

THE LEVEL OF SULPHUR DIOXIDE IN THE ATMOSPHERE OF BOR (EASTERN SERBIA)

Ana A. Ilic, Snezana M. Serbula
Jelena V. Kalinovic, Tanja S. Kalinovic, Marina J. Ilic
University of Belgrade, Technical faculty in Bor, VJ 12, 19210 Bor, Serbia

ABSTRACT

The air quality monitoring has been performed during the period 2008-2011 in Bor (Serbia). Five measuring sites were distributed in the urban-industrial and suburban zones of the town. Continuous monitoring of sulphur dioxide (SO₂) indicates that the most endangered areas are in close vicinity of the copper smelter and in the prevailing wind directions. Frequent exceedances of the limit value (LV) were observed at the sites Town park and Jugopetrol, where the average number of days above the limit value was >100. During the study period, only one average annual SO₂ concentration was within the annual LV regarding all the sites, which suggests poor quality of the air in the study area.

Keywords: air pollution, copper smelter, sulphur dioxide

1. INTRODUCTION

The main aims of air monitoring are implementation of continuous measurements of: meteorological parameters and emissions of polluting substances from major pollution sources [1,2]. Polluting substances such as SO₂ and PM are considered to be indicators of air quality in urban and industrial areas [3]. SO₂ is the main product of burning of fossil fuels and metallurgical operations, which includes sulphide ores processing [2,4]. SO₂ is a precursor of acid rain, while sulphuric acid is a precursor of smog. Also, SO₂ could oxidize in the atmosphere and form sulphates which are one of the components of particulate matter [4].

The paper presents the results of SO₂ concentration measurements in the Bor area during the period from 2008 to 2011 at five measuring sites in the town of Bor.

2. STUDY AREA

The study area represents the urban-industrial (UI) and suburban (SU) zone of Bor (Eastern Serbia) where the mobile and stationary measuring stations were placed. The mining-metallurgical complex is located in the close vicinity of the town. A copper smelter, in which sulphide ores are melted, is a part of the complex and it has been a dominant air pollution source since the late 1960s. The SO₂ emission depends on the amount of processed copper concentrate and operation of sulphuric acid plant in which SO₂ from waste gasses is converted to H₂SO₄ acid. Due to its dated technology, the plant can utilize less than 60% of waste gasses, while the rest of the gasses are discharged into the atmosphere. Long-term air pollution from the mining-metallurgical complex is a trans boundary problem. The impact of the complex on the environment is evident in the Western and central Balkans [5].

2.1. Measuring sites

The measuring sites where the SO₂ concentrations were monitored are: Town park (located in the UI zone), Institute (UI), Technical faculty (UI), Jugopetrol (SU) and Brezonik (SU). The observation of meteorological parameters, as well as air quality monitoring, was performed by the Mining and Metallurgy Institute Bor. At the sites Town Park and Jugopetrol SO₂ concentrations were measured

automatically by the UV fluorescent SO₂ analyzer (Model AF22M) according to ISO standard, while at the sites Institute, Technical faculty and Brezonik, concentrations were measured using the hydrogen peroxide method [5]. In Fig. 1 wind rose is given for Bor for the 4-year study period [6]. As can be seen, the prevailing wind direction is to the west, while the less frequent winds blow in the east and south direction.

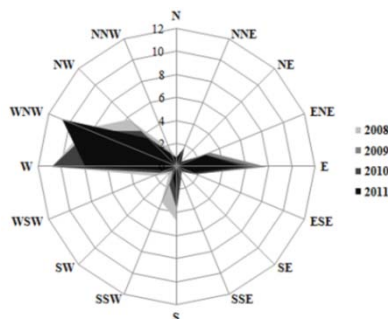


Figure 1. Wind rose diagram (%) for the Bor region in the period 2008-2011

3. RESULTS AND DISCUSSION

3.1. Legislative

Until the 2010, the daily limit value (LV) for SO₂ concentrations in the populated areas was 150 µg m⁻³ [7] when new regulation started being applied. The daily tolerant value (TV) for SO₂ according to the new Regulation is lower, 125 µg m⁻³ [8] and cannot exceed more than three times during a calendar year. The LV for SO₂ concentrations on an annual level is 50 µg m⁻³ [9], which is lower compared to the US National Ambient Air Quality Standard amounting to 80 µg m⁻³ [9]. The proposed daily target value in the European Union (EU) is 125 µg m⁻³ [10], and Air Quality Guidelines enacted by the World Health Organization (WHO) is 20 µg m⁻³, also on a daily basis [11]. The WHO and the EU do not have annual limitations for SO₂ concentration in the air.

3.2. Sulphur dioxide concentrations

In Figs. 2-5 the average monthly SO₂ concentrations and a number of days above the LV are shown at three to five measuring sites, depending on the active monitoring network [6].

