Meteorological Parameters and Air Pollution in Urban Environments in the Context of Sustainable Development

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Abstract. In big cities, certain meteorological phenomena can affect air quality even in cases where the main sources of pollution such as traffic have low intensity. The air pollution varies greatly, depending on the emission source and the type of pollutant. In addition, the dispersion of air pollutants is influenced by weather conditions, as well as other factors such as the type of pollutant and regional and local topography. The air quality is one of the targets of the 11th goal of the UN 2030 AGENDA for sustainable development, also adopted at the national level. This study aims to correlate temperature and humidity with atmospheric pollutants, like PM₁₀.

The data were obtained by continuous monitoring for a period of 9 days (5 days when precipitation was recorded and 4 days when precipitation was absent) in which the relative humidity varying between 32-104% while the concentration of PM₁₀ between 13-118 μg/m³. The measurements on air quality parameters were performed in the central area of Bucharest city, near an important boulevard with intensive vehicle traffic and sometimes traffic jams. During daytime period, it was observed that the temperature inversion could be the cause the accumulation of high PM₁₀ levels near the road surface for some hours of the monitoring period.

1. Introduction

Air pollution in big cities is a complex phenomenon caused by a number of different factors, such as a large number of emission sources, the chemical transformations of the pollutants and the impact of weather and topography [1]. The available information for Europe show that traffic (25%), combustion and agriculture (22%), domestic fuel burning (20%), natural dust and salt (18%), and industrial activities (15%) are the main sources of particulate matter contributing to cities’ air pollution [2]. Nowadays, road traffic emissions have become the main cause of concern about the effects of urban air quality on human health and tropospheric ozone production [3]. There are various types of vehicles, with engines that use different cycles, are powered by various fuels which emit different amounts of pollutants [4]. At the European level over the past decades, measures include the introduction of the three-way catalytic converters, the renewal of the car fleet, and the improvement of...
fuel quality have been made. As a result, emissions of many air pollutants have decreased substantially but air pollution remains a major problem at the EU level [4]. Do to continue growth of population, some of the urban and suburban areas are still exposed to concentrations of pollutants that exceed the daily PM$_{10}$ limit value of 50 $\mu$g/m$^3$ imposed by the Directive 2008/50/EC of the European Parliament and of the Council on ambient air quality and cleaner air for Europe [5]. Various studies have shown that in both developing and developed countries, particulate matter emissions are high. In developed countries, emissions from traffic are less hazardous due to emission control technologies and the use of clean fuels [4]. Other sources of particulate matter in cities are paved and unpaved streets and other processes as the erosion of buildings. Highly concentration of particles in the air is a cause of both newly formed and previously deposited particulate matter and is a process initiated by meteorological parameters and traffic and conditioned by the relief and the location and dimensions of the buildings. The raised dust has a significant contribution to the quantity of coarse particulate matter in the volume of the air [6,7]. In Europe, between 13 and 37% of PM$_{10}$ is dust, while in arid areas dust is more than 80% of PM$_{10}$ concentration. [8]. Depending on the area, the air could contain a mixture of gases and particulates, in different concentrations [9]. Suspended particulate matters fall into the category of breathable particulate [10]. Health effects may be caused by acute exposure to pollutants (high concentrations of pollutants, short exposure period) or chronic (low concentrations of pollutants, long exposure period) [11].

Global population growth and changes in the percentage of the population living in urban areas have led to the cities with large numbers of inhabitants, where the impact of anthropogenic activities on air quality is high [12]. As a result of population growth, cities must ensure in the process of continuous urbanization, the maintenance of air quality through smart solutions in respect of the 11th goal of the UN 2030 AGENDA for sustainable development. Although air quality monitoring networks have been greatly improved, interpreting their expanding data in both simple and efficient ways remains challenging [13].

This study analyzes the concentrations of PM$_{10}$ measured by continuous monitoring in a central area of Bucharest city, near an important boulevard with large vehicle traffic and sometimes traffic jams. Also, the monitored area is considered one of the main crowded areas of the city. The main objective was to assess the air quality and to analyze the influence of meteorological parameters on the dispersion and accumulation of the pollutants in the area. The study is relevant, taking into account the fact that, according to a decision of the Court of Justice of the European Union, Romania has repeatedly and continuously violated the limit values for PM$_{10}$ emissions in the capital Bucharest.

