



YEAR-LONG MEASUREMENTS OF THE PM₁₀ AND PM_{2.5} IN AN APARTMENT IN BOR (SERBIA)

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Abstract

The results of measurements the PM₁₀ and PM_{2.5} concentrations in an apartment in the town of Bor, Eastern Serbia, are presented in this paper. Measurements were made throughout 2023 using a low-cost PM monitor placed in the apartment's living room. The measurement results were categorized on the basis of several dominant activities of the tenants, namely: morning activities, cooking, cleaning and sleeping. The average annual PM₁₀ and PM_{2.5} concentrations in the apartment were 8.7 µg/m³ and 5.7 µg/m³ respectively. The highest average hourly PM concentration occurred during the cleaning activity with the PM₁₀ concentration of 61.5 µg/m³ and PM_{2.5} concentration of 41.5 µg/m³. The lowest average of hourly PM concentrations was recorded during the vacation period with the average PM₁₀ concentration of 5.3 µg/m³ and average PM_{2.5} concentration of 4.0 µg/m³. The lowest hourly PM concentration occurred during period of sleeping with the PM₁₀ concentration of 0.4 µg/m³ and PM_{2.5} concentration of 0.3 µg/m³. The presented results indicate that the activities of cleaning and morning activities are the most responsible for increase the PM concentrations in the observed apartment.

Keywords: copper smelter, air pollution, suspended particles, arsenic

1. INTRODUCTION

Exposure to the particulate matter (PM) pollution is associated with respiratory and cardiovascular diseases [1-5]. The health impacts of indoor air pollution are complex and not yet fully elucidated. In the indoor environments, the PM levels are influenced by both indoor and outdoor sources. The indoor PM can originate from the outdoor infiltration and activities such as cooking, heating, tobacco smoking, and emissions from building materials. For health impact assessments, it is essential to characterize the mass concentration, particle size distribution, and chemical composition of the PM in the indoor environments. Assessing the impact of the indoor PM on human health is critical since the individuals spend most of their time indoors [6].

Bor, a town with approximately 40,000 inhabitants in eastern Serbia, is a representative hotspot of the urban-industrial pollution in the country. The primary source of air pollution in Bor, including the sulfur dioxide, toxic metals, and metalloids in particulate matter, is the Copper Mining and Smelting Complex Bor. Emissions from these facilities have made the air pollution as the main environmental issue in Bor [7]. According to the SEPA Annual Report

2022 [8], the mean yearly PM_{10} concentration at the Town Park sampling site in Bor was $30 \mu g/m^3$. This was among the lowest annual average PM_{10} concentrations compared to the other Serbian cities [8]. Typically, the PM_{10} concentrations in Serbian cities are higher during the cold season than in the warm season. However, the PM_{10} concentrations were only 10% higher during the cold season in Bor [9].

In Serbia, the PM concentrations inside the residential buildings are not well-documented. Various physical and chemical processes affecting particles in indoor environments can alter their chemical composition and physical characteristics.

2. EXPERIMENTAL

The impact of human activities on the PM_{10} and $PM_{2.5}$ concentrations was investigated in an apartment in the urban area of Bor. The measurement was carried out throughout the year 2023. The selected apartment is situated about 1 km away from the copper smelter, as shown in Figure 1. The apartment was occupied by 2-3 persons.



Figure 1. Location of the selected apartment (1) in relation to the Copper Smelter Bor

The real-time measurements of the PM concentrations were conducted using the low-cost PM monitor PAQMON [10]. This monitor provides the continuous real-time readings of the PM_{10} and $PM_{2.5}$ mass fractions. The PM monitor was positioned on a table in the living room. The living room was carpeted and lacked an air conditioning system. The window surface area in the living room was approximately $2 m^2$. During the measurements, the windows in the room were predominantly kept closed. The living room had a volume of approximately $15 m^3$.

During the first week of the summer and winter measurements campaigns, the Sven/Leckel low-volume samplers (LVS3) were collocated with the PAQMON monitor to collect the PM_{10} and $PM_{2.5}$ gravimetric samples. Gravimetric samples were collected daily (from 9 AM to 9 AM) on the Quartz fiber filters (Whatman QMA 47 mm diameter filters). The results obtained from the PAQMON monitor were adjusted according to the method suggested by Ramachandran et al. [11], using the daily average PM concentrations derived from the gravimetric method.

