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THE INFLUENCE OF WEATHER CONDITIONS AND LOCAL CLIMATE ON PARTICULATE MATTER (PM10) CONCENTRATION IN METROPOLITAN AREA OF IASI, ROMANIA

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Key words: PM10, LOCAL CLIMATE, Iasi,thermal inversions.

Abstract: The aim of this study is to evaluate the role of the weather conditions and local climate on the temporal and spatial variability of particulate matters (PM 10) in Iași city which is facing major pollution problems in the recent years. Daily data from 4 monitoring stations of Environmental Protection Agency-Iași–for main weather parameters and particulate matters – and the temperature from an inner temperature and relative humidity observation network inside the city were used for a three year study (2013-2015). Linear correlation, composite analysis and multiple regression are the main statistical methods applied in the analysis. In brief, the most important meteorological parameters enhancing air pollution in Iași seem to be represented by thermal inversions developing in the region strongly related to local climate conditions. The Pearson correlation coefficient (stronger than -0.40) between PM10 and thermal gradient, the difference in the PM10 concentration exceeding 20 μg/m^3 between strong thermal inversions and unstable conditions and the leading role of thermal gradients in multiple regression are the main indicators of the great role of thermal inversion in generating and sustaining pollution conditions in this area. The maximum concentrations of PM10 occur in May and March, gathering more than 30% of the days for the entire year. Complementary studies were taken into account in order to analyse the aerosol optical properties retrieved from Aerosol Robotic Network (AERONET-NASA).

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Introduction

The high number of days exceeding the thresholds limits for particulate matter pollution (PM10) in Iași City (fig. 1), during the last years, has become a case leading to possible infringement from the European Union to Romania on atmospheric pollution issues (European Comission, 2017). However, this represents a common problem in many other European cities, being the reason for the high interest in particulate matter pollution all across Europe (Vardoulakis and Kassomenos, 2008; Ferrario et al., 2008, Czernecki et al., 2016, Zibert et al., 2016) and also in Romania (Dunea et al., 2015, Dumitrache et al., 2016). Meteorological factors play a crucial role in air pollution studies (Bashkar et al., 2008), hence, in order to take proper measures to eradicate PM10 pollution, a very clear understanding of the role played by weather in this problem is needed, which represents the main goal of this study.

The progress in describing the role of weather in the PM10 variability has lead to an image which implies somewell defined correlations. So, the mechanism of wet removal defined by Flossman et al. (1985) explains the negative correlation between PM10 and the amount of precipitation which was documented in many studies (Vardoulakis and Kassomenos, 2008; Klingner and Sahn, 2008, Czernecki et al., 2016). Also, a negative correlation links the wind velocity and the PM10 concentration (Vardoulakis and Kassomenos, 2008, Kuzu and Saral, 2017). Though, the relation is more complex due to the fact that a high wind speed during drought periods inducesa resuspension mechanism (Triantafyllou, 2001).As far as temperature is concerned, the correlation is rather non-linear, PM10 pollution events being possible at both high and low temperatures. Among temperature parameters, the most important role is played by the temperature stratification, thermal inversions being in most cases related to high PM10 concentrations, not only in large cities (Olofson et al., 2009; Guzman-Torres et al., 2009, Czernecki et al., 2016), but also in rural area (Silva et al., 2007, Saaroni, 2015, Largeron, 2016).

Besides this, certain synoptic conditions are generally related to high concentrations of PM10. These conditions could be separated in two major categories: anticyclonic conditions (Triantafyllou, 2001, Wang et al., 2009; Kuo et al., 2008; Schaefer et al., 2008; Wang et al., 2010, Largeron, 2016) and synoptic conditions leading to long-range transport of pollution (Pateraki et al., 2012).Due to temporal and spatial variability, all of this data must be correlated with the optical parameter of tropospheric aerosols loading (by the modern remote sensing techniques) both from local/regional sources and from various transport processes (Binietoglou et al., 2015; Seo et al., 2015).

1. Data and methodology

The following data sources for 2013-2015 were used in order to accomplish this study:

- mean daily concentrations of PM10 from the archive of the Environmental Protection Agency - Iași (EPA);
- time series for the main weather elements (solar radiation, air temperature, relative humidity, atmospheric precipitation, wind direction, wind speed) from the archive of the EPA - Iași;
- vertical temperature gradient calculated at daily level on the basis of the observations from Dancu (70m height) and Păun (380 m height) monitoring points within the experimental temperature monitoring points of the Faculty of Geography and Geology from "Alexandru Ioan Cuza"University of Iași (fig. 1)

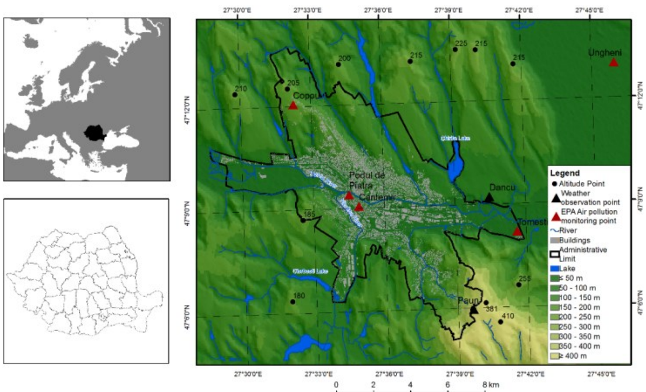

Fig. 1.Physical-geographic position of Iași and observation network for air pollution and weather conditions

