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# POLITEHNIKA 2023

# CONFERENCE PROCEEDINGS

Belgrade, 15th December 2023


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# POLITEHNIKA 2023

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## FOREWORD

The International Scientific and Professional Conference POLITEHNIKA 2023 represents the seventh edition of the POLITEHNIKA scientific and professional events, occurring biannually since its inaugural event in 2011. POLITEHNIKA 2023 upholds a distinguished tradition and commitment to integrating higher education and practical application across a diverse spectrum of disciplines represented by defined thematic scopes.

Organized with the patronage of the Ministry of Education of the Republic of Serbia, the Ministry of Environmental Protection of the Republic of Serbia, the Ministry of European Integration of the Republic of Serbia, the Directorate for Occupational Safety and Health, the Office for Dual Education and National Qualifications Framework, the Conference of Academies of Applied Studies in Serbia, the Chamber of Commerce of Serbia, the Chamber of Commerce of Belgrade, the Institute for Standardization of Serbia, the Association of Belgrade Architects, the City of Požarevac and the Tourist Organization of the City of Požarevac, POLITEHNIKA 2023 stands as a collaborative platform at the intersection of academia, governmental institutions and industry.

This year heralds a notable progression with its international status and the incorporation of 10 conference scopes. Expanding beyond the thematic domains featured in previous events, the Conference now encompasses Environment and Sustainable Development, Occupational Safety and Health and Fire Safety, Smart Management Systems, Graphic Engineering, Design, Traffic Engineering, Biotechnology and Healthcare, Mechanical Engineering, Ecotourism and Rural development, and Mechatronics. By engaging experts, emerging professionals, and practitioners from these domains, the conference unifies fields of study programs of the Academy of Applied Technical Studies Belgrade. The thematic scopes, coupled with the structure of the compiled papers in this Proceedings, exhibit a rich diversity and multidisciplinary approach, fundamentally contributing to a holistic examination and resolution of societal and scientific challenges.

Comprising over 220 peer-reviewed contributions, the Proceedings represent a substantial intellectual asset, aligning with the conference's overarching objective of fostering the exchange of knowledge, research findings, and professional experiences among experts from industry, research institutions, and higher education establishments.

The Proceedings of the International Scientific and Professional Conference POLITEHNIKA 2023 serve as a comprehensive snapshot of the current landscape within the thematic realms of the conference, offering both insights and directives for ongoing scientific and professional development. Moreover, they proffer concrete solutions to practical challenges grounded in contemporary trends and pertinent insights.

The Academy of Applied Technical Studies Belgrade extends its sincere appreciation to all conference supporters whose financial contributions played a pivotal role in its successful realization. Special acknowledgment is reserved for the authors of the papers, whose diligence and eagerness to present their work to a wider audience, alongside the reviewers and members of the International Scientific Committee, Program Committee and Organizational Committee, have collectively contributed to the triumph of the International Scientific and Professional Conference POLITEHNIKA 2023.

Belgrade, December 2023
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*Advances in understanding of a role of unit metallurgical operations for recycling*

**Svetlana Grujić, PhD, Faculty of Technology and Metallurgy, University of Belgrade**
*Emerging pollutants in the environment: contamination of the Danube river basin in Serbia*

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**Jelena Ristić Trajković, PhD, Faculty of Architecture, University of Belgrade**
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## MECHANICAL ENGINEERING

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*Energy savings and $CO_2$ emission reduction potential through the existing building renovation*

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*Analysis of remediation of horizontal cylindrical tank for oil storage*

## ECOTURISAM AND RURAL DEVELOPMENT

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*Selective forms of tourism and sustainable development of rural tourist destinations*

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*Education as a pillar of sustainable agritourism in Serbia*

