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COMPREHENSIVE ANALYSIS OF PARTICULATE MATTER VARIABILITY IN AN URBAN ENVIRONMENT USING Rapid-E MONITORING

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Abstract

Fine particulate matter (PM) pollution is a significant environmental and public health concern in urban areas. This study presents an extensive assessment of PM concentrations in Galați, Romania, using the RAPID-E monitoring system. The equipment was deployed at the RI REXDAN (Research Infrastructure REXDAN – George Coşbuc no. 98) to continuously measure PM concentrations at 0.3, 0.5, 1, and 5 µm from December 31, 2023 (22:00) to December 30, 2024 (22:00). The collected data were analysed to determine temporal variations in particulate matter, including monthly means, daily averages, weekday versus weekend patterns, and variations between working days and weekends. By identifying key pollution trends and fluctuations over the monitoring period, this study provides insights into the dynamics of urban air quality and potential emission sources. The findings contribute to a better understanding of PM pollution variability and support the development of effective air quality management strategies in urban environments.

Key words: *air pollution, particulate matter, urban monitoring, RAPID-E, PM variability, temporal analysis, air quality assessment.*

INTRODUCTION

In recent decades, air quality has become a significant global issue, raising concerns about its impact on public health, the environment and ecosystems. The pollutants that influence air quality are SO_2, NO_2, CO, CO_2, O_3 and particulate matter (Constantin et al., 2013; Dragomir et al., 2015; Meier et al., 2017). SO_2, NO_2 and particulate matter arise from the combustion of fossil fuels (Constantin et al., 2020; Merlaud et al., 2018; 2020; Roșu et al., 2020; 2021; 2023). Particulate matter air pollution is a serious problem, especially when we are dealing with fine and ultrafine particles, between 0.3 and 5 µm (Sanda et al., 2023; Iordache, 2017). These particles, often invisible to the naked eye, can penetrate deep into the respiratory tract and even enter the bloodstream, posing significant health risks. Primary sources of these particles include industrial activities, road traffic and natural phenomena such as volcanic eruptions and desert dust (Baldacchini et al., 2019; Lonati & Giugliano, 2006; Ramgolam et al., 2008). The size of these particles determines their ability to reach the lungs and bloodstream, increasing the risk of respiratory and cardiovascular diseases. Prolonged exposure to air polluted with fine particles can exacerbate pre-existing conditions such as asthma and chronic lung disease and may even contribute to reduced life expectancy (Alemayehu et al., 2020; Kelly et al., 2017). Vulnerable groups, such as children, the elderly, and people with compromised immune systems, are particularly susceptible (Kirešová et al., 2023; Pétremand et al., 2022). The economic burden of air pollution, including healthcare costs and loss of working productivity, further underscores the urgency of addressing this issue (Conte et al., 2020; Zoran et al., 2023). Air pollution also has a wider environmental impact, including contamination of water sources, soil degradation, and

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disruption of ecosystems. The European Commission has set air quality limit values for particulate matter (PM10) and requires the collection of PM2.5 data to protect public health. However, data on finer particles, such as $PM_{0.5}$, PM_1, and PM_5, are less available. To address this gap, the Rapid E+ equipement, the successor of Rapid E and PA-300, has emerged as a crucial tool for measuring fine particles in the air (Aït-Khaled et al., 2009; Šaulienė et al., 2019). This device uses optical detection technology and laser illumination to measure particles in the 0.3-5 µm range with high accuracy (Boldeanu et al., 2021; Tešendić et al., 2020). Rapid E+ provides a fast and accurate method for continuous monitoring of particle concentrations in a variety of environments, from polluted urban areas to industrial and natural environments (Crawford et al., 2023; Yanagi et al., 2023) . In this study we present the results of one year (2024) of data analysis from our Rapid E+ equipment installed at RI REXDAN (Galați city, Romania).

MATERIALS AND METHODS

Study area and localization

For our study, we conducted continuous dust measurements in the city of Galați, one of the largest urban areas in Romania. The measurements were carried out over a whole year, from January 1, 2024, to December 30, 2024, at the specific location at George Coșbuc Blvd, no. 98 (coordinates: 45°26'6.66"N 28° 2'14.02"E). This location was chosen because it is an area with intense traffic and urban activity. It is also important to note that during this period, significant infrastructure repair works were underway in the area, which could have affected air quality. To collect accurate and reliable data on particle levels, we used the Rapid-E+ equipment, which was placed in the courtyard of the RI Rexdan. The location of the Rapid-E+ device is shown in Figure 1. The aim of this study was to analyse particulate levels in the context of ongoing construction activities and urban development.

