

# The State of Air Pollution with PM<sub>2.5</sub> in the City of Targu Jiu

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*Atmospheric particle matters which have many negative effects to the environment and human health have raised the public awareness in last years. Urban centers, through their specific activities, generate a new and complex form of pollution that affects all the quality factors, including those of the environment, the population being the main victim. This paper presents the status of PM<sub>2.5</sub> in the air of Targu-Jiu city for for 2015-2017, and assessment of the effect of meteorological factors to the values of PM<sub>2.5</sub> content. The results indicate that from the three years under study, the annual PM<sub>2.5</sub> concentration values exceeded the admissible limit value only for 2015. The highest pollution levels occurred during the months of February, March, October and November of the three analyzed years due to a higher fuel consumption for heating. Regarding the effect of meteorological factors such as: rainfall and temperature to the PM<sub>2.5</sub> level, it was observed a decrease of the concentration of PM<sub>2.5</sub> as air humidity increases and an increase of PM<sub>2.5</sub> concentration as air temperature decreases.*

*Keywords: air pollution, particulate matter, PM<sub>2.5</sub>, atmospheric particle matters*

The evolution of humans and rapid industrialization over time have been the events that have had the most significant and powerful influence on the environment. Among the most important moments in the evolution of the humankind, which also represented the beginnings of the pollution of the environment, was the one in which man began to use the sources of energy. While plants and animals adapt to environmental conditions, the human being has imposed his will, thereby trying to adapt the environment to his and society's needs.

By doing this people became aware of what was done only when the alarm triggered naturally. They then began to develop strategies and programs to prevent, reduce and restore destruction caused by their own evolution. These strategies and programs are primarily focused on global and regional environmental issues such as ozone layer protection, greenhouse effect limitation, acid rainfall, and biodiversity conservation. In this regard, new production technologies, high-performance measuring equipment for pollutants were created, and severe national and international legislation on the quality of environmental factors was developed and imposed, mainly by limiting pollution directly to sources [1-5].

Of all the environmental factors, atmospheric air is the most difficult to control, because pollutants, once they reach the atmosphere, disperse rapidly and they can not be virtually captured. Under these conditions, the only ways to reduce air pollution remain the limitation of pollutant evacuation into the air, and this can be achieved by the application of advanced technologies [6-9].

Recent data suggest that globally, air pollution is one of the largest environmental health risks being responsible for many diseases [2, 10-15].

Particulate matter (PM) as one of the greatest concern air pollutants is released into the atmosphere from antropogenic, but also from natural sources. PM primarily comes from anthropogenic sources such as: coal combustion for domestic heating, fuel combustion in thermal power generation, incineration, and vehicle exhaust fume. The main natural sources of PM are considered volcanic ash, pollen, naturally suspended dust, and sea salt.

Unlike other pollutants, PM is a mixture of particles, coming from different sources and having different sizes,

different compositions and different properties. The sizes of particulate matter are identified by the aerodynamic diameter in micrometers such as PM<sub>10</sub>, PM<sub>2.5</sub>, and PM<sub>0.1</sub> [16]. The larger size classes are those that include all smaller PM [16]. The larger size classes PM<sub>10</sub> and PM<sub>2.5</sub> are considered less toxic and they are trapped into the upper airways, while the PM<sub>0.1</sub> and smaller (ultrafine) are even more toxic than PM<sub>2.5</sub> [16]. Epidemiologic studies generally reveal robust associations of health hazards with the level of PM<sub>2.5</sub> into ambient air [16]. The main diseases associated with PM air pollution are: cancer of lung, neurodegeneration cognitive decline including dementia, Alzheimer's disease, and Parkinson's disease in elderly population, chronic bronchitis, cardiac arrhythmias, cardiovascular decline and mortality, brain damage [17-19]. Therefore, many governments including our government have implemented air quality standards and regulations for PM<sub>2.5</sub> pollution to limit its adverse health effects [20, 21].

Even though Targu Jiu industry suffered a severe decline since 1990, there are still many anthropogenic sources of air pollution.