The occurrence of the urban/industrial type of aerosols and their impact on the ambient air over the Iași area (Romania) during one year (May 2012 - May 2013) had already been proved by specialized literature (Cazacu et al., 2015). Accordingly, a Cimel Automatic Sun Tracking Photometer CE 318 has been used. This is a solar-powered, weather-hardy, robotically- pointed sun and sky spectral sun photometer, located in Iasi, Romania (Latitude: 47.193061 North, Longitude: 27.555561 East, Elevation: 175.0 m), part of AERONET – NASA (Aerosol Robotic Network) as IASI_LOASL site. The changes of the optical parameters due to the properties of aerosols to absorb and scatter differently the optical radiation will be discussed here for the period 2013 – 2015, except for a few months, due to the photometer calibrations procedures. In this work, a similar methodology based on previous studies by (Cazorla et al., 2013; Dubovik et al., 2002; Giles et al., 2012) was applied. Thus, from

AERONET,direct and inversion products (level 2.0) theSingle Scattering Albedo (SSA at 440 nm), Extinction Ångström Exponent (EAE at 440–870 nm), Absorption Ångström Exponent (AAE at 440–870 nm and AAE at 440 – 675 nm) andScattering Ångström Exponent (SAE at 440 – 675 nm) were used.All of the optical parameters that will be discussed below will complete otherstudiesalready reported at national level (Bucharest, Cluj-Napoca, Iaşi and Timişoara – AERONET sites) regarding the aerosols type classification by using the AERONET data (Ajtai et al., 2013; Cazacu et al., 2015; Malan et al., 2013; Nemuc et al. 2011).

2. Source of particulate matters in Iași region -an AERONET data investigation 2013 – 2015 overviews

Giles et al. have proposed to use the dependence of both Single Scattering Albedo (SSA at 440 nm) and Absorption Ångström Exponent (AAE at 440–870 nm) on Extinction Ångström Exponent (EAE at 440–870 nm) in the density plot to define the aerosol type from AERONET retrievals. According to the clustering by aerosol type given in Giles et al., Cazacu et al. indicate that the urban/industrial aerosols have a strong influence above the Iasi_LOASL monitoring point for the period of May 2012 – May 2013. By analysing the same optical parameters for the period January 2013 – December 2015, in Fig. 2 (left), we can observe an agglomeration of points at values of SSA [440 nm] between $0.94 \pm 0.01 \div 0.99 \pm 0.01$. At the same time,the values of EAE [440–870 nm] varied between 1.57 ± 0.01 and 1.97 ± 0.01. Taking into account the spectral dependence of SSA values with wavelength according with Dubovik et al., these belong to the urban/industrial aerosol type as well. A similar type of aerosols can be observed in the Fig. 2 (right) by AAE[440–870 nm] in relation with EAE[440–870 nm] at values between 1.0 ± 0.1 and 1.2 ± 0.1 of AAE and values of EAE between 1.5 ± 0.1 and 1.9 ± 0.1.

Regarding the SSA, values are higher but in the same time AAE and EAE keep the values for urban and industrial type. In 2013, Cazorla et al.showed, for 33 AERONET stations, that the Ångström matrix (Division of the Absorption Ångström Exponent vs. Scattering Ångström Exponent at 440 – 675 nm) can be used for complementary studies regarding the aerosol type identification uncertainness. Based on this method, the IASI_LOASL data can be characterized as a predominant presence of the elemental carbon (EC) and organic carbon (OC) mixture (fine mode particles) in the 74.09 %ofall measurements during the 2013 – 2015 periods. The EC/OC mixture type indicates the fossil fuel as pollution sources, where the overlapping of the optical properties dominating the classification.

Based on the Bahadur et al. (2012) studies, dust dominated the regionthreshold from figure 2, as 2.99% represents a small amount of dust measurements particularly due to some Saharan dust intrusion events, already reported for the IASI_LOASL monitoring site (Bahadur et al., 2012; Belegante et al., 2015; Cazacu et al., 2016). Due to the main influence of the urban/industrial activity, the optical parameters were affected during the dust intrusion events in very small proportions as OC/dust mix (~2%) and dust/EC mix (~1%).

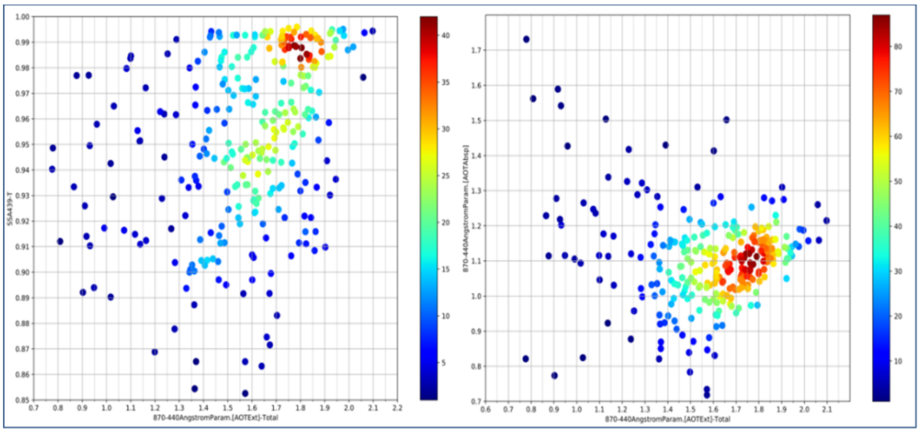

Fig. 2. Single Scattering Albedo at 440 nm [SSA 440 nm] vs Extinction Ångström Exponent [EAE 440–870 nm] (left) and Absorption Ångström Exponent [AAE 440–870 nm] vs Extinction Ångström Exponent [EAE 440–870 nm] in number density plot. no average data [2013–2015] from Iasi_LOASL monitoring site (right)

