Air pollution with fine particulate matter in the Romanian area of the Lower Danube

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Air pollution with fine particulate matter in the Romanian area of the Lower Danube. *The aim of the paper is to identify regularities of hourly concentrations of fine particulate matter PM10, which can be described by the statistical characteristics of their distributions. Three major problems were solved. A sampling measurement data in automatic stations of the Romanian section of the Lower Danube were presented. The data samples were processed and were determined the empirical distributions of hourly concentrations.*

Key words: *fine particulate matter, air, pollution, distribution.*

INTRODUCTION

The problem of air pollution in the Romanian - Bulgarian border is mutual and actual. Among the countries of the European Union the pollution with fine particulate matter (PM10) in Bulgaria and Romania is significantly high - Fig.1. It is possible that the contamination of the territory of one state to be transferred to the territory of the other country. However, concentrations of air pollutants in the border areas are not bilaterally known. In 2008 it was stopped the exchange of information between the environmental agencies of the two countries. Therefore, the analysis and evaluation of pollution in the boundary is particularly important.

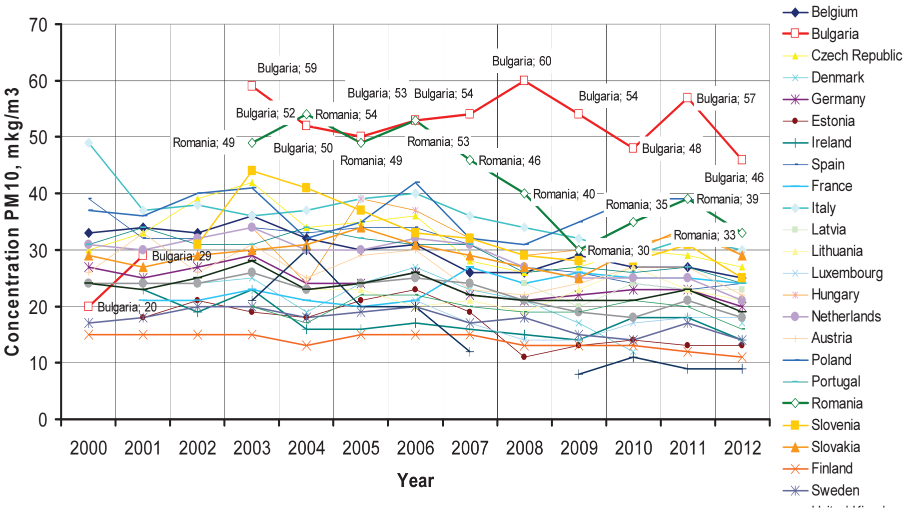

Fig.1. Concentrations of particulate matter (PM10) in European union

So far, the hourly and daily average concentrations of fine particulate matter PM10 as a function of time in a day, by day of the month in astronomical seasons were not statistically tested. It can be carried deep into the lungs where it can cause inflammation and a worsening of the condition of people with heart and lung diseases.

The purpose of the presented paper is to derive the dependencies of the hourly concentrations of PM10, described and simulated through their statistical distributions characteristics. To achieve this purpose, three main tasks are to be solved: 1. Creation of a sampling measurement data of hourly and daily average concentrations from the automatic stations in Romanian section of the Lower Danube; 2. Computer processing of the data samples; 3. Definition of the laws of empirical distributions of concentrations, their parameters and characteristics.

EXPOSITION

1. Method of research.

The samples were formed based on the information of the Executive Environment Agency of Romania during the spring and summer of 2014. A database of concentration values is determined at four measuring stations. Within the county of Teleorman data from station TR-1 in Alexandria and station TR-2 in Turnu Magurele. In Giurgiu County - Station GR-1 and GR-2, which are located in Giurgiu city. Measuring stations CL-1 and CL-2 in Calarasi County, located on the Lower Danube do not function. Hourly concentrations measured at intervals of 1 hour per day for the period from 23 March to 23 September were processed.

