SCREENING OF PARTICULATE MATTER IN THE URBAN AREA OF SARAJEVO

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ABSTRACT
Particulate matter enters the atmosphere as a result of human activity, as well as natural processes. Since we still cannot influence natural processes, reducing the concentration of floating particles is possible only by adjusting human activity. The emission of solid particles occurs during a large number of everyday activities. Depending on the activity, particles of different chemical compositions and sizes will be emitted. In this work, PM1, PM2.5, and PM10 particles were measured and their daily ratio was calculated over a period of three months in 2022. In Sarajevo's urban area. The measurement was carried out with a laser sensor installed in the urban part of Sarajevo. The results showed the presence of all three types of particles. Continuous monitoring should suggest serious measures to the authorities in order to significantly reduce PM's impact on the health of Sarajevo residents.

1. INTRODUCTION

1.1. Particulate matter (PM)

PM is an important indicator of air pollution and the type and the ratio of coarse and fine PM particles differentiate the possibility to affect urban population health [1,2,3]. Some of the main meteorological conditions that affect the concentration of suspended particles in the air are wind, temperature, precipitation, and relative humidity. Investigations of suspended particles in the open air are important both for climatological research and for assessing the impact on human health. However, people spend most of their time in closed spaces [2,3,4], so PM particles in such spaces can have a much greater impact on their health. Many studies investigated the composition, size, and transport of PM particles in residential areas, schools, and catering facilities, as well as the dependence of indoor concentrations on outdoor concentrations [4-7]. Research shows that the quality of the air in a closed space largely depends on the quality of the outdoor air. From the different foreign studies that indicate the negative consequences of air pollution, not only on human health but also on the ecosystem, it is evident how important it is to improve air quality in the whole world. In order to improve air quality, it is necessary to measure the concentrations of suspended solid particles in the air. Measurements of the concentration

of floating particles in the air are made using the reference method that is, by the gravimetric method or one of the methods for which equivalence has been proven, for example, the oscillating microbalance method, the β-radiation absorption method or the scattering method laser light [8-12]. The number of PM particles at a fine time resolution can be measured with an optical PM particle detector. Optical particle counters work on the principle of laser light scattering on particles. The laser light passes through a chamber containing air with suspended particles, due to which the light is scattered. The scattered light is directed by an optical system toward a photodetector that creates a signal for the processor. Concentrations and particle sizes are further calculated from the intensity of the scattered light [8-14]. A wider availability of small and low-cost PM sensor devices will enhance our ability to estimate the PM particles with high spatial and temporal resolution. A large number of such devices can be deployed simultaneously. They are designed to be used also as mobile wearable devices for personal exposure assessment in a larger population. They will help empower the citizen through, for example, citizen science which includes projects and programs designed to engage the public in scientific investigations, such as asking questions, collecting data, or interpreting results [15].

1.2. Chemical composition and impact on human health of different PM

According to WHO statistics, Bosnia and Herzegovina (BiH) has the highest European mortality rate attributed to air pollution. However, there are no official national data to support or deny this finding [16]. Public health institutes in the country currently do not collect data on the health impacts of air pollution and communicate environmental health risks to the public only sporadically. Although the legal framework for air quality is largely in place, implementation and enforcement remain weak. National recognition of the problem through strategic documents, local action plans with implementable solutions, and public awareness of the air pollution impacts and mitigation measures are all key to tackling the issue but are all missing in the country. According to new research conducted by the WHO, the main source of air pollution is traffic, and there is evidence that it has a direct impact on the increase in mortality, as well as on the increase in respiratory and cardiovascular diseases [16-21]. In the European Union, according to WHO research, around 100,000 premature deaths of adults occur each year that can be attributed to air pollution, and emissions from road traffic represent a significant part of this burden [11]. PM metals can be used as indicators of their emission sources, that is their origin. Fossil fuel combustion is one of the main anthropogenic aerosol sources [22,23]. Heavy metals in the composition of PM particles (As, Cd, Pb, Co, Cu, and Mo) are emitted due to the combustion of coal, while particles with a predominant V, Ni, and Pb are emitted due to the combustion of oil fuels. Cu, Zn, and Pb are usually related to traffic emissions [22,23].

