



University of Belgrade, Technical Faculty in Bor
29th International Conference Ecological Truth
& Environmental Research



EcoTER'22

Proceedings



Editor

Prof. Dr Snežana Šerbula

21-24 June 2022, Hotel Sunce, Sokobanja, Serbia



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PREFACE

In today's world, the environment has been endangered by the use of outdated technology, fossil fuels and environmental law violations. Therefore, environmental and many other scientists all over the world have been concerned about finding sustainable technology in resolving these issues. That is why environmental research and ecological truth are at the focus of the 29th International Conference Ecological Truth & Environmental Research 2022 (EcoTER'22), which will be held in Sokobanja, Serbia, 21–24 June 2022. On behalf of the Organizing Committee, it is a great honor and pleasure to wish all the participants a warm welcome to the Conference.

We hope to convey the message of the conference, which is that a transformation of attitudes and behavior would bring the necessary changes. This is also an opportunity for the participants who are experts in this field to exchange their experiences, expertise and ideas, and also to consider the possibilities for their collaborative research.

The 29th International Conference Ecological Truth & Environmental Research 2022 is organized by the University of Belgrade, Technical Faculty in Bor, and co-organized by the University of Banja Luka, Faculty of Technology, the University of Montenegro, Faculty of Metallurgy and Technology – Podgorica, the University of Zagreb, Faculty of Metallurgy – Sisak, the University of Pristina, Faculty of Technical Sciences – Kosovska Mitrovica and the Association of Young Researchers, Bor.

These proceedings include 85 papers from the authors coming from the universities, research institutes and industries in 6 countries: Bulgaria, Italia, Albania, Bosnia and Herzegovina, Montenegro and Serbia.

As a part of this year's conference, the 4th Student section – EcoTERS'22 is being held. We appreciate the contribution of the students and their mentors who have also participated in the Conference.

Financial assistance provided by the Ministry of Education, Science and Technological Development of the Republic of Serbia is gratefully acknowledged by the Organizing Committee of the EcoTER'22 conference.

The support of the Platinum donor and their willingness and ability to cooperate have been of great importance for the success of EcoTER'22. The Organizing Committee would like to extend their appreciation and gratitude to the Platinum donor of the Conference for their donation and support.

We appreciate the effort of all the authors who have contributed to these Proceedings. We would also like to express our gratitude to the members of the scientific and organizing committees, reviewers, speakers, chairpersons and all the Conference participants for their support to EcoTER'22. Sincere thanks go to all the people who have contributed to the successful organization of EcoTER'22.

Prof. Snežana Šerbula,

President of the Organizing Committee

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ARSENIC IN PARTICULATE MATTER ORIGINATED FROM MINING-METALLURGICAL PROCESSES

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Abstract

The air quality in Bor is determined at the measuring sites in the urban-industrial, suburban and rural area during the 2010–2022 period. High level of arsenic in suspended particulate matter (PM) is of a predominantly industrial origin. The major source of pollution is the copper smelter, which is situated in the close vicinity of the urban area of Bor. The ambient level of As in PM is influenced by meteorological parameters as well as the remoteness from the copper smelter. Continual exceedances of the annual limit value (LV) for As (6 ng m^{-3}) were recorded at the measuring sites in the urban-industrial and suburban areas. Maximum annual As concentration recorded at the site Jugopetrol (550 ng m^{-3}) in 2019, was more than 90 times higher compared to the LV. The daily concentration of arsenic in April 2022 also exceeded the limit value by more than 100 times in relation to the LV.

