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Statistical analysis of ambient air PM10 contamination during winter periods for Ruse region, Bulgaria

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Abstract. The sources of dust on the territory of Ruse region, Bulgaria are industry, transport and domestic heating by solid fuel. PM10 (particulate matter with a diameter between 2.5 and 10 μm) levels for Ruse mark a significant increase during the autumn-winter period compared to the levels during the spring-summer period [1]. Obviously there is a relationship between PM10 contamination levels and ambient air temperature. The lower the temperatures are, the higher the PM10 levels are. The biggest peak of PM10 levels for the autumn-winter period is usually observed in January months. It is in January that the number of days in which there is exceedance of the limit values of the PM10 levels is maximum observed. Also in January months the day and night temperatures are the lowest and usually they do not pass 0°C for many days of the month. To understand better this relationship we provide a statistical analysis of ambient air PM10 contamination during winter periods. Correlations between the measured PM10 values and the respective temperatures measured for January months for different years are presented. Descriptive statistics of PM10 and some atmospheric characteristics as well as linear regression analysis are calculated and commented in the paper.

1 Introduction

According to European Commission surveys, every year poor air quality causes the premature death of more people than the road accidents. Ambient air contamination by fine particulate matter (PM10) mainly is result of human activities - transport, industry and domestic heating. Nowadays this pollutant cause more and more respiratory problems, asthma, lung cancer and premature death.

The problem of PM10 air pollution is very serious. For Bulgaria it is clear that sources of PM10 pollution come mainly from old cars usage and from solid fuel stoves for heating. The combination of these factors leads to a worsening of the ecological situation which consequently leads to serious damages to human health.

Besides the above mentioned human factor also some climate and meteorological conditions probably contribute to the increase of PM10 levels. It is known that the factors which affect PM10 levels are air temperature, humidity, atmospheric pressure, presence or absence of wind, wind direction and so on.

The relationship between the PM10 levels measured by the automated measuring station in Ruse, Bulgaria and the ambient air temperatures for several January months is analyzed in this paper. The January months of the period 2011 – 2017 are chosen, as most of the days

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with the exceedance of the PM10 limit values are usually observed during this period of the year [1].

2 Material and methods

The period selected for the purpose of the survey covers 7 recent years (since 2011 to 2017).

We use official data for measured PM10 concentrations for Ruse, Bulgaria, for January months (2011 – 2017) published by Regional Inspectorate of Environment and Water [3]. We use SPSS software to analyze the data measured in January months in Ruse, Bulgaria for the period 2011 – 2017.

3 Results and comments

On the Figures 1 - 7 the measured levels of PM10 for Ruse are presented [3]. It is obvious that the characteristics of these levels are quite different and there are many days each year when the PM10 level is much more than the daily limit value (50 µg /m^3)

All graphs (Fig. 1 – Fig.7) are summarized on Fig 8.