Concentrations of contaminants are analyzed as random variables. The empirical laws of distribution are established. The hypotheses are tested with 18 law of continuous random variables: 1) Law of Equal Probability (*Uniform*). 2) Beta distribution (*Betta*). 3) Range - Distribution (*Gamma*). 4) Normal distribution (*Normal*). 5) Triangle distribution (*Triang*). 6) Log - normal distribution (*LogNormal*). 7) Exponential distribution (*Expon*). 8) Logistic Distribution (*Logistic*). 9) log - logistic distribution (*LogLogistic*). 10) Inverse Gaussian distribution (*InvGauss*) - distribution of Gumbel. 11) Weibull distribution (*Weibull*). 14) Distribution of Rayleigh (*Rayleigh*). 15) Distribution of Pearson (*Pearson*). 16) Distribution of Erlangen (*Erlang*). 17) Distribution of extreme value (*ExtrValue*) - distribution of the Wald. 18) Distribution of Pareto (*Pareto*).

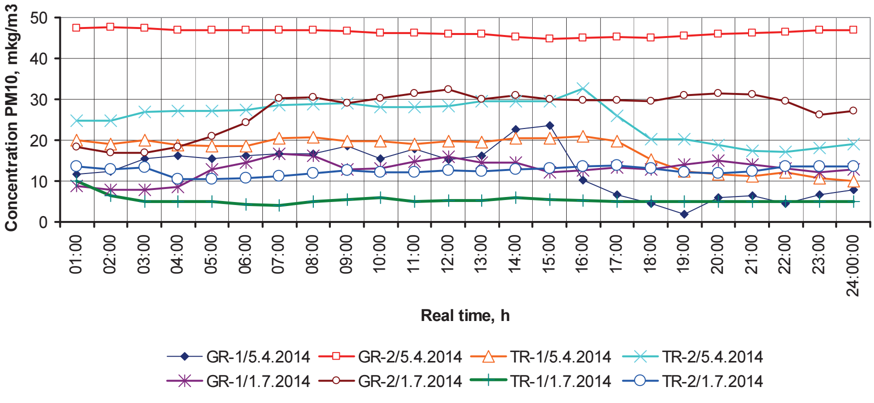

Fig.1. Time series of hourly concentrations of PM10

Hypothesis testing is done by χ^2 criterion of Pearson, criterion of Anderson – Darling and criterion of Kolmogorov - Smirnov. The software program used is Risk 4.5.

12 numerical features were defined: 1) Absolute left (*Left X)* and rigth (*Right X*) variation borders 2) Relative left (*Left P)* and right (*Right P)* variation borders 3) Absolute (*Diff. X)* and relative (*Diff. P)* range, 4) Minimum values (*Minimum)*, 5) Maximum values – (*Maximum)*, 6) Averages (*Mean)*, 7) Mode (*Mode)*, 8) Median (*Median)*, 9) Standard deviation (*Std. Deviation)*, 10) Variation (*Variance)*, 11) Asymmetry (*Skewness)*, 12) Kurtosis (*Kurtosi)s*. Numerical characteristics are defined statistical best for hourly concentrations of fine particulate matter PM10 defined at the measuring stations. Further

are established series *Con (T)* and trend *Trend* of change used for approximation of the empirical values of concentrations.

2. Results of research.

Table 1 shows the numerical characteristics of statistical distributions of PM10 in seasons. Prevailing laws are logistic and logarithmic - logistic distribution. It is noteworthy that the average Mean concentrations in plant GR-2, which is within the central part of Giurgiu, is greater compared to GR-1, which is the output of Giurgiu near the time of intensive traffic. In the County of Teleorman the higher mean concentrations are defined in TR-2 station, which is in Turnu Magurele located at Nikopol. These patterns are established during the spring and summer of 2014

Illustration of levels change hourly concentrations in the four measuring stations are shown in Figure 2.