Keywords: arsenic, particulate matter, air quality, mining-metallurgical processes

INTRODUCTION

Air pollution represents one of the most important environmental, as well as social problems, which poses multiple challenges in terms of managing and mitigation of harmful pollutants [1]. Weather patterns alter the transport, dispersion, deposition and formation of air pollutants in the atmosphere [2]. Air pollution can lead to the increase in the incidence of respiratory and cardiovascular diseases, as well as cancer, but it can also cause premature death [1]. Human health and the environment are undoubtedly influenced by the air quality, hence its monitoring is essential, especially in the regions affected by different industrial processes. Copper production based on pyrometallurgical processes is regarded as an important source which emits vast quantities of air pollutants such as sulphur dioxide (SO_2) and particulate matter (PM) with high content of toxic elements, i.e. arsenic (As) [3].

Particulate matter, air pollutant consisting of a mixture of suspended solid and liquid particles, can be either directly emitted (denoted as the primary PM) or be formed secondarily in the air from gaseous precursors (mainly SO_2 , NO_x , NH_3 and non-methane volatile organic compounds). The most important chemical constituents of PM are sulphates, nitrates, ammonium, inorganic ions, organic and elemental carbon, particle-bound water and toxic elements. PM is generated by anthropogenic activities, such as transport, energy production, domestic heating and could be emitted from a wide range of industries [4]. PM poses high risk to human health due to its ability to enter the respiratory system. Both acute and chronic exposure to PM from the ambient air has been linked to different health outcomes, ranging

from the modest transient changes in respiratory tract and impaired pulmonary function to the increased risk of death from cardiovascular and respiratory diseases or lung cancer. Since PM can be transported in the atmosphere for hundreds or even thousands of kilometres, it represents not only a serious local but also regional, as well as international environmental problem [4]. In terms of the potential to harm human health, besides NO₂ and ground-level O₃, PM is recognised as Europe's most serious air pollutant [3].

The primary pollution sources in the environment of the Bor city are the mining and metallurgical processes. They are a source of sulphur-dioxide emission, dust with high content of heavy metals (lead, arsenic, cadmium, copper, zinc, etc.), soot, carbon-dioxide and other pollutants [3].

One hundred and nineteen years of mining activities on the territory of Bor and its surroundings resulted in numerous ecological problems and enormous consequences as an inheritance. This kind of pollution endangers not only the biotope, but all the living organisms including humans [3].

Taking into account the long-term and extreme air pollution with substances originating from mining and metallurgical processes, this study aimed to determine the level of air quality when the smelter is operating and when it is under repair. In this paper, the level of arsenic air pollution in PM in the area of Bor is presented during the period 2010–2021 as well as on a daily basis during April 2022.

METHODOLOGY

The study area and measuring sites

The primary sources of environmental pollution in Bor (Serbia) are mining (surface mining of copper ore) and metallurgy (pyrometallurgical copper production from the following sulfide ores: chalcopyrite (CuFeS₂), chalcocite (Cu₂S) and covellite (CuS). Additional sources of air pollution in Bor and the surroundings are flotation tailings and open pits, from which particles are emitted with a high concentration of sulfates. The main pollutants are SO₂, particulate matter with a high content of As, Pb, Cu, Zn, Cd, and aero sediments, which also contain heavy metals and sulfates [3].

The monitoring of As concentrations in the air was performed by the Mining and Metallurgy Institute Bor [5]. A detailed description of experimental procedure was given in the paper of Serbula *et al.* 2013 [6]. In this study, the presented data of air quality monitoring data are from the following measuring sites (Figure 1a): Krivelj (KR), Town Park (TP), Institute (IN), Jugopetrol (JP), Brezonik (BR), Technical Faculty (TF), Oštrelj (OŠ) and Slatina (SL). Daily As concentrations in PM were measured at the sites: KR, JP, OŠ, BR, IN and TP during April 2022 [7]. A wind rose diagram for the study area of Bor is shown in Figure 1b [7]. The predominant winds in the study area were of WNW, NNW, SSW, SW and E directions. Less frequent winds were of S, NE, ESE and NNE directions. The measuring sites JP and SL were characterized by the high-frequency WNW winds. The surroundings of the sites TP and TF were characterized by the prevailing east wind directions, while the site IN was along the directions of prevailing north winds.