In the west part of Targu Jiu there are three commercial companies in the field of building materials industry: CRH Romania - Targu Jiu Factory; SC MACOFIL S.A. and S.C. SIMCORVAR S.A. Oradea - Factory Targu Jiu. This type of industry is based on the processing of natural rocks (silicates, clays, marl, and limestone) for the production of cement, bricks, tiles and lime. Pollutants resulting from technological processes are mainly solid particles, but also carbon monoxide and sulfur dioxide. Also, in this part of Targu Jiu city is the Urban Waste Warehouse, situated in the former clay quarry of the Cement Factory. Physical, chemical and bacteriological processes occurring in the Urban Waste Warehouse result in a series of pollutants such as H<sub>2</sub>S, CH<sub>4</sub>, CO<sub>2</sub>, solid particles, and volatile acids which can reach the atmospheric air and cause air pollution.

To the northern area of Targu Jiu city, there are industrial units such as S.C. ARTEGO S.A. which produces rubber conveyor belts for the mining industry, S.C. GRIMEX S.A. which manufactures spare parts for mining activities and S.C. VEL PITAR S.A. specialized in bakery products. During the production processes, a series of specific pollutants such as VOC and aromatic hydrocarbons are produced from S.C. ARTEGO S.A. activities, compounds of various

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heavy metals (Pb, Cu, Zn, etc.) are released from S.C. GRIMEX S.A. activities, and fine powders from S.C. VEL PITAR S.A.

In the south of Targu Jiu is S.C. AVICOLA S.A. which produces poultry (hens) and it also has its own slaughterhouse. During the technological processes specific to this industry result ammonia pollutants, but also SO<sub>2</sub>, CO, particulate matter and NO<sub>x</sub> as a result of the combustion of fossil fuels in its own plant.

By far, however, the first place in terms of air pollution is the road transport. Generally in a city, 60% of all pollutant emissions come from cars, and in large urban agglomerations it can reach up to 90%.

An equally important source, especially in the cold season, is *domestic* activities. For various household purposes, various fuels such as wood, coal, oil and natural gas are used, resulting in polluting substances, some very toxic. For Trgu Jiu city the main fuel used is natural gas, but there are also a lot of residential houses that are using coal and wood for heating.

An important source of air pollution is dust storms. Particularly, in non-precipitation periods, vegetation-free land is exposed to wind erosion. Long, continuous winds pick up some of the particles form the mineral skeleton and turn them into aerial suspensions that are held in the atmosphere for long periods of time. The deposition of these suspensions as a result of the sedimentation process or the rain-washing effect may occur at great distances from the place where they were removed.

Also, natural or induced fires are another source of air pollution. Natural fires occur when climate humidity drops naturally below the critical threshold. In this respect, forests that contribute to maintaining a certain degree of humidity that do not favor the outbreak of fire are of great importance. Unfortunately, more frequent fires are caused, and especially the burning of dry vegetation or the burning of various household waste. This is a frequent practice in all localities and is practiced by those who live at home.

Therefore, daily records of air quality and further research are imperative now for the city of Trgu Jiu. This research study deals with monitoring of air quality of Târgu Jiu city regarding PM<sub>2.5</sub> content for 2015-2017, and assessment of the effect of meteorological factors to the values of PM<sub>2.5</sub> content.

## Experimental part

The reference method according to SR EN 14907 has been used for the sampling and measurement of PM<sub>2.5</sub> level [22]. Air quality monitoring in Targu Jiu municipality regarding the presence of PM<sub>2.5</sub> is carried out from 2014, this parameter being determined in parallel with measurements on PM<sub>10</sub>. The sampling points for the two particle sizes of the suspended particles are located at the Environmental Protection Agency Targu Jiu.

The sampling is carried out for 24 h, 5 days a week, except for the winter period.

In this case, a sampler Sven-Leckel, Germany (fig. 1), was used to collect particulate matter PM<sub>2.5</sub>, which was placed near the PM<sub>10</sub> sampler, thus complying with the provisions of Article 5 of Council Directive 1999/30/EC which states that „where possible sampling points for PM<sub>2.5</sub> have to be located in the same locations as sampling points for PM<sub>10</sub>” [23].

The sampling system has a vacuum pump with a flow rate of 2 m<sup>3</sup>/h. The sampling time is 24 h, and it is monitored by a microcontroller and saved in the system memory. The information stored in the memory can be viewed on a screen. In the event of power failure, all data stored in the system memory are saved.