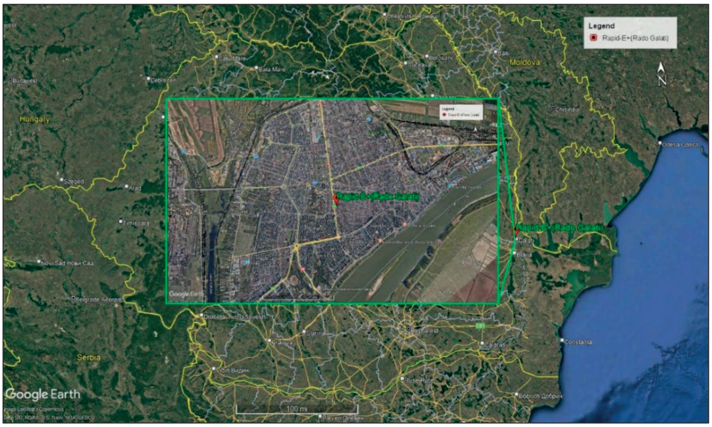

Figure 1. Location of the deployment of the measuring equipment (REXDAN)

Equipment and data used

Rapid-E+ is an advanced bioaerosol sensor that uses proprietary laser technology to analyze individual aerosol particles in real time. Its integration with GPU (Graphics Processing Unit) acceleration significantly improves the speed of data acquisition and processing, providing exceptional performance in tracking and identifying aerosols in complex environments. The sensor continuously monitors and characterizes airborne particles ranging in diameter from 0.3 to 100 µm. Values of 0.3 µm indicate particles with sizes between 0.3 and 100 µm, while values of 0.5 µm refer to particles between 0.5 and 100 µm. Also, values of 1 µm cover particles between 1 and 100 µm, and values of 5 µm include particles between 5 and 100 µm. Backed by years of continuous measurements, Plair technology combines scattered light pattern analysis and fluorescence spectroscopy, ensuring reliable, real-time monitoring of ambient air. Rapid-E+ operates autonomously and remotely, giving users access to data anytime, anywhere. Detailed characteristics of the device (Rapid-E+) are provided in the following table, Table 1, which outlines its specifications and key features of the equipment (https://www.plair.ch/rapid-e.html).

Table 1. Specification of the intelligent bioaerosol sensor Rapid-E+ used for data collection in the city of Galați throughout the year 2024

Parameter	Value	Details
Particle size range, micrometers (µm)	0.3-100	-
UV laser wavelength, nanometers (nm)	337 ± 5	-
Scattering laser wavelength (nm)	447 ± 5	-
Imaging laser wavelength (nm)	637 ± 5	-
Fluorescence spectral range (nm)	390-570 ± 5	12 nm per pixel
Fluorescence spectral ranges of lifetime module (nm)	375-397 ± 5 415-450 ± 5 467-487 ± 5	1 photodetector per spectral range
Fluorescence decay resolution, nanoseconds (ns)	1	For each spectral range
Sample airflow, liters per minute (LPM)	5	-
Maximum counts (scattering only), Maximum counts (fully analysed)	1,000,000 4.800	Particles per minute
Power supply (Volts AC)	90-240	-
Power consumption (watts)	less than 200	Maximum value
Size (H x W x D), centimeters	40 x 34 x 55	-
Operating temperature (°C)	-10 ... +40	Temperature range can be extended with an outdoor box
Humidity (%)	0-95	Without condensation
Weight (kg)	25	-

Rapid-E+ comes with an online platform or dashboard called PlairGrid, which allows users to visualize data collected in the field. PlairGrid is a free, easy-to-use tool that allows users to explore raw data and create a machine learning model capable of classifying particles in real time. This advanced functionality is designed to help users accelerate their data analysis processes, giving them the ability to take full control of their experiments and projects. With these tools, users can start working with their data immediately and easily, without the need for complex setup or additional software. The device was designed to meet the growing need for efficient, accurate, and real-time monitoring of bioaerosols, which include particles such as pollen, bacteria, and fungal spores, among others. By enabling continuous and accurate data collection, Rapid-E+ helps users better understand the dynamics of airborne particles, which can have a significant impact on health, environmental quality, and various research areas. Its design allows researchers, healthcare professionals, and environmental specialists to detect, classify, and analyse these particles in real time, making it a powerful tool for studying air quality, biological hazards, and public health risks. The integration of machine learning and real-time data visualization improves the overall efficiency and effectiveness of experiments, ensuring that users have the flexibility to adapt their approaches and make informed decisions quickly.