All PM particles can be inhaled and deposited in the respiratory system. Floating particles from the air entering the respiratory system usually stop immediately in the nose due to a change in direction. When changing the direction of movement, particles from the air are retained in the mucous membranes of the respiratory system, and this is called impaction. Since the particles are of different mass and size, their impact will differ in size. Larger aerosol or dust particles do not penetrate the lower respiratory tract because they stop on the hairs and mucous membranes of the upper respiratory tract, unlike them, smaller particles of a size of several micrometers pass through the upper part of the respiratory tract and reach the bronchi on whose walls they settle [17-19]. For the smallest particles, PM1, their size enables the furthest penetration through the respiratory tract, i.e. penetration all the way to the lung alveoli. When talking about the penetration of gaseous pollutants, the key factor is their solubility, i.e. the more soluble the pollutants are, the easier they will pass through the mucous membrane and the faster they will be absorbed and broken down

in the respiratory system. It is assumed that PM1 particles represent the greatest danger because they can penetrate deep into the respiratory system [17-20]. Thus, PM1 is the smallest and therefore potentially dangerous particles whose aerodynamic diameter is less than 1 μm. Legal regulations do not yet have a limit value for this type of particle.

2. MATERIAL AND METHODS

2.1. Measuring point

Dolac Malta (43°51′13.91″N 18°22′40.79″E) is a Sarajevo settlement within the municipality of Novo Sarajevo, with about 12,500 inhabitants. It consists of the local communities of Dolac with headquarters in Marko Marulića Street and Malta with headquarters in Envera Šehovića Street (Fig.1). The settlement is located in the west of the municipality, and consists of the local communities of Dolac and Malta, which are separated by Paromlinska street. The south of the settlement consists of plains with residential buildings and large commercial buildings, while the north of the settlement (around the Obad cemetery) is hilly, and houses have been built. In the north and northeast, it borders Pofalići, in the southeast with Željeznička, in the south with Hero's Square and Čengić Villa, while in the west it borders Buća Potok in the neighboring municipality of Novi Grad. Drinska Street and an active railway line run through the north of the settlement.