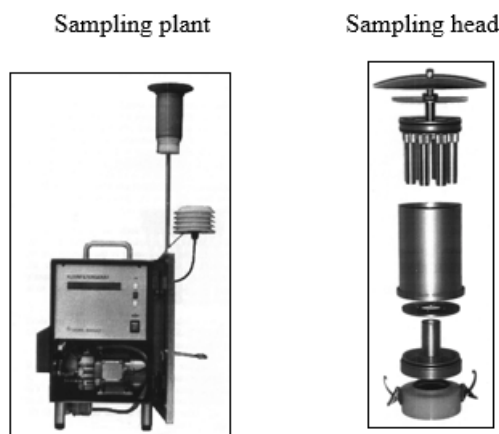


Fig. 1. Particulate matter sampling system

The sink is designed for outdoor use without the need for rain protection devices. When the outdoor temperature drops below 5°C, an automatic heating system enters, and when the temperature rises above 30°C, a fan automatically opens and the equipment will be ventilated [5].

Filters with separation efficiency ≥ 99.5% have been used. Each filter is conditioned under the same conditions before and after sampling, and after it is weighed [5].

Concentrations of PM<sub>2.5</sub> retained on the filter are calculated using the formula:

$$C_{PM_{2.5}} = \frac{M}{V} (\mu\text{g}/\text{m}^3) \quad (1)$$

where:

$C_{PM_{2.5}}$  = concentration of PM<sub>2.5</sub> (μg/m<sup>3</sup>);  
 $M$  = the weight (mass) of the powders on the exposed filters (ig);

$V$  = volume of air sample sucked (m<sup>3</sup>) [5].

The weight of the powders monitored is calculated as the difference between the weight of the filter after sampling and sampling:

$$M = m_2 - m_1 \quad (2)$$

where:

$m_2$  = the weight of the exposed filter(ig);

$m_1$  = the weight of clean filter(μg) [5].

## Results and discussions

The regulations provided in Law 104/2011 have been used for interpretation of results obtained regarding PM<sub>2.5</sub> content in the air from Targu-Jiu city. According to this Law a value of 25μg/m<sup>3</sup> has been imposed for the annual limit for protection of human health [20].

The analysis of the values obtained during the three years of study allows us to make a series of comments regarding the air pollution with PM<sub>2.5</sub> at the level of Targu Jiu city.

The results of the recorded values for PM<sub>2.5</sub> monthly average concentration in the period 2015-2017 in the Trgu Jiu area are presented in figure 2.

By analyzing the values of the monthly average concentrations of PM<sub>2.5</sub>, it was found that the highest ones are those registered in the year 2015 (fig. 2). Thus, out of a total of 11 monthly average concentrations, 45% were higher than the annual limit value. The monthly average concentration with the highest value was recorded in December, exceeding 2.5 times the limit value. The smallest values were recorded during April, June and September.

In the year 2016, the number of monthly average concentrations above the limit value accounted for about 36% of the total monthly average concentrations, and in 2017 only 33%. It can be concluded thus that the value of PM<sub>2.5</sub> level in the air of Targu-Jiu city has experienced a gradual decreasing.

Regarding to the daily  $PM_{2.5}$  daily concentrations, it was observed that the lowest values were recorded during each month, and they were progressively decreasing during the all three years of study (fig. 3).

Thus, in 2015, the annual average of concentrations with the lowest values recorded at the level of each month accounted for 46% of the limit value, 2016 - 39% and 2017 - 33%.

Somewhat the same situation is found in the daily concentrations with the highest values recorded during each month of the three years of study (fig. 4).

In 2015, all monthly maximum concentrations were more than twice above the limit value. The same finding is valid for the year 2016, with the specification that this time the annual average of the monthly maximum concentrations was only 1.8 times the limit value.

At 2017, the percentage of exceedances of maximum monthly concentrations compared to the limit value was about 78%.

As regards the seasonal variability of  $PM_{2.5}$  particulate concentrations, it is somewhat different. Although April to September is the period when pollution levels of  $PM_{2.5}$  are the smallest, however, these levels do not occur in the same months of each year.