Figure 2. Image of REXDAN RI Rapid-E+ equipment

RESULTS AND DISCUSSIONS

Using the detailed data collected by the Rapid-E+ sensor, we have created a series of complex graphs that highlight the average values of airborne particle concentrations throughout

2024. We have separated each category of particles data, so we were able to organize the values so that they showed the values for different categories i.e. 0.3µm (particles between 0.3µm and 0.5µm), 0.5µm (0.5-1µm), 1µm (1-5µm), and 5µm (5-100µm), respectively. These results of data analysis are structured for each day of the week, for particle size interval in the air: 0.3, 0.5, 1 and 5 µm. Analysis of these data allows for a detailed assessment of daily variations in fine particle concentrations, providing valuable information about the behaviour and distribution of aerosols in the atmosphere over an entire year. These observations are essential for understanding the factors that influence air quality that could affect public health and the environment, especially regarding the sizes of respirable particles that can have significant effects on human health. We also present the σ = RMSA to determine the errors that may arise from external conditions, measurement errors, and systematic errors. In this formula, σ represents the standard error, and RMS (Root Mean Square) measures the average magnitude of the errors, calculated by the square root of the average of the squares of the differences between the estimated and actual values. All data representation was created using python code i.e. using matplotlib a native Matlab ploting library implemented with python code via the open-source IDE Spyder (Scientific Python Development Environment).

As can be seen in Figure 3, the values increase exponentially with the size of the particles included in that range. This phenomenon is due to the fact that small particles (below 1 µm) persist longer in the air, due to their small mass and the reduced influence of gravity on them (Casale et al., 2009). Thus, they are suspended for a longer period of time and can be transported over long distances by winds and atmospheric currents. In contrast, larger particles (above 5 µm) settle more quickly due to their greater weight and rapid sedimentation in the atmosphere.

In the analysed graphs, the size range 5-100 µm does not exceed values over 4 thousand per hour, which suggests that larger particles are fewer, because they sediment quickly. In contrast, particles in the range 0.3-0.5 µm can reach concentrations of up to 1.5 million particles per hour, since they are more numerous and remain suspended longer in the air.

As can be seen in the seven graphs presented, the values corresponding to particles of 0.3 and 0.5 µm are represented on the vertical axis on the left, and the data are collected periodically, at one-hour intervals. These values reflect the particle concentrations in a specific period, and the collection interval allows for a detailed observation of their variability over time. On the other hand, the values corresponding to particles of 1 and 5 µm are displayed on the vertical axis on the right, and the scale of this axis varies from one day to the next, depending on the distribution of larger particles. As we progress further into the week, we notice that the values increase slowly but progressively, with Mondays having relatively low values due to the break period of the weekend, when traffic was reduced and work-related activities were at lower end, and Fridays having the highest values of the week and some of the most visible fluctuations in the measured parameters.

On October 19, 2024, between 10:00 and 11:00, a significant and sudden increase in the values of particles in the size range of 1-5 µm was observed in the monitoring carried out on the PlairGrid online platform. This increase was remarkable, with values exceeding by more than 100 times the average values recorded in previous reference periods. Moreover, this fluctuation not only had an immediate impact on the data from that period, but also affected the annual average of Saturday, causing an unusual increase in the values recorded for this day compared to other Saturdays of the year. The significant change in the annual average underlines the importance of a detailed analysis to identify the causes of this abnormal behaviour.

As for the possible causes of this phenomenon, they may include a technical error in the measuring equipment. Another possible cause may be temporary contamination of the environment or equipment. If an external source of contamination was active at that time, this could have led to a punctual accumulation of particles, influencing the measurements, without affecting the entire monitoring time frame.

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To facilitate the observation of the differences between weekdays and weekends, we have created two distinct graphs. The first graph includes the average values for weekdays (Monday-Friday), and the second graph presents the average values for weekend days (Saturday and Sunday).

