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ANALYSIS OF AIR TEMPERATURE AND POLLUTANT ARIATIONS IN SOFIA

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Abstract

Urban climate is the most modified by humans among local climates. Industry, traffic and heating emit artificial heat, water vapor and pollution to the atmosphere. Air pollution and air temperature are becoming ones of the major factors for the quality of life of urban dwellers. The aim of present paper is to analyze the temperature conditions in Sofia, Bozhurishte and Bankya. For this purpose long term (1961–2011) meteorological data of their stations were used. The amendment of certain atmospheric pollutants, observed in southwestern areas of Sofia city – Hipodruma and Pavlovo, where there is high urbanization, intensive traffic and industrial activity is studied too. The relationship between pollutants and the temperature has been examined.

Key words: air pollutants, climate, temperature extremes, threshold.

Aims and Background

Urban climate is the most modified by humans among local climates. Industry, traffic and heating emit artificial heat, water vapor and pollution to the atmosphere. Air pollution and air temperature are becoming ones of the major factors for the quality of life of urban dwellers, posing a risk both to human health and to the environment (Berlyand 1985, Vassilev et al. 1989, Batchvarova et al. 1996, Dimitrova 2001, Zujic et al. 2005, Doncheva-Boneva and Koleva-Lizama 2013, Kadinov et al. 2014). The anthropogenic impact on climate is unique in Sofia (Blaskova et al. 1983, Blaskova and Lingova 1991). After 1965 the city has been expanding, increasing the number of floors of buildings, formation of new residential neighbourhoods, increasing industrial and other areas. Sofia is the largest city and industrial center in Bulgaria, in which territory there are operating a number of industrial enterprises, half of which are among the residential areas or adjacent to them. From the industry activities directly in the air are discharged sulphur, nitrogen and carbon monoxide, dust and carcinogenic substances. The number of vehicles that emit large amounts of harmful gases is increasing. The peripheral low-rise neighbourhoods of the city are using inefficient domestic heaters. These various sources concentrated in a relatively small area lead to changes in weather elements and

the formation of the 'urban environment'. The aim of the study is to investigate the characteristics of temperature conditions in Sofia, their changes under the influence of urbanization and the amendment of certain atmospheric pollutants in the central part of town.

Object and Methods

The city of Sofia is situated in the central and southern parts of Sofia hollow with mean altitude of about 580 m. Sofia hollow valley itself consists of two parts: the bottom (often called 'field') and the surrounding mountain slopes. The climate in this region of Bulgaria has a continental character (Stanev et al. 1991). Meteorological data from 'Vasil Levski' Square station (1), Meteorological Observatory (2) and Central Meteorological Station (3), situated in Sofia city, are used. Data from suburban stations – Bozhurishte and Bankya are used too. In order to investigate the temperature changes methods of complex climate science and mathematical statistics are used (Koleva-Lizama and Rivas 2004). In addition, the amendment of certain atmospheric pollutants, observed in southwestern areas of Sofia city – Hipodruma and Pavlovo, where there is high urbanization, intensive traffic and industrial activity is studied too. Analysis and assessment of air pollution in the selected area is made based on validated data provided by the Executive Environment Agency (EEA). Information includes 1-hour concentrations of the measured pollutants and meteorological elements for the period 2009–2013. The temperature and air pollutants database are systematized for each year. The average annual concentrations, maximum daily average and number of exceedances per year are determined. The evaluation of the database was performed using the existing regulations, lower limit values and overall assessment thresholds. The relationship between pollutants (SO_2, NO_2, PM10) and the temperature has been studied.

Results and Discussion

In the region of Sofia and its surroundings are situated several weather stations, with which the local temperature of the city and surrounding area can be characterized (Fig. 1). The coldest month is January with an average monthly temperature of minus 1.7 °C. In the early spring and mainly in March in line with the increase of day and the solar height occurs an increase in the radiation sheet. The spring conditions in the region are relatively cooler that autumn ones. The average annual temperature of the spring (March, April,

