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Original scientific paper

AIR QUALITY IN THE TOWN OF BIJELJINA - TRENDS AND LEVELS OF SO_2 AND NO_2 CONCENTRATIONS

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ABSTRACT: Abstract: The paper presents results of the measurements of the sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) concentration and meteorological parameters: temperature, air pressure, relative humidity and wind speed. The data were collected from January 2019 to December 2020 at two stations, namely Center and Heating plant, in the City of Bijeljina, Republic of Srpska, Bosnia and Herzegovina. SO_2 and NO_2 are one of the major air pollutants that could negatively affect the human health. Levels of SO_2 and NO_2 in air samples and meteorological variables from urban zone of Bijeljina were determined at both localities, which represent a highly-populated area with intensive traffic. This topic has not been studied up to now in Bijeljina, although the recent research data indicates that there is a correlation between meteorological parameters and air pollutants. Statistical analysis confirms direct corelation between SO_2 and NO_2 and meteorological parameters, specially temperature in locality Center ($r = -0.639$), the wind speed in locality Heating plant ($r = 0.399$) and relative humidity ($r = 0.162$). Correlation of NO_2 with temperature is not confirmed in both localities. The wind speed increase is followed by rises of the NO_2 concentration values and vice versa. Correlation of NO_2 with pressure is confirmed in locality Center ($r = 0.128$) but it is not confirmed in locality Heating plant. Correlation between NO_2 and relative humidity found to be negative in locality Center ($r = -0.062$). These parameters are the most important meteorological factors influencing the variation in SO_2 and NO_2 concentration in the air during the research. Depending on the obtained correlation, meteorological parameters had a positive or negative impact on air pollution.

Keywords: air quality, sulfur dioxide (SO_2), nitrogen oxides (NO_x), nitrogen dioxid (NO_2).

INTRODUCTION

Air pollution can be defined as the emission of various gases, particulate matters, biological materials, and other pollutants into the atmosphere. The sources of emissions could be natural and anthropogenic (Stanek & Brown, 2019). Natural sources include physical disasters, such as forest fires, volcanic eruptions, dusty storms and various agricultural activities (Barbosa et al., 2008; Von Glasow et al., 2009; Prato & Huertas, 2019). Anthropogenic sources produce most of the environmental pollutants and, they could be stationary and mobile sources (Fino, 2019). Stationary sources include all activities related to the combustion of fossil fuels in the production of electricity or heat, the combustion of fossil fuels in production processes, emissions from households and waste incinerators, furnaces, and other heating devices, traditional biomass combustion, various industrial plants, mining and agricultural activities (Cardu & Baica, 2005; Ge et al., 2004; Yadav & Devi, 2019; Pandey et al., 2014). Since these activities are performed on a large scale, they contribute the most to air pollution. Mobile sources include all types of transport vehicles: motor vehicles, trains, ships, and planes (Hesterberg et al., 2006; Abbasi et al., 2013; Mueller et al., 2011). Among the anthropogenic sources of air pollution, the most important are thermal power plants, industrial and domestic furnaces that use fossil fuels to obtain electricity or heat and means of transport. Industrial and domestic heating stoves have a seasonal character, while thermal power plants pollute the atmosphere throughout the year. The greatest influence of individual fireplaces on the air quality in our region is from October to May. Regardless of the source, pollutants have a considerable impact on the living world and the environment. Some of them cause diseases and even death, lead to reduced visibility, block sunlight, cause acid rain, ozone holes, damage materials and infrastructure, damage ecosystems, cause climate promenades that affect the entire planet (Ramanathan & Feng, 2009; Maduna & Tomašić, 2018).

According to World Health Organization (WHO) estimates, about seven million people die each year from air pollution. WHO data show that 9 out of 10 people breathe air in which the WHO guidelines for air pollutants are exceeded, and low-and middle-income countries suffer from the major exposure. Air pollution poses a serious threat to health and the climate. The combined effect of ambient and indoor air pollution causes about seven million premature deaths each year. That is an outcome of increased mortality from stroke, heart disease, chronic obstructive pulmonary disease, lung cancer, and acute respiratory infections. Estimations say that about 4.2 million deaths per year are the result of exposure to polluted ambient air, and 3.8 million deaths per year are the result of polluted indoor air (www.who.int/health-topics/air-pollution#tab=tab_1; www.who.int/phe/eNews_63.pdf).

The law defines the control of emitters of pollutants at the point of discharge, and it is necessary to carry out a series of complex technological procedures to achieve the prescribed permitted emission levels. National legislation defines allowable concentrations of pollutants emitted from stationary sources and allowable emissions of pollutants in ambient air (Regulation 124/12; Directive 2008/50/EC; Rulebook 3/15, 51/15, 47/16 and 16/19). Different compounds (gases, liquids, and solid particles) can appear in the air as pollutants. The most common pollutants that appear in the air of urban areas are sulfur oxide (SO_x), nitrogen oxides (NO_x), carbon monoxide (CO), particulate matter (PM_{10} and $PM_{2.5}$), ground-level ozone (O_3), volatile organic compounds (VOCs), photochemical oxidants, lead, dust or aerosediment, soot, etc (Manisalidis et al., 2020). The WHO offers global guidelines on thresholds and limits for key air pollutants that pose a health risk. The guidelines are applied worldwide, and they are based on expert assessment of current scientific evidence for PM_{10}, $PM_{2.5}$, O_3, nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) (www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health).

During the combustion of fossil fuels, a mixture of different pollutants is emitted. Oxides of sulfur and nitrogen are emitted to a significant extent. SO_x originate from the sulfur present in fossil fuels or ores, while NO_x are formed at high temperatures due to the reaction between nitrogen and oxygen from the air. The most common SO_x are SO_2 and SO_3. NO_x primarily produce nitrogen monoxide (NO), which oxidizes to NO_2. After discharge from coal-fired power plants and motor vehicles, SO_2 and NO_x may have sufficient time to transform into sulfuric and nitric acid under favorable atmospheric conditions, especially in the presence of water vapor. Monitoring the concentration of SO_2 is important because of its potential to be converted into sulfuric acid (H_2SO_4), and because of the harmful effects on metals, building and construction materials, urban ecosystems, vegetation and human health. (Đuković & Bojanić, 2000; Ilić, 2015). Monitoring of NO_2 concentration is important due to its constant emission during the combustion process at high temperatures, negative impact on wildlife, vegetation and human health, and the occurrence of acid rain due to conversion to nitric acid. In the presence of hydrocarbons increases the impact of NO_2 on photochemical ozone occurence (Warmiński & Bęś, 2018).

Although other pollutants have the detrimental effect on air quality, in this paper attention is focused on SO_2 and NO_2, because these are gases emitted in large quantities from different stationary and mobile sources, and they have a proven harmful effect on materials, wildlife and human health, affect the formation of acid rain (Grennfelt et al., 2020), and NO_x participate in the formation of ozone (Warmiński & Bęś, 2018