3. RESULTS AND DISCUSSION

Table 1 and Figure 2 present the basic statistics of concentrations the suspended particles measured in the apartment during the whole period of measurements and during a certain period or activity. Based on the results, shown in Table 1, it can be concluded that there is no significant difference between the measurement results in the heating and non-heating seasons. The annual average PM_{10} concentration in the apartment was $8.7 \mu\text{g}/\text{m}^3$. The annual average $PM_{2.5}$ concentration in the apartment was $5.7 \mu\text{g}/\text{m}^3$. The highest average hourly PM concentration occurred during the cleaning activity with a PM_{10} concentration of $61.5 \mu\text{g}/\text{m}^3$ and a $PM_{2.5}$ concentration of $41.5 \mu\text{g}/\text{m}^3$. The lowest average of hourly PM concentrations occurred during the vacation period with an average PM_{10} concentration of $5.3 \mu\text{g}/\text{m}^3$ and an average $PM_{2.5}$ concentration of $4.0 \mu\text{g}/\text{m}^3$.

Table 1 Basic statistics of the PM in the apartment (stdev - standard deviation)

Annual	Unit	average	stdev	min	max	Sleeping	Unit	average	stdev	min	max
PM_{10}	$\mu\text{g}/\text{m}^3$	8.7	6.1	0.4	61.5	PM_{10}	$\mu\text{g}/\text{m}^3$	7.7	5.4	0.5	51.4
$PM_{2.5}$		5.7	4.1	0.3	41.5	$PM_{2.5}$		5.6	3.9	0.4	28.9
Heating season		average	stdev	min	max	Morning activities		average	stdev	min	max
PM_{10}		8.6	5.9	0.4	61.5	PM_{10}		9.5	7.1	0.4	58.9
$PM_{2.5}$		5.8	4.1	0.3	41.3	$PM_{2.5}$		5.7	4.3	0.3	36.5
Non-heating season		average	stdev	min	max	Cleaning activities		average	stdev	min	max
PM_{10}		8.8	6.3	0.6	58.9	PM_{10}		10.8	6.3	0.6	61.5
$PM_{2.5}$		5.5	4.2	0.5	41.5	$PM_{2.5}$		6.1	4.2	0.6	41.5
Vacation		average	stdev	min	max	Cooking activities		average	stdev	min	Max
PM_{10}		5.3	3.5	0.9	43.3	PM_{10}		7.5	7.7	1.0	48.4
$PM_{2.5}$		4.0	2.2	0.7	17.2	$PM_{2.5}$		5.0	4.6	0.9	41.3

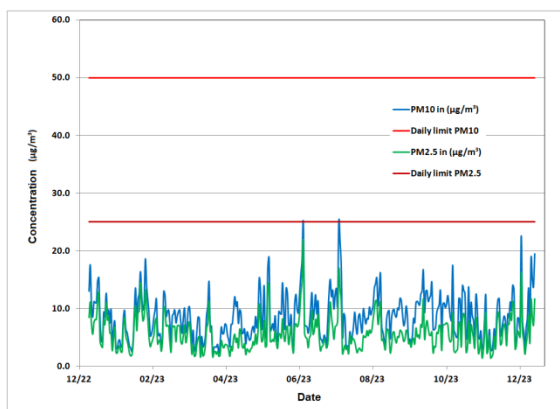


Figure 2. Average daily concentrations of the PM_{10} and $PM_{2.5}$ measured in the apartment

The coarse airborne particles were positively affected by many occupants and by the cleaning activities [12,13], so it is not surprising that the activity of cleaning the apartment caused higher concentrations of suspended particles, especially the PM_{10} fraction, as well as the activities during getting up and preparing for the start of the working day. It is known that the human activities lead to the resuspension of deposited particles from horizontal surfaces, such as floors, carpets, and furniture [14], and that the



resuspension rates increase with a particle size. Since the floors in the apartment are covered with carpets, this significantly affects the occurrence of particle resuspension.

4. CONCLUSION

In the Republic of Serbia, the investigations into the origin of suspended particles in the apartments are rare, so there is still not enough data on residents' exposure to the suspended particles in the interior space. In the observation period, the average daily concentrations of the PM₁₀ and PM_{2.5}, recorded in the apartment, were below prescribed limits. The presented results indicate that the cleaning and morning activities cause the largest increase in the PM concentrations in the observed apartment.

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