Concerning the large particles (coarse mode) as strong absorbers, recent studies showed that coated black carbon and polluted dust present the similar spectral response at shorter wavelengths of the SAE [at 440 – 675 nm] with AAE [at 440 – 675 nm] < 1 (Cazorla et al., 2013; Lack and Cappa, 2010). Labelled as “Coated Large Particles” their presence is up to ~6% of all measurements. The particles emitted from biomass burning processes are richer in the EC absorption (soot) (Jacobson 2009, Bahadur et al., 2012). The biomass burning or soot particles(labelled as EC dominated in figure 3) occur with a presence up to 10% at the Iasi_LOASL site, especially in the winter and spring time as shown by reported case studies for short periods (Cazacu et al., 2015; Unga et al., 2013). Certainly, no pure EC or OC can be represented in the Fig.3, and as it is well known that all combustion processes produce both EC and OC,and at the same time new mixed classes are the result of the various sources of dust (3.65 %). These classes are very difficult to characterise, more complementary studies being necessary.

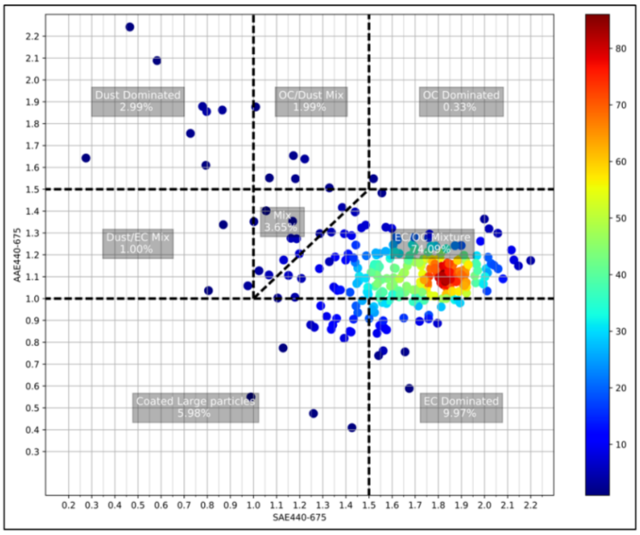

Fig. 3. Division of the Absorption Ångström Exponent [AAE at 440 – 675 nm] Scattering Ångström Exponent [SAE at 440 – 675 nm] in number density plot. no average data [2013–2015] from Iasi_LOASL monitoring site

3. Meteo-climatic analysisfor the period 2013-2015

The period analysed in the present study represents a very warm one in terms of ***air temperature,*** if we compare it to the long-term multi-annual average (1961-2009). According to the data provided by the NCEP / NCAR for the North-Eastern part of Romania (Kalnay et al., 1996), Iași included, this interval was characterized by a positive temperature deviation of 1.5°C.The average annual temperature of the analysed period was 2˚C higher (tab.1) than the multi-annual average in the period 1961-2009, as indicated by Alexe (2012) for Iași. The characteristics induced by the urban heat island have led to an average temperature of 1°C higher in the central part of the town compared to observation points located on the outskirts of the city (Sfîcă et al., 2017).

The summer season of 2015 especially was very warm, with more than 40 days of over 25°C average air temperature – and, in addition to this,three mild winter seasonscomplete the thermal characteristicsof the period (Sfîcă et al., 2017).

The ***atmospheric dynamics*** at regional level was generated by atmospheric pressure conditions close to multi-annual averages over the 3-year study period, according to the NCEP/NCAR (Kalnay et al., 1996), with cyclonic conditions that prevailed throughout the year of 2013 and anticyclonic conditions throughout the year 2015. The prevalence of anticyclonic conditions is also related to a significant ***rainfall*** deficit manifested mostly during 2015.

Tab. 1. Mean air temperature Iași weather station (˚C) for 1961-2009 interval (Alexe, 2012), Ciric-UAIC (Sfîcă et al., 2017) and Cantemir-EPA for 2013-2015 interval

	J	F	M	A	M	J	J	A	S	O	N	D	Mean
Tmean Iași (1961-2009)	-3.0	-1.2	3.4	104	16.3	19.6	21.2	20.4	15.8	10.2	4.3	-0.8	9.7
Tmean Ciric-UAIC	-1.6	0.5	5.6	11.6	17.9	20.6	22.4	22.4	17.2	10.0	6.6	-0.9	11.7
Tmean Cantemir-APM	0.8	3.4	8.0	14.3	20.8	23.5	25.2	25.0	19.3	11.9	8.2	2.4	13.6

To sum up, we must emphasize that the period 2013-2015, characterized by very warm conditions, is integrated into the characteristic pattern of climate changes in the region (Piticar et al., 2017), which indicates for the future a possible perpetuity of this type of meteo-climatic features.

