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VARIATION CONCENTRATION OF SULFUR DIOXIDE AND CORRELATION WITH METEOROLOGICAL PARAMETERS

Ilić Predrag[1], Nešković Markić Dragana[2], Stojanović Bjelić Ljiljana[3]

[1] *PSI Institute for protection and ecology of the Republic of Srpska, Banja Luka, Vidovdanska 43, 78000 Banja Luka, Republic of Srpska, Bosnia and Herzegovina, predrag.ilic@institutzei.net*
[2] *Public utility „DEP-OT" Regional landfill Banja Luka, Republic of Srpska, Bosnia & Hercegovina*
[3] *Pan-European University "APEIRON", Banja Luka, Republic of Srpska, Bosnia & Hercegovina*

ABSTRACT

Levels of SO_2 in air samples from urban zone of Banja Luka were determined at locality Center in Banja Luka (administrative center of the Republic of Srpska, in Bosnia and Herzegovina) which is highly populated area, with intensive traffic and industry. Through experimental measuring, daily and weekend variation of SO_2 concentration was determined. Daily variations are directly connected to regime and intensity of traffic and using fossil fuels. The paper presents measured average values of sulfur dioxide, together with max and min values and relationship between some parameters of air quality and meteorological parameters, i. e. for pollution modelling together with meteorological parameters.

Keywords: air pollution, Banja Luka, monitoring, sulfur dioxide, urban zone

INTRODUCTION

Eastern European and Balkan countries suffer the highest rate of the air contamination and air pollution related deaths throughout Europe. Bosnia and Herzegovina (B&H), Bulgaria, Albania and the Ukraine have the highest European mortality rates attributed to home and air pollution B&H is listed as the worst European performer and had European highest average of 55.1 µg particular matter per m^3. B&H in 2012 registered nearly 231 deaths per 100,000 people and had European highest death rate [1]. The problem of air pollution is largely present in the Republic of Srpska, B&H. A small number of local community control of air pollution, and monitoring of emissions is not represented to the extent necessary [2]. Numerous studies have analysed the impact of meteorological parameters and air quality parameters [3,4,5,6,7,8], where the results were often uncoordinated or even opposed. For example, by examining the effect of air temperature on the concentration PM10, Kassomenos et al. [9] they get positive correlation values, and Giri et al. [10] hey get negative correlation values. As an explanation for these differences may indicate different locations research studies, timing and so on.

The importance of air pollution prevention has been increasing in recent years, due to increasing knowledge of polluting sources and their pollution levels. Sulfur dioxide (SO_2) is one of the environmentally important air pollutants that has been closely associated with urban air quality problems during winters [11]. Sulfur dioxide is a colourless gas with a sharp, irritating odour. Sulfur dioxide is added to the atmosphere primarily as a by-product of combustion of coal, fuel oil, diesel engine fuel; biological processes; sea spray; and to a lesser extent, the combustion of wood [12]. It smells like burnt matches. It can be oxidized to sulfur trioxide, which in the presence of water vapour is readily transformed to sulfuric acid mist. SO_2 can be oxidized to form acid aerosols. SO_2 is a precursor to sulphates, which are one of the main components of respirable particles in the atmosphere [13,14].

Sulfur dioxide is considered one of the indicators of air quality. It is formed primarily from the combustion of sulfur-containing fuels and can affect the health of people and have a negative impact on the environment. Modelling of environmental parameters is a basis for a better understanding and prevention of air pollution [15]. On concentration from 800 to 2600 mg/m^3 it is possible to smell characteristic taste [16], which most of population smells on concentration of 1 ppm. Sulfur dioxide (SO_2), a major air pollutant with a strong disagreeable sulfurous odour, is both water-soluble and a strong respiratory irritant. In the atmosphere, SO_2 is a precursor to acid sulfates (including sulfuric acid), which are neutralized by ammonia, which is usually present. SO_2 and its reaction products have been steadily dropping in concentration in the atmosphere, mainly due to decreasing sulfur levels in fuels [12].