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

# OVERVIEW OF AIR POLLUTION IN THE CITY OF BOR DURING THE PERIOD OF 2020–2022

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**Abstract:** *The annual levels of $SO_2$, $PM_{10}$, as well as As, Pb, Cd and Ni in $PM_{10}$ were assessed in the City of Bor, as an environmental hotspot, from 2020 to 2022. The given period included the data when copper smelting activities were not performed due to the enlargement of the production capacities. The data were compared to the air quality in the study area before 2020 and to the current air quality status in the Republic of Serbia and Europe. The defined annual limit values were exceeded for $SO_2$, $PM_{10}$, and Pb concentrations in $PM_{10}$, while the annual target values were exceeded for As and Cd content in $PM_{10}$. Among the measuring sites, the poorest air quality was observed at the site Jugopetrol, located in the prevailing NW wind direction. The standstill in the copper smelting activities was perceived in the reduction of the annual levels of $SO_2$, As, Pb, Cd and Ni in $PM_{10}$. Compared to the current data for the Republic of Serbia and Europe, the air quality in the City of Bor was poor.*
**Keywords:** air pollution, $SO_2$, $PM_{10}$, toxic elements, copper smelter

## 1. INTRODUCTION

Air pollution originates from natural and anthropogenic emission sources, whereby the latter ones are considered dominant in the areas endangered by different industrial activities. Air pollutants such as: sulphur dioxide ($SO_2$), particulate matter (PM), ozone ($O_3$), nitrogen dioxide ($NO_2$), and carbon monoxide (CO) are recognised by the World Health Organization (WHO) as crucial environmental threats to the human health on the global level [1] based on their association with numerous negative health conditions. Both inhalation and dermal contact with $SO_2$ could lead to respiratory problems, lung damage, skin burn or irritation etc. PM, as a major component of air pollutants, are classified as carcinogenic [2]. PM exposure is associated with increased rate of hospitalization, lung cancer, as well as respiratory and cardiovascular diseases. It should be emphasised that toxic elements present in PM are associated with carcinogenic and non-carcinogenic health risks [3]. Environmental impacts of air pollutants could be observed through the damages of ecosystems, acid rain, soil acidification, ozone depletion, deforestation, climate change etc. [2,4,5].
Mining and metallurgical activities in the City of Bor have contributed to the significant environmental pollution, whereby extreme air pollution was denoted in previous decades [6,7,8,9]. Thus, modernization of the copper production was performed and pyrometallurgical copper production was replaced with the flash smelting technology (FST) with higher productivity and

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smaller negative environmental impact, as the main advantages. However, the data for the period after the FTS implementation indicated that the City of Bor is still a hotspot concerning air pollution with As and $SO_2$ [10]. Thus, the continuous monitoring of the air pollution in the City of Bor still represents one of the most important issues in terms of protection of human health and the environment.

This paper summarizes the annual concentrations of $SO_2$, $PM_{10}$, as well as As, Pb, Cd and Ni in $PM_{10}$ for the period 2020–2022, aiming at comparing the periods before and after the FST implementation, regarding the current air quality status in the Republic of Serbia and Europe as well. The given 3-year period includes the air pollution data when copper smelting was out of order due to the enlargement of the copper production capacities.

## 2. METHODOLOGY

Mining in Bor started 120 years ago with the discovery of copper rich ore deposits, which were afterwards exploited and processed. The pyrometallurgical copper production from sulphide ores (chalcopyrite – $CuFeS_2$, chalcosine – $Cu_2S$, coveline – CuS and arsenopyrite – FeAsS) was the main pollution source of $SO_2$ and particulate matter, along with the copper mining activities. The outdated technology was replaced with the FST as an advanced and energy-efficient production method, during 2016 [9,10].

Monitoring of the air pollution levels in the City of Bor is performed by Mining and Metallurgy Institute Bor. In the given period (2020–2022), polluting substances ($SO_2$, $PM_{10}$, as well as As, Pb, Cd and Ni in $PM_{10}$) were measured at seven sites (Table 1) which were part of the local and the national Air Quality Monitoring network. The air pollution levels are given in the annual reports by Mining and Metallurgy Institute Bor [11,12,13].

The analysed period also included the data when the smelting was fully stopped, due to the enlargement of the copper production capacities from April 2022 till the end of the year 2022.

