SEASONAL AND SPATIAL VARIATION OF PM10 IN AN URBAN AREA FROM ROMANIA

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Abstract. The cyclic variance of PM10 mass concentration in the urban area in the South-East of Romania has been analysed in the article. SE of Romania is considered to be a territory which has medium level of pollution for a period of last ten years, from 2009 to 2018. The spatial dispersion of PM10 concentration was obtained using the METI-LIS soft wear for each season. The objective of dispersion models is to evaluate how pollutant concentration is spread out taking into account the diffusion. The average measurements of PM10 and meteorological parameters as inputs has been used. An evident seasonal change of PM10 concentrations is observed in the article. In order to establish national measures (including economic ones) for the improvement of the atmospheric pollution control it was analysed the mechanism of atmospheric pollution. It was observed that the air quality was overall better in spring and in summer in comparison to the other two periods. With regard to the seasonal variation characteristics of PM10 significant differences for the air quality registered in different months in the researched region were observed. The impact of air temperature on atmospheric pollution was insignificant in spring and autumn; moreover, precipitation was defined as an important influence factor upon the atmospheric pollution. The impact of precipitation on the possibility of atmospheric pollution was obviously different in the four seasons. The research results indicate the meteorological parameters that influence the air pollution become active during the cold seasonal days. It was shown that relative humidity and wind speed are the meteorological parameters that impact the PM10. It was found out that the probability of atmospheric pollution decreased with the increase of air temperature in summer. The research results also testify that the air pollution mapping could be enhanced using atmospheric dispersion models and in-situ measurements.

Keywords: PM10, air pollution, meteorological parameters, seasonal variation, dispersion model.

1. INTRODUCTION

The paper focuses on the following aspects: (1) characterizing the temporal variations of PM10 in Brăila, Romania during the interval 2009-2018 and (2) analysing the effect of meteorological parameters on the dispersion of PM10. In this paper our intention is paid to the analysis of temporal and spatial dispersion of particulate matter (PM10) and its variation depending on meteorological parameters for the period of 2009-2018. The detailed analysis of meteorological factors' influence on the atmospheric pollution describe exactly the pollutants formation mechanism as well as the dispersion of the

pollutants under different meteorological conditions and ensure the forecasting of the atmospheric pollution based on meteorological conditions with the aim of decreasing the atmospheric pollution.

The most important atmospheric pollutants include nitrogen dioxide (NO2), Sulphur dioxide (SO2), particulate matter (PM) and ozone (O3). For several years particulate matter has become one of the major components of atmospheric pollutants due to its effect on public health, namely due to the increase of cardiopulmonary morbidity and mortality [1; 2; 3].

PM10 consists of inhalable particles with an aerodynamic diameter less than 10 μm. PM10 originates in several sources including industrial emissions, traffic gases and natural dust [4]. Many studies had shown that PM10 was frequently observed as the most wide-spread atmospheric pollutant in an urban area. Air quality has acquired an increasingly greater importance in recent years with respect to the investigation of the formation mechanism of pollutants and their dispersion depending on certain parameters.

Various studies using air pollutants concentration and meteorological data have concluded that meteorological conditions have direct effects on the dispersion of atmospheric pollution [5; 6; 7; 8; 9]. Statistical studies have confirmed that there are seasonal and diurnal variations of the atmospheric pollutants depending on meteorological conditions [10].

The atmospheric pollution may be influenced by meteorological conditions directly (atmospheric cycle) or indirectly (traffic during working days, increase in energy consumption for heating in cold seasons) [11; 12; 13].

Meteorological factors have a major importance through the effect of dispersion, transformation and removal of air pollutants from the atmosphere depending on a series of spatial and temporal characteristics.

Seasonal and monthly variability of atmospheric pollution has led to the conclusion that the air quality was the most polluted in spring whereas becoming better in summer with a tendency to increase in autumn and winter. On the whole, atmospheric temperature was the most important meteorological parameter influencing PM10, followed by wind speed, relative humidity, atmospheric pressure and wind direction. Nevertheless, the prevailing meteorological factors that influenced the atmospheric pollution had a different significance throughout the four seasons [14; 15].

The Directive 2008/50/EC was adopted on 1 January 2008 and according to its stipulations the maximum accepted values for PM10 in the European Union are 40 μg/m3 while the short-term maximum value refers to the fact that the 24-hour average of 50 μg/m3 is not to be exceeded more than 35 times a year. EU had assumed many directives and strategies in order to reduce the atmospheric pollution and to improve air quality [16; 17]. Air pollution is a frequent phenomenon in the developing countries.