Decreasing of sulfur in atmosphere is result of lesser use fossil fuel for individual house heating [17]. Coal usage and the rise of newer industrial activities, such as the smelting of metal ores, produced acidic, odorous, and irritating sulfur-containing pollutants, which would have also contained toxic levels of metals such as lead and iron. The success of coal as a fuel and its widespread availability for industrial and domestic uses not only led to increasingly polluted air in outdoor and indoor environments, but it also served as the impetus that would eventually drive regulatory actions [12]. Sulfur dioxide concentration in atmosphere is varied for different places. Urban and industrial regions contains bigger concentration this pollution material. Rated concentration in urban area is 0.01-0.02 ppm. However, momentary concentration can be much bigger. Therefore, one-hour concentration can be bigger 4-7 times than rated annual concentration.

Despite the legal obligation, the state of monitoring is at a very low level and it is necessary to improve it in the Republic of Srpska [18,19], but there are significant research in the field of air pollution [20,21,22,23,24,25,13,26,18,19,20]. The present study aimed analysed concentration of SO_2 and investigate the relationship SO_2 with meteorological parameters, over the period from January – December 2016 in Banja Luka, Republic of Srpska, B&H.

MATERIALS AND METHODS

Location

Subject of the research is testing air pollution and meteorological parameters at locality Center in Banja Luka, with intensive traffic and high population. Banja Luka is the administrative center of the Republic of Srpska, in Bosnia and Herzegovina. It is located in the southern part of Europe. Banja Luka is located in Vrbas valley and is surrounded by hills 200-600 meters above sea level high. Banja Luka lies on a bank of the river Vrbas, which flows into Sava River, and later into Danube. It is the second largest city in Bosnia and Herzegovina, after Sarajevo, and as large industrial and financial centre with dense population and industry in the city itself and its surroundings, which are sources of air pollution. The largest sources of pollution are heating plants, traffic, foundries, metal-processing and chemical industry, and fireboxes in households, municipal waste, etc. It is necessary to take urgent measures in order to improve air quality in these and other areas, and in that way, to protect health of people living in urban areas [26].

Analytical procedure

Sulfur dioxide has been measured by equipment Teledyne Advanced Pollution Instrumentation, Inc. (TAPI) Sad Diego, California, United States. Monitoring of sulfur dioxides concentration was performed by the Model T 100 (*UV Fluorescence* SO_2 *Analyzer*). For the level of pollution by SO_2, *UV Fluorescence* method was used. Range 0-50 ppb / 0-20 ppm. For monitoring of sulfur dioxides, there is BAS EN 14212 standard, as reference method for the measurement of sulfur dioxide [27]. The Model T100 uses the proven UV fluorescence principle, coupled with a state of the art user interface to provide easy, accurate, and dependable measurements of low level SO_2. Model T 100 is based on the principle that SO_2 molecules absorb ultraviolet (UV) light and become excited at one wavelength, then decay to a lower energy state emitting UV light at a different wavelength.

Pictures 1. SO_2 monitor

Simultaneously is supplied data on average temperature, air pressure, and relative humidity, speed and wind direction, recorded at the meteorological monitoring site at the outer rim of the inner city every day for the entire duration of the study. These results of concentration of polluting particles monitoring were compared in accordance with current law regulations regarding air quality, issues on pollution and air quality control. Based on both data and Regulation on air quality values [28], Directive 2008/50/EC on ambient air quality and cleaner air for Europe [29] and standards recommended by World Health Organization (WHO) and EU countries, an assessment of the current state will be given. It will be determined if the measured values satisfy recommended and limit values specified by the Law.

Statistical analysis

For statistical data processing while determining interdependence and relationship between some parameters of air quality and meteorological parameters, i. e. for pollution modelling together with meteorological parameters, were used EXCEL and SPSS statistical software tool. Descriptive statistical parameters like mean, Standard deviation (SD), minimum (min) and maximum (max) applied to the data.

RESULTS AND DISCUSSION

Measured average values of sulfur dioxide are shown in Table 1, together with max and min values. Research show that variation of SO_2 dominantly depend on both human activity during a day (Graph 1). For example, concentration of sulfur oxides in early hours without solar insolation and human activities is mostly constant. Daily variations are directly connected to regime and intensity of traffic and using fossil fuels. During a day, population activities such as traffic frequency increase, and this causes concentration of polluting substance sulfur dioxide to grow, but probably and sulfur trioxide and of sulfuric acid. Thus, under the right conditions SO_3 can lead to the formation of sulfuric acid, a strong irritant and corrosive agent. Ultimately, sulfuric acid is formed in water droplets from the interaction of SO_2 and hydroxyl radicals (OH•) [12].