4. Results and discussions

4.1. Annual, seasonal and weekly regime of PM10

The influence of the meteorological conditions on the variability of PM10 concentrations is clearly shown in *the annual regime of monthly maximum concentrations* of PM10 – those that are related to the overflows of the thresholds limits – that has two maximum values, the first one at the beginning of the year (January-Podul de Piatră, February- Copou, Tomești, Ungheni) – and the second one in November (Fig. 4).

It is clear enough that the maximum values, also indicating more frequent overflows of situations of the maximum thresholds limits, are recorded in the cold period of the year, being also connected to the weather conditions specific for this period. Practically, the maximum concentrations of PM10 increase with the cessation of the vegetation cycle, marked by the leaf fall during October. Even if the traffic is not as intense in the winter season as is in the other seasons, the occurrence of other emission sources linked to the specific burns of the period generates harmful increases of PM10concentration, in combination with the high atmospheric stability and the high frequency of the atmospheric steadiness and of the thermal inversions (Ichim, 2014). These conditions contribute in fact to the attainment of the maximum values of medium concentration in October-November. Carrying out an in-depth analysis we have established that the critical period with the greatest number of maximum allowable limits exceedances is between the 20th of October and the 10th of November, namely the period with the highest frequency of anticylonic conditions in this region.

At the same time, the lowest mean values of PM10 are recorded in June and July, months known to have, from a meteorological point of view, an intense atmospheric dynamics and a high degree of atmospheric instability. The same active atmospheric dynamics, linked in particular to the action of the Mediterranean cyclones, determines the lowest values, both at the level of the maximum and the one of average values of December (Fig. 4).

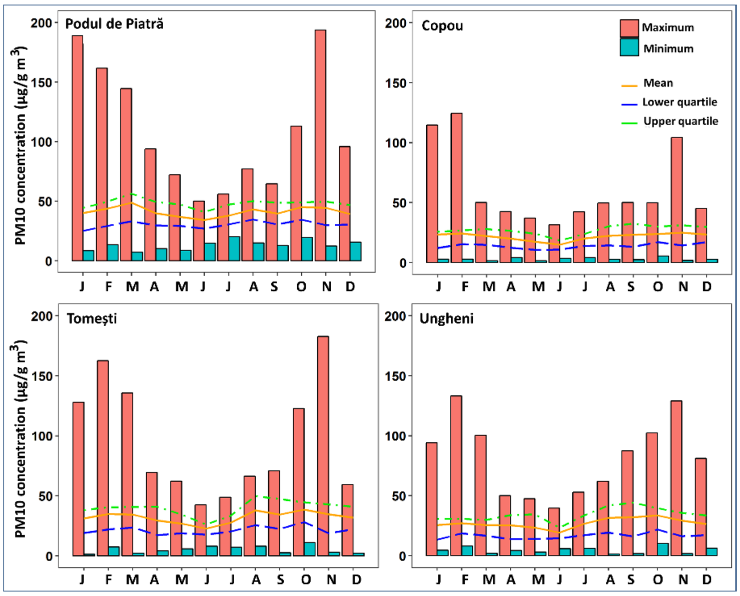

Fig. 4. Annual regime of MP10 in air quality monitoring points of EPA-Iaşi (2013-2015)

The weekly cycle of the PM10 regimeanalysed for the period 2013-2015, points out better the influence of different contributors to the exceeding values of the maximum thresholds limits with this pollutant (Fig. 5).

Thus, in Ungheni, the weekly regime is independently compared to the anthropic emissions associated with the urban environment (combustions, traffic, building sites, etc.) and it directly indicates the high concentrations of natural causes in connection with the weather conditions. Therefore, absolutely at random, the maximum values are achieved in Ungheni on Wednesday and

Saturday. Also, as a reflection of the natural conditions, the maximum value is registered on Saturday at the Copou station. We must emphasize the fact that this observation point is located in an area with a high level of vegetal cover in which the road traffic has low values. Instead, the two monitoring points that are strongly influenced by the conditions of urban traffic record the maximum values on working days, respectively on Thursday in Tomeşti and on Friday in Podul de Piatră.

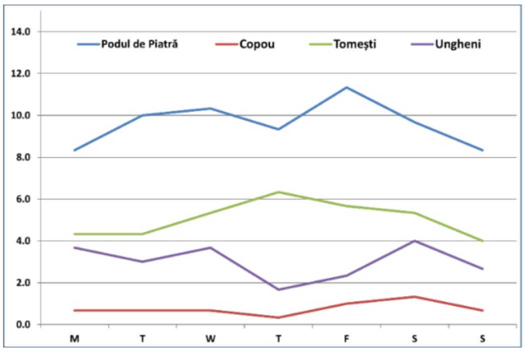

Fig. 5. Weekly cycle of days with overflow values of the maximum allowable limits for MP10 in air quality monitoring points of EPA-Iaşi (2013-2015)

The weekly concentration of PM10 varies throughout the year (Fig. 6). That way, we can consider that the days with the highest concentrations of PM10 are working days belonging to the transition between winter and spring (February-March), respectively from the end of the fall (November).