**Table 1.** Description of the measuring sites for monitoring of the air pollutants in the City of Bor
**Source:** MMI reports [11,12,13]

| Measuring sites | Zone | Coordinates | Location* | Measured parameters |
|---|---|---|---|---|
| Institute (IN) | Urban–industrial | N 44º3’35’’ E 22º6’05’’ | 2 km S | $SO_2$ |
| | | | | $PM_{10}$ |
| Jugopetrol (JP) | Suburban | N 44º3’15’’ E 22º7’46’’ | 3.3 km SE | $SO_2$ |
| | | | | $PM_{10}$ |
| Technical faculty (TF) | Urban–industrial | N 44º4’54’’ E 22º5’43’’ | 1 km WNW | $SO_2$ |
| Town Park (TP) | Urban–industrial | N 44º4’33’’ E 22º5’58’’ | 0.5 km SW | $SO_2$ |
| | | | | $PM_{10}$ |
| Krivelj (KR) | Urban–industrial | N 44º7’47’’ E 22º5’42’’ | 6 km N | $PM_{10}$ |
| Oštrelj (OŠ) | Suburban–industrial | N 44º4’08’’ E 22º9’36’’ | 4 km ESE | $PM_{10}$ |
| Brezonik (BR) | Suburban–industrial | N 44º5’53’’ E 22º5’30’’ | 3 km NNW | $PM_{10}$ |

*in regard to the copper smelter.

Data visualization was done using the R programming language (v 4.1.0, R Core Team) [14] and the R package ggplot2 [15].

## 3. ANALYSIS OF AIR POLLUTING SUBSTANCES LEVELS

### 3.1 The levels of $SO_2$

The annual levels of $SO_2$ for the study period are given in Figure 1. Annual $SO_2$ concentrations have exceeded the defined limit value (LV, 50 μg $m^{-3}$) [16,17] at the sites TF (during 2020 and 2021), TP (2020) and JP (in the period 2020–2022). Considering the 3-year period, it can be seen that $SO_2$ levels decreased at all the measuring sites, with the highest levels in 2020 and the lowest in 2022. This could be attributed to the fact that smelting activities were not performed since April 2022. Among the measuring sites, the highest levels of $SO_2$ were observed at the site JP. This site was also characterised by the poorest air quality, regarding $SO_2$ levels, in the previous years [7,8,9,10]. This can be attributed to the location of this measuring site, which is located in the prevailing NW wind direction.
Although the levels of $SO_2$ were not as high as in the previous decades [7,8,9,10], in the Serbian Environmental Protection Agency reports [18,19], during 2020 and 2021, the air quality in the study area was of the third category (*i.e.* over-polluted air). The City of Bor was the only agglomeration in this category due to the high $SO_2$ levels. During 2020 and 2021 the levels of $SO_2$ were measured in the Republic of Serbia at 44 and 39 stations (excluding stations in Bor), respectively, and the annual limit value was not exceeded at any of these stations [18,19]. The $SO_2$ annual levels have been decreasing across the European countries from 2009 to 2018, with the highest decrease noted at the stations in suburban, and the lowest at the stations in urban areas [2].

### 3.2 The levels of $PM_{10}$

The levels of $PM_{10}$ were above the defined LV (40 μg $m^{-3}$) [16,17] only at the site JP (2022) (Figure 2). The exceedances of the annual LV were not pronounced as in the period after the implementation of FST [10].
High levels of $PM_{10}$, along with the levels of $SO_2$, have contributed to the fact that the air in the City of Bor was overly polluted (III category) during 2021 [19]. During 2020 and 2021, the annual LV was exceeded at 18 and 15 stations, respectively, which makes $PM_{10}$ the dominant polluting substance in the Republic of Serbia [18]. In Europe, during 2018, $PM_{10}$ levels above the annual LV were noted at 6% out of more than 3000 stations [2].

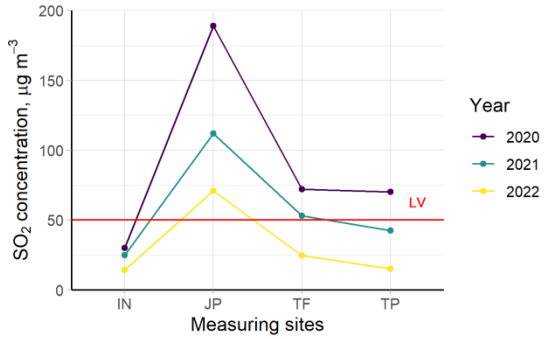


**Figure 1.** $SO_2$ concentrations at the measuring sites in the City of Bor (horizontal line represents annual limit value – LV)