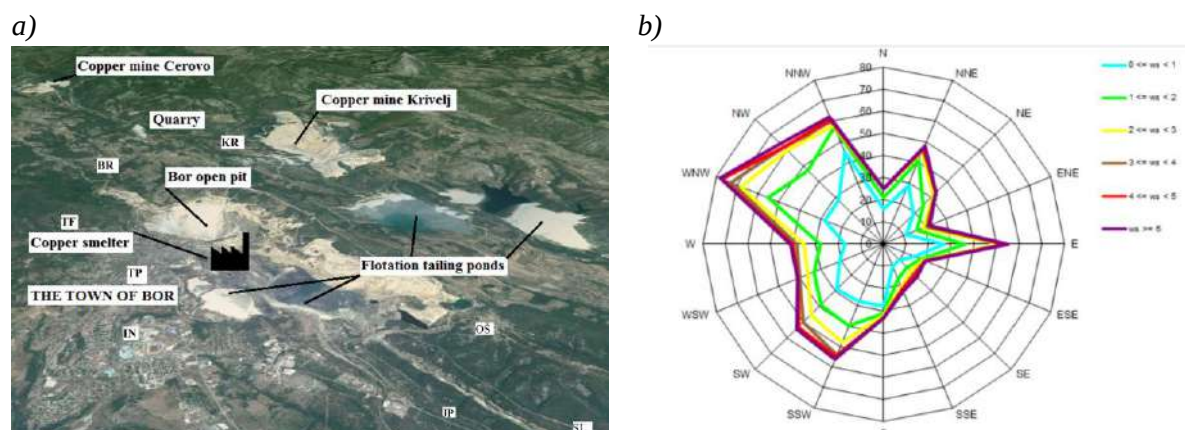


Figure 1 a) Location of the measuring sites in Bor (KR – Krivelj, BR – Brezonik, TF – Technical Faculty, TP – Town Park, IN – Institute, JP – Jugopetrol, OŠ – Oštrelj and SL – Slatina) in respect of the copper smelter; b) Rose diagrams for different wind speeds for the period 01.04.2022–30.04.2022 at the measuring site IN in Bor [7]

RESULTS AND DISCUSSION

From Figure 2 it can be seen that all the available annual As concentrations in the air of Bor and the surroundings exceeded the target value (TV) defined by the Serbian Regulation and the European Commission Regulation [8]. However, the exceedances of the annual TV for As in the period 2015–2021 were more pronounced than in the previous period 2010–2015, which is the period of application of the new smelter [3]. Maximum annual As concentrations measured at the site JP during 2019 was 550 ng m^{-3} , which is more than 90 times the allowable value.

