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CHEMICAL COMPOSITION OF PARTICULATE MATTER IN THE INDOOR AIR AT THE TECHNICAL FACULTY IN BOR (SERBIA)

Viša Tasić[1], Mira Cocić[2], Bojan Radović[1], Tatjana Apostolovski-Trujić[1]

[1]Mining and Metallurgy Institute Bor, Zeleni bulevar 35, 19210 Bor, Serbia

[2]Technical Faculty in Bor, University of Belgrade, V.J. 12, 19210 Bor, Serbia

Abstract

This paper presents part of the research results of human's exposure to air pollution with suspended particles in selected educational and residential buildings in the town of Bor. In recent years, special attention has been paid to indoor air quality, because people spend a large part of their time during the day in closed micro-environments. Mass concentrations of 24 chemical elements were determined from PM_{10} *samples collected in the selected classroom at the Technical Faculty in Bor during March 2018. Major elements (Fe, Al, Na, Mg, Ca, K) and trace elements (As, Cd, Pb, Ni, Zn, Cu, Ti, Co, V, among others) were analyzed by Inductively Coupled Plasma Optical Emission Spectrometry (ICP OES) and Inductively Coupled Plasma Mass Spectrometry (ICP MS), respectively. The phase composition of the total suspended particulate matter (TSPM) samples was determined by X-ray powder diffraction (XRPD) analysis. XRPD analysis of the SPM samples identified: calcite* ($CaCO_3$)*, quartz* (SiO_2)*, gypsum* ($CaSO_4x2H_2O$)*, dolomite* ($CaMg(CO_3)_2$) *and plagioclase (albite –* $NaAlSi_3O_8$)*.*

Keywords*: indoor air pollution, particulate matter, copper smelter, arsenic*

1. INTRODUCTION

This work aims to present a part of the results of an ongoing study on human's exposure to suspended particulate matter in the indoor air in the town of Bor. The Bor town is situated in the eastern part of the Republic of Serbia. It has been a major center for mining and processing of copper and other precious metals for more than 100 years. So that, the town of Bor is assumed as a good representative of an urban-industrial environment in the Republic of Serbia, due to the sulfur oxides and particulate matter emissions from the copper smelter, situated next to the town. The amount of harmful substances contained in the copper smelter waste gases depends on many factors, such as: the choice of technological procedure for processing copper ore, the composition of the input raw material, temperature and duration of the process, type and amount of process gases and the like. Numerous exposure studies have associated the level of outdoor particulate matter with mortality and morbidity [1,2,3,4]. Thus the relationships between outdoor air pollution and health are beyond doubt. The influence of indoor air pollution on health is complex and still unexplored in detail so that more researchers explores this topic these years. In the indoor environment, in which people spend most of their time, both indoor and outdoor sources contribute to changes in PM levels. PM in indoor air originates from outdoor infiltration and additional indoor sources such as cooking and heating devices, tobacco smoking, etc. For health impact assessment studies, it is very important to determine PM mass concentration, PM particle size distribution, and chemical composition of PM in indoor microenvironments.

2. EXPERIMENTAL

The collecting of PM samples was carried out in the selected classroom at the Technical Faculty in Bor, from March 5th to March 19th in 2018 (as shown in Figure 1). There was a maximum of 20 people in the selected classroom during lectures and exercises (period from 8 am to 6 pm).

The window area in the classroom is 4 m^2 and the volume of the classroom is 50 m^3. A sampling of the PM_{10} and TSPM was performed with reference samplers Sven/Leckel LVS3 [5] simultaneously, indoors and in ambient air in the immediate vicinity of the classroom. Quartz fiber filters (Whatman QMA, 47 mm) were used throughout this study. Before and after sampling, the filter mass was measured in accordance with the procedure prescribed by the standard SRPS EN12341: 2015 [6]. Based on the difference between the masses of exposed and unexposed filters and the known airflow through the sampler, the mass concentrations of suspended particles of the PM_{10} fraction were calculated.