Table 1. Laws of distribution of daily average PM10 levels during the spring and summer

Spring season							
Station GR-1 Pearson 5 (40.066; 1378.9)		Station GR-2 Logistic (26.7830; 6.6225)		Station TR-1 Logistic (8.5589; 1.9406)		Station TR-2 Pareto (2.3714; 9.0000)	
Minimum	-24.689	Minimum	-Infinity	Minimum	-Infinity	Minimum	9.0000
Maximum	+Infinity	Maximum	+Infinity	Maximum	+Infinity	Maximum	+Infinity
Mean	10.607	Mean	26.7830	Mean	8.5589	Mean	15.5624
Mode	8.8878	Mode	26.7830	Mode	8.5589	Mode	9.0000
Median	10.014	Median	26.7830	Median	8.5589	Median	12.0554
Std. Dev	5.7208	Std. Dev	12.0119	Std. Dev	3.5199	Std. Dev	16.5815
Variance	32.728	Variance	144.286	Variance	12.3894	Variance	274.9472
Skewness	0.6658	Skewness	0.0000	Skewness	0.0000	Skewness	
Kurtosis	3.8498	Kurtosis	4.2000	Kurtosis	4.2000	Kurtosis	
Left X	2.34	Left X	7.28	Left X	2.84	Left X	9.20
Left P	95.00%	Left P	95.00%	Left P	95.00%	Left P	95.00%
Right X	20.89	Right X	46.28	Right X	14.27	Right X	31.83
Right P	5.00%	Right P	5.00%	Right P	5.00%	Right P	5.00%
Diff. X	18.5489	Diff. X	38.9992	Diff. X	11.4280	Diff. X	22.6354
Diff. P	90.00%	Diff. P	90.00%	Diff. P	90.00%	Diff. P	90.00%
Summer season							
Station GR-1 Gamma (1.3671; 6.9139)		Station GR-2 LogLogistic (0.079493; 22.327; 2.0906)		Station TR-1 LogLogistic (-6.3725;18.149; 4.45)		Station TR-2 Normal (16.8245; 6.4139)	
Minimum	-24.689	Minimum	0.079493	Minimum	-6.3725	Minimum	-Infinity
Maximum	+Infinity	Maximum	+Infinity	Maximum	+Infinity	Maximum	+Infinity
Mean	10.607	Mean	33.708	Mean	13.372	Mean	16.8245
Mode	8.8878	Mode	13.646	Mode	10.010	Mode	16.8245
Median	10.014	Median	22.406	Median	11.777	Median	16.8245
Std. Dev	5.7208	Std. Dev	99.508	Std. Dev	8.9795	Std. Dev	6.4139
Variance	32.728	Variance	9901.780	Variance	80.631	Variance	41.1385
Skewness	0.6658	Skewness		Skewness	3.1783	Skewness	0.0000
Kurtosis	3.8498	Kurtosis		Kurtosis	68.3500	Kurtosis	3.0000
Left X	2.34	Left X	5.5	Left X	3.00	Left X	6.27
Left P	95.00%	Left P	95.00%	Left P	95.00%	Left P	95.00%
Right X	20.89	Right X	91.4	Right X	28.77	Right X	27.37
Right P	5.00%	Right P	5.00%	Right P	5.00%	Right P	5.00%
Diff. X	18.5489	Diff. X	85.8427	Diff. X	25.7640	Diff. X	21.1000
Diff. P	90.00%	Diff. P	90.00%	Diff. P	90.00%	Diff. P	90.00%

Daily averaged concentrations were determined by the arithmetic mean with the average statistical laws. In Figure 2 it is shown the time series of mean values. The values of the levels are below the daily limit value of 50 μg/m^3 for the protection of human health according to [1,2].

The laws of distribution of hours and days were established. A excerpt of the laws of the daily average distributions is given in Table 2.