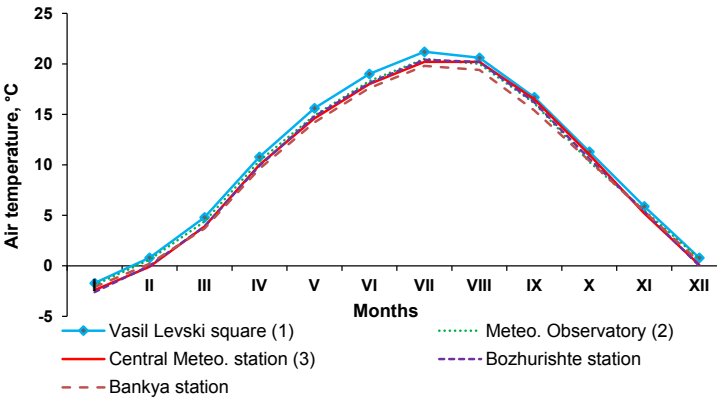

Fig. 1. Mean monthly air temperature.

May) is about 1 °C lower than that for the autumn (September, October, November). The warmest month of the year is July, but sometimes it is August. The annual temperature range in Sofia is 23 °C. The measured lowest and highest temperatures were minus 31.1 °C (abs. min) and 40.2 °C (abs. max).

The largest difference between urban and suburb stations can be seen in the warm part of the year.

The statistical parameters of annual air temperature in studied meteorological stations are shown in Table 1.

Table 1. Statistical parameters of annual air temperature (1961–2011).

Station	Latitude	Longitude	H, m	Mean, °C	Min, °C	Max, °C	σ	As	Es	Cv
Sofia Central Meteostation	42°39'13.16"	23°22'58.43"	584	10.2	8.9	11.7	0.62	0.44	-0.23	0.061
Bankya	42°42'17.94"	23°9'3.10"	640	9.5	8.5	10.8	0.49	0.30	0.01	0.052
Bozhurishte	42°45'12.46"	23°12'24.09"	554	9.8	8.4	11.4	0.63	0.31	-0.29	0.064

The average annual temperature in Sofia Central meteorological station is 10.2 °C, in Bozhurishte – 9.8 °C and in Bankya – 9.5 °C. The average annual temperature of the city is higher than the surrounding areas with 0.4 °C to 0.7 °C, demonstrating the differences in temperature inside and outside the city. The greatest difference between the city and its environs is in the minimum temperatures (Fig. 2). Their values are negative from December to March. The average monthly minimum temperature during the period for Sofia (1) and Sofia (3) varies from -4.8 °C to -6.2 °C. The highest minimum temperatures are in July. The weather is warmest in the city center near 'Vasil Levski' Square (Sofia 1). The decisive factor determining the higher minimum temperatures in the city during the winter months are significantly reduced effective radiation and resulting from anthropogenic activity in the city.

The analysis of temperature conditions is essential to study the maximum values that determine the evaporation and superheating of enclosed spaces in the central parts of the urban environment (Fig. 3).

During the cold part of the year, the lowest maximum temperatures were measured in January, and the average monthly values were within 1.3 °C and 1.6 °C. The highest values of maximum temperatures were recorded in July and August. The average monthly maximum of air temperatures in urban stations in Sofia was between 26.5 °C and 27.2 °C in August and in the outskirts was between

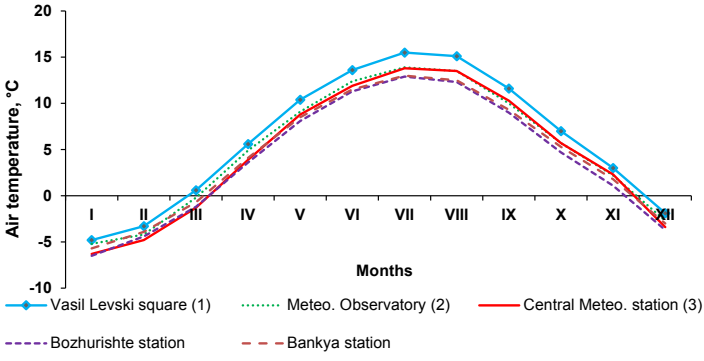

Fig. 2. Average monthly minimum air temperature.