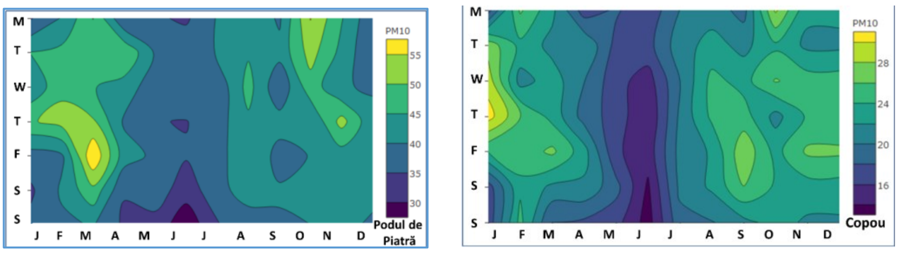

Fig. 6. Weekly cycle at annual level of mean daily concentrations in air quality monitoring points of metropolitan region of Iaşi (2013-2015)

The high impact of the anthropogenic factor in the overruns of the PM10 represents one of the factors that reduce the intensity of the Pearson correlations between PM10 and the parameters of the climatic conditions in Podul de Piatră with regard to the other air quality monitoring points we are going to discuss in the following chapter (Tab.2).

Tab. 2. Statistical significance of the Pearson correlations between the parameters of the climatic elements of monitoring point Cantemir and the PM10 values from the 4 air quality monitoring points of Environmental Protection Agency (annual/warm season/cool season) – data source: EPA - Iași

	Podul de Piatră	**Copou**	**Tomești**	**Ungheni**
Average temperature	/+0.33/	/+0.40/	/+0.36/	/+0.37/
Maximum temperature	/+0.42/+0.17	/+0.47/	/+0.45/+0.20	0.15/+0.46/+0.21
Minimum temperature	-0.13/+0.16/-0.14	-0.12/+0.24/-0.14	/+0.17/	/+0.18/
Vertical thermal gradient	-0.41/-0.17/-0.41	-0.43/-0.21/-0.44	-0.49/-0.29/-0.49	-0.45/-0.21/-0.49
Relative humidity	-0.17/-0.40/-0.21	/-0.44/	-0.13/-0.45/	-0.21/-0.49/-0.12
Precipitation	-0.18/-0.21/-0.21	-0.18/-0.20/-0.17	-0.20/-0.26/-0.21	-0.21/-0.24/-0.19
Atmospheric pressure	+0.16/ /+0.14	+0.15/ /	+0.17/+0.12/+0.15	+0.17/+0.18/+0.16
Wind- average speed	-0.23/-0.35/-0.19	-0.30/-0.34/-0.29	-0.34/-0.41/-0.31	-0.35/-0.40/-0.31
Wind-maximum speed	-0.19/-0.29/-0.14	-0.28/-0.31/-0.26	-0.30/-0.37/-0.26	-0.32/-0.37/-0.27
Solar radiation	/+0.24/+0.32	/ /+0.11	/+0.15/+0.22	/+0.14/+0.18

4.2. The correlation analysis between the PM10 concentration and the meteo-climatic conditions

For a brief assessment of the influence of meteo-climatic conditions on the PM10 concentrations in the metropolitan area of Iași we have calculated *the Pearson's linear correlation coefficient* between the two sets of elements. In table no. 2 we represent the values of this coefficient calculated at annual and semestrial level in the 4 air quality monitoring points. Also, in order to emphasize these correlations from a quantitative point of view, *a composite analysis of PM10 concentrations* was performed on an annual and semestrial basis according to the values of the main meteo-climatic elements.

In this respect, in the first phase, the daily values of the climatic elements corresponding to the 3 years of study have been sorted downwards and they have been associated with the daily values of PM10. The second phase consisted in the calculation of the average values of PM10 corresponding to the upper third of the values of climatic elements, respectively the average values of PM10 corresponding to the lower third of the values of climatic elements. The difference between the two average values represents thus an indicator of the influence of the meteo-climatic element on the PM10 concentration. In the case of atmospheric precipitation, the differences were calculated between the average values of PM10 during days with precipitation or days without precipitation. These differences have been tested as statistically significant using a t-test, and in table no. 3 we kept only the differences which were statistically representative in terms of significance. The analysis was applied at the annual value level, but also at the semestrial level.

The main conclusions of these two analyses are synthesizedbelow:

- for the monitoring stations within the city (Podul de Piatră and Copou), the values of the coefficients are smaller than those out of the dense built-up area, which obviously denotes the contribution of non-meteorological conditionsto the variability of PM10 in the city;

- during the warm season, the influence of climatic elements on air pollution is a generalized one, while during the cold season, air pollution is influenced by fewer weather elements - that do play, however, an increasingly important role (the role of the vertical thermal gradients is to be noted, in this respect,indicating the important role of the thermal inversions in the installation and persistence of pollution conditions);

- during the warm season, the high concentrations of PM10 are positively correlated with all the parameters of air temperature and with high values of the solar radiation, a fact explained by associating the pronounced air pollution with the heatwaves (Hůnova et al., 2017) or, in general, with periods of positive thermal anomalieswhich are triggered by synoptic conditions leading to long-range transports of pollution (Pateraki et al., 2012) from North Africa toward Europe(Zabalza et. al., 2005);