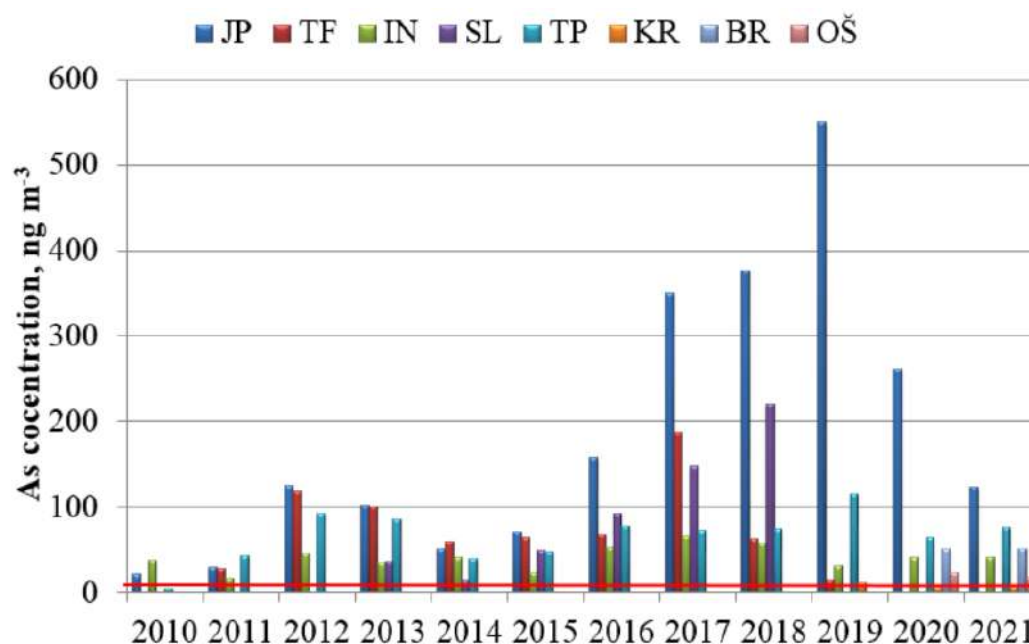


Figure 2 Average annual As concentrations in PM at eight measuring sites in the Bor area during period 2010–2021; Target value (TV) (red horizontal line) is defined at 6 ng m^{-3} [8]

The influence of wind direction on pollutant distribution from industrial facilities to populated areas has been shown in many research results. According to the estimates of the World Health Organization (WHO) for Europe, arsenic concentrations range from 1 to 10 ng m^{-3} in rural areas to 30 ng m^{-3} in urban areas. Near emission sources, such as non-ferrous metal smelters and power plants in which arsenic-rich coal is burned, concentrations of airborne arsenic can exceed 1 $\mu\text{g m}^{-3}$ [4]. According to the data presented in Figure 3, the average daily As concentrations in the rural area of Bor were within the WHO guideline values, whereas the As concentration at the measuring site Jugopetrol was higher than the WHO estimations due to influence of the unfavourable wind direction [9]. The average daily concentrations of arsenic were the highest at the measuring site Jugopetrol during April 2022. The production in the copper smelter in Bor was stopped on April 20, 2022, due to the scheduled maintenance and overhaul. At all the measuring sites, the average daily concentrations of arsenic were less than recorded on April 20, 2022, except on April 23/24 when was recorded one exceedance at the measuring site JP which amounted 120.1 ng m^{-3} . This confirms the influence of meteorological factors on arsenic concentrations in the ambient air, because the measuring site JP is located in the direction of the dominant winds. The higher the wind speed, the more the deposited PM particles rise from the ground. Resuspension is the second largest source of arsenic after the copper smelter. Large areas of mining and flotation tailings surrounding of Bor are also a source of resuspension particles of the smallest dimensions, which contain high concentrations of arsenic compounds. Over the 100 years of mining and metallurgy in Bor have had great consequences for the environment, which is desirable to be rehabilitate as soon as possible.