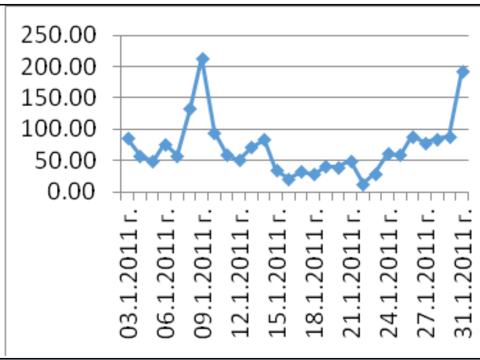

Fig. 1 PM10 concentration (µg /m^3) for January 2011

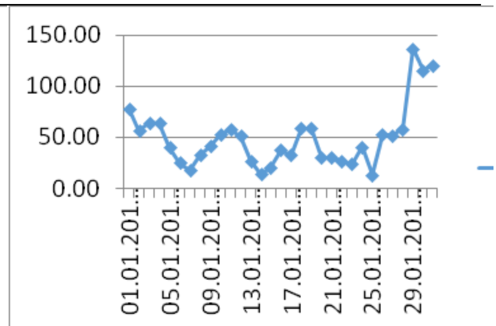

Fig.2 PM10 concentration (µg /m^3) for January 2012

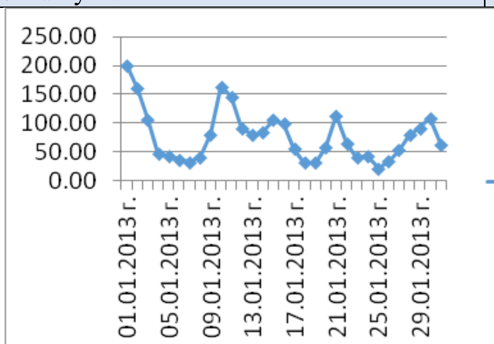

Fig. 3 PM10 concentration (µg /m^3) for January 2013

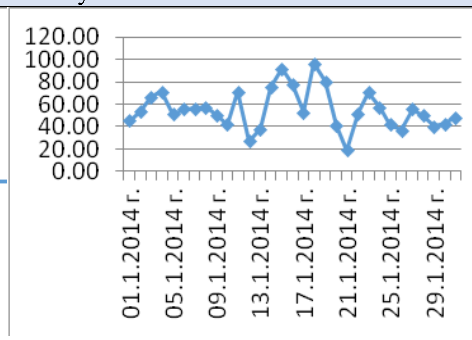

Fig. 4 PM10 concentration (µg /m^3) for January 2014

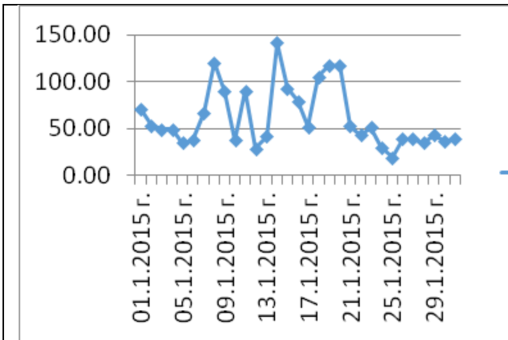

Fig. 5 PM10 concentration (µg /m^3) for January 2015

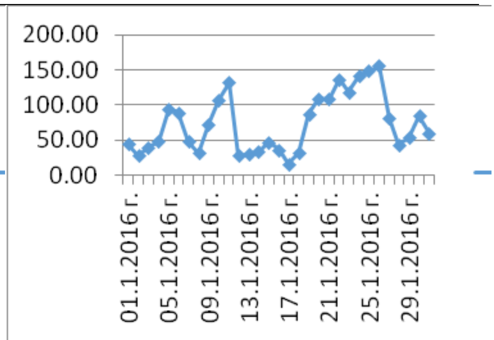

Fig. 6 PM10 concentration (µg /m^3) for January 2016

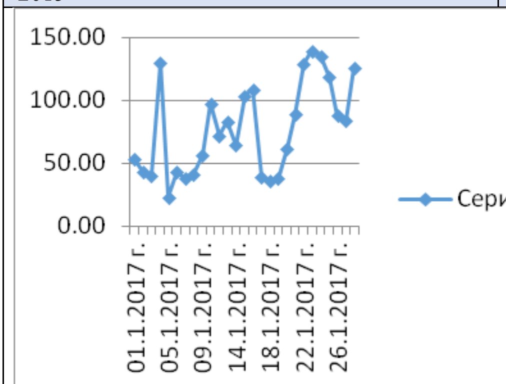

Fig. 7 PM10 concentration (µg /m^3) for January 2017

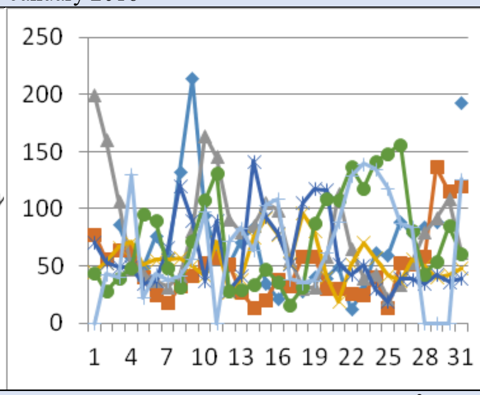

Fig. 8 Daily average PM10 levels (µg /m^3) for January months for the period 2011 – 2017

On the next Table 1 is shown the descriptive statistics of PM10. It is very important that the mean value of the PM10 for the period 2011 – 2017 for Ruse is greater than the limit value of PM10 (50 µg /m^3). The maximum PM10 value is more than 4 times bigger than the limit value.

Table 1. Descriptive Statistics for PM10

	N	Minimum	Maximum	Mean	Std. Deviation
PM10	210	12,50	214,10	66,1521	37,54768
Valid N (listwise)	210				

The average number of days in January that PM10 levels exceeded the limit value for PM10 is 18 days per a month for the period 2011 - 2017. During 2011, 2013 and 2014 20 days have been reported with PM10 concentration measured bigger than the limit value. During 2012 and 2015 only 15 days were registered with PM10 concentration greater than the limit.

The average excess of the PM10 (50 µg / m^3) is 0.86 times for the period.
The largest exceedance of the limit was recorded on 9.01.2011 - 214,1 µg /m^3 which is 4,282 times greater than the norm.

In the years with the highest number of days when PM10 levels are above the limits the average minimum air temperature was -3,13^{0}C and the mean maximum air temperature was 3,11^{0}C.