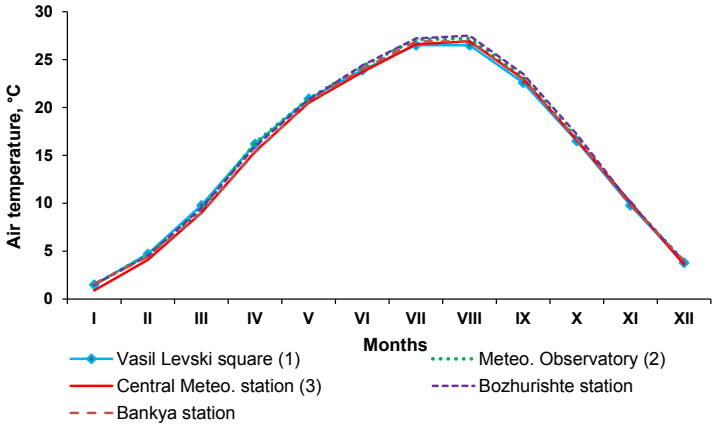

Fig. 3. Average monthly maximum air temperature.

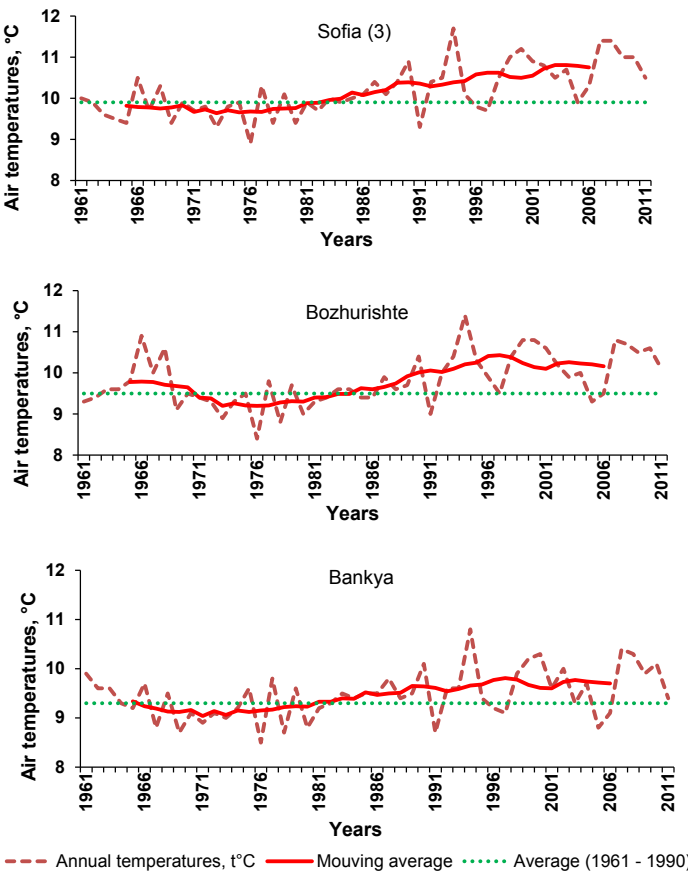

Fig. 4. Mean annual temperatures and their mouving average at Sofia 3, Bozhurishte and Bankya stations.

26.9 °C and 28.1 °C. The lowest maximum of temperatures in July and August were observed in the city center – Station 'Vasil Levski' Square. The main reason for this is that in the afternoon region is located in the shade of large trees. The winter season does not affect the maximum temperature.

The dynamics of annual temperatures and their moving average values observed in the region of Central Meteorological station, Bozhurishte and Bankya is shown in Figure 4.

The annual temperature tends to increase after 1982. The temperature increase in the last decade is most pronounced.

In this study amendment of the annual concentrations of some pollutants in the selected areas of Sofia city – Hipodruma and Pavlovo were examined. The average annual sulphur dioxide concentration is shown in Figure 5. It varies in the range of 7.4 mg/m^3 to 13.4 mg/m^3 without pronounced difference between the two districts. The highest values were observed in 2011, and the lowest – in 2013.

