation of disturbed terrains (mines, quarries, embankments and waste repositories) and measures leading to reduction of emissions from Residential combustion.

The Program carried out forecast mathematical models and assessed the expected improvement of the AAQ. From the results obtained for improvement of AAQ after the application of the adopted measures, the following conclusions can be drawn:

- AAC of PM₁₀ will be below the AALV for the entire residential territory of the municipality;
- reducing the number of ADLV exceedances for PM₁₀, but further efforts are needed to achieve the permissible number of exceedances. In two relatively small areas in the central part of Pernik and in "Tzarkva" sq., as well as in "Ladovica" sq. the exceedances of ADLV are more than the permissible for a calendar year;
- to reduce the number of ADLV exceedances for PM₁₀ in "Ladovica" sq. it is necessary to undertake activities related to the reclamation of additional parts of the "Republika" mine;
- by 2021, throughout the municipality, the AALV for PM_{2.5} will be achieved. Values higher than normal will remain only on the territory of the "Republika" mine;
- AALV exceedances for PAH could be expected for a very small area in the central part of Pernik by 2021. Possible AALV exceedances will be up to 0.08 ng m⁻³.

3. RESULTS AND DISCUSSION

The conclusions of the PMAQs described in 2.1 and 2.2 are related to the measures in the Programs. Measures for the domestic heating sector are directly linked to the implementation of a project of Sofia Municipality "Improving ambient air quality in Sofia Municipality by replacing solid fuel heaters with

environmental alternatives", funded under the Operational Plan "Environment 2014-2020", through the Cohesion Fund of the European Union and from the national budget. Although the operational Plan is for the period 2014-2020, application documents are still being collected at this stage and the effect of these measures will likely reflect in the coming years.

For Pernik Municipality, the problem is even more serious because there is no possibility to finance the municipality under the Operational Plan "Environment 2014 -2020" for replacement of solid fuel heaters with environmental alternatives.

The Programs predict that, on the basis of measures implemented to reduce PM_{10} emissions, compliance with the established AALV will be achieved. The results of the 2020 Annual AAQ Bulletin confirm these predictions [4]:

- measured AAC of PM_{10} from MS located on the territory of Sofia Municipality are between 20 and $33 \mu g m^{-3}$ for 2020. By comparison, in the background rural near city MS "Kopitoto" AAC of $12.5 \mu g m^{-3}$ (over 30% of the established AALV of $40 \mu g m^{-3}$) was measured. The trend of significant contribution of pollution from external sources is maintained;
- measured AAC of PM_{10} from MS located on the territory of Pernik Municipality are between 26 and $35 \mu g m^{-3}$ for 2020. By comparison, the complex background MS "Rojen" has also recorded a high value of PM_{10} - $9.3 \mu g m^{-3}$, which is over 20% of the established AALV.

The PMAQ for Sofia Municipality predicts that the requirements of the ADLV for PM_{10} framework will be met in 2020, but this is based on the projected implementation of measures aimed at Residential combustion. The results of the annual bulletin for the AAQ for 2020 are indicative for the lack of effective measures implemented: almost all MS on the territory of Sofia have registered more than 35 exceedances of ADLV for PM_{10} , including in the MS "IAOS/ Pavlovo" and MS "Gara Yana". [4]

The PMAQ for Pernik Municipality predicts that the AAQ indicators will not be met in relation to the permissible number of exceedances of ADLV for PM_{10} . The results of the annual bulletin for AAQ for 2020 confirm this prediction. [4]

The prediction for achieving the established AALV for $PM_{2.5}$ cannot be confirmed due to a lack of sufficient number of registered data. In 2020, MS "Rojen" registered high value of $PM_{2.5}$ - $4.08 \mu g m^{-3}$, which is 20 % of the 2020 AALV of $20 \mu g m^{-3}$.

Both PMAQs predicted a disturbance in the AAQ with respect to the PAH indicator, but due to a lack of published information, this could not be confirmed. Information on the recorded concentrations of PAH during the year is presented in the National Report on the State and Protection of the Environment. The last published national report in 2021 is for 2019.

Urgent measures are needed for the implementation of the Sofia Municipality project "Improving ambient air quality in Sofia Municipality by replacing solid fuel heating devices with environmental alternatives", funded under operational program "Environment 2014-2020". Any further delay in the absorption of funds for replacing solid fuel heaters with environmental alternatives, is a real danger for the AAQ under the three indicators and for the current year 2021.

The lack of financial resources for the Pernik Municipality and the delay in the implementation of the measures of the Program aimed at „Residential combustion“ lead to a violation in the established norms for the indicators under consideration.

4. CONCLUSIONS

Based on the analyses, estimates and conclusions in the PMAQs for Sofia Municipality and Pernik Municipality, the following main conclusions may be drawn:

- for both municipalities, and for the whole country, there is a serious transmission (incl. transboundary) of PM_{10} and $PM_{2.5}$, which significantly hinders the effective implementation of measures to ensure compliance with the established AAQ standards;

- the absence of PAH in the fine particulate matter caught in the extra-urban background MS "Kopitoto" and the complex background MS "Rojen" prove that the sources of PM from external sources do not originate from Residential combustion;
- the most significant source of ambient air pollution for both municipalities is Residential combustion during the heating season;
- the delay or lack of absorption of the funds under operational Plan "Environment 2014-2020" for the replacement of solid fuel heaters with environmental alternatives is one of the main reasons for the recorded exceedances of the permissible number of ADLV for PM₁₀ for both municipalities;
- the industry does not have a material impact on the AAQ in terms of the indicators concerned for both municipalities.

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