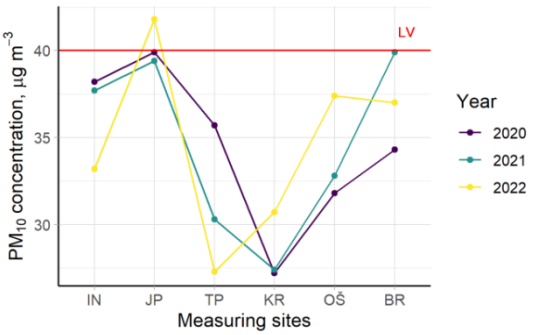


**Figure 2.** $PM_{10}$ concentrations at the measuring sites in the City of Bor (horizontal line represents annual limit value – LV)

### 3.3 The levels of As, Pb, Cd and Ni in $PM_{10}$

Arsenic concentrations have exceeded the annual target value (TV, 6 ng $m^{-3}$) [16,20] at all the sites, during the analysed period, except at the site KR (2022) (Figure 3a). Compared to the As levels in 2020, during 2021 and 2022, the concentrations were lower, which could be attributed to the standstill in the copper smelting activities. The annual As concentrations were lower compared to the period

after the implementation of FST (2016–2019) [10]. The measuring site with the highest levels of As was the JP, which is located in the prevailing NW winds [10]. The high levels of this toxic element in $PM_{10}$ were also noted during 2022, when smelting was not performed, which indicated that As could also have originated from other anthropogenic activities, such as resuspension of dust from the flotation tailings, as well as handling of the copper concentrates during transportation.
In Serbia, As levels on an annual basis were far below the TV during 2020 and 2021 [18,19]. During 2018, As levels above the annual TV were recorded at 6 out of more than 650 stations in Europe [2].