Thus, if in 2015 the smallest  $PM_{2.5}$  concentrations were registered in April, June and September, in 2016 they were recorded in May, June and July, and in 2017 the levels of the lowest pollution occurred in June, July and September. Excluding February 2015, the months January, February and December were not taken into account due to the small number of measurements or their lack.

Diagram 5 shows the sum of the monthly concentrations of  $PM_{2.5}$  for all the three years analyzed.

It is noted that except September 2017 when the lowest concentrations of  $PM_{2.5}$  were recorded in the air in Târgu Jiu, the period May-July 2016 represents the longest period of the time when the pollution levels were lower.

At the level of 2015, the sum of the lowest concentrations (April, June, September) accounted for 19%

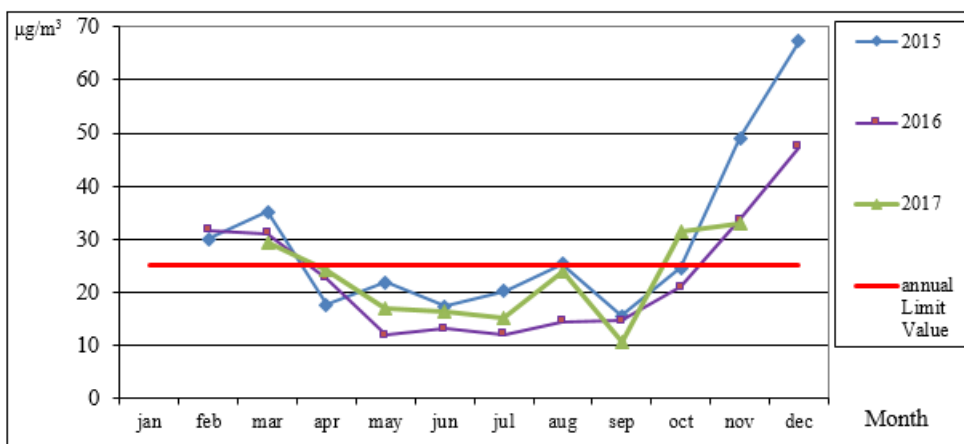


Fig. 2. Monthly average concentrations of  $PM_{2.5}$  in Targu Jiu city

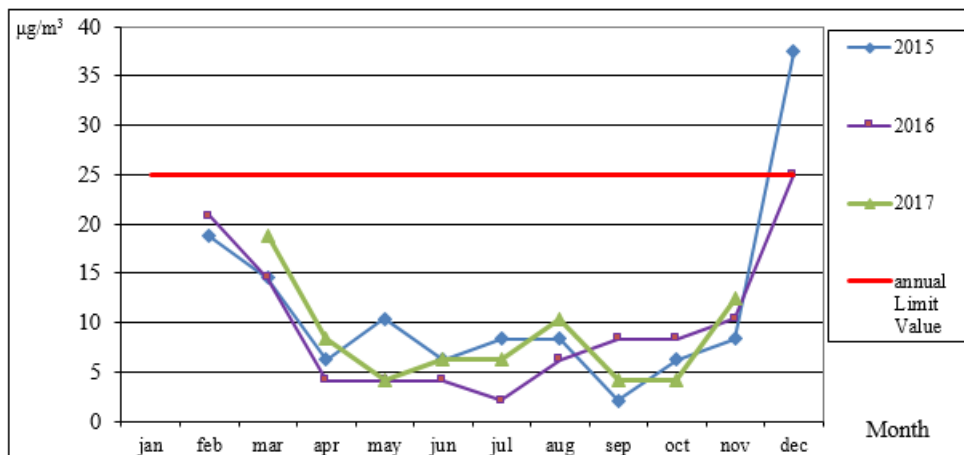


Fig. 3. Minimum monthly concentrations of  $PM_{2.5}$  in Targu Jiu city

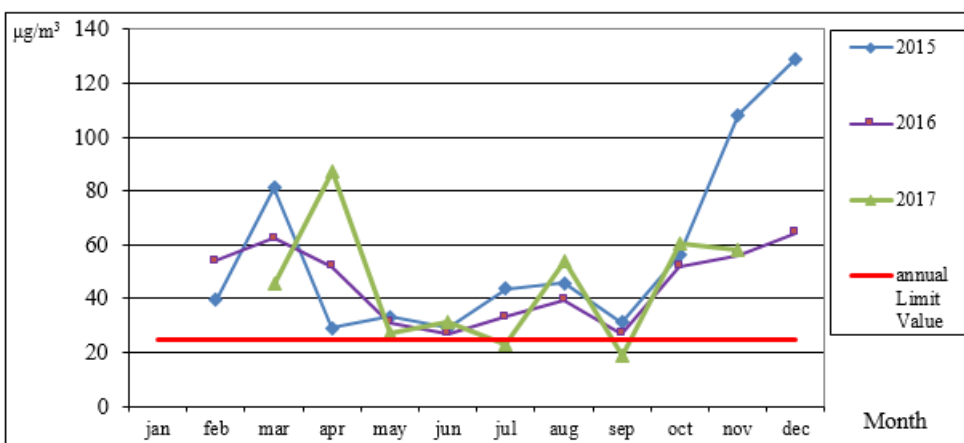


Fig. 4. Monthly maximum concentrations of  $PM_{2.5}$  in Targu Jiu city

of the annual amount, in 2016 it was 18%, and in 2017 - 20%.