The permanent monitoring of air pollutants concentration as well as the analysis based on the dependence between meteorological parameters and PM10 would have significant results in reducing atmospheric pollution.

2. RESULTS

In order to establish national measures for the improvement of the atmospheric pollution control it is very important to analyse the mechanism of atmospheric pollution.

Hourly PM10 concentration data were collected over a 10 years period from 2009 to 2018 by the Local Environmental Protection Agency observation stations, which are distributed crosswise the city. In our study, we analyse the relationships between PM10 and six meteorological parameters: relative humidity, atmospheric pressure, air temperature, relative humidity, wind speed, wind direction and precipitation.

The METI-LIS, model ver. 2.03 is a Gaussian dispersion model and calculates, in steps of one hour, the pollution dispersion in lower atmosphere using the pollutant concentrations and meteorological data. Wind direction, wind speed and atmospheric stability have a major contribution to dispersion.

The METI-LIS model includes the downdraft effect, which often influences the atmospheric dispersion from lower emission sources and gives solutions of simple Gaussian plume and puff formula [18] for elevated sources [19].

The parameters in the dispersion widths describing the downwash effect are based on that of the US Environmental Protection Agency's (EPA) Industrial Source Complex (ISC) model. Sources with line-shaped characteristics are calculated in the model by numerically integrating the point-source plume equation (Formula 1),

$$C(x, y, z) = \frac{Q}{2\pi\sigma_y u}\exp(-\frac{y^2}{2\sigma_y^2})[\exp(-\frac{(z - He)^2}{2\sigma_z^2}) + \exp(-\frac{(z + He)^2}{2\sigma_z^2})], \tag{1}$$

where C is the concentration (g/m³), x is the downwind distance from the emission source (m), y is the crosswind distance from the emission plume centreline (m), z is the distance above the ground level (m), Q is the pollutant emission rate (g/s), *He* is effective plume-rise height, *u* is wind speed (m/s), σ_y is horizontal dispersion width (P-G curve) (m), σ_z is vertical dispersion width (P-G curve)(m).

With regard to the seasonal variation characteristics of PM10 there were significant differences for the air quality registered in different months in Brăila. The 2009-2018 air quality was the worst in December, 36.5 μg/m³ and the best in July, 19.5 μg/m³.

Having a seasonal perspective, we can state the fact that the air quality was the best in summer (June-August). There was a pollution proportion of 20.67% in summer, followed by spring (March - May) with 24.63% and autumn (September - November), 26.42% on average, respectively. The air quality was the worst 34.5 %, in winter (December - February) (Table 1). Lower atmospheric pressure, 1008 hPa, resulted in a lower atmospheric pollution in summer, 20.92 μg/m³. When the atmospheric pressure was lower, the probability of occurrence of the atmospheric pollution was reduced, especially in summer.

	PM10 μg/m³	Air temperature °C	Precipitation l/m²	Relative humidity %	Atmospheric pressure hPa	Wind direction °nord	Wind speed m/s
Winter	34,50	-1,09	47,53	87,83	1012,58	11,60	8,92
Spring	26,38	12,50	29,31	70,17	1009,50	10,25	4,32
Summer	20,92	23,84	26,50	66,33	1008,08	9,33	1,38
Autumn	25,58	13,63	32,18	76,75	1012,83	11,00	2,75

Tab. 1. Seasonal average of PM10 and meteorological parameters, for 2009 - 2018

The probability of occurrence of the atmospheric pollution increases when atmospheric pressure increases in spring. The influences of the atmospheric pressure had a similar effect in autumn (1012,83 hPa) and a concentration of 25,58 μg/m³ and 34,50 μg/m³ in winter with 1012,58 hPa. Lower relative humidity had the effect of a lower atmospheric pollution in summer whereas higher relative humidity easily led to atmospheric pollution in other seasons, especially in winter. In summer, relative humidity had a value of 66.33% and a PM10 concentration of 20,92 μg/m³. When relative humidity reached 87.83% the probability of atmospheric pollution increased to the maximum in winter, with a 34.50 μg/m³ PM10 concentration.

The probability of occurrence of the atmospheric pollution had a medium level in autumn and in spring, when relative humidity reached a value close to 70%. In this case the probability of atmospheric pollution was still smaller in comparison with the winter period. The probability speeds up in accordance with the increase of relative humidity.