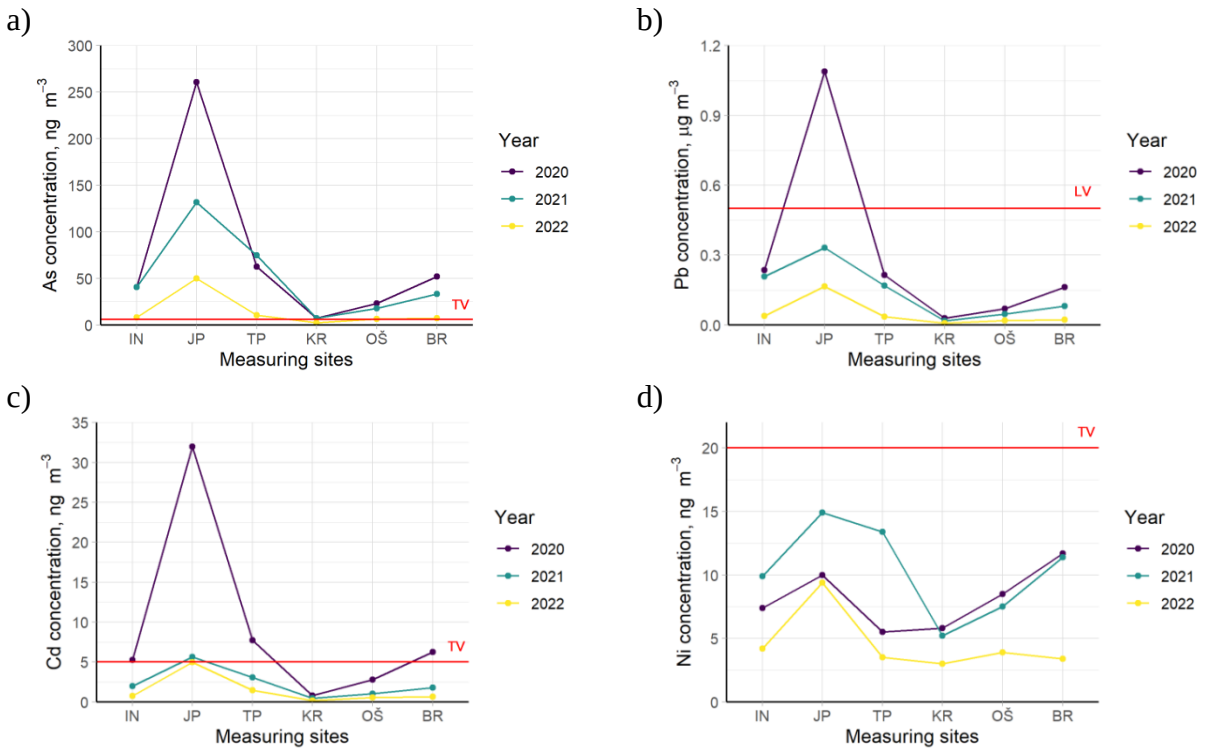


**Figure 3.** Toxic elements concentrations (a) As, (b) Pb, (c) Cd and (d) Ni in $PM_{10}$ at the measuring sites in the City of Bor (horizontal line represents annual target value – TV for As, Cd and Ni, and limit value – LV for Pb)

Pb levels were above the defined annual LV (0.5 µg $m^{-3}$) [16,17] at the site JP (2020) (Figure 3b). Compared to the Pb concentrations during 2020, the concentrations of this toxic element were lower during 2021 and the lowest during 2022 when smelting activities were stopped. However, the JP stands out with the highest levels of Pb, due to its location on the prevailing wind directions, resuspension of dust from the flotation tailings, as well as handling of copper concentrates during transportation. The levels of Pb at the site JP frequently exceeded annual LV in the periods before and after implementation of FST [9,10].
In Serbia, during 2020 and 2021, the levels of Pb in $PM_{10}$ did not exceed the LV, both at the stations where fixed and indicative measurements were done [18,19]. The Pb levels above the annual LV were recorded only at one out of nearly 700 stations across Europe during 2018 [2].
From Figure 3c it can be seen that concentrations of Cd were above the defined TV (5 ng $m^{-3}$) [16,20] at the sites IN (2020), JP (2020 and 2021), TP (2020), and BR (2020). Since 2020, the levels of Cd decreased on an annual basis, with the lowest ones during 2022 when smelting was not performed. The measuring site JP stands out with the highest levels of Cd, due to the dust resuspension from the flotation tailings, as well as copper concentrate handling during transportation. At the site JP the exceedings of the defined TV were observed in the periods before and after the implementation of FST [9,10].
In Serbia, the Cd levels on an annual basis were far below the TV during 2020 and 2021 [18,19]. In Europe, concentrations above the annual TV for Cd were not recorded during 2018 [2].

The Ni levels were below the defined annual TV (20 ng $m^{-3}$) [16,20] (Figure 3d). Among the measuring sites, the highest levels of Ni were observed at the site JP during 2021 and 2022, and the site BR during 2020. The lowest levels of Ni were noted for all the sites in the period when smelting activities were not performed, which could indicate its dominant anthropogenic origin. The annual levels of Ni did not exceed the defined TV in the period after FST implementation [10].
The levels of Ni on an annual level were below the defined TV during 2020 and 2021 in Serbia [18,19]. The concentrations of Ni were above the annual TV at 3 out of nearly 700 stations in Europe during 2018 [2].

## 4. CONCLUSION

The aim of this study was to analyse the concentrations of the air pollutants monitored at the measuring sites in the City of Bor, which is recognised as one of the most polluted region in the Republic of Serbia and beyond, due to the copper mining and smelting activities. The annual levels of $SO_2$, $PM_{10}$, as well as As, Pb, Cd and Ni in $PM_{10}$ from 2020 to 2022 were compared to the defined limit and target values, as well as the current air quality in the Republic of Serbia and Europe. The data were also compared to the air quality in the study area before the analysed period. The exceedances of the defined annual LVs were observed for $SO_2$, $PM_{10}$, and Pb concentrations, and the annual TVs for As and Cd. Regarding the measuring sites, the site Jugopetrol located in the prevailing NW wind direction was characterised by the poorest air quality. The standstill in the smelting activities, due to the reconstruction of the copper smelter, was noted for the lower content of $SO_2$, As, Pb and Cd during 2022. Considering the air quality in the study area in previous years, the concentrations of the given pollutants were generally lower. However, the air quality in the City of Bor, for the given period, was poor, regarding the air quality in the Republic of Serbia and Europe, as well.

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