In 2008 (Fig. 2a) the most frequent exceedances of the LV were observed at the site Jugopetrol (for 6 months). The highest average monthly SO₂ concentration was at the Jugopetrol in February (283 µg m⁻³), where the maximum daily concentration was also detected in January, amounting to 1,038 µg m⁻³ (not shown in Fig.). During 2008, at the site Jugopetrol, the concentrations were above the LV for 115 days, with the exception of October, when it exceeded the LV for 21 day (Fig. 2b). At the sites Town park and Institute, the SO₂ concentration was above the LV, for 94 and 25 days, respectively, which indicates lower air pollution at these sites.

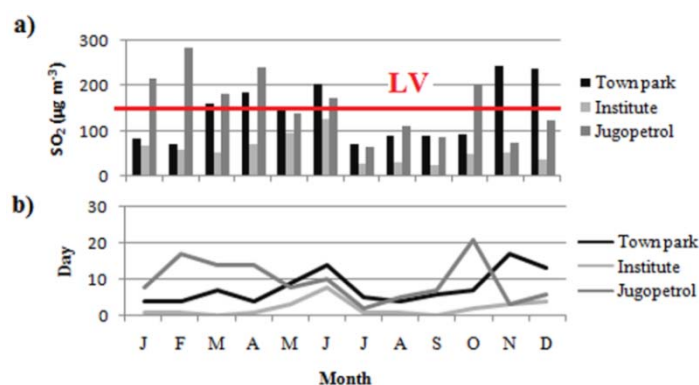


Figure 2. a) Average monthly SO₂ concentrations at the measuring sites Town park, Jugopetrol and Institute during 2008 (LV - limit value); b) Number of days above the LV

During the first four months of 2009 (Fig. 3a), relatively higher SO_2 concentrations were observed, but the LV exceeded mainly at the site Jugopetrol (for 4 months). The highest average monthly SO_2 concentration in February ($200 \mu\text{g m}^{-3}$) and maximum daily concentration in January ($1,412 \mu\text{g m}^{-3}$) were detected at the Jugopetrol. A number of days above the LV was: 36 at the Town park, 83 at the Jugopetrol and 18 days at the site Brezonik (Fig. 3b).

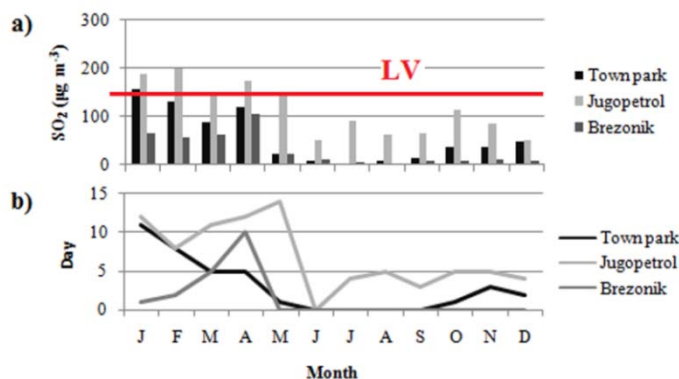


Figure 3. a) Average monthly SO_2 concentrations at the measuring sites Town park, Jugopetrol and Brezonik during 2009 (LV - limit value); b) Number of days above the LV

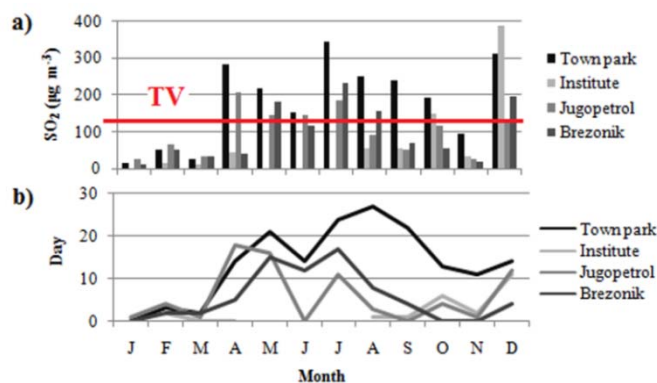


Figure 4. a) Average monthly SO_2 concentrations at the measuring sites Town park, Institute, Jugopetrol and Brezonik during 2010 (TV - tolerant value); b) Number of days above the TV

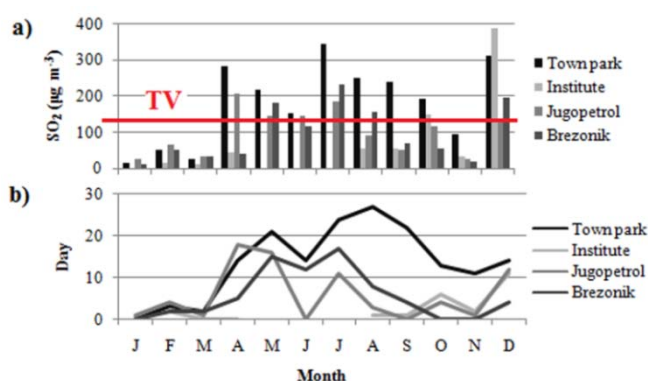


Figure 5. a) Average monthly SO_2 concentrations at the measuring sites Town park, Institute, Technical faculty, Jugopetrol and Brezonik during 2011 (TV - tolerant value); b) Number of days above the TV

