ASSESSMENT OF THE AIR POLLUTION WITH PARTICULATE MATTERS IN URBAN AND OUTDOOR REGIONS OF SOFIA

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Abstract

Air pollution with dust and particulate matter (PM) is a global problem. A major source of PM in urban environments is road transport (Schauer et al 1996 [12], Kleeman et al 2000 [2]), which directly or indirectly influences their levels. Motor vehicles produce significant amounts of PM by combustion - predominantly fractions <2.5 μm (Mulawa et al., 1997 [6]; Sagebiel et al., 1997 [11]) and the wear of tires and brakes (Pierson and Brachaczek, 1983 [9]; Rogge et al 1993 [10]; Garg et al 2000 [1]). In addition, they indirectly contribute to the increase of PM concentrations by suspending road dust (Kupiainen et al 2005 [3]) from unpaved roadside sections (Moosmüller et al 1998 [5]) and its resuspension from the surface of the lanes (Nicholson et al. 1989 [8], Sternbeck et al. 2002 [13]).

Keywords: *particulate matter, meteorological elements, correlation coefficients, air pollution*

1. INTRODUCTION

Unlike atmospheric gases characterized by a certain chemical structure and physical properties, PM in urban environments varies in size, shape and chemical composition (Limbeck and Puls, 2010 [4]). Size and chemical composition are some of their most important characteristics as they differentiate their different physicochemical properties. PM, especially fine fractions, also have a secondary origin whose precursors are sulphur-dioxide, nitrogen oxides and ammonia.

In most Bulgarian cities, PM levels reach 60-80 μg / m^3. Air pollution with PM_{10} is a major air quality issue throughout the country (National Report on the Status and Environmental Protection in 2012 [7], EEA). This fact is extremely worrying because PM_{10} damages lung tissues and those smaller than 2.5 μm reach the alveoli from where they spread into the blood and through it to all organs and systems in the human body.

1.1. Purpose of the study

Assessment of the atmospheric air pollution with Fine Particulate Matter (PM) in the urban and outdoor areas of Sofia and its correlation with some meteorological elements (temperature and relative humidity of the air, the intensity of the solar radiation and wind direction).

2. SUBJECTS AND METHODS

2.1. Subjects

Subjects of the research are two regions - "Hipodruma", Sofia and the "Kopitoto" area - Nature Park Vitosha. The territory of "Hipodruma" district is under the influence of emissions from vehicles and domestic sources, and the "Kopitoto" area, located at 1340 m above sea level, is under the influence of harmful substances.

2.2. Methods

The estimation of the air pollution with PM_{10} and the correlation with some meteorological elements is based on the interpretation of statistical data from measurements of selected indicators, taken on an hourly base for a period of 5 years (2009 - 2013). Average daily (24-hour), average seasonal and average annual values are calculated as well as correlation coefficients (in Excel). For the estimation of air pollution with PM, the permissible standards published in Directive 2008/50/EC have been applied. Output data is provided by the Executive Environment Agency, the measurements are carried

out by an automatic measuring station (AMS) with continuous mode of operation. PM_{10} concentrations are determined by the absorption of beta-rays after separation in a PM_{10} head (BDS EN14907: 2006).

3. RESULTS

From the analysis of the change of the main meteorological elements (air temperature and humidity) at the AMS stations - "Hipodruma" and "Kopitoto" for the period 2009 - 2013 (Figure 1) it was found that the maximum air temperature in most of the years (excluding 2012) is observed in August, and the minimum is in January. In the area of "Hipodruma", the August temperatures are in the range of 22 and 25°C and this may be due to the influence of the city's heat island. By approaching Vitosha, the monthly air temperatures decrease by 1-2°C. At "Kopitoto", the monthly air temperatures during the summer months are decreased, with July and August's temperatures ranging between 19-22°C, which is related to the influence of the altitude and the distance from the city's influence. The hottest year is 2012, and coldest are 2009 and 2011 years.