The impact of wind speed on air quality was mainly different in the four seasons. Under the circumstances of a wind speed around 1.38 m/s, the probability of atmospheric pollution was reduced in summer. The probability of occurrence of atmospheric pollution was higher when the wind speed was 8.92 m/s in winter. Furthermore, a medium level of the wind speed reached a mean probability of

atmospheric pollution in spring and summer. For example, in spring the wind speed was 4.32 m/s with a 26.38 μg/m³ PM 10 concentration while in autumn the wind speed was 2.75 m/s with a PM 10 concentration of 25.58 μg/m³.

Analysing the wind direction, we found that an average of 9.33°north in summer led to a lower air pollution while 11.60°north, the highest value corresponds to the higher pollution in winter.

The influences of air temperature had significantly different effects in the four seasons. The atmospheric pollution mainly occurred when air temperature had an average of 1.09°C in winter. This phenomenon occurs especially when it develops a thermal inversion layer in winter that would cause a stable atmospheric condition. Consequently, the dispersion of pollutants is reduced and remains accumulated on the soil surface, in the low atmosphere. Likewise, the atmospheric pollution occurred when the air temperature was around 20°C. Higher radiation heats urban area in summer.

Atmospheric turbulence and atmospheric instability have a major effect, rapid pollutant dispersion and diffusion. This phenomenon leads to the conclusion that the probability of atmospheric pollution decreased with the increase of air temperature in summer. The average value of air temperature in summer was 23.84°C and the PM10 concentration had a value of 20.92 μg/m³.

The impact of air temperature on atmospheric pollution was insignificant in spring and autumn. Moreover, precipitation was an important influence factor upon the atmospheric pollution. The impact of precipitation on the possibility of atmospheric pollution was obviously different in the four seasons. A larger amount of precipitation resulted in major pollution, whereas a small quantity of precipitation resulted in lower air pollution. In winter the 2009- 2018 average of precipitation was 47.53 l/m² and the PM10 concentration was of 34.50 μg/m³, in comparison with summer when the PM10 concentration was 20.92 μg/m³ and the precipitation average level was 26.50 l/m². In spring the average of precipitation was 29.31 l/m² while in autumn was 32.18 l/m².

The diffusion, dilution and accumulation of the pollutants are influenced by meteorological conditions. Pollutant concentration depends to a great extent on meteorological conditions even under the same conditions of pollutant sources. In this paper, the correlation degrees between PM10 and meteorological factors, including relative humidity, precipitation, atmospheric pressure, air temperature, wind speed and wind direction were analysed by using the SPSS software (Figure 1).
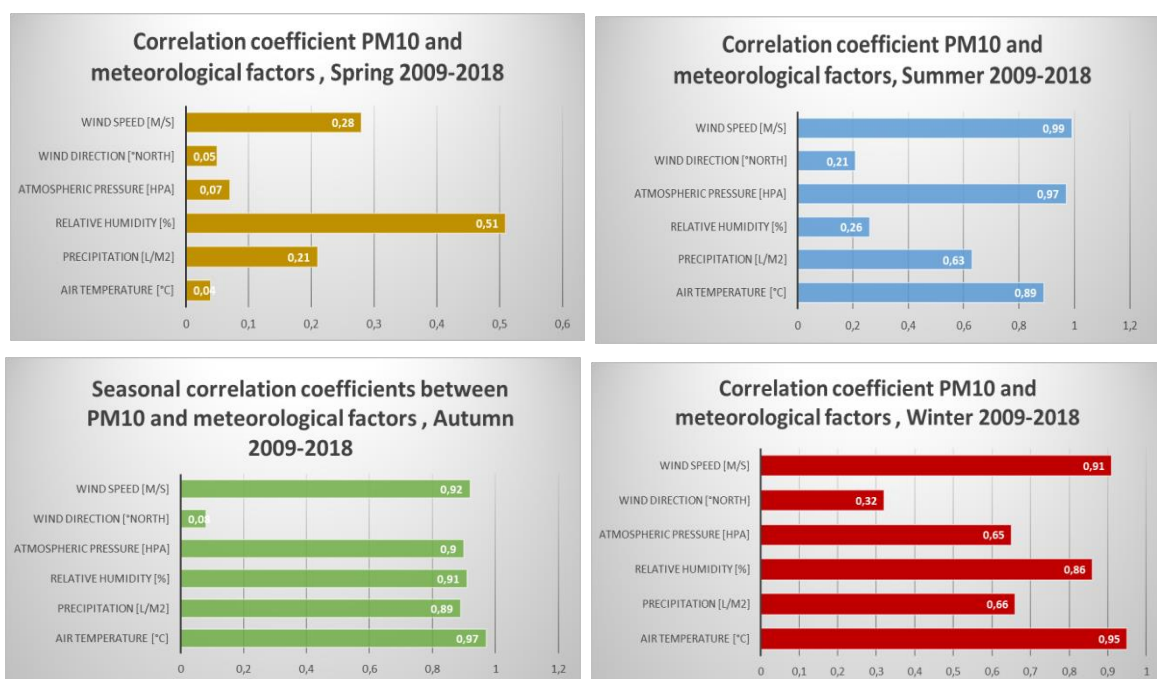