In the years with the lowest number of days when PM10 levels are above the norm the average minimum temperature was -2.45^{0}C and the average maximum temperature was 4.14^{0}C.

We will examine next the daily average temperatures, measured in Ruse for January months for the period 2011 – 2016, because we suppose that there is a relationship between the PM10 levels and ambient air temperature.

On the Fig.9 the daily average temperatures for January months for Ruse for the period 2011 – 2016 are presented. On Table 2 the descriptive Statistics of these temperatures are presented, too.

The temperatures for the period have small negative mean value, while the interval between the minimum and maximum values is almost 25^{0}C.

Next we calculate Pearson Correlation coefficients between PM10 levels and the measured temperatures.

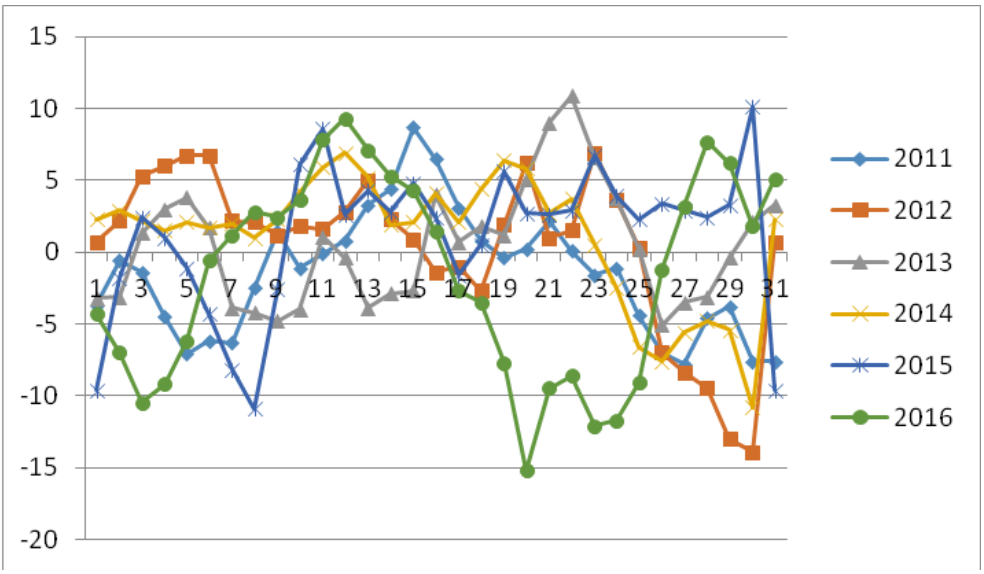

Fig. 9 Daily average temperatures for Ruse for January months for the period 2011 – 2016 [2].

Table 2. Descriptive Statistics for temperature (^{0}C) for Ruse for January months for the period 2011 – 2016

	N	Minimum	Maximum	Mean	Std. Deviation
Temperature	186	-15,20	10,90	-0,0177	5,23151
Valid N (listwise)	186				

On the Table 3 the correlation coefficients between PM10 levels and temperature measured for January months for Ruse for the different years can be seen.

Only for 2012 and 2016 correlations are significant. Pearson correlation coefficient for 2012 is -0,574** and it is significant at the 0.01 level (2-tailed) and Pearson correlation coefficient for 2012 is -0,398* and it is significant at the 0.05 level (2-tailed).

If we calculate the Pearson correlation coefficient for the whole period we receive the result, shown on the next Table 4. The Pearson correlation coefficient for the whole period 2011 – 2016 is -0,283** and it is significant at the 0.01 level (2-tailed). As the Pearson correlation coefficient is negative number then PM10 levels grow up when the temperature go down.

Finally we will develop a linear regression model for PM10 levels (Y) and the ambient air temperature (X) also using SPSS software. The result of the modeling is presented on the next Tables 5 – 7 and on Fig.10.

Table 3.The correlation coefficients between PM10 levels and temperature measured for January months for Ruse for the different years

Correlations for 2011

		X1PM	X1T
X1PM	Pearson Correlation	1,000	-0,308
	Sig. (2-tailed)		0,111
	N	28,000	28
X1T	Pearson Correlation	-0,308	1,000
	Sig. (2-tailed)	0,111	
	N	28	31,000

Correlations for 2012

		X2PM	X2T
X2PM	Pearson Correlation	1,000	-0,574*
	Sig. (2-tailed)		0,001
	N	31,000	31
X2T	Pearson Correlation	-0,574**	1,000
	Sig. (2-tailed)	0,001	
	N	31	31,000