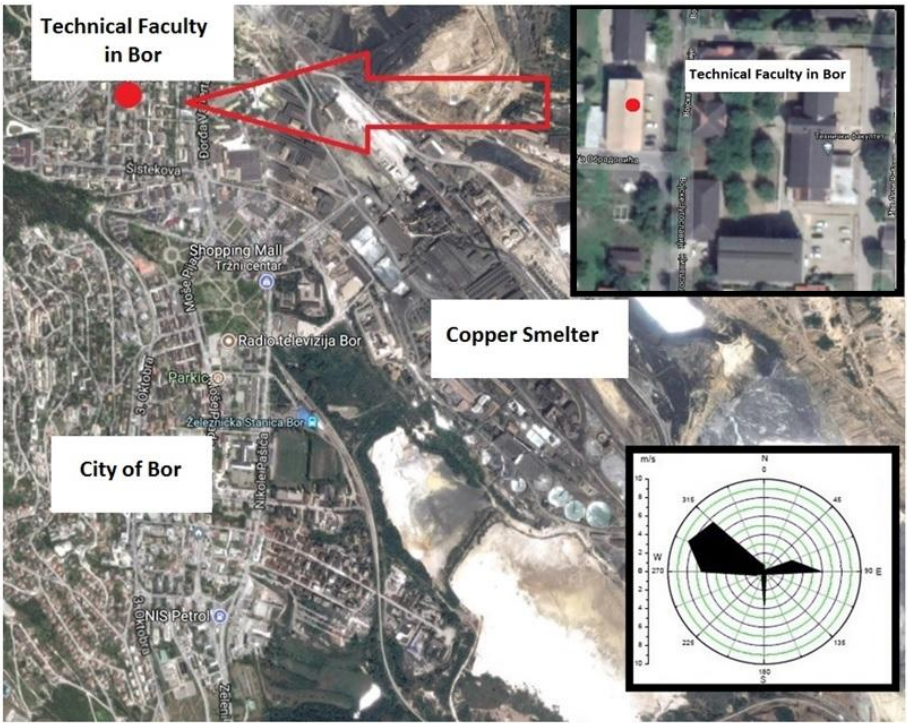

Figure 1 - Position of the Technical Faculty in Bor and the selected classroom in relation to the copper smelter

After measuring the mass of the exposed filters, they were further prepared for chemical analyzes in accordance with the procedure of SRPS EN14902: 2008 [7]. Major elements (Fe, Al, Na, Mg, Ca, K) and trace elements (As, Cd, Pb, Ni, Zn, Cu, Ti, Co, V, among others) were analyzed by Inductively Coupled Plasma Optical Emission Spectrometry (ICP OES) and Inductively Coupled Plasma Mass Spectrometry (ICP MS), respectively. The loaded filters, after gravimetric measurements, were prepared for chemical analyses following the procedure from CEN/TC 264 N779 (EU, 2008). Urban particulate matter Certified Reference Material 1648a [8] was analyzed for quality control and verification of the applied procedures for microwave digestion and trace element analysis. Recoveries were in the range from 80 to 120% for all measured elements. In this way, the mass concentrations of 24 chemical elements from the PM_{10} samples were determined.

The phase composition of the composite TSPM sample was determined by x-ray powder diffraction analysis (XRPD). Diffractograms were obtained using the Siemens D500 diffractometer with CuKα radiation (λ = 1.54184 Å) and Ni-filters at a current of 20 mA and a voltage of 35 kV in the range of 5 - 85 o2θ, with a step of 0.02° and an exposure of 0.5 s per step. The relationship between phases is determined by the Powder Cell (PCW) software using structural models of: calcite [9], quartz [10], gypsum [11], dolomite [12] and plagioclase [13].

3. RESULTS AND DISCUSSION

The indoor average daily concentration of PM_{10} in the classroom in the observed period was 28.2 $\mu g/m^3$. Similarly, the outdoor average daily concentration of PM_{10} was 46.1 $\mu g/m^3$. The obtained results indicate that the average concentrations of PM_{10} particles measured in the classroom were on average 1.6 times lower than those measured in the ambient air. According to national legislation [14], aiming to protect human health, annual limits for Pb, Cd, Ni, and As contents in PM_{10} are 500, 5, 20, and 6 ng/m^3, respectively. According to data shown in Table 1, average levels of As in PM_{10} in the classroom, as well as in the ambient air, were above the prescribed annual limit in the studied period. Based on the results shown in Table 1, it can be noticed that there are no significant additional sources of suspended particles PM_{10} in the classroom, so that mostly particles enter the classroom by infiltration from the external environment.