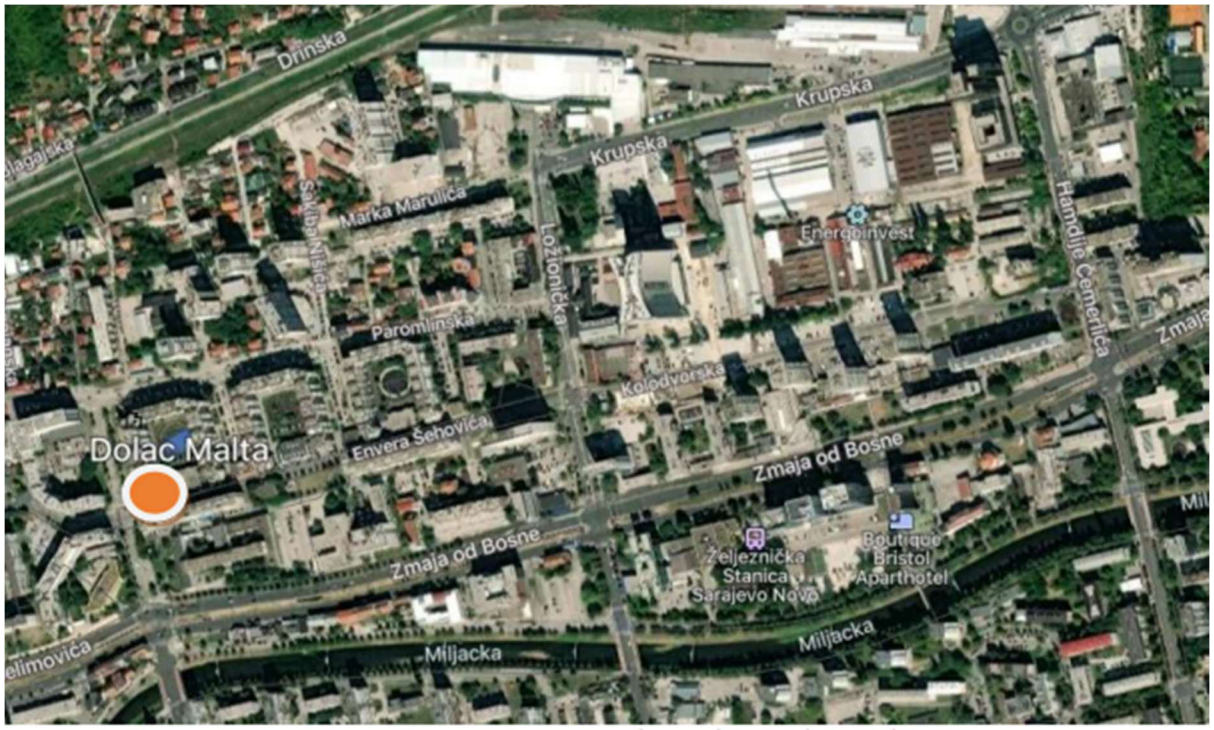

Figure 1. Measuring point in the Dolac Malta settlement

2.2. Measuring device

A laser particle sensor (Air quality monitor indoor/outdoor BR-V, Shenzen, China) is placed inside the balcony on the 3rd floor of the building (Envera Sehovica Street) in the area of the Dolac Malta settlement. In the immediate vicinity is a road with intensive traffic and a city heating plant. The device was not moved from the fixed measuring point during the three months period (Fig. 2).

Figure 2. Measuring device

2.3. Methods

The sensor measured the mass concentration (μg/m^3) of PM1, PM2.5, and PM10 particles from the outdoor air. The measurement was carried out every day at the same time (5 p.m. during rush hour) in the months of April, May, and June 2022. A permissible limit of 25 μg/m^3 for PM2.5 and 50 μg/m^3 for PM10 was used for the estimation of pollution epizodes [24]. Legal regulations do not yet have a limit value for PM1 particles. From time to time, our measured concentration of PM10 was compared with public data (obtained by reference method) in the nearest measuring points in Sarajevo's urban area. Public data for PM2.5 particles were not always available from public measurement points, and PM1 particles are not measured at all. Correlations between PM1 and PM2.5, a correlation between PM1 and PM10, and a correlation between PM2.5 and PM10, (respectively*)* were calculated [25]. To identify the dominant contribution of PM particles and to make aerosol-type classification, during the investigation period of the year, the ratio of PM1 and PM 2.5 to PM10 was calculated [26].

3. RESULTS AND DISCUSSION

Because of Sarajevo's geographical location and terrain configuration, during spring its tropospheric mixing is frequently low with regularly occurring temperature inversions. Extensive use of solid fuels during the cold, heating season and an old vehicle fleet coupled with Sarajevo's orography and meteorology causes the accumulation of pollutants within the city's plane, leading to episodes of high air pollution [13,14]. Other researchers investigated PM10 filter samples (for the concentration of heavy metals) collected at the site in the Sarajevo Canton: Bjelave (urban background site) in the city of Sarajevo operated by the Federal Hydrometeorological Institute of BiH (FHMIBiH) [13,14,22,23].

This study for the first time investigated the content of PM1 particles as the most dangerous for human health. Other researchers investigated the PM particles by using different sensors [8-14]. The obtained results, in our study area, of the content of PM1, PM2.5, and PM10 particles during April 2022 are shown in Figure 3.