The highest pollution levels occurred between February-March and October-November for 2015, March and November for 2016 and March, October and November for 2017.

Thus, by reporting the values of the average annual concentrations obtained at the admissible limit value, it is found that at the level of 2015 it was exceeded by 5.4% (fig. 6).

It can be seen from figure 6 that the annual average concentration of 2016 was below the limit value, representing 82.4% of it, being also the lowest of the annual values of the three years of study. In 2017, the annual

concentration accounted for 89.6% of the limit value, below it.

The period with the highest pollution level was recorded in 2015, in March and November, the sum of their concentrations representing 30% of the annual amount.

At the level of 2016,  $PM_{2.5}$  concentrations representing the highest values were also recorded in March and November, accounting for 30% of the annual amount, and in 2017 in March, October and November, and accounted for almost half of the amount annually.

The effect of meteorological factors such as: rainfall and temperature has been assess. Figures 7, 8 and 9 show the relation between rainfalls and concentration of  $PM_{2.5}$  for the period 2015 -2017.

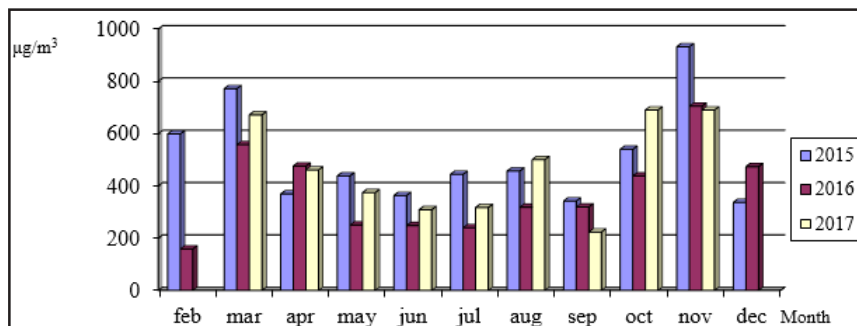


Fig. 5. Monthly total  $PM_{2.5}$  concentrations over the period 2015-2017 in Targu Jiu city