Fig. 1. Correlation of coefficients between PM10 and meteorological factors, 2009 - 2018

The relationships between PM10 and meteorological factors were complex. The correlation degrees were particularly influenced by seasons. The dominant meteorological factors influencing the atmospheric pollution were different in each season. The influence of air temperature on PM10 was most significant in winter with the worst air quality. Air temperature, wind speed and atmospheric pressure were the dominant meteorological factors in spring. In addition, the impact of precipitation should not be omitted.

Furthermore, air temperature, precipitation, relative humidity, wind speed and atmospheric pressure had an evident impact on PM10 in autumn. In summer when the air quality was the best, air temperature, wind speed and atmospheric pressure influenced PM10. On the whole, air temperature, wind speed and atmospheric pressure were the most important meteorological parameters influencing PM10, followed by relative humidity and precipitation. Wind direction has the lowest influence on the PM10 dispersion in an urban area.

The METI-LIS model was used to produce PM10 seasonal dispersion maps for 2009-2018, which are presented in figure 2.
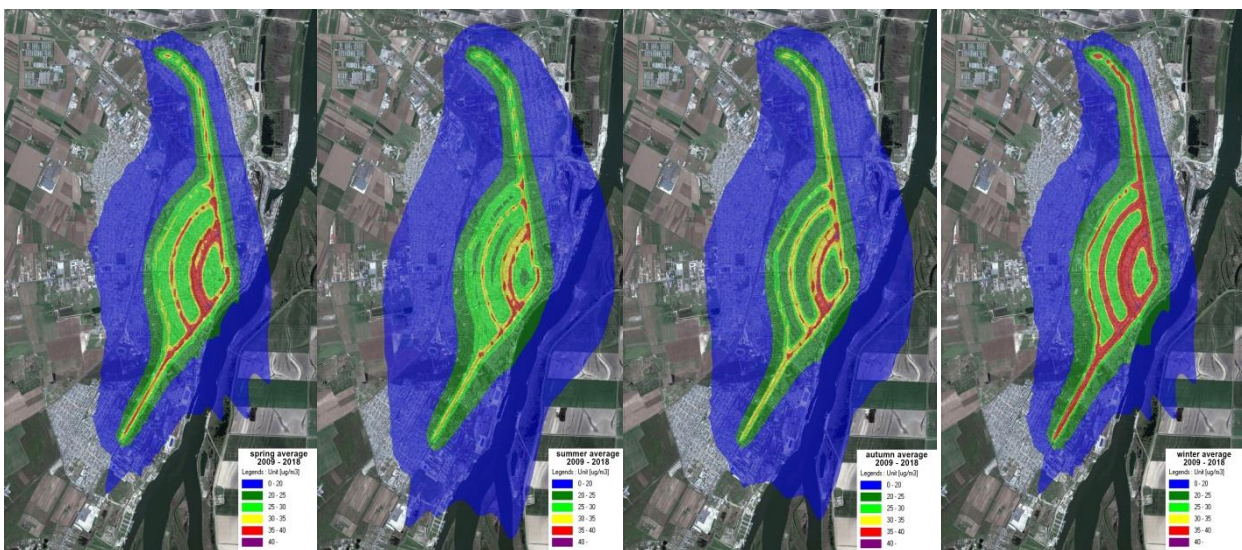

Fig. 2. Dispersion of PM10 for 2009-2018. PM10 concentrations between 0 and 20 μg/m³ are displayed in blue colour, the concentrations from 20 to 25μg/m³ are displayed in dark green, 25-30 μg/m³ - in light green, 30-35 μg/m³ - in yellow, 35-40 μg/m³ - in red and concentrations over 40μg/m³ – in violet. Note that the intense green/blue on the SE of the map is due to superposition with the dark colours used in the map

For the purpose of obtaining a spatial distribution of seasonal averages of PM10 emission in Brăila four maps were created. A different scale pattern provides distinct influence on the air quality dispersion and assesses sundry precision of air quality analyses. The METI-LIS soft calculates the PM10 concentration dispersion in a wide area, such as Brăila with a 50 × 50 m square spatial grid. In order to determine a high precision of PM10 dispersion we should use smaller grids. The most polluted areas were in the closeness of crowded streets and boulevards in connection with the traffic.