2. Methodology

2.1. Studied area

The monitoring of the air quality parameters was performed for a period of nine consecutive days, starting with 02.10.2017, (hour: 11:00), until 10.10.2017, (hour: 16:00). The studied area is located in the center of Bucharest, in the immediate vicinity of Cismigiu Park, a recreation area that covers approximately 14 ha. Near the monitored area is located Gheorghe Lazar - High School, with primary, secondary, and high school education units. The air pollution mainly affects those people living or spending their time in large urban areas, where road emissions contribute the most to the degradation of air quality [14]. Taking into account the information provided by the WHO according to which children are the category of people most vulnerable to air pollution [15], the study analyzes the air quality and determines the concentrations of pollutants to which they are exposed daily.

In Bucharest, there are 8 stations of the-RNMCA (National Air Quality Monitoring Network) that monitor the level of pollution [16]. The RNMCA station nearest to the area where the air quality monitoring was performed by INCDPM during 02-10.10.2017 is B6 [17]. The data provided by B6 was compared with those registered by the mobile laboratory for the same period of time in order to analyze the tendency of PM$_{10}$ concentration in the monitored area. The distance between the location
area of the INCDPM (National Institute for Research and Development in Environmental Protection) mobile laboratory and B6 was 520 m, according to the spatial distribution in figure 1.

![Figure 1. Map of sampling point (Bucharest, Romania).](image1)

From the analyzed data although there was a symmetrical tendency, the values of the Pm10 concentration measured at the same time and for the entire monitoring period by the B6 and mobile laboratory was different.

2.2. In-Situ Monitoring

*In-situ* monitoring of air quality indicators and meteorological parameters is the most efficient process to analyze the air quality in certain areas. The activities were carried out by INCDPM using the mobile laboratory shown in figure 2.

![Figure 2. Monitoring air quality parameters - Mobile laboratory of INCDPM.](image2)

The INCDPM mobile laboratory for air quality monitoring is equipped with a weather station and analyzers for sulfur compounds (SO$_2$, H$_2$S), nitrogen compounds (NH$_3$, NO$_2$, NOx) and carbon compounds (CO), O$_3$ and VOC analyzers and sampler for particulate matter (PM$_{10}$, PM$_{2.5}$ and TSP). During the monitoring activities, measurements of suspended particles with a diameter of less than 10 $\mu$m were performed using both the mobile laboratory (measuring at a 2.5 m height above the road).

Throughout the monitoring period, the meteorological station recorded each minute the values of the following parameters: wind speed and direction, atmospheric pressure, air temperature, solar radiation, humidity. At the same time, the equipment has recorded the values of the concentrations of the pollutants monitored. Regarding VOCs, benzene and toluene were identified, but the value of their
concentrations was well below the limit allowed by law. In addition, the concentrations of sulfur compounds and \( \text{O}_3 \) did not exceed the limit values specified in Law 104/2011 (Directive 2008/50/EC).

Although the monitoring was carried out near an intense circulated boulevard, near an intersection where some frequent traffic jams are created, for certain categories of pollutants generated by road traffic (\( \text{NO}_2 \), \( \text{NO}_x \), \( \text{CO} \)) there were no exceedances of the limit values. The only exceedances of the limit values were for PM\(_{10}\) concentrations. The results have been obtained by processing the data provided by the WinAQMS software, based on which the values of particulate matter concentrations and weather data were processed.

### 3. Results and Discussions

#### 3.1. Temperature and humidity effects on particulate matter concentrations

Figure 3 represents the maximum and minimum values of relative humidity (RH), and the values of particulate matter concentrations recorded on each monitoring day.

![Figure 3. Effect of RH to PM\(_{10}\) concentration.](image)

The monitoring activities were performed under different conditions of temperature and humidity, so that a realistic assessment of air quality in the area could be achieved depending on the variation of meteorological parameters and the intensity of pollution sources. The first part of the monitoring period (02-06.10.2017) was characterized mainly by temperature values higher than usual and lack of precipitation. In these meteorological conditions, average daily concentration of PM\(_{10}\), exceeded the limit value of 50 \( \mu \text{g} / \text{mc} \) provided by national Law 104/2011. Figure 4 shows the variation between RH and traffic emission to the PM\(_{10}\) concentration in period 03.10.2017-06.10.2017, period characterized by the lack of precipitation.