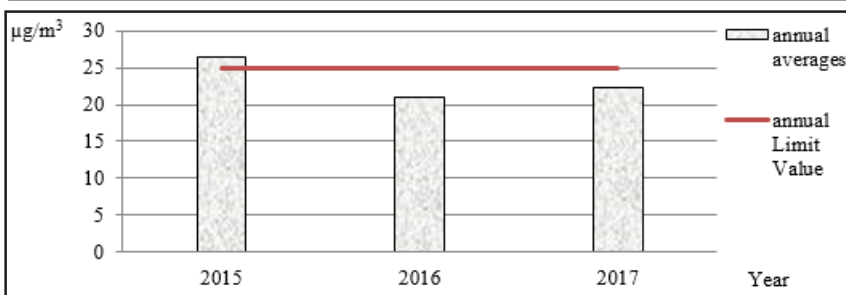


Fig. 6. Annual average concentrations of  $PM_{2.5}$  in Targu Jiu city

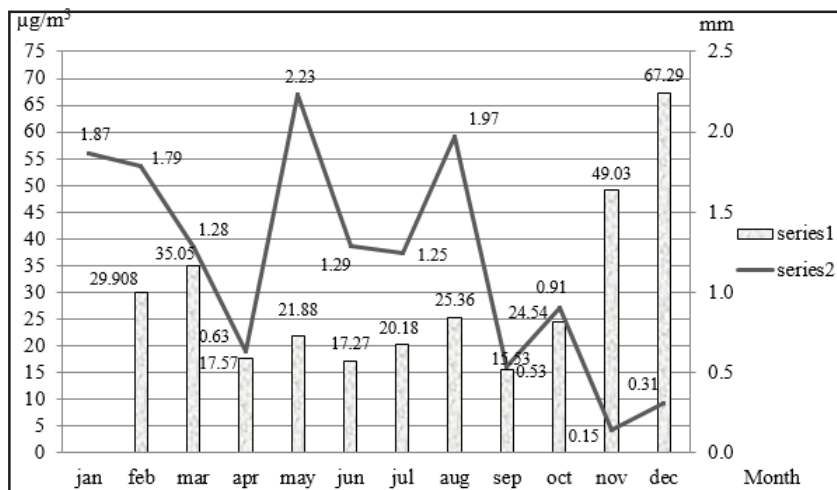


Fig. 7. Variation of monthly average concentrations of  $PM_{2.5}$  (series1) and rainfall (series2) in 2015 for Targu Jiu

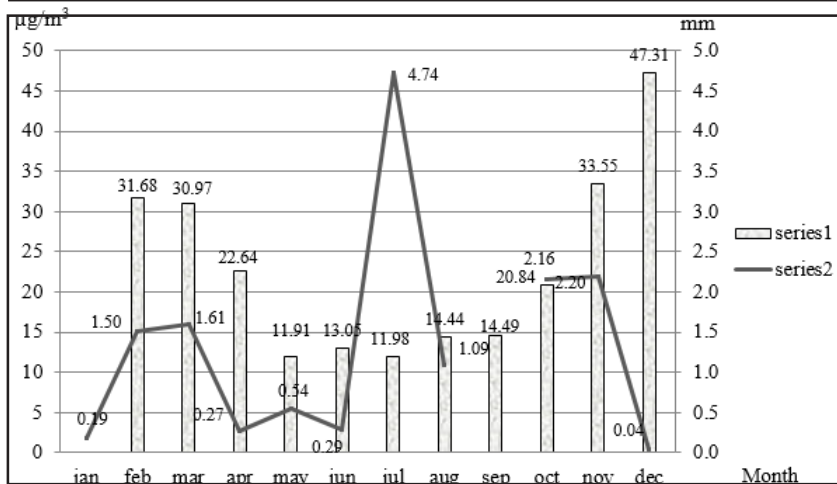


Fig. 8. Variation of monthly average concentrations of  $PM_{2.5}$  (series1) and rainfall (series2) in 2016 for Targu Jiu

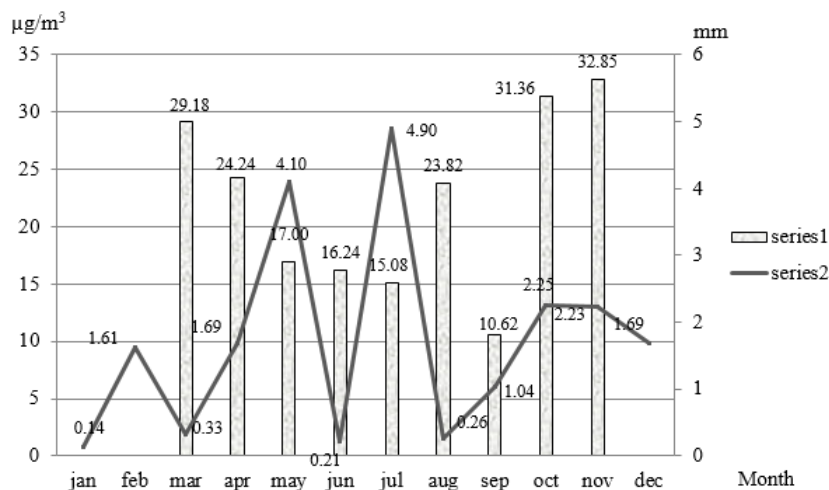


Fig. 9. Variation of monthly average concentrations of PM<sub>2.5</sub> (series1) and rainfall (series2) in 2017 for Targu Jiu