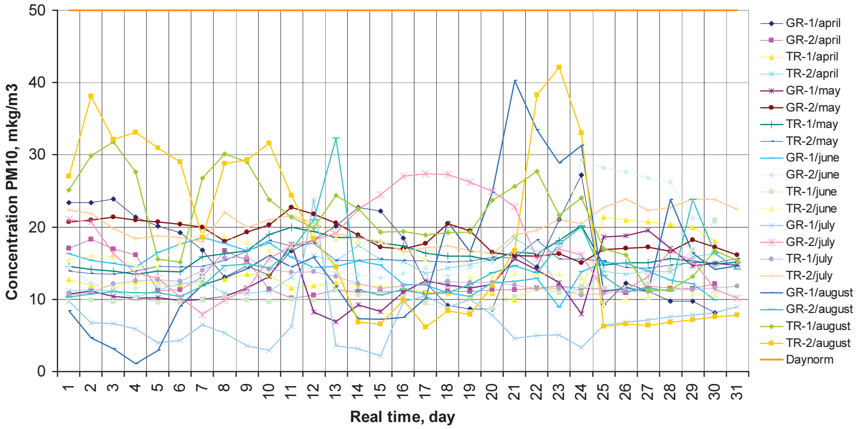

Fig.2. Series the daily PM10 levels determined by the arithmetic average of the levels of pollutants in days per month

Table 2. Statistical laws of daily average concentrations – a sample for the month of May 2014

Test by the criterion γ^2 of Pierson							
Station GR-1 Pareto (3.3075; 9.8629)		Station GR-2 ExtValue (22.0679; 4.5116)		Station TR-1 Logistic (6.85982; 0.35119)		Station TR-2 LogLogistic (11.67; 1.56; 2.57)	
Minimum	9.8629	Minimum	-Infinity	Minimum	-Infinity	Minimum	11.6789
Maximum	+Infinity	Maximum	+Infinity	Maximum	+Infinity	Maximum	+Infinity
Mean	14.1371	Mean	24.6721	Mean	6.85982	Mean	13.7091
Mode	9.8629	Mode	22.0679	Mode	6.85982	Mode	12.8177
Median	12.1623	Median	23.7215	Median	6.85982	Median	13.2429
Std. Dev	6.7980	Std. Dev	5.7863	Std. Dev	0.63699	Std. Dev	2.2520
Variance	46.2130	Variance	33.4813	Variance	0.40576	Variance	5.0714
Skewness	17.6135	Skewness	1.1395	Skewness	0.0000	Skewness	N/A
Kurtosis	N/A	Kurtosis	5.4000	Kurtosis	4.2000	Kurtosis	N/A
Left X	10.02	Left X	17.12	Left X	5.826	Left X	12.18
Left P	95.00%	Left P	95.00%	Left P	95.00%	Left P	95.00%
Right X	24.40	Right X	35.47	Right X	7.894	Right X	16.58
Right P	5.00%	Right P	5.00%	Right P	5.00%	Right P	5.00%
Diff. X	14.3812	Diff. X	18.3503	Diff. X	2.0681	Diff. X	4.3993
Diff. P	90.00%	Diff. P	90.00%	Diff. P	90.00%	Diff. P	90.00%
Test by the criterion of Anderson - Darling							
Station GR-1 LogLogistic		Station GR-2 Normal		Station TR-1 ExtValue		Station TR-2 Pearson 5	

(9.7454; 2.5808; 1.51)		(24.4563; 4.8243)		(6.60270; 0.50985)		(4.2835; 8.3713)	
Minimum	9.7454	Minimum	-Infinity	Minimum	-Infinity	Minimum	13.7010
Maximum	+Infinity	Maximum	+Infinity	Maximum	+Infinity	Maximum	12.7360
Mean	15.8955	Mean	24.4563	Mean	6.89699	Mean	13.2681
Mode	10.6439	Mode	24.4563	Mode	6.60270	Mode	1.6871
Median	12.3262	Median	24.4563	Median	6.78957	Median	2.8465
Std. Dev		Std. Dev	4.8243	Std. Dev	0.65390	Std. Dev	4.7093
Variance		Variance	23.2736	Variance	0.42759	Variance	174.7632
Skewness		Skewness	0.0000	Skewness	1.1395	Skewness	12.18
Kurtosis		Kurtosis	3.0000	Kurtosis	5.4000	Kurtosis	95.00%
Left X	10.11	Left X	16.52	Left X	6.043	Left X	16.61
Left P	95.00%	Left P	95.00%	Left P	95.00%	Left P	5.00%
Right X	27.88	Right X	32.39	Right X	8.117	Right X	4.4350
Right P	5.00%	Right P	5.00%	Right P	5.00%	Right P	90.00%
Diff. X	17.7680	Diff. X	15.8705	Diff. X	2.0737	Diff. X	13.7010
Diff. P	90.00%	Diff. P	90.00%	Diff. P	90.00%	Diff. P	12.7360