Table 1 - Summary of the chemical composition of PM_{10} (ng/m^3)

	TF Bor PM10-in	TF Bor PM10-out	MES Bor PM_{10}-in [15]
As	17.0	49.9	1.9
Cd	1.4	2.1	0.3
Mn	2.4	13.1	7.6
Pb	43.7	87.7	16.1
Cu	179	574.5	39.1
Zn	44.9	100.9	45.6
Ni	0.1	1.9	4.3
Cr	0.2	1.2	21.6
Ti	10.0	21.9	23.4
Sr	13.0	11.5	4.2
S	905	1134.5	1691.7
Fe	803.9	915.2	414.2

	TF Bor PM10-in	TF Bor PM10-out	MES Bor PM_{10}-in [15]
Ca	455.3	896.7	541.4
Al	189.7	600.2	78.2
Mg	656	687.6	243.4
Na	55.1	77.2	303.3
K	1004	964.1	502.7
Co	1.1	0.9	0.2
Zr	0.9	0.8	2.4
V	1.8	1.6	0.8
Ce	0.5	2.2	
Se	5.8	6.1	1.5
Rb	1.2	1.5	0.6
Ag	1.1	3.1	1.9

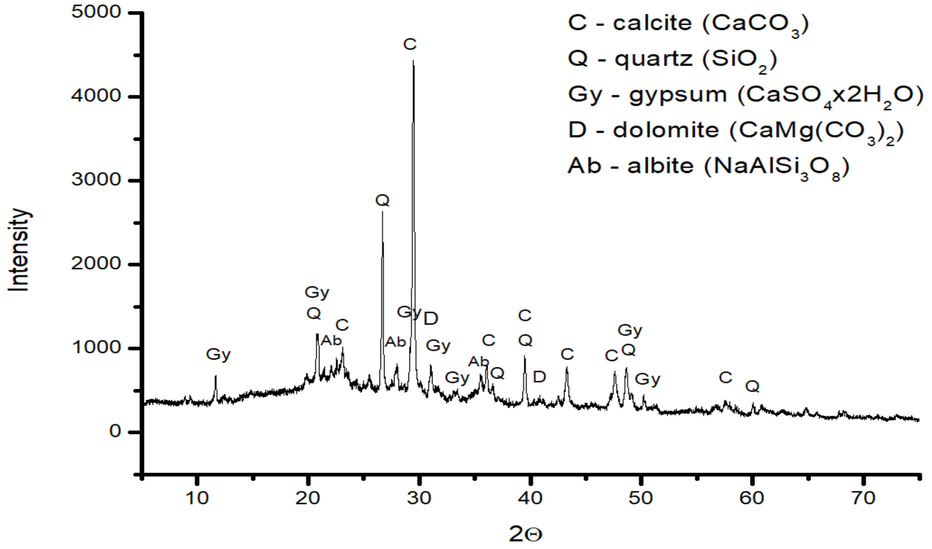

Figure 2 - X-ray powder diffraction diagram of TSPM samples collected in the classroom

The results from the reference [15], where the content of PM_{10} in the high school classroom in Bor was presented for the winter period in 2019 (Table 1) shows that the contents of As, Cd, Pb, and Cu in PM_{10} were significantly lower in comparison with these obtained for the classroom at the Technical Faculty. This school is not located at the dominant wind direction in relation to the copper smelter, so the impact of pollutant emissions from the smelter is weaker.

Phase identification of TSPM samples was determined using XRPD analysis. The main peaks occur between 10 and 50^{o} 2θ as shown in Figure 2. XRPD analysis of TSPM samples identified: silicate minerals (quartz and plagioclase (albite)), carbonate minerals (calcite and dolomite) and gypsum as a representative of hydrated sulfates. The most dominant minerals are calcite, followed by quartz, dolomite, gypsum and plagioclase (albite).

4. CONCLUSION

The results of the examination of the content of suspended particles of the PM_{10} fraction in the classroom at the Technical Faculty in Bor show that a significant part of the air pollution from the external environment reaches the classroom. Of particular concern is the fact that the detected average arsenic content in PM_{10} is almost three times higher than the annual limit value. The analyses of the PM_{10} content show that there are no significant additional sources of suspended particles PM_{10} in the classroom, so that mostly particles enter the classroom by infiltration from the external environment. This fact indicates the need to take additional measures to reduce the infiltration of particles from the external environment.

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