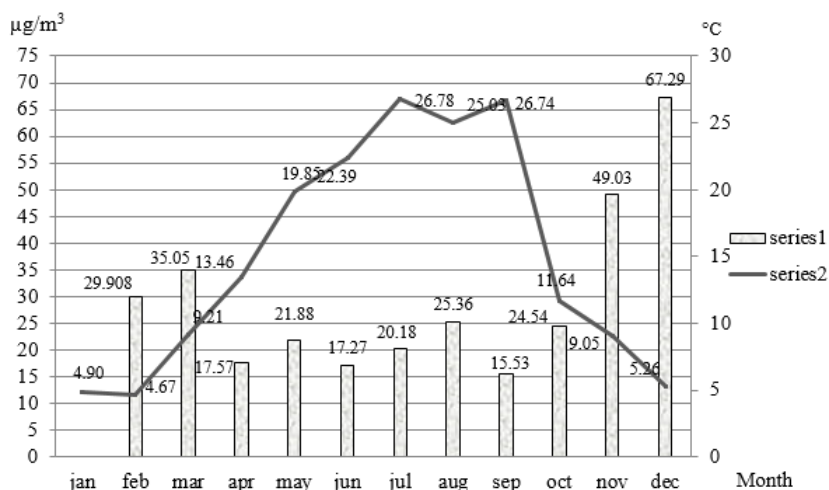


Fig.10. The variation of the monthly average concentrations of PM<sub>2.5</sub> (series1) and air temperature (series2) in 2015 Targu Jiu

As it can be seen from figures 7-9, the high values of rainfalls are correlated with low values of PM<sub>2.5</sub> content. At lower values of rainfalls (0.21-0.27 mm), the concentration of PM<sub>2.5</sub> is between 16.24 and 23.82 µg/m<sup>3</sup>. At high values of rainfalls (4.74 -4.90mm), the concentration of PM<sub>2.5</sub> is between 11.98 and 15.08 µg/m<sup>3</sup>. Thus, the concentration of PM<sub>2.5</sub> decreases as air humidity increases.

The relation between air temperature and PM<sub>2.5</sub> content is presented in figures 10-12.

The temperature recorded at the sampling site range from -2.86 to 26 to 26.5 °C. When temperature is lower (0.32 °C), the concentration for PM<sub>2.5</sub> is higher (47.31µg/

m<sup>3</sup>) as compare to higher temperature (26.5 °C) with a concentration of only 13.05µg/m<sup>3</sup>. This is due to the fact that in winter season with low temperature is a higher fuel consumption for heating. Furthermore, the high temperature enhanced the vertical mixing of air particles which pulls the air components/pollutants upwards, thus reducing the content of air pollutants on the surface of the earth.

By comparing our results with results presented in other research studies, similar values were observed for PM<sub>2.5</sub> level in the air from Targu-Jiu [5].