The highest PM10 concentration has been registered alongside the major streets in winter in the interval 2009-2018, with some intermittence on the outskirts of Brăila. In spring and autumn, the PM10 concentration was lower compared to winter, but higher than in summer. The lowest level of PM10 pollution is observed in the summer season.

Several intermittencies are outlined progressively in the city centre and disappear towards the less circulated areas. This phenomenon may occur due to the influence of meteorological parameters, i.e. the wind speed, air temperature and relative humidity. Likewise, a detailed analysis of the four maps points out that spots of PM10 crop up close to the cross-roads and near the traffic lights.

3. CONCLUSIONS

In reality, the effects of meteorological conditions on PM10 atmospheric pollution were evidently different in the four seasons, during the analysed period. There were clearly seasonal variations of atmospheric pollution in Brăila. The air quality was the best in summer, followed by autumn and spring, and the air quality was the worst in winter. The influence of meteorological parameters (including air temperature, relative humidity, atmospheric pressure, wind speed, wind direction and precipitation) on atmospheric pollution was analysed by using the correlation analysis method.

On the whole, air temperature and wind speed were the most important meteorological parameters influencing PM10, followed by atmospheric pressure, relative humidity and wind direction and precipitation.

Nevertheless, the prevailing meteorological factors influencing the PM 10 atmospheric pollution were different in each season. The influence of wind speed on PM10 was most significant in spring. Wind speed and air temperature were the main meteorological factors in summer. In autumn the most important parameter was air temperature, while relative humidity had a significant contribution in winter. In addition, wind direction had an important influence on atmospheric pollution. Besides this, for the period 2009 -2018, air temperature and wind speed had the most considerable impact on PM10 dispersion.

Taking all of the afore-mentioned aspects into account, this paper has analysed the seasonal specific feature of PM10 and its dependence on meteorological factors between 2009 and 2018, and the final purpose is the feasible actions to ameliorate the air quality in Brăila urban area. All in all, it is extremely important to explore and to understand the impact of different meteorological factors on the atmospheric pollution and the effects on human health, taking into consideration the urbanization process.

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У статті проаналізовано циклічну дисперсію масової концентрації PM10 у міській місцевості в Південній Румунії. Південна Румунія вважається територією, яка має середній рівень забруднення протягом останніх десяти років (2009-2018 роки). Просторову дисперсію концентрації PM10 отримували, використовуючи м'який знос METI-LIS для кожного сезону. Мета дисперсійних моделей - оцінити розподіл концентрації забруднюючих речовин з урахуванням дифузії. Були використані середні вимірювання PM10 та метеорологічні параметри в якості вхідних даних. У статті спостерігається очевидна сезонна зміна концентрації PM10. Для встановлення заходів держави (в т.ч. економічного характеру) щодо вдосконалення контролю над забрудненням атмосфери було проаналізовано механізм її забруднення. Визначено, що якість повітря в цілому покращувалася навесні та влітку порівняно з двома іншими періодами. Щодо сезонних коливань характеристик PM10, то встановлено значні відмінності у якості повітря, зафіксованому у різні місяці у досліджуваному регіоні. Вплив температури повітря на забруднення атмосфери спостерігали весною та восени; крім того, виявлено, що атмосферні опади є важливим фактором впливу на забруднення атмосфери. Встановлено, що вплив опадів на можливість забруднення атмосфери був різним у кожному з чотирьох сезонів. Результати досліджень вказують на те, що метеорологічні параметри, що впливають на забруднення повітря, стають активними в холодні сезонні дні. Показано, що відносна вологість і швидкість вітру - це метеорологічні параметри, що впливають на PM 10. З'ясовано, що ймовірність забруднення атмосфери зменшувалася зі збільшенням температури повітря влітку. Результати досліджень свідчать також про те, що картографування забруднення повітря можна покращити за допомогою моделей дисперсії атмосфери та вимірювань на місці.

Ключові слова: PM10; забруднення повітря; метеорологічні параметри; сезонні зміни, дисперсійна модель.