- during the cold season, the influence of temperature is not directly experienced by the appearance of high concentrations of PM10, these being both possible in conditions of higher and lower values of temperature, the dominant role being carried out by the vertical thermal gradients whose negative values – specific to temperature inversionconditions – are most strongly linked to high values of PM10, this being also emphasized by the negative correlation between minimum temperature and the PM10 concentrations within the city;

- the very small values of the thermal gradient (negative values corresponding to intense thermal inversions) are associated to very high PM10 concentrations (Tab. 3), especially in the cold period of the year (19.9 units of PM10 more on the average lower third of the thermal gradients compared to the upper third in Podulde Piatră). The same values are maintained at all monitoring points located in the lower area of Iași metropolitan area (Podulde Piatră, Ungheni, Tomești), where the intensity of the inversion horizon is higher, whereas in Copou-Sadoveanu the variability that the PM10 concentrations receive as a result of the thermal gradient is lower (10,7 units in the cold season);

- wind speed, atmospheric precipitation and even relative humidity can be considered, through their negative correlations with PM10 concentrations, as pollution clean-up elements, wind speed and relative humidity holding a pollution clean-up role which is significant during summer, whileatmosphericprecipitation plays a constant role throughout the year as common in other regions of the world (Zu et al., 2017);

Tab. 3. Statistical significant differences (t-test with probability of 0.001) in daily concentration of PM 10 (µg/m³) depending on the upper and lower daily values of meteo-climatic elements at air quality monitoring points of Iași (annual/warm season/cool season) - data source: EPA - Iași

	Podul de Piatră	**Copou-Sadoveanu**	**Tomești**	**Ungheni**
Solar radiation	/5.5/18.2	/ /5.4	/ /12.9	3.7/ /10.5
Thermal gradient	-17.7/-7.9/-19.9	-9.7/-6.6/-10.9	-17.8/-12.9/-21.1	-15.7/-11.1/-18.8
Atmospheric pressure	7.4/4.8/	4.1/ /	6.5/ /	6.1/ /6.5
Wind – average speed	-9.9/-9.5/-11.3	-8.5/-7.7/-9.6	-13.9/-13.4/-15.4	-13.1/-13.5/-13.4
Wind – maximum speed	-8.1/-8.2/	-7.6/-6.8/-8.5	-11.7/-11.8/-11.9	-11.3/-12.1/-11.2
Relative humidity	-6.7/-11.6/-10.9	-10.6	-5.3/-14.3/	-8.6/-16.9/
Precipitations	12.2/9.6/14.7	7.6/7.6/7.3	12.3/11.5/12.8	11.4/12.9/9.7

- very specific for Iași is the fact that the thermal gradient plays a more important role in the variability of PM10, even more important than that of the atmospheric precipitation and wind, the other two elements with significant action throughout the year; it is worth underlining the greater role of the average wind speed compared to the maximum one (gust) as a pollution clean-up element (Tab. 3);

Tab. 4. The results of the General Linear Model analysis for the PM10 concentrations (dependent variable) at Podul de Piatră and the meteo-climatic elements (predictors) for 2013-2015 period - data source: EPA - Iași

	Est.	**St. Error**	**T**	**Pr (>ItI)**	**Significance**
Intercept	-1.9	7.8	-2.5	0.0138	
Thermal gradient	**-4.2**	**3.3**	**-12.7**	**0.0002**	***
Relative humidity	**-2.5**	**4.5**	**-5.5**	**0.0005**	***
Global radiation	-3.9	3.6	-1.01	0.2783	
Wind – average speed	-1.3	4.3	-3.1	0.0020	**
Wind – maximum speed	3.1	2.8	1.1	0.2899	
Atmospheric pressure	**2.6**	**7.6**	**3.3**	**0.0007**	***
Precipitations	-1.8	1.1	-1.7	0.0984	·

Statistically significant with p: 0.0001***, 0.001**, 0.01* , 0.1·

As a summary of the influence of meteo-climatic elements on the variability of the PM10 concentration, a multiple linear regression (GLM method) has been applied for the monitoring point Podul de Piatră, the most problematic point when it comes to maximum thresholds level exceedances.This statistical technique allows the assessment of the significance of several parameters (predictors) – in our particular case the daily values of the weather elements – in what concerns the variability of a certain element (dependent variable), in our case the daily PM10 concentration at the monitoring point Podul de Piatră (Tab. 4).

The results of this analysis reconfirm the role of the vertical thermal gradient in the appearance of high concentrations of PM10 in air quality monitoring point Podulde Piatră. Moreover, the atmospheric pressure and relative humidity play an important role also; high pressure and low relative humidity are frequently associated with exceedance of tresholds limits for PM10.

4.3.Local climate conditions influencing the PM10 concentration in Iași

4.3.1. Particularities of the physical-geographic site of the municipality of Iașias part of the Hilly Plain of Jijia relevant for the analysis of the atmospheric pollution

North-Eastern Romania, the region in which Iași city is located, represents the most open region of Romania, due to the absence of orographic obstacles, consequently benefiting from the free atmospheric circulation from the North-Western region.This leads,in this part of the country,to a greater exposureto the westerlyatmospheric circulation. Therefore, in many winter weather situations, this is the region in Romania that heats up in the first place after very cold periods against the background of air advection of Atlantic origin on a north-western component (Apostol and Sfîcă, 2011). This aspect is very important at a local level, because, together with the predominant orientation of the Bahlui Valley (WNW-ESE), it determines a canalization effect of wind in the same direction. It should be emphasized that these directions (NW and WNW) total an annual frequency of almost 33% (Fig. 7), in other words, in 3-4 days out of 10 the wind blows from these two directions. Winds directed towardsthe South-East and the East, two complementary directions, totalapprox. 20% of the frequency of the winds blowing from particular directions. The *canalization of the wind* direction on the passage imposed by the Valley of the Bahlui River is maintained throughout the year and has the highest values during summer (Fig. 8), when the North-Western directions total 45% of the wind directions.