During 2010, SO_2 concentrations were monitored at four sites (Fig. 4a). At the site Town park, SO_2 concentration was above the LV for eight months. The highest average monthly concentration was at the Institute in December ($387 \mu\text{g m}^{-3}$) and maximum daily concentration was detected at the Town park in December ($2,079 \mu\text{g m}^{-3}$). At the Town park, the highest number of daily exceedances of TV were observed, which is a total of 165 days, followed by the Jugopetrol and Brezonik, 71 and 69

days respectively, while the least number of days above the TV were at the Institute, only 23. However, at the site Institute, the measuring station was out of order in January, May, Jun and July, which maybe a reason of lower level pollution at this site.

In 2011, the air quality monitoring was performed at five sites, and the results are presented in Fig. 5. Regarding the LV, in 2011 at the sites Town park, Technical faculty and Jugopetrol there were more than eight months in which monthly SO₂ concentration exceeded the allowable value. The highest average monthly (765 µg m⁻³) and maximum daily (2,565 µg m⁻³) SO₂ concentration were detected at the Jugopetrol in August. As can be seen from Fig. 5b, the most frequent exceedance of the TV was observed at the Town park (164 days in total), followed by the Technical faculty and Jugopetrol (156 and 136, respectively), and the Institute with 68 days during the calendar year. The site Brezonik was also polluted, but in smaller extent with 52 days above the TV.

4. CONCLUSION

Based on the monitoring of SO₂ concentrations at the sites in Bor, air quality assessment was done. Comparing the number of days above the daily limit value, on average 114.75 of days are above the LV at the Town park (4-year measurements), 101.25 day at the Jugopetrol (4-year), 46.33 days at the Brezonik (3-year) and 38.67 days are above the LV at the Institute (3-year). At the site Technical faculty, SO₂ measurements were conducted only during 2011 and there were 156 days above the LV. In the analyzed period, the sites with the most frequent exceedance of the monthly LV were Town park and Jugopetrol (23 months in total) and Technical faculty (11 months). At all the measuring sites, only at the Brezonik, the average annual SO₂ concentration was within the annual limit value (<50 µg m⁻³) in 2009. The maximum average annual concentration was recorded at the Jugopetrol site during 2011 (365.16 µg m⁻³). Considering that the pollution depends on wind roses of the studied area, the increased level of air pollution is present at the site Jugopetrol, which is located at the prevailing west winds. Also, the endangered area is around the site Town park, since it is located 0.5 km away from the copper smelter.

ACKNOWLEDGEMENT

The authors are grateful to the Ministry of Education and Science of the Republic of Serbia for financial support (Projects No. 46010 and No. 33038).

5. REFERENCES

- [1] Hrdličková Z., Michalek J., Kolar M., Vesely V.: Identification of factors affecting air pollution by dust aerosol PM₁₀ in Brno City, Czech Republic, *Atmospheric Environment* 42 (2008) 8661–8673.
- [2] Pires J.C.M., Sousa S.I.V., Pereira M.C., Alvim-Ferraz M.C.M., Martins F.G.: Management of air quality monitoring using principal component and cluster analysis-Part I: SO₂ and PM₁₀, *Atmospheric Environment* 42 (2008) 1249–1260.
- [3] Elminir H.K.: Dependence of urban air pollutants on meteorology, *Science of the Total Environment* 350 (2005) 225-237.
- [4] Karademir A.: Evaluation of the potential air pollution from fuel combustion in industrial boilers in Kocaeli, Turkey, *Fuel* 85 (2006) 1894–1903.
- [5] Serbula S.M., Kalinovic T.S., Stevanovic J., Strojic J.V., Ilic A.A.: Hazardous materials in mining-metallurgical production process. 15th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology" TMT 2011, Prague, Czech Republic, 12-18 September 2011, pp. 841–844.
- [6] The Mining and Metallurgy Institute Bor, Annual reports about quality of ambient air in Bor from 2008 to 2011. Group for measuring and control of gaseous and dust parameters.
- [7] The Official Gazette of Republic Serbia, No. 19/06.
- [8] Regulation on alterations and annexes of the Regulation on conditions for monitoring and the requirements for air quality improvement. The Official Gazette of the Republic of Serbia, No. 75/10.
- [9] US EPA, NAAQS <http://www.epa.gov/air/criteria.html>
- [10] Council Directive 2008/50/EC of the European Parliament and of the Council on ambient air quality and cleaner air for Europe. Official Journal of European Union, L 152/1.
- [11] World Health Organization: air quality guidelines, Global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Regional Office for Europe, Copenhagen.