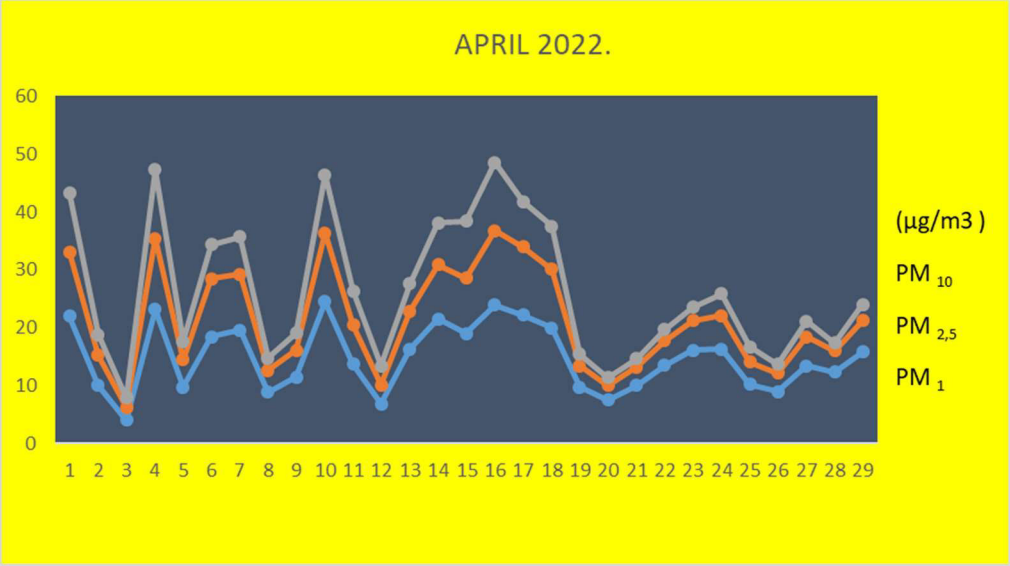

Figure 3. The daily variations of PM1, PM2.5, and PM10 particles during April 2022

Figure 3 shows the movement of the average daily concentrations of PM1, PM2.5, and PM10 particles in the air measured at the aforementioned measuring site during the month of April 2022. The concentration (µg/m^3) of measured PM1, PM2.5, and PM10 particles in April of 2022, were in the ranges of 4,06-24,48; 6,26-36,76 and 7,9-48,54, respectively. The obtained results of the content of PM particles during May 2022 are shown in Figure 4.

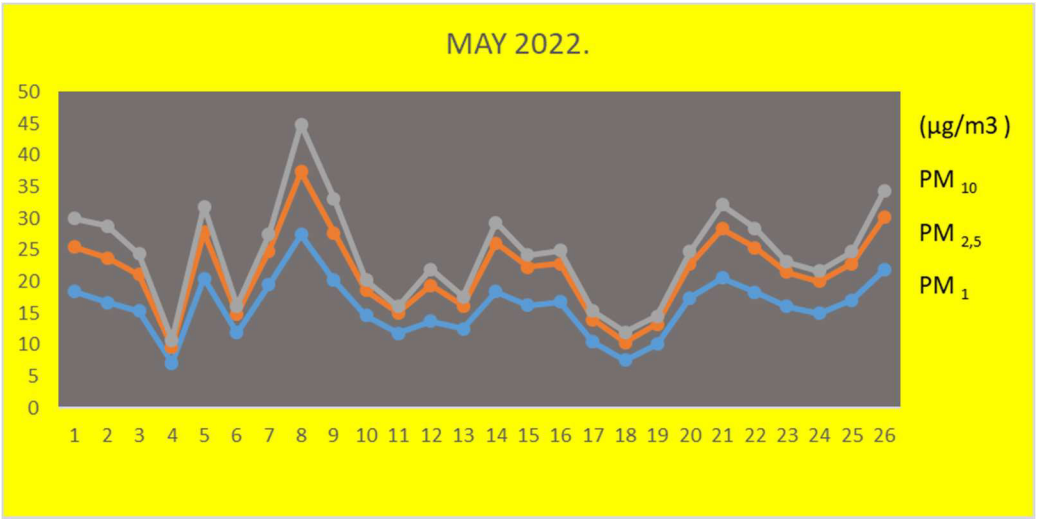

Figure 4. The daily variations of PM1, PM2.5, and PM10 particles during May 2022

Figure 4 shows the movement of the average daily concentrations of PM1, PM2.5, and PM10 particles in the air measured at the aforementioned measuring site during the month of May 2022. The concentration (µg/m^3) of measured PM1, PM2.5, and PM10 particles in May of 2022, were in the ranges of 7,12-27,39; 9, 67-37,4 and 10,73-44,84, respectively. The obtained results of the content of PM particles during June 2022 are shown in Figure 5.