This canalization on NW-SE axis plays a decisive role in the occurrence of atmospheric pollution situations. The analysis of the average concentrations ofPM10 on directions and average speeds of wind at the monitoring points

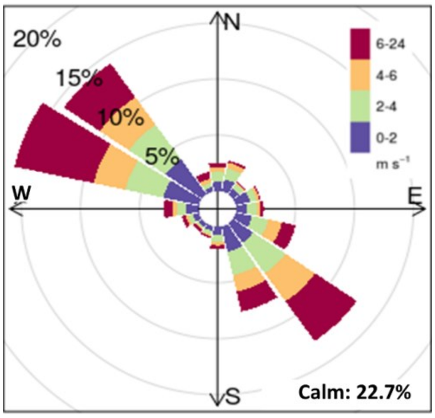

Fig. 7. Frequency and annual average speeds of wind for cardinal directions in Iași (2013-2015) at air quality monitoring points of Dimitrie Cantemir of the municipality of Iași (data source: EPA-Iași)

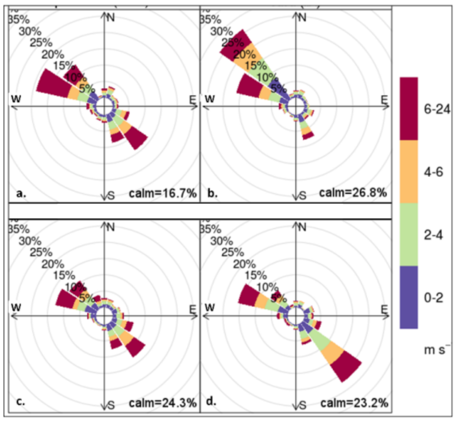

Fig. 8. Frequency and seasonal average speeds of wind (a. spring; b. summer; c. autumn; d. winter) for cardinal directions in Iași (2013-2015) at air quality monitoring points of Dimitrie Cantemir of the municipality of Iași (data source: EPA-Iași)

Podul de Piatră and Copou-Sadoveanu (Fig. 9, Fig. 10) shows, first of all, the role of the low speeds of wind in the installation of high concentrations of PM10 at both stations at all temporal levels analysed. At the same time, it is noted that at the Podul de Piatră point the high concentrations of PM10 are possible in any directions of the wind and even in the case of high speeds. The pollution clean-up effect of the wind is felt only at over 10-15 m/s speed from the west, south-west and north-west. Conversely, the Copou-Sadoveanu point there is an obvious contrast between the pollution clean-up effect of the winds from the W, NW and W and the pollution effect of the wind with E, SE direction. As we have stated below, the explanation is linked to the fact that the W, NW winds are associated with maritime polar air advections with a very low concentration of fine particulate matter, and the E and SE winds are associated with the transport of continental tropical air with a large load of fine particulate matter.

In general, on the basis of this analysis of the concentrations in relation to the wind direction and speed, it is considered that in the central part of the city the average wind speeds capable of reducing the PM10 values must exceed 10 m/s, whereas on the outskirts of the city the average pollution clean-up speeds exceed 5 m/s.

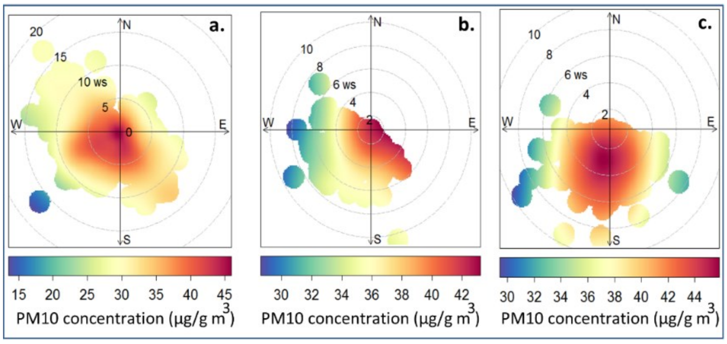

Fig. 9. PM10 concentrations in monitoring point Podu de Piatră depending on the direction and speed of wind at Dimitrie Cantemir annualy (a). warm season (b) and cool season (c) - data source: EPA - Iași

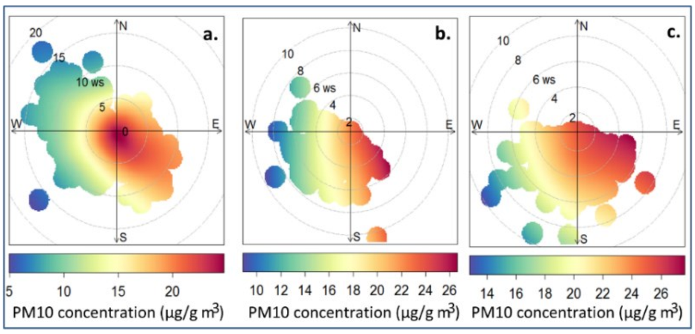

Fig. 10. PM10 concentrations in monitoring point Copou-Sadoveanu depending on the direction and speed of wind at Dimitrie Cantemir annually (left), warm season (centre) and cool season (right) - data source: EPA – Iași