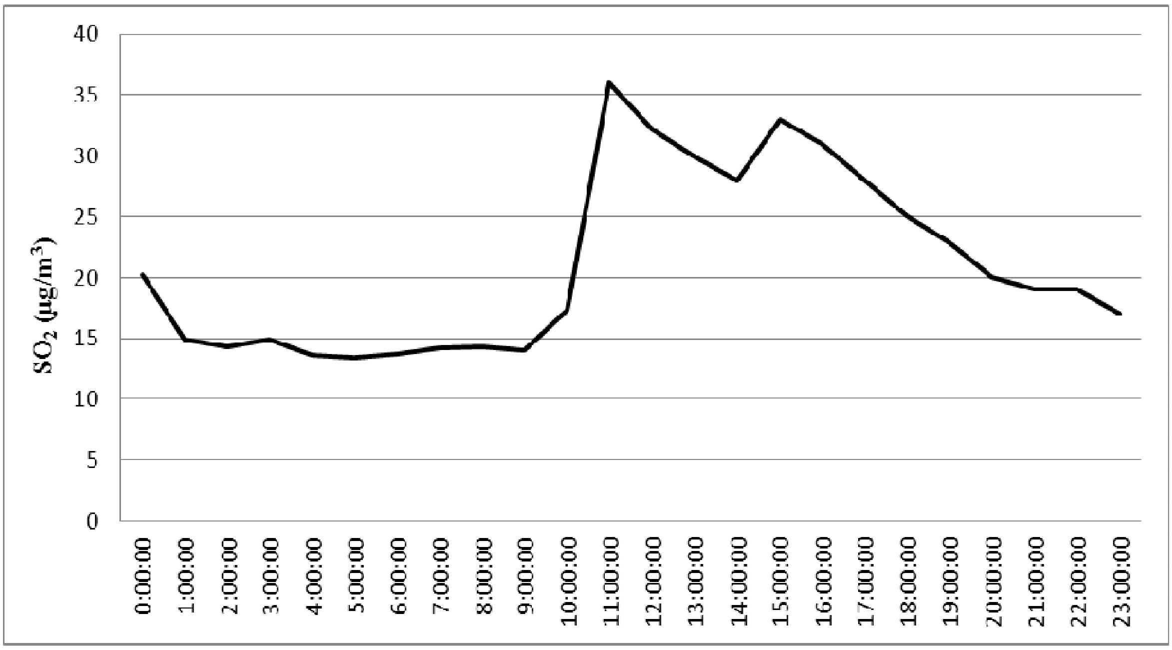
In combustion-generated plumes, a large number of other substances, organic and inorganic, surrounds SO_2 and the above reaction products. The result is the formation of particulate sulfates other than sulfuric acid (e.g., $(NH_4)_2SO_4$ and metal-containing sulfates). Sulfates contribute significantly to the fine particulate mass, PM2.5, in regions that use fuels containing sulfur [12].

Mean annual value with the aim of protection of human health for sulfur dioxide, for sampling period of 1 hour is 350 μg/m^3 and period of 24 hours is 125 μg/m^3 [28], as prescribed and Directive 2008/50/EC [29]. In a research field, it is not exceeded and is 21.81 μg/m^3 (Table 1) is lower than the value 39.35 μg/m^3, which was measured during previous research [20]. Although high levels of sulfur dioxide have not been recorded during the investigated period, humidity during the analysed period of 66.40%, due to a number of chemical reactions in which sulfur dioxide is converted into sulfuric acid, can affect the increase in harmful effects caused by the action of sulfur dioxide. The presence of sulfur dioxide in the phenomenon of "temperature inversion" and in the absence of horizontal movement of the air it can lead to the appearance of acid smog, which usually occurs in the winter months, when concentrations of sulfur dioxide in the air are increased due to heating [28, 20].