It was found that the mean values differ from the average of the laws of distribution. We believe that it is appropriate to take the average, since the laws describe more accurately and adequately regularities of variation of random variables as concentrations of PM10.

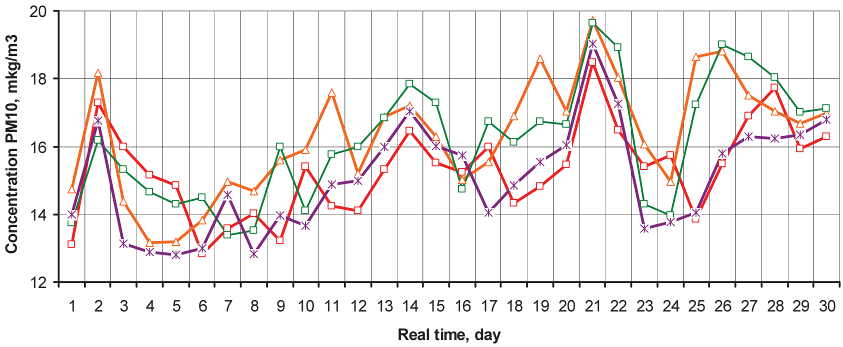

Fig.3. Series of concentrations of PM10 determined by the average level (-✱-) and average Mean statistical laws of distribution of the measuring station TR-2 tested by : -●- criterion of Pearson; ■ - criterion of Anderson-Darling; ▲- criterion of Kolmogorov - Smirnov

In the processing of the database it has been demonstrated that there are differences in the results of the statistical laws of distributions tested by three criteria: γ^2 - Pearson criterion, the criterion of Anderson - Darling test and Kolmogorov - Smirnov. This finding is demonstrated by the data presented in Table 2. It can be seen the differences that occur in some of the situations of pollution in the four measuring stations. Illustration of the differences are also given in Figure 3.

Choosing the right law distribution is also important in terms of determining the environmental risk. Using the given law to determine the likelihood or daily average hourly concentrations is able to obtain with the values in the studied range of concentrations of PM10. Therefore it is necessary preliminary to justify the adoption or rejection of the criteria for testing the hypotheses for the statistical laws.

CONCLUSION

The basic laws of air pollution with PM10 in the Romanian section along the Lower Danube are established.

That is made on the basis of a database of information created by the Romanian Executive Environment Agency. During their processing the hypotheses were tested with 18 distribution laws. The parameters and their numerical characteristics suitable for a full and accurate description of the pollution were defined.

The series in time hours days during the spring and summer of this calendar year were established.

Mean values and the average values of the laws of distribution, which are mathematical expectation of occurrence of the valuesof the concentrations of PM10 showed that there is not exceed of the norms according to Bulgarian and Romanian regulations.

It was proved that there are significant differences between the numerical characteristics of the laws of distribution verified by different criteria. This impose that it is not acceptable for precision studies to apply relevant criterion without evidence to check the hypothesis.

REFERENCES

[1]. A Concise Summary of @RISK Probability Functions. Palisade Corporation, 798 Cascadilla St. Ithaca, NY USA 14850. www.palisade.com

[2]. LEGEA nr. 104 din 15 iunie 2011 Pulberi in suspensie - PM10.

[3]. Ordinance №12 of 15 July 2010 for norms of sulphur dioxide, nitrogen dioxide, particulate matter, benzene, carbon oxide and ozone in the air, promulgated in State Gazette 58/2010.

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Report has been reviewed.