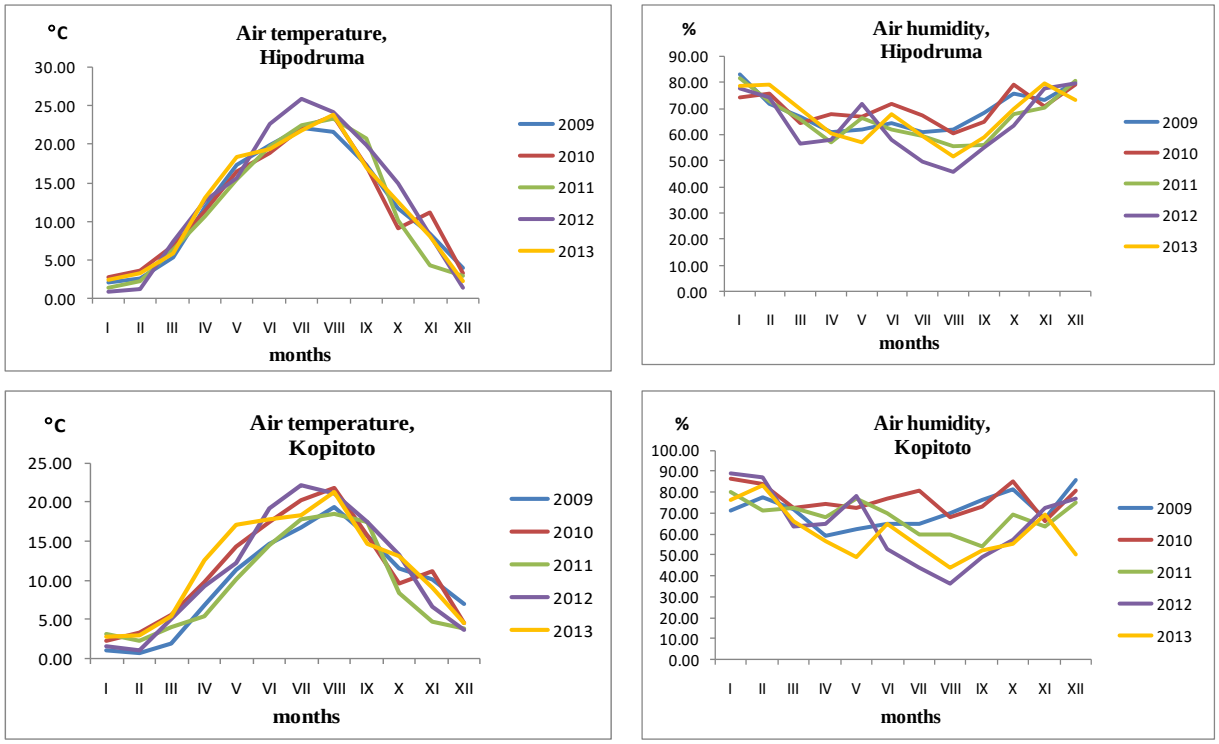


Figure 1. Yearly distributions of air temperature and humidity for “Hipodruma” and “Kopitoto” differentiated by years

The air humidity is characterized by a maximum in January and a minimum in August (Figure 1), which confirms the proportional correlation between the thermal conditions and the air's saturation with moisture. During the different years, the monthly values fluctuate sharply, which is most pronounced at "Kopitoto".

Due to the higher temperature in the city, there is a tendency for a lower relative humidity with 2-3% and a higher humidity deficiency of 1-2%, which occurs most frequently in August. The most humid year is 2010, and the least - 2012.

The average annual concentrations of PM_{10} in “Hipodruma” range from 41.53 μg / m^3 in 2013 to 62.81 μg / m^3 in 2011 (Figure 2). An increase in the values is observed for the year 2011 and a decrease -

towards the end of the period. In all years, the permissible rate (40 μg / m^3) was exceeded, with 57% and 37% respectively in 2011 and 2009, which is the result of the lower temperatures during those years and the higher influence of domestic heating in the overall emissions. The excess is at a minimum in 2013 - just 4%.