Besides this canalization effect the specificity of the Valley of the Bahlui River is added to these dynamic characteristics, with the valley acquiring a *trough-like depression* aspect along the major riverbed by reference to the neighbouring interfluvial peaks and mostly in relation to the Repedea-PăunHill (approx. 400 m), compartment of the Central Moldavian Plateau, a higher region, bordering the municipality of Iași to the South.

This depression-like appearance represents the main factor facilitating the accumulation of pollutants during synoptic meteorological situations of atmospheric steadiness recorded concomitantly with the lack of precipitation for extended periods. According to studies conducted by Mihăilescu (2006), the frequency of the atmospheric calmness registered at the weather station Iaşican be assessed at approx. 20%, being necessary to mention the establishment of this weather station at Ciric-Chiriţainterfluve level, region in which the wind speeds are higher due to altitude, and the frequency of the atmospheric steadiness is lower. Instead, at the Podu-Iloaiei weather station, located in the meadow of the Bahlui River, in a closeobservation period, the same author indicates a frequency of the atmospheric steadiness of approx. 30-35%, value also considered representative for the lower area of the municipality of Iaşi, where the majority of the built urban surface as well as the major part of the population are concentrated. The frequency of the atmospheric steadiness is estimated by us at 23% on an annual level from the meteorological observation data of the Cantemir point on the 3 years reviewed (2013-2015).

4.3.2. Frequency of thermal inversions. The concern related to the atmospheric steadiness is in close connection with that of temperature inversions. This phenomenon strongly influences the temperature stratification in the atmospheric boundary layer.

These are reported during all the months of the cold season, but are not restricted to those.The thermal inversions are more frequent especially under conditions of polar or arctic air advections inside which a cap is formed that impede the dispersion of pollutants by the predominantly descending movements under conditions of gravitational stabilization. In this manner the atmospheric pollutants progressively accumulate and concentrate in the lower atmosphere.

The gases and the fine particulate matters have an ascending evolution and are subjected to a rapid dissipation when the temperature gradient has normal values (gradual cooling as the altitude increases). In the case of thermal inversions, the layers of cold air, locked under the warm air, prevents the formation of convection currents (ascending) and block the emissions to dissipate. In some situations this process is clearly visible above Iaşi city (Fig. 11).

An extremely suggestive highlight of the importance of thermal inversions – associated with anticyclonic conditions –in prolonged situations of atmospheric pollution is the period with record exceedances of maximum tresholds for particulate pollution recorded between 10/28-11/13/2015. This episode, which is detailed below,corresponds to exceptional conditions from the meteo-synoptical point of view at the continental level. It is known in the climatological literature that the months of autumn are characterized by dominant continental and regional anticyclonic conditions (Sfîcă, 2015), therefore, as wementioned, a great number of tresholdslimits exceedancesfor PM10 are registered at this time of the year. As describedbelow, these anticyclonic conditions maintain an accentuated atmospheric stability directly reflected in the high frequency of thermal inversions (Ichim et al., 2014), conditions that provide a low dispersion of pollutants.

Fig. 11. Accumulation of fine particulate matter in the temperature inversion horizon in the Valley of the Bahlui River in the municipality of Iași (foto: Sebastian Sava, 01/09/2016)

As a matter of fact, starting from the persistence known in terms of meteo-climatic anticyclonic conditions in the region of Romania (Bâzâc, 1983) we can once more highlight the fact that, at a continental level, the Iași region of concern is one of the most unfavourable regions from the European Union in the light of the dispersion of pollutants and therefore the effort to combat has to be much more extensive, requiring financial involvement higher than in most European regions.

Conclusions

Based on the considerations presentedabove, the Iași Cityregioncan be considered extremely susceptible to accentuated atmospheric pollution as a compound effect of meteo-climatic conditions and of physical-geographic site conditions of the metropolitan area. It should be noted that most of the situations of exceeding thresholdstook place in weather conditions favourable to the concentration of pollutants. We can consider it natural that this susceptibility represents an argument for the allocation of additional funding compared to the EU average, in order to efficiently take measures that would lead to a significant reduction of atmospheric pollution.

The persistent thermal inversion, the low speeds of wind and the lack of precipitations for a prolonged period of time are the most important elements in the appearance of the particulate matter pollution situations. Moreover, the persistence of the anticyclonic conditions and the reduced values of relative humidity represent enhancing elements of solid particulate matter high concentration.

Taking into account the conditions of susceptibility of meteorological elements mentioned above, there is an obvious need for the implementation of a weather warning system regarding pollution issues, on the basis of which the local authorities from Iași should be made aware of the weather episodes that could lead to a high atmospheric pollution (dust transport, persistence of stability conditions, prolonged periods of lack of precipitation). The measures to combat pollution should also be focused on the minimisation of emissions of anthropic origin, but at the same time on the reduction ofthe negative effects of the background meteo-climatic susceptibility.

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