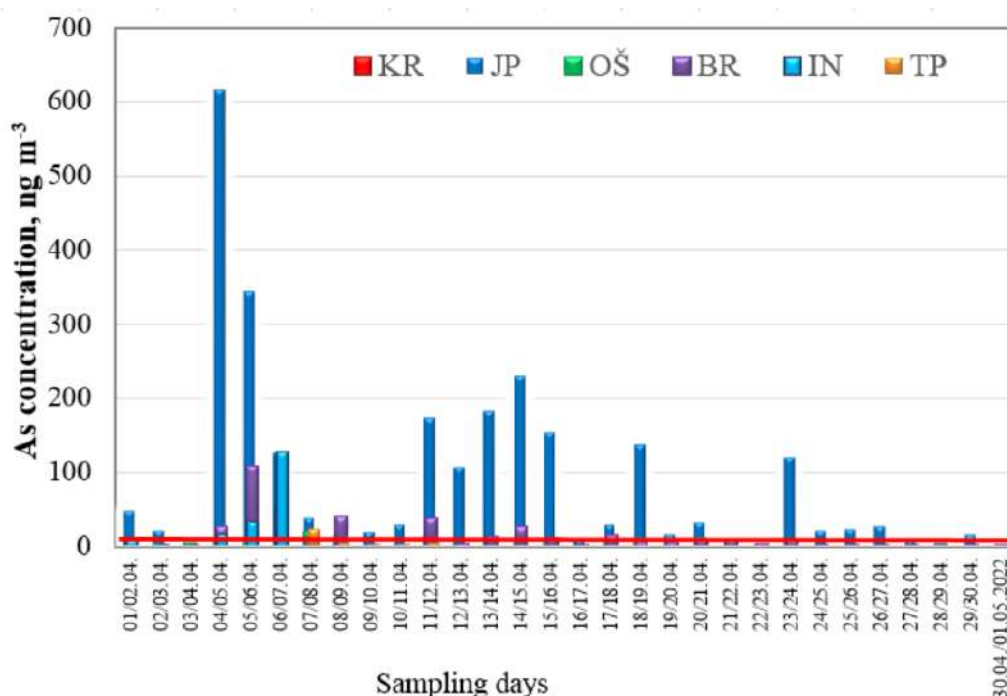


Figure 3 Average daily As concentrations in PM at six measuring sites in the Bor area during April 2022; Target value (TV) (red horizontal line) is defined at annual level at 6 ng m^{-3} [8]

CONCLUSION

Situated in the close vicinity of the urban zone of the town of Bor, the Mining and Smelting Complex is the major pollution source emitting particulate matter into the atmosphere of the city of Bor and its surroundings. Air quality measurements are conducted at the measuring sites in the urban-industrial, suburban and rural areas, from 2010 to 2021. Long-term monitoring of air-quality parameters in the Bor area, and scientific studies as well, prove that the mining-metallurgy complex, is the major pollution source emitting particulate matter into the atmosphere.

Airborne PM with high content of heavy metals, pollute not only the urban parts of the city in the close vicinity of the mining-metallurgical complex, but also the suburban and distant rural zones. Data analysis showed a direct influence of the wind direction on the pollutant transport to the particular measuring sites. Due to unfavourable meteorological conditions (e.g. wind directions), as well as the periods of calm weather conditions, the area around the measuring site Town Park is considered to be pollution risk area. As far as suburban settlements are concerned, the areas around the measuring sites Jugopetrol and Brezonik are endangered. Long-term measurements of the content of As in PM have shown permanent exceedance of the TV for As concentrations. The greatest danger for the environment and all the living organisms are the high concentrations of arsenic in PM. Over 50% of the measured arsenic concentrations at all the sites in the examined period by far exceeded the allowed values. Arsenic is a carcinogenic matter, so that this state of matter is troublesome. During the last eleven years not a single average annual As concentration has been within the annual limit value at the measuring sites Town Park, Institute and Jugopetrol in Bor. The maximum arsenic concentration in the period 2010–2021 was recorded in 2019 at the measuring site Jugopetrol which amounted 550 ng m^{-3} . The immediate vicinity of the measuring site Town Park to the pollution source, as well as the position of the measuring site Jugopetrol along the prevailing wind direction caused high pollution levels of As in the air.

The predominance of a particular wind direction determined the distribution of PM and As. A one-month analysis of data during April 2022 showed a direct influence of the wind direction on the pollutant transport to the particular measuring sites. Due to unfavourable wind conditions, the area around the measuring site Jugopetrol is considered to be pollution risk area. As far as suburban settlements are concerned, within the municipality of Bor, the rural settlement Oštrelj is most endangered with pollution. The rural settlement Krivelj is located in the direction of a less frequent S wind, which accounts for a lower pollution level in this area.

In toxicological risk assessment it should be taken into consideration that the inhabitants of Bor are simultaneously exposed to other types of pollutants, which also increases the health risk. High concentrations of sulfur dioxide, heavy metals and their compounds in suspended particles are constantly present in the atmosphere of Bor.

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