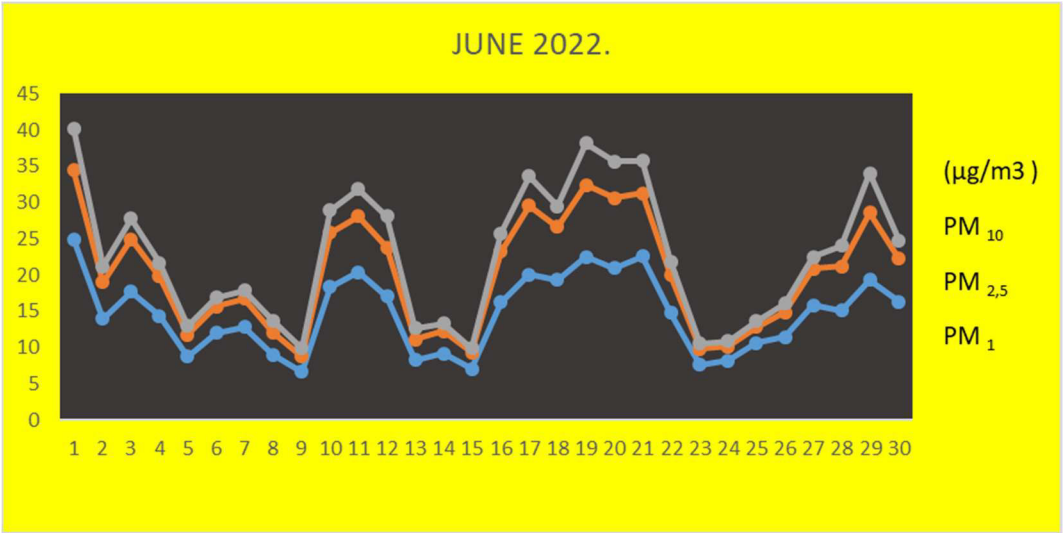

Figure 5. The daily variations of PM1, PM2.5, and PM10 particles during June 2022

Figure 5 shows the movement of the average daily concentrations of PM1, PM2.5, and PM10 particles in the air measured at the aforementioned measuring site during the month of June 2022. The concentration (µg/m^3) of measured PM1, PM2.5, and PM10 particles in June of 2022, were in the ranges of 6,63-24,95; 8,79-34,43 and 9,87-40,22, respectively. In the investigated three months period the PM1 particles were at high levels and PM2.5 levels were beyond the permissible limit of 25 µg/m^3 [24] these particles have a significant impact on mortality and morbidity caused by respiratory and cardiovascular diseases. More severe impacts affect people who are already ill. The elderly, children, and poor people are more susceptible. The concentration of PM10 particles was under the permissible limit of 50 µg/m^3 [24] and that was in accordance with weather conditions during the investigated period. The correlation between PM1 and PM2.5, the correlation between PM1 and PM10, and the correlation between PM2.5 and PM10 (respectively) are shown in Figures 6, 7, and 8.