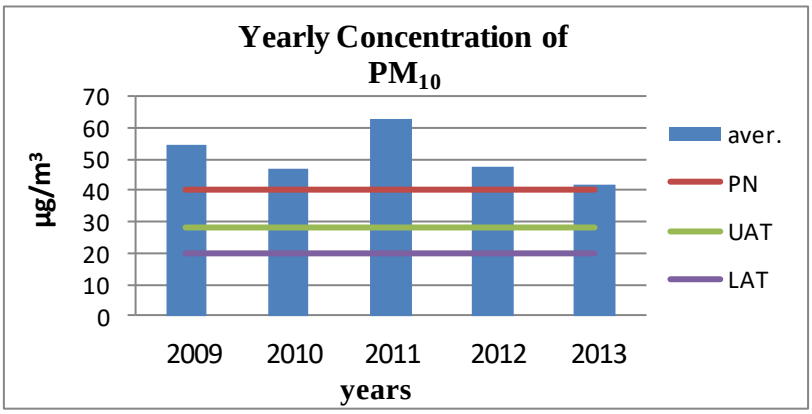
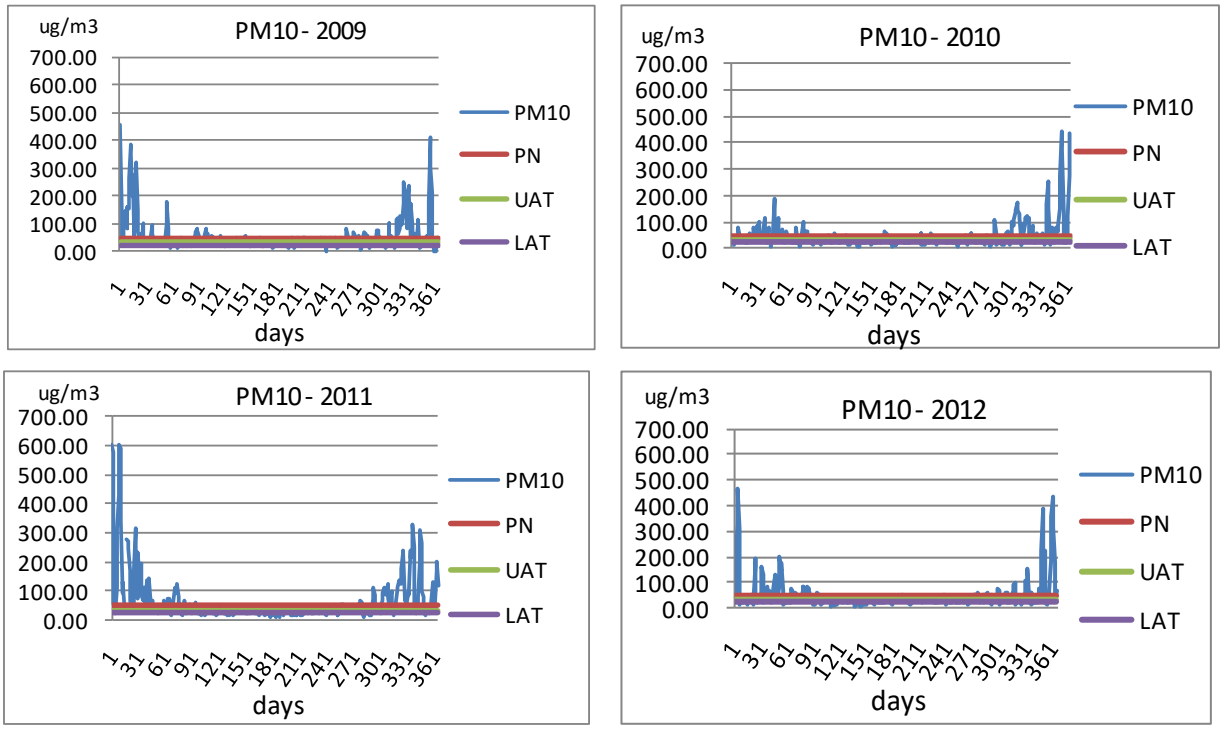


Figure 2. Yearly Concentration of PM_{10} – "Hipodruma"

The maximum daily average concentrations of PM_{10} in individual years reach from 7.5 to 12 times the Permitted Limit (PL) (Figure 3). The highest values were measured in 2011. Days with PL exceedances are significantly more than the allowed (35) per year. The highest number of days during which the PL of PM_{10} was exceeded, has been observed in 2011 - 106, while the lowest has been observed in 2013 - 72 days. For the remaining years, for about 3 months (80-95 days) of the year, pollution with PM_{10} is detected, mainly during the autumn-winter period (January and December).