In the first part of monitoring period, the relative humidity was specific to a dry to normal air during the day (RH = 31-50% - dry air; RH = 51-80% - normal air) and humid air during the night (RH = 81-90%). It can be observed the increase in PM\(_{10}\) concentrations during the night is largely influenced by dry air but also from other sources, such as waste incineration, functioning of thermal plants, or due to the other meteorological process. It can be seen that in some hourly intervals, although the traffic was not high during the night, the PM\(_{10}\) concentrations were increasing and that could be the causes of thermal inversion generated by meteorological phenomena or other causes.
Figure 4. Effect of RH and traffic emissions to PM$_{10}$ concentration in the first period of monitoring.

Starting with 06.10.2017 (hour: 22.10) until 08.10.2017 (hour: 13.30), the air was humid (RH = 81-90%) to very humid (RH = 91-99%), both during the day and at night. From figure 5, it shows the variation between RH and traffic emission to the PM$_{10}$ concentration in the second monitoring period 07.10.2017-10.10.2017, characterized by precipitation and lower temperatures common for that autumn month.

From the data presented it is found that the problems related to PM$_{10}$ pollution are only in the first period of the investigation when the values of the registered concentration were higher in the night compared with the day. Regarding the particulate matter concentrations recorded in the studied area, it can be concluded that a possible cause of PM$_{10}$ increase could be traffic emissions corroborated with other factors, among which the meteorological parameters [18].

In order to identify a possible link between pollutant concentrations and the weather regime, a synoptic analysis was performed above the Romanian territory, for one day of the period of monitoring study (04.07.2017). For this, synoptic maps available from the Wetterzentrale Meteorological Center in Germany were used. Such an analysis is useful to determine to what extent the high values of some pollutant concentrations can be caused by a high thermal regime.
Figure 5. Effect of RH and traffic emission to PM$_{10}$ concentration in the second period of monitoring.

Figure 6 shows an anticyclone structure extended above Europe, so we find the Azores Anticyclone above the area of Romanian country in the day of 04.07.2017. Figure 7 shows the effect of this meteorological phenomenon, which has favored the transport of cold air mainly over northern and central Europe in that period.

By analyzing the figure 6 and figure 7, it can be concluded that the higher values of the PM$_{10}$ parameter in the nighttime intervals in which the traffic was reduced, can be associated with the persistence of the high-pressure field, which allowed a warm air advection above the territory of Romania and favored the apparition of thermal inversion.
As shown in another study of the scientific literature, high concentrations of PM$_{10}$ occur frequently in the situation where anticyclone structures persist above some areas determining conditions of atmospheric stability and atmospheric calm. These conditions usually cause a rainfall deficit in the cold season, which allows the accumulation of pollutants in the atmosphere [20]. From the analysis performed for the period when there were high values of PM$_{10}$ results with a high level of confidence that the anomalies regarding higher concentrations of PM$_{10}$ in night periods are due to the thermal inversion phenomenon. Taking into consideration that a more extensive investigation has not been conducted, we cannot exclude the influence of other sources that may contribute to these anomalies.

4. Conclusions
In this study, PM$_{10}$ concentrations were continuously measured and analyzed, in a central area of Bucharest city, where high traffic is recorded, as well as frequent traffic jams. The analysis was performed in different weather conditions, both on days when precipitation was recorded and on days when precipitation was absent. The monitored area is considered one of the main crowded of the city but there is also an urban park with an area of 14 ha. The main objective was to assess the air quality and to analyze the influence of meteorological parameters on accumulation of the pollutants in the area. During the air quality monitoring activities, different temperature and humidity conditions were recorded, so that an analysis could be performed regarding the influence of meteorological parameters on air pollution. The results obtained, as a result of processing the data obtained with the WinAQMS software, were analyzed to identify potential links between the weather conditions and the recorded concentrations of pollutants. In both monitoring periods, a possible influence of the meteorological parameters on the recorded PM$_{10}$ concentrations is observed. In the first part of the monitoring period, average daily concentration of PM$_{10}$, exceeded the limit value of 50 µg/m$^3$ provided by national Law 104/2011. Regarding the particulate matter concentrations recorded in the studied area in the night intervals of the first investigation period, it can be concluded that a possible cause of PM$_{10}$ increase could be traffic emissions corroborated with other factors like anticyclone phenomenon which causes the thermal inversion and favored the accumulation of pollutant concentration in some specific areas.

Acknowledgement
This work was financially supported by the Programme “Nucleu” (2019-2022) coordinated by the Romanian Research and Innovation Ministry

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