Table 1. Statistical summary of SO_2 and meteorological parameters

		Mean	SD	Min	Max
SO_2		21.81	19.46	0.05	254.35
Meteorological parameters	VW (m/s)	0.33	0.0054	0	2.27
	DW (Å)	134.5	107.05	0.24	359.7
	P (Pa)	995.90	7.91	9710.93	1017.1
	T (^{0}C)	12.36	8.64	-8.39	34.57
	RH (%)	66.40	18.38	16.8	95.85

The Graph 1. shows the dependence of the concentration of SO_2 from the time of day during the measurement period. As can be seen from the graph the concentration of SO_2 is dependent on human activities. During the early morning hours (from 0:00 to 8:00) concentration of SO_2 was very low. Its maximum concentration was recorded in the period from 11 to 17 hours, and the values were reduced after 17 hours. Pollution by SO_2 in the area is believed to be dominated by road traffic [20, 22]. Sarigiannis et al. [31] SO_2 concentration starts to increase in the morning hours, reaching a morning peak (2.3 μg/m^3) from 11:00 until 20:00. A gradual increase of SO_2 concentration was noticeable, accompanied by the average hourly increase of trucks and buses.



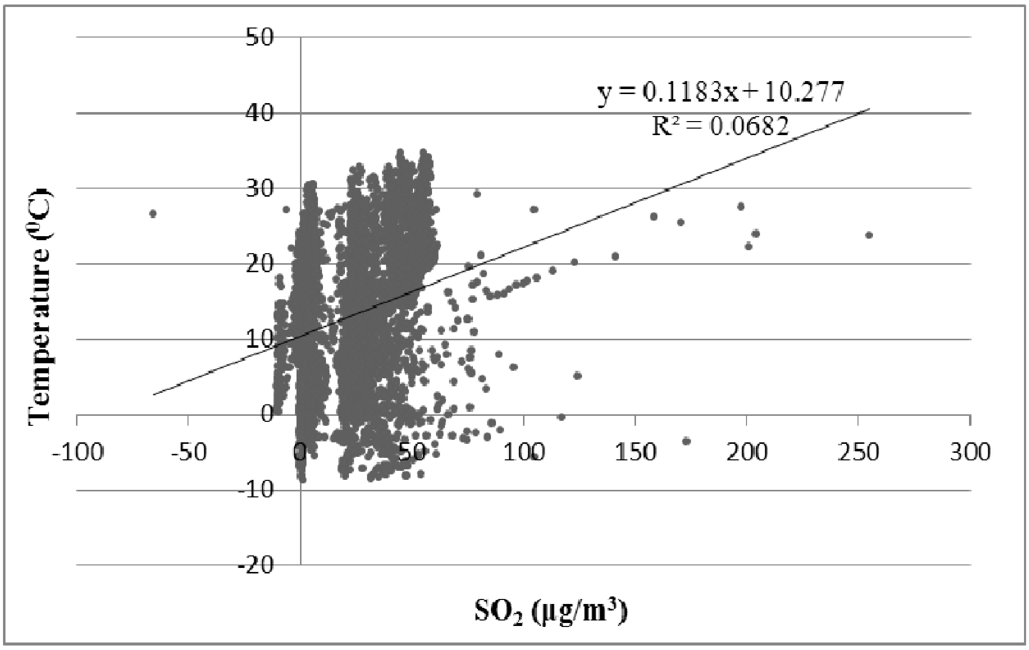
Graph 1. Mean SO_2 values during 2016 at certain times of the day

The relationship between SO_2 concentrations and other meteorological parameters in the study area was analysed using correlation analysis. The results of the correlation analysis between SO_2 concentration and meteorological parameters are shown in Table 2. Between the meteorological parameters of pressure and temperature there is a significant negative correlation (r = -0.27), respectively a significant negative correlation between the temperature and RH (r = -0.56). By increasing the pressure, the temperature values were reduced, i.e. by reducing pressure, the temperature has grown. The increase in temperature has affected the reduction in value RH, i.e. the decrease in temperature has affected the increase RH.