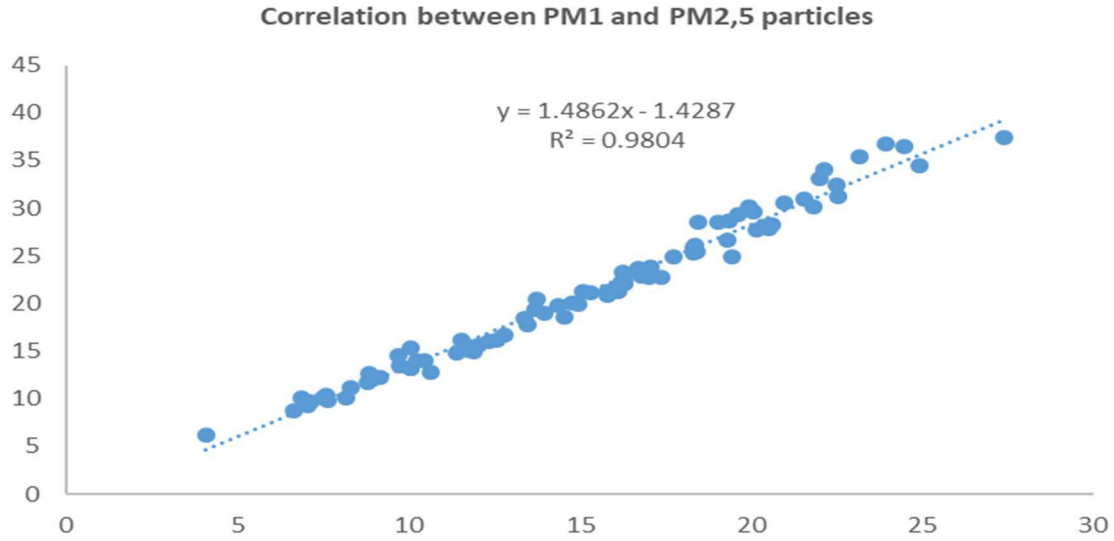

Figure 6. The correlation between PM1 and PM2.5 in investigated three-month period

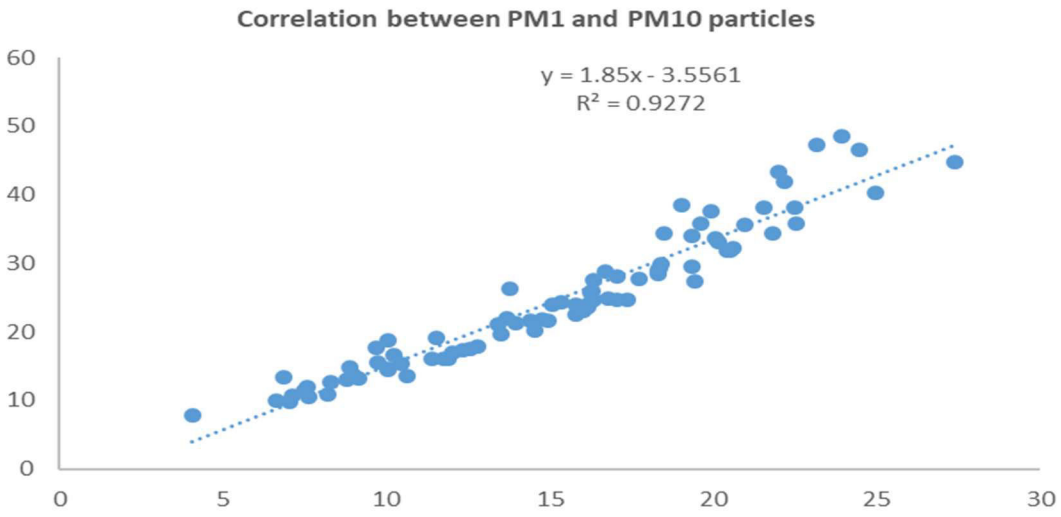

Figure 7. The correlation between PM1 and PM10 in investigated three-month period