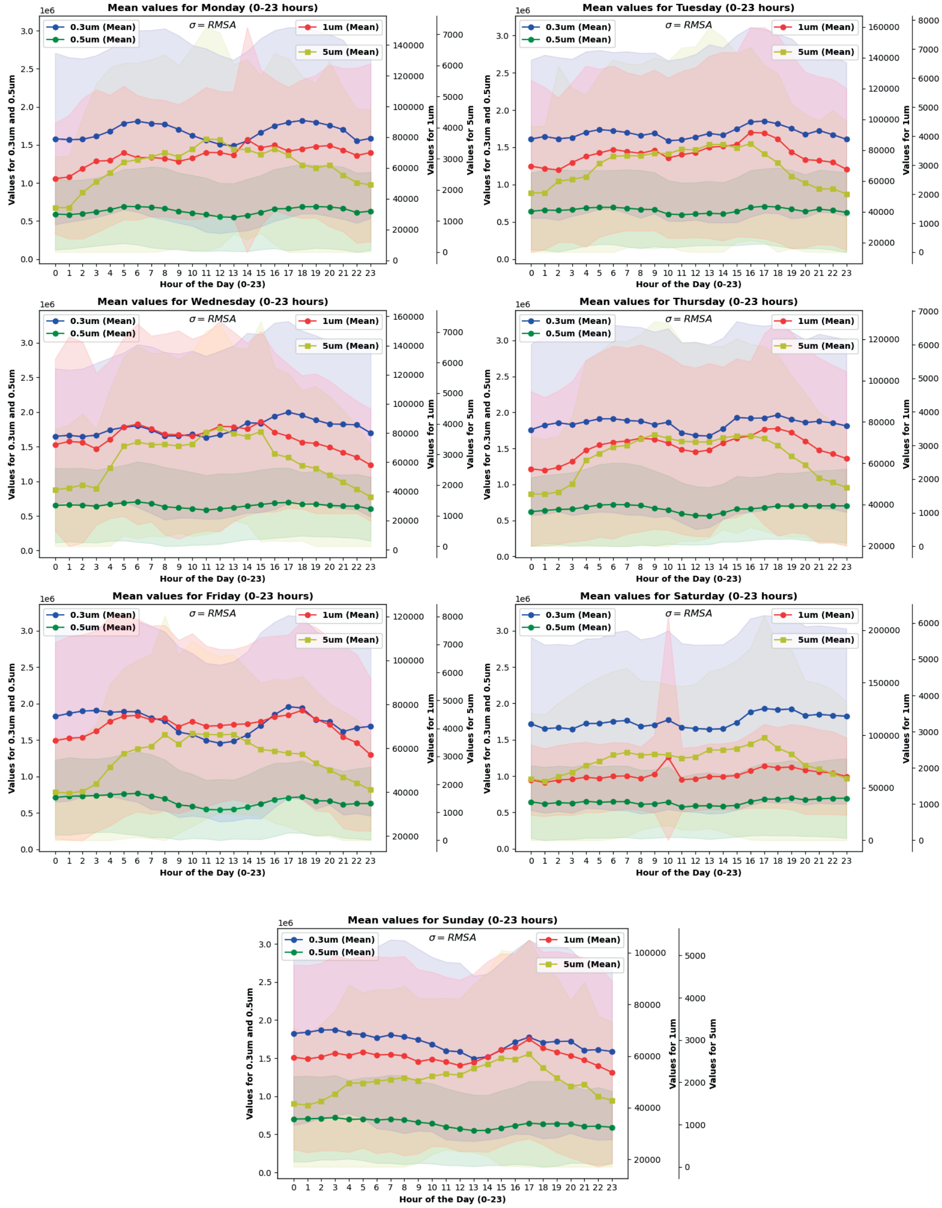

Figure 3. Mean value for each day of the week

These graphs allow a clear visual comparison of the trends and variability characteristic of each category of days, facilitating the identification of possible anomalies or significant differences in the behaviour of particle values depending on the week period (Figure 4).

By comparing the two data sets, it is possible to observe fluctuations that could be attributed to external factors specific to weekdays or weekends, such as changes in industrial activities, transportation, weather conditions or other environmental influences that may vary depending on the day of the week.