Table 2. Pearson's correlation coefficients between SO_2 concentrations and meteorological parameters

	SO_2 (μg/m^3)	VW (m/s)	DW (Â°)	P (Pa)	T (°C)	RH (%)
SO_2 (μg/m^3)	1					
VW (m/s)	-0.14	1				
DW (Â°)	0.02	-0.07	1			
P (Pa)	-0.25	0.06	0.05	1		
T (°C)	0.26	0.13	0.09	-0.27	1	
RH (%)	-0.11	-0.18	-0.07	0.11	-0.56	1

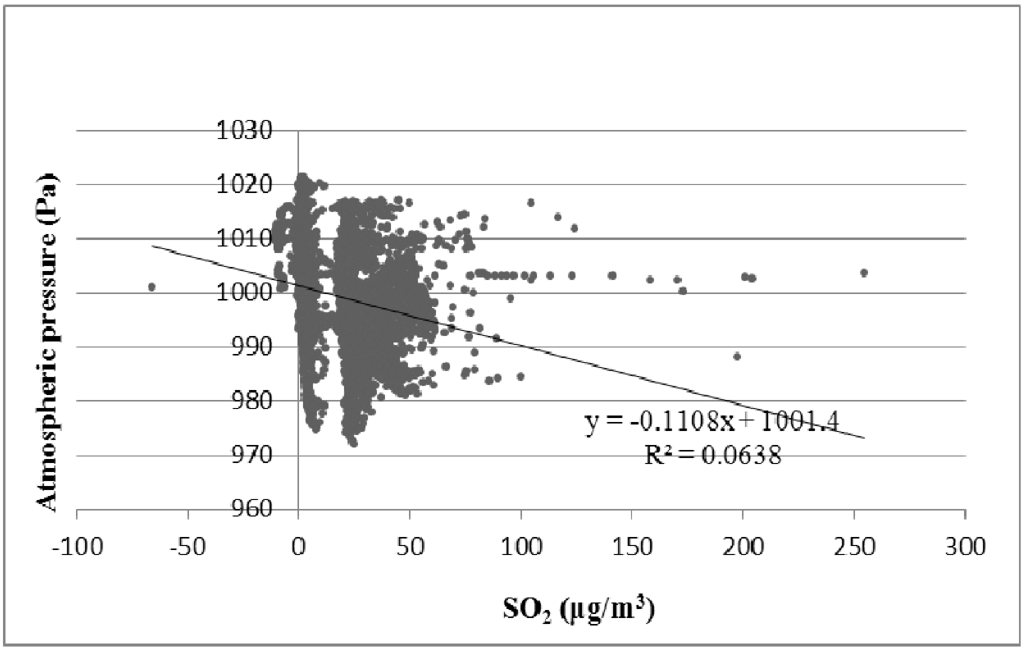
Correlation between SO_2 and temperature was positive and significant during the study period (r=0.26). With increase of temperature the SO_2 concentration increase, i.e., the decrease in temperature decreases the concentration SO_2. The Graph 2 shows the dependence of the concentration of SO_2 on the temperature, as well as the equation describing this dependence.



Graph 2. Correlation between SO_2 concentrations and temperature

Correlation between SO_2 and atmospheric pressure was negative and significant during the study period (r=0.26). With increase of atmospheric pressure the SO_2 concentration decrease, i.e. by decreasing atmospheric pressure, the concentration of SO_2 decreases. The Graph 3 shows the dependence of the concentration of SO_2 on the atmospheric pressure, as well as the equation describing this dependence.

24-hour average is recommended from World Health Organization (WHO) for sulfur dioxide is 125 μg/m^3 [32], as well as in Republic of Srpska. In test area, average annual value is exceeded which is probably caused by combustion of liquid, solid and gas fuel and traffic frequency. In winter seasons on lower temperatures, fuel consumption is higher, great amounts of nitrogen dioxide, sulfur dioxide and particles that cause winter smog are created. Winter smog is created by mild airflow and temperature inversion that disables vertical airflow and diluting of pollution materials in lower layer of atmosphere [21]. High values of sulfur dioxide with presence of wind can contribute to transformation those contamination materials in sulfur, continuing in forming sulphate salt [33].