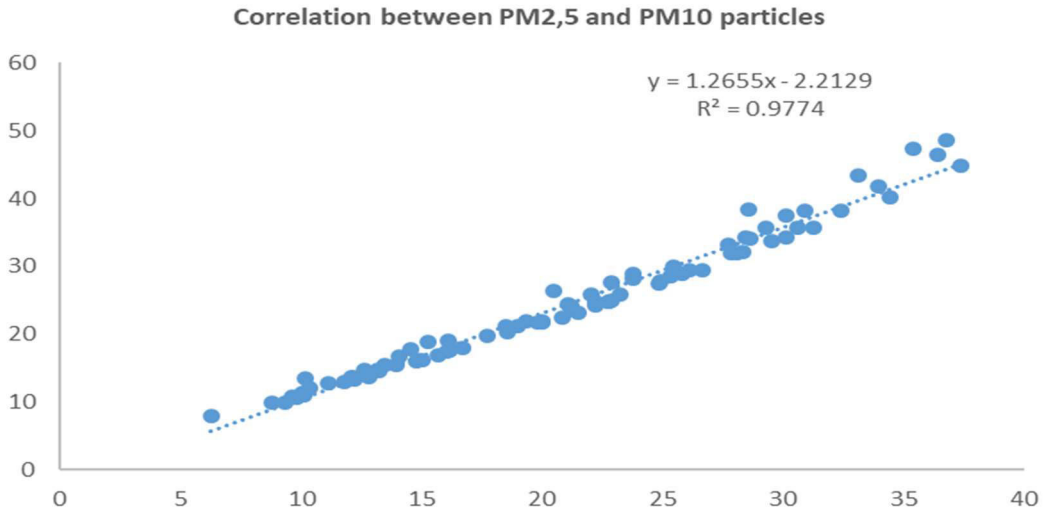

Figure 8. The correlation between PM2.5 and PM10 in investigated three-month period.

Results showed a very strong positive correlation. A similar investigation was conducted by foreign researchers [25]. The monthly variation in the ratio of PM particles is shown in Figure 9.

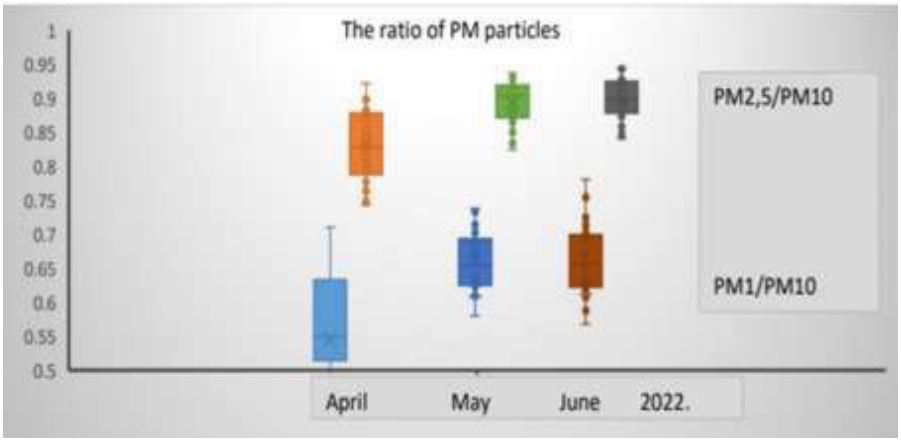

Figure 9. The monthly variations in the ratio of PM1 and PM2.5 to PM10

Results from Figure 9 generally showed that the ratio of PM1/PM10 and the ratio of PM2.5/PM10 was found to be > 0,5, in the three months period. Obtained results suggest an increase in fine-mode aerosol particles and coarse-mode aerosol particles and indicated a precaution to human respiratory health. A similar investigation was made in other countries [8-12,26]. Furthermore, modern laser sensor technology is available today to implement low-cost and reliable devices which are used by citizens as well as researchers. When such devices are deployed in multiple locations in urban areas of the city, they can provide highly temporal and spatial results and significantly contribute to the set of information important for exposure assessment and subsequent hazard mitigation. Experiences from foreign studies showed that for the wider use of such devices and the data that can be collected, it is necessary to develop the appropriate infrastructure and systems for quality assurance and control [8-13].

4. CONCLUSION

This study gives a short view of the content of different particulate matter determined by the commercially available laser sensor for indoor/outdoor monitoring in the urban environment of Sarajevo.

Measuring by laser sensor the content of PM1, PM2.5, and PM10 particles were registered at the three months period. The results showed lower contents of PM particles in the month of June compared to April and May, which is in accordance with meteorological conditions that significantly affect the movement of PM particles in the urban air.

Air Quality Management Plans shall address and recognize all sources of pollution prioritizing innovative and comprehensive measures that can provide multiple benefits.

Moving means of PM1, PM2.5, and PM10 and their concentrations in different seasons are useful in policy-making decisions aiming to improve the air quality in Sarajevo.

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