Correlations for 2013

		X3PM	X3T
X3PM	Pearson Correlation	1,000	-0,186
	Sig. (2-tailed)		0,318
	N	31,000	31
X3T	Pearson Correlation	-0,186	1,000
	Sig. (2-tailed)	0,318	
	N	31	31,000

Correlations for 2014

		X4PM	X4T
X4PM	Pearson Correlation	1,000	0,237
	Sig. (2-tailed)		0,200
	N	31,000	31
X4T	Pearson Correlation	0,237	1,000
	Sig. (2-tailed)	0,200	
	N	31	31,000

Correlations for 2015

		X5PM	X5T
X5PM	Pearson Correlation	1,000	-0,111
	Sig. (2-tailed)		0,552
	N	31,000	31
X5T	Pearson Correlation	-0,111	1,000
	Sig. (2-tailed)	0,552	
	N	31	31,000

Correlations for 2016

		X6PM	X6T
X6PM	Pearson Correlation	1,000	-0,398**
	Sig. (2-tailed)		0,027
	N	31,000	31
X6T	Pearson Correlation	-0,398*	1,000
	Sig. (2-tailed)	0,027	
	N	31	31,000

* Correlation is significant at the 0.01 level (2-tailed).
** Correlation is significant at the 0.05 level (2-tailed).

Table 4. The correlation coefficients between PM10 levels and temperature measured for January months for Ruse for the period 2011 - 2016

		PM10	Temperature
PM10	Pearson Correlation	1,000	-0,283**
	Sig. (2-tailed)		0,000
	N	210,000	183
Temperature	Pearson Correlation	-0,283**	1,000
	Sig. (2-tailed)	0,000	
	N	183	186,000

** Correlation is significant at the 0.01 level (2-tailed).

Table 5. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0,283[a]	0,080	0,075	36,08507

a. Predictors: (Constant), Temperature

Table 6. ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	20483,376	1	20483,376	15,731	0,000[a]
	Residual	235685,948	181	1302,132		
	Total	256169,323	182			

a. Predictors: (Constant), Temperature

b. Dependent Variable: PM10

Table 7. Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	64,664	2,668		24,240	0,000
	Temperature	-2,026	0,511	-0,283	-3,966	0,000

Dependent Variable: PM10

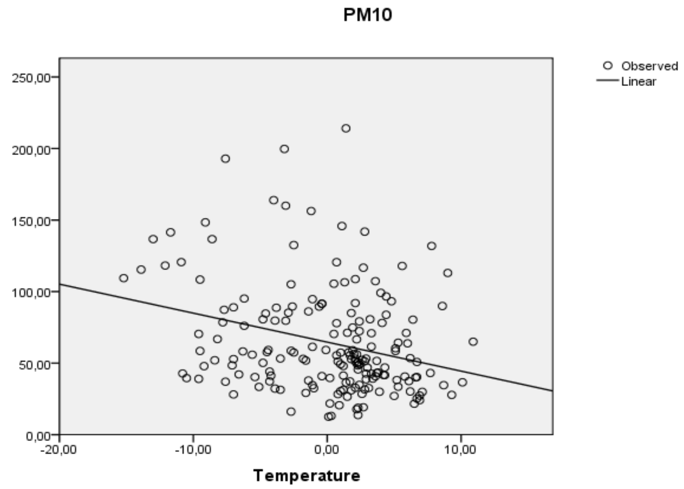

Fig.10. The linear regression model plot (the line) and measure PM10 levels as a function of the temperature (the points)

Therefor the linear regression model is Y = -2,026 + 64,664.X. In the model the both coefficients are statistically significant.

4 Conclusions

There are many factors that influence PM10 levels in the ambient air. Some of them do not depend on human activities but others, such as the use of solid fuel for domestic heating, the industry and the transport affect the PM10 content and can be controlled by man.

For better understudying of the processes which cause contamination of ambient air with PM10 and to realize which are the factors mostly influence the PM10 levels more scientific researches have to be provided.

In order to solve at least partly the air pollution problem, different solutions can be applied. For example by investments in newer urban transport so that the urban transport can be improved to meet better the needs of the population and become a preferred form of transport in the cities and be chosen in front of private cars. Also it is clear that the heat supply in urban zones has to be improved, expand the district heating and gasification network so that people can use their services rather than using solid fuel stoves. Also under certain non-favorable weather conditions, temporary restrictions can be introduced to reduce pollution levels. For example, in such days the use of private cars could be limited.

References

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2. http://www.stringmeteo.com/synop/bgold_stday.php
3. http://www.riosv-ruse.org/mesechna-spravka-za-nivata-na-fpch10.html
   Data on the measured PM10 concentrations by automated measuring station "Vazrazhdane" Ruse (January, 2011; January, 2012; January, 2013; January, 2014; January, 2015; January, 2016; January, 2017).