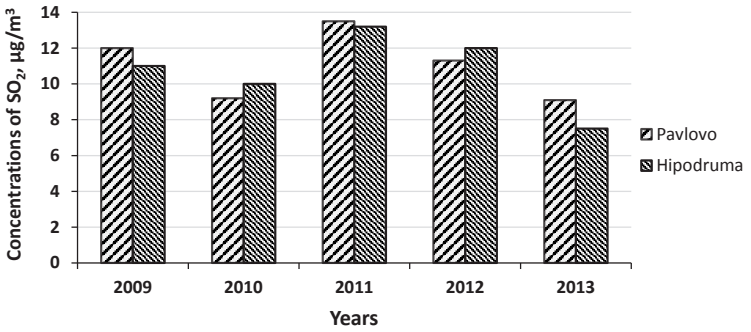

Fig. 5. Average annual concentrations of SO_2.

The higher concentration of SO_2 can be explained by the cold winter.

The annual average concentration of NO_2 ranged from 28.94 µg/m^3 to 43.00 µg/m^3 in the area of district Hipodruma and from 32.55 µg/m^3 to 41.78 µg/m^3 in the district Pavlovo (Figs 6 and 7). The values of annual average

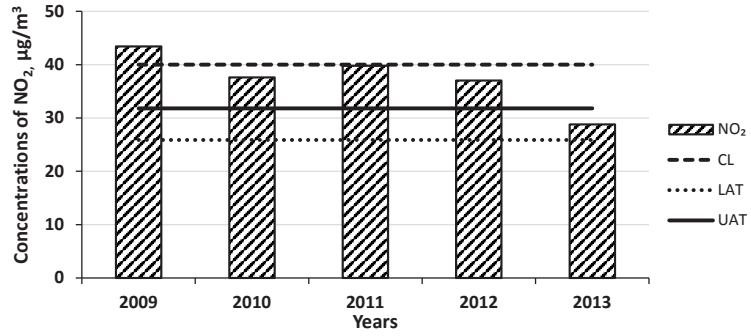

Fig. 6. Average annual concentrations of NO_2 – Hipodruma.
Legend: CL – Critical levels for the protection of health; LAT – Lower assessment threshold; UAT – Upper assessment threshold.

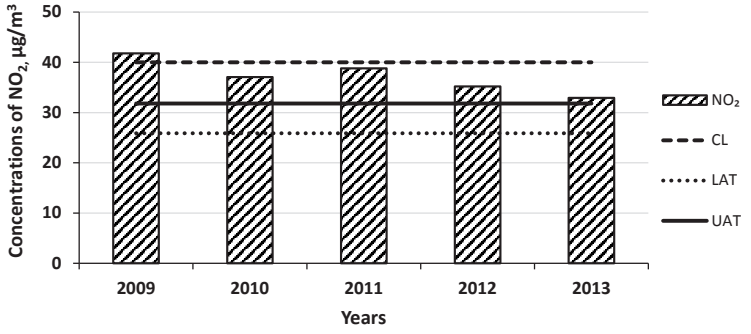

Fig. 7. Average annual concentrations of NO_2 – Pavlovo.
Legend: CL – Critical levels for the protection of health; LAT – Lower assessment threshold; UAT – Upper assessment threshold.

concentrations exceed the assessment thresholds in all years.

The average annual concentration of PM10 (particulate matter < 10 micrometers) are shown in figures 8 and 9.

The average annual concentration of PM10 ranged from 41.53 μg/m^3 to 62.81 μg/m^3 in the district Hipodruma (Fig. 8) and from 43.17 μg/m^3 to 59.73 μg/m^3 in Pavlovo (Fig. 9). There were increases in 2011. Exceedances of the limit value (40 μg/m^3) are observed in all years. The assessment of temperature influence on contaminants is conducted by means of correlation analysis. The values of obtained correlation coefficients between daily concentrations of major pollutants with data of diurnal air temperature in areas of Pavlovo and Hipodruma station are shown on Table 2.