Graph 3. Correlation between SO_2 concentrations and atmospheric pressure

CONCLUSION

This paper presents results of simultaneous measurement of SO_2 and meteorological parameters at locality Centre in Banja Luka. Mean annual value for sulfur dioxide in a research field and is 21.81 $\mu g/m^3$. The results obtained for SO_2 were bellow limits Regulation on air quality values. Concentration of SO_2 is dependent on human activities. Its maximum concentration was recorded in the period from 11 to 17 hours. Correlation between SO_2 and temperature was positive and significant during the study period (r=0.26). Correlation between SO_2 and atmospheric pressure was negative and significant during the study period (r = -0.2).

Statistical analysis confirms string of rolls, which shows directional connection between air pollution and meteorological parameters.

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REFERENCES

[1] WHO (2017) World health statistics 2017, Monitoring health for the SDGs, Sustainable Development Goals. Geneva, World Health Organization.

[2] Ilić, Predrag: Pollution and control of air quality in the function of environment protection. 2015; Independent University, Banja Luka.

[3] Ilić, Predrag. (2009). Quality control and research of air pollution influence in function of protection and environmental improvement in Banja Luka. Doctor thesis, University of Novi Sad. 12/2009

[4] Galindo, N., Varea, M., Gil-Molto, J., Yubero, E., Nicolas, J. (2011). Influence of meteorology on particulate matter concentrations at an urban Mediterranean location. Water Air Soil Pollution 215, pp. 365-372.

[5] Krynicka, J., Drzeniecka-Osiadacz, A. (2013). Analysis of varialility in PM10 concentration in the Wroclaw agglomeration. Polish journal of environmental studies 22, pp. 1091-1099.

[6] Li L., Qian, J., Ou C-Q., Zhou, Y-X, Guo, C., Guo, Y. (2014). Spatial and temporal analysis of Air Pollution Index and its timescale-dependet relationship with meteorological factors in Guangzhou, China, 2001-2011, Environmental Pollution 190, pp. 75-81.

[7] Lin, M., Tao, J., Chan, C-Y, Cao J-J., Zhang, Z-S., Zhu, L-H, Zhang, R-J., (2012). Regression analyses between air quality and visibility changes in megacities at four haze regions in China. Aerosol and air quality research 12, pp. 1049-1061.

[8] Zhang, H., Wang Y., Hu, J., Ying, Q, Hu, X-M, (2012). Relationships between meteorological parameters and criteria air pollution in three megacities in China. Environmental Research 140, pp. 242-254.

[9] Kassomenos, P.A., Vardoulakis, S., Chaloulakou, A., Paschalidou, A.K., Grivas, G., Borge, R., Lumbreras J. (2014) Study of PM10 and PM2.5 levels in three European cities: Analysis of intra and inter urban variations. Atmospheric Environment 87, pp. 153-163.

[10] Giri, D., Krishna Murty, V., Adhikary, PR. (2008). The influence of meteorological conditions on PM10 concentrations in Kathmandu Valley. International journal of environmental research 2(1), 49-60.

[11] Yildirim, Y., Demircioglu, N., Kobya, M., & Bayramoglu, M. (2002). A mathematical modeling of sulfur dioxide pollution in Erzurum City. Environmental pollution, 118(3), pp. 411-417.

[12] Phalen, R. F., & Phalen, R. N. (2012). Introduction to air pollution science. Jones & Bartlett Publishers.

[13] Preradović, L., Ilić, P., Marković, S., & Janjuš, Z. (2011). Meteorological parameters and pollution caused by Sulfur dioxide and their influence on construction materials and heritage. Facta universitatis-series: Electronics and Energetics, 24(1), pp. 9-20.

[14] Vidaković, M., Djurić, N., Savković, P., & Babić, R. (2013). pH of precipitation in the area of the town of Bijeljina. Archives of Technical Sciences No 8 (1), pp. 75-80.

[15] Abdul-Wahab, S. A. Al-Alawi, S. M. (2008). Prediction of sulfur dioxide (SO_2) concentration levels from the mina al-fahal refinery in oman using artificial neural networks," American Journal of Environmental Sciences, vol. 4, no. 5, pp. 473–481.