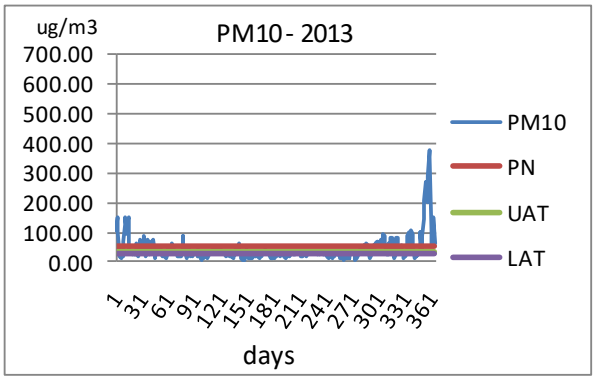


Figure 3. Average daily concentration of PM10 – "Hipodruma"

For the "Kopitoto" region, the average annual concentrations of PM_{10} for the period 2009-2013 range between 16.37 μg / m^3 in 2013. and 22.33 μg / m^3 in 2011. The established values do not exceed both the Permitted Limit (PL) and the Upper Assessment Threshold (UAT). In three of the years, the lower assessment threshold was negligibly exceeded (Figure 4). There is a slight increase in the PM_{10} quantity from 2009 to 2011, but it declines again towards the end of this period. In 2009 and 2010 the values are very close - 20.06 μg / m^3 and 20.37 μg / m^3 respectively.

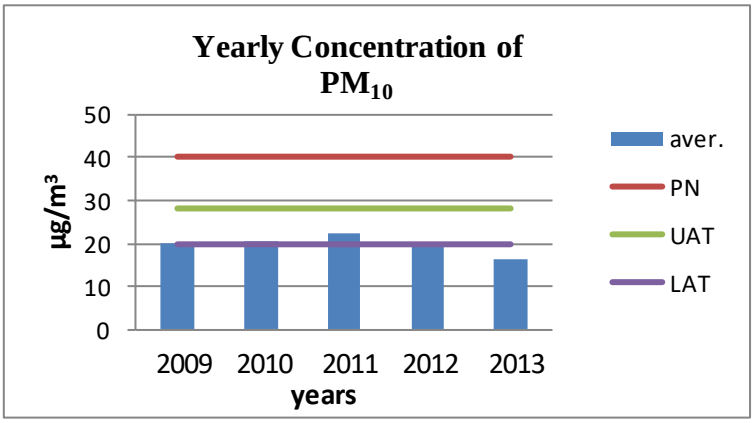


Figure 4. Yearly Concentration of PM_{10} – "Kopitoto"

The average daily concentrations of PM_{10}, measured at the "Kopitoto", vary within narrow limits and only in individual cases exceed the Permitted Limit (PL). This has been observed most often in 2010 - 19 days and 2011 - 14 days (Figure 5). For these periods, the maximum daily concentrations were measured - 3 times the PL. Unlike "Hipodruma", "Kopitoto" is characterised by a summer peak in the PM_{10} concentration.

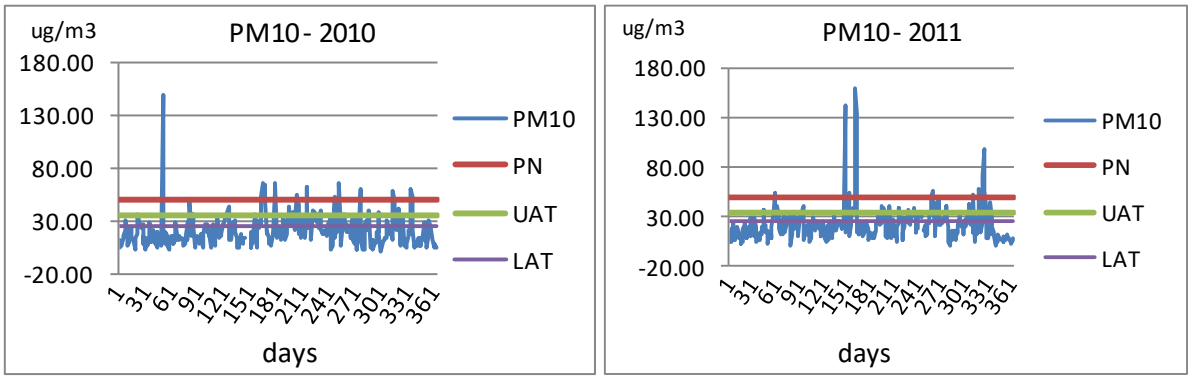


Figure 5. Average daily concentration of PM10 – "Kopitoto"

The assessment of the influence of the meteorological elements on the PM_{10} air pollution was carried out using a correlation analysis while correlations were sought between them.