In Pavlovo region (Table 2) air temperature have relatively little impact on nitrogen oxides (r = -0.29 – -0.45) and particulate matter (r = 0.25 – 0.44). More significant influence of air temperature is on sulphur dioxide (r = -0.44 – 0.70) and ozone (r = 0.45 – 0.79). In Hipodruma region (Table 2) air temperature have relatively little impact on nitrogen oxides (r = -0.23 – -0.38) and particulate matter

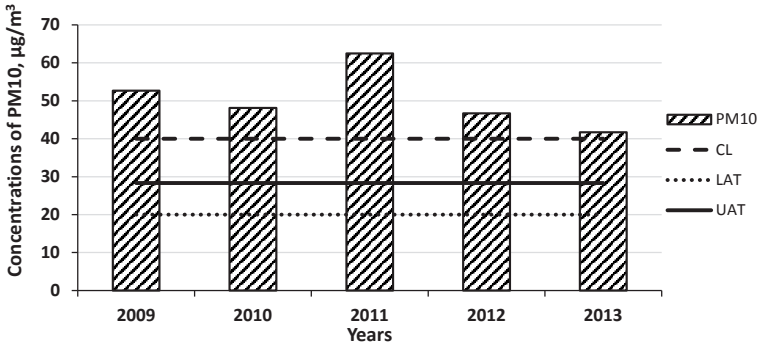

Fig. 8. Average annual concentrations of PM10 in Hipodruma.
Legend: CL – Critical levels for the protection of health; LAT – Lower assessment threshold; UAT – Upper assessment threshold.

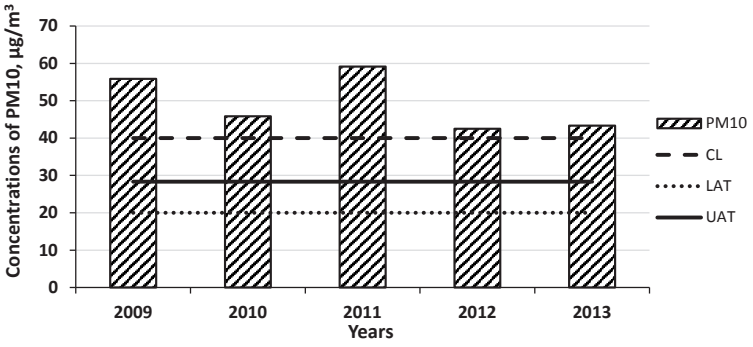

Fig. 9. Average annual concentrations of PM10 in Pavlovo.
Legend: CL – Critical levels for the protection of health; LAT – Lower assessment threshold; UAT – Upper assessment threshold.

Table 2. Correlations between daily concentrations of air pollutants and temperature in the area of Pavlovo and Hipodruma.

Air pollutants	Years				
	2009	2010	2011	2012	2013
		Pavlovo			
NO, mg/m^3	-0.291	-0.292	-0.452	-0.360	-0.345
NO_2, mg/m^3	-0.125	-0.236	-0.461	-0.282	-0.289
NOx, ppb	-0.254	-0.285	-0.466	-0.343	-0.334
O_3, mg/m^3	0.454	0.520	0.795	0.649	0.662
SO2, mg/m^3	-0.436	-0.583	-0.704	-0.613	-0.557
PM10, mg/m^3	-0.251	-0.272	-0.439	-0.338	-0.353
		Hipodruma			
NO, mg/m^3	-0.280	-0.230	-0.383	-0.308	-0.342
NO_2, mg/m^3	-0.231	-0.269	-0.370	-0.269	-0.359
NOx, ppb	-0.275	-0.246	-0.389	-0.305	-0.366
O_3, mg/m^3	0.565	0.449	0.611	0.432	0.525
SO_2, mg/m^3	-0.354	-0.588	-0.612	-0.525	-0.325
PM10, mg/m^3	-0.258	-0.246	-0.404	-0.314	-0.347

PM10 (r = 0.25 – 0.40).

More significant influence of air temperature is on sulphur dioxide (r = -0.32 – 0.61) and ozone (r = 0.43 – 0.61).

Conclusion

The obtained results showed that:

• The average annual temperature in the city is higher than in the surrounding areas with 0.4 to 0.7 °C approximately. In recent years, temperatures in Sofia have increased on average with about 1.2 °C, being more expressed in 1996 and over the past 3 years.

• Air quality in Sofia is poor, as the main reason for this is the high concentration of PM10. The average annual concentrations of PM in Pavlovo and Hipodruma exceed acceptable norm for the entire period (2009–2013). The highest rates were recorded in 2011 and 2009 as a result of lower temperatures during those years.

• In the studied areas of Sofia city air temperature have relatively little impact on nitrogen oxides and PM10. More significant influence of air temperature is on concentration of sulphur dioxide and ozone.

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