[16] Kristoforović-Ilić, M., Radovanović, M., Vajagić, L., Jevtić, Z., Folić, R., Krnjetin, S., & Obrknežev, R. (2002). Communal Hygiene, Novi Sad.

[17] Đuković, J. & Bojanić, V., (2000). Air pollution, definition, state, sources, control and technological solutions, Institute of protection and ecology, Banja Luka.

[18] Ilić, P., Ilić, S., Janjuš, Z. (2013). Environmental protection in Republic of Srpska, status end perspectives. Scientific-professional conference with international participation "Environment protection between science and practice – status and perspectives", Banja Luka, Republic of Srpska, Bosnia and Herzegovina, 12/2013.

[19] Ilić, P., Ilić, S., Janjuš, Z., (2014). Air protection in Republic of Srpska. IX International Conference Risk and Safety Engineering, Kopaonik, Serbia; 02/2014.

[20] Ilić P., Janjuš Z. (2008). Air quality assessment regarding the presence of SO_2. Scientific-professional Conference with international participation "Modern technologies for cities' sustainable development", Banja Luka, Republic of Srpska, Bosnia and Herzegovina; 11/2008

[21] Ilić, P., Preradović, Lj. (2009). Simulation of pollution, i.e. modelling levels of nitrogen dioxide and meteorological parameters. grkg/Humankybernetik. 01/2009; 50(3), pp.146-150.

[22] Lammel, G., Klánová, J., Ilić, P., Kohoutek, J., Gasić, B., Kovacić, I., Lakić, N. & Radić, R. (2010). Polycyclic aromatic hydrocarbons in air on small spatial and temporal scales–I. Levels and variabilities. Atmospheric Environment, 44(38), pp.5015-5021.

[23] Lammel, G., Klánová, J., Ilić, P., Kohoutek, J., Gasić, B., Kovacić, I., & Škrdlíková, L. (2010). Polycyclic aromatic hydrocarbons in air on small spatial and temporal scales–II. Mass size distributions and gas-particle partitioning. Atmospheric Environment, 44(38), pp. 5022-5027.

[24] Gasic, B., MacLeod, M., Klanova, J., Scheringer, M., Ilic, P., Lammel, G., Pajovic, A., Breivik, K., Holoubek, I. & Hungerbühler, K. (2010). Quantification of sources of PCBs to the atmosphere in urban areas: A comparison of cities in North America, Western Europe and former Yugoslavia. Environmental Pollution, 158(10), pp. 3230-3235.

[25] Lammel, G., Klánová, J., Erić, L., Ilić, P., Kohoutek, J., & Kovacić, I. (2011). Sources of organochlorine pesticides in air in an urban Mediterranean environment: volatilisation from soil. Journal of Environmental Monitoring, 13(12), pp. 3358-3364.

[26] Ilić, P., Marković, S., Račić, M., Janjuš, Z. (2012). Municipal noise and air pollution in urban part of Banja Luka. Skup. 01/2012; 4(2), pp. 32-42

[27] The reference method for the measurement of sulfur dioxide is that described in EN 14212:2012 'Ambient air quality-standard method for the measurement of the concentration of sulfur dioxide by ultraviolet fluorescence'.

[28] Regulation on air quality values ("Official Gazette of the Republic of Srpska", No. 124/12).

[29] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe. Off. J. Eur. Union 11 June 2008.

[30] Jablanović, M., Jakšić, P., Kosanović, K. 2003. Introduction to ecotoxicology. University of Priština, Faculty of Natural Sciences. Kosovska Mitrovica.

[31] Sarigiannis, D. A., Handakas, E. J., Kermenidou, M., Karakitsios, S. P., Charisiadis, P., & Makris, K. (2015). Monitoring of air pollution levels related to Charilaos Trikoupis bridge. 10^{o} National scientific congress of chemical engineering, Patra.

[32] WHO. (2006). Air Quality Guidelines: Global Update 2005. Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide. World Health Organization.

[33] Bešlić, I. 2007. Interpretation and assessment of air pollution levels in Zagreb based on meteorological parameters. D. thesis. Faculty of Science and mathematics, University of Zagreb, Zagreb, Croatia.