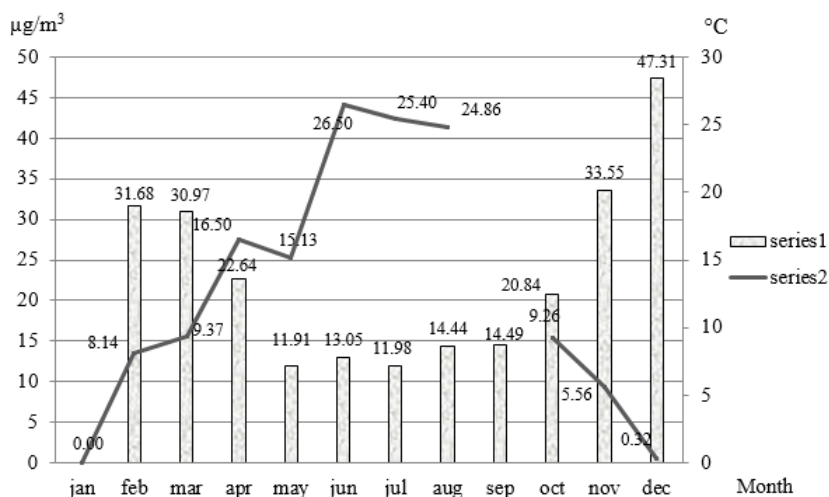


Fig. 11. The variation of the monthly average concentrations of PM<sub>2.5</sub> (series1) and air temperature (series2) in 2016 Targu Jiu

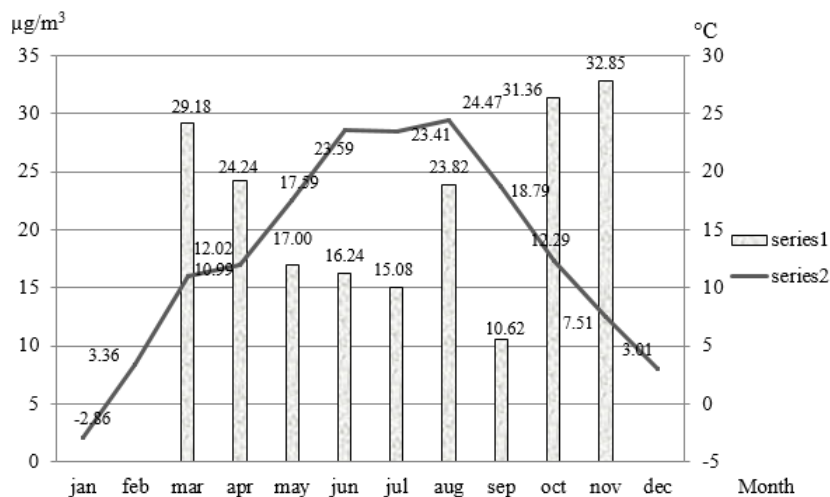


Fig. 12. The variation of the monthly average concentrations of PM<sub>2.5</sub> (series1) and air temperature (series2) in 2017 Targu Jiu

## Conclusions

On the basis of the above, the following conclusions can be drawn:

- the degree of urban pollution is directly related to the territorial dimension of the urban center, correlated with the population density, the infrastructure serving the respective community, the structure, the development and the placement of the productive systems;

- by their nature, size and chemical composition, suspended particles are one of the major components of pollutant air in urban areas;

- from the point of view of air pollution in urban areas, the main source of pollution is road traffic, with the most exposed areas being along the most intensely circulated arteries and those near the intersections;

- together with road traffic, the industrial units present in the north and west, the small industry and the heating of the dwellings, especially in the cold season contribute to the air pollution in Targu Jiu;

- reporting the annual PM<sub>2.5</sub> concentration values to the admissible limit value has highlighted that this was exceeded only for 2015 from the three years under study;

- the analysis of monthly average concentrations shows that the highest values were recorded in the year 2015, 45% of which were above the limit value;

- all PM<sub>2.5</sub> concentrations with the maximum values recorded each month during the years 2015 and 2016 were higher than the limit value compared to 2017 when 78% of the maximum concentrations were higher;

- PM<sub>2.5</sub> levels show the smallest values were between April and September for the three analyzed years, with the specification that they did not appear in the same months of each year;

- for 2015, the smallest PM<sub>2.5</sub> concentrations were recorded in April, June and September, for 2016 in May, June and July, and for 2017 in June, July and September;

- the smallest concentrations of PM<sub>2.5</sub> in Targu Jiu were registered in the period May-July 2016, the longest period in which the PM<sub>2.5</sub> level was the lowest;

- the highest pollution levels occurred during the months of February, March, October and November of the three analyzed years;

- the concentration of PM<sub>2.5</sub> decreases as air humidity increases;

- the concentration of PM<sub>2.5</sub> increases as air temperature decreases;

- given the chemical nature of air pollutants and different forming conditions, measures to reduce them before they reach the air are applied separately for each one.

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Manuscript received: 12.03.2018