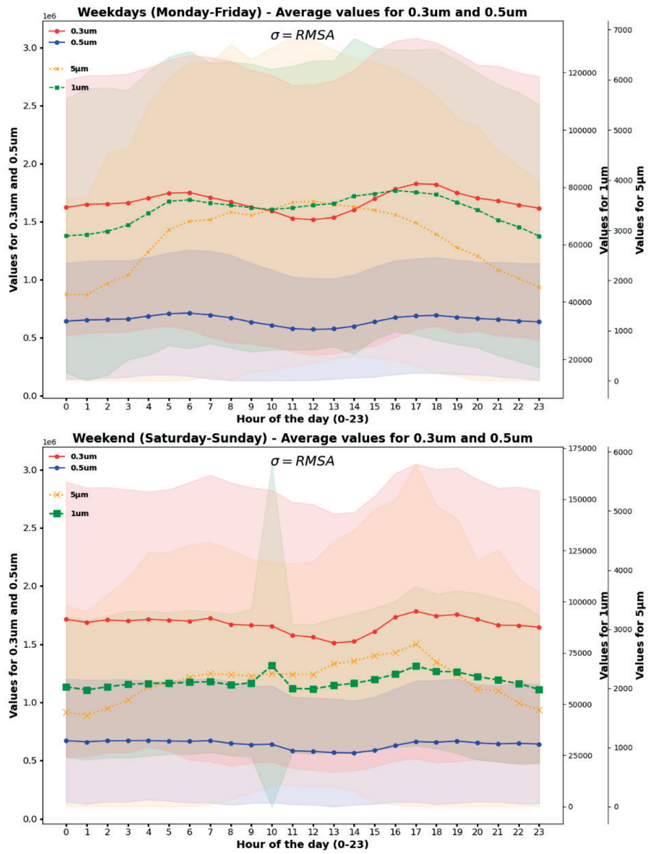

Figure 4. Mean value for workdays and weekend

Analysing the 2 graphs presented in Figure 4, a clear trend of variation of the measured values of particulate matter depending on the time of day is observed, with significant particularities on weekdays compared to weekends. During the week, the data reveal notable fluctuations, with substantial increases in the values around peak hours (6:00 and 17:00), intervals in which, usually, the highest values can be attributed the peak of human activity or intensified traffic. These peaks are significant, indicating moments of increased traffic or other activities related to the daily schedule of employees or workers.

In contrast, on weekends, the data show a relative stability of the values, without notable fluctuations, with only a few isolated exceptions that do not reach the intensity of those observed on weekdays. This behaviour suggests that, on weekends, activity is more constant and less influenced by the rigid schedule of weekdays, making it possible that variation factors are reduced and the activities carried out are more uniform. A significant external factor that can influence these variations on weekdays is represented by the road restoration projects carried out near the measurement area during the respective period.

Considering that infrastructure works involve periodic interventions that can affect the traffic flow or the schedule of activities, we can hypothesize that the significant decrease in the values around 12:00 on weekdays can be attributed to the lunch breaks of the workers involved in these projects. Thus, during the mentioned time interval, the activity of the workers is considerably reduced, which implicitly leads to a decrease in the measured values, even if the values are related to traffic, economic activities or other variables. It can be seen that particles larger than 5 µm do not follow the same rule as particles below 5 µm, as they do not have their maximums during peak hours of the day, but at 12:00 when small particles decrease in number. Another significant difference between weekdays and weekends is made by particles over 1 µm, which during the week reach values of over 80 thousand particles per hour, while during the weekend they do not exceed values of 75 thousand particles.

CONCLUSIONS

The results of this study demonstrate that the Rapid-E+ device is a complex and useful tool for local urban monitoring of airborne particulate matter as we presented in the results of measurements made throughout 2024 at REXDAN RI located at no 98 George Coşbuc Blvd, Galati, Romania. The main advantage of this device is the accuracy of its measurements on an extended scale (0.3-100 µm) and the ease with which the data can be recorded and processed. By making continuous measurements for particulate matter, we can more easily observe the dynamics of these pollutants and determine the factors that influence these parameters and the main sources (traffic, constructions and other natural or anthropogenic factors). The main objective of this research was to determine the average values of some air parameters over a whole year, with a particular focus on monitoring particulate matter. During the analysis, we observed that the factor that most influences the variation of pollutants is human activity, especially construction-related activities. These activities contribute significantly to fluctuations in particulate matter concentrations, especially during peak periods of the day. The most pronounced pollution values were observed during peak hours, when the number of construction sites and associated activities are increasing. This trend suggests that particulate matter emissions generated by such activities have a significant impact on air quality and public health. It is also important to note that these fluctuations are much more evident in urban areas, where economic activity and construction are at a high level. The next study will analyse the diurnal and nocturnal variations of particulate matter, as well as their changes according to the seasons (spring, summer, autumn, winter), using the Rapid-E+ device. This method will provide us with detailed information on how pollutant concentrations fluctuate throughout the day and at different times of the year. Thus, we will be able to observe the differences between day and night, but also how the seasons influence the level of particulate matter in the air. This analysis will contribute to a clearer understanding of the behaviour of pollution under different temporal conditions, providing essential data for long-term air quality management.

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