Table 1 shows the values of the correlation coefficients based on daily PM_{10} concentrations and daily data about: air temperature, solar radiation intensity, atmospheric pressure, air humidity and wind speed in the "Hipodruma" area.

Years	2009	2010	2011	2012	2013
PM10, μg/m^3					
Temperature °C	-0,258	-0,246	-0,404	-0,314	-0,347
Solar Radiation Intensity W/m^2	-0,254	-0,199	-0,367	-0,263	-0,309
Atmospheric Pressure hpa	0,134	0,139	0,247	0,201	0,199
Relative Humidity %	0,173	0,151	0,302	0,239	0,218
Wind Speed m/s	-0,234	-0,283	-0,326	-0,262	-0,295

Table 1. Correlation coefficients showing the relation between the daily concentrations of PM10 and the meteorological elements in the "Hipodruma" region.

From the presented data (Table 1) it is established that the greatest influencers of the PM_{10} pollution are: the air temperature (r = -0,25 ÷ -0,44), the intensity of the solar radiation (r = -0,20 ÷ -0.31), and the wind speed (r = -0.23 ÷ -0.33), with constantly negative correlation for the whole period. The influence of the atmospheric pressure and the relative air humidity is weaker but with a positive correlation. The connection of the air pollution with PM_{10} and the relative humidity and atmospheric pressure in 2011, which are characterized by the highest levels of PM and the lowest temperatures, is more pronounced. In this case, the PM is influenced by household sources, mostly during the cold months of the year, and of secondary origin - when the air humidity is important.

Table 2 shows the values of the correlation coefficients obtained between daily PM_{10} concentrations and the daily data for the meteorological elements in the "Kopitoto" region.

Years	2009	2010	2011	2012	2013
PM10, μg/m^3					
Temperature °C	0,444	0,432	0,330	0,519	0,522
Solar Radiation Intensity, W/m^2	0,353	0,251	0,138	0,431	0,406
Atmospheric Pressure, hpa	0,210	0,096	0,051	0,300	0,203
Relative Humidity %	-0,267	-0,126	-0,047	-0,374	-0,359
Wind Speed m/s	-0,248	-0,198	-0,168	-0,279	-0,288

Table 2. Correlation coefficients showing the relation between the daily concentrations of PM10 and the meteorological elements in the “Kopitoto” region.

The biggest determinants for the fine particle pollution, with most pronounced positive correlation, are air temperature (r = 0.33 ÷ 0.52) and the intensity of solar radiation (r = 0.14 ÷ 0.43). In some years, the influence of wind speed, atmospheric pressure and relative humidity are increased. The correlation between the PM_{10} concentration and wind speed and relative humidity is negative. The most pronounced is the dependence between PM_{10} and the weather elements in 2012, which is the driest year from the period. In this case, it is influenced by natural sources and transmission, which are caused by convective movements of air masses.

4. CONCLUSIONS

For the period under review, the hottest year is 2012 and coldest are 2009 and 2011. The wettest is 2010 and the driest - 2012. Due to the higher temperature, in the city (Hipodruma) there is a tendency for lower relative humidity by 2-3% and higher humidity deficiency by 1-2%, which occurs most often in August.

The air quality in “Hipodruma” is degraded. For the whole period, the average annual PM_{10} concentration values exceed the Permitted Limit (PL), while at the “Kopitoto”, they are 2 times lower than the norm. The highest values were recorded in 2011 and 2009, which is the result of lower temperatures during these years and higher contribution from domestic heating sources. The frequency of air pollution levels in "Hipodruma" is relatively large - about 2 to 3 months per year.

The maximum daily concentrations exceeded the PL from 7.5 (2013) up to 12 (2011) times in the "Hipodruma" and up to 3 times at “Kopitoto”. Seasonality is typical for the PM levels, with maximum values in the cold months - January, December in the urbanised areas and a summer maximum for "Kopitoto". This is a result of the nature of the emissions' sources and the weather conditions.

The greatest impact on the air pollution with PM_{10} have the air temperature, the intensity of the solar radiation and the wind speed. Regarding the temperature and the relative humidity of the air, correlations in the urban and suburban environments are observed, which is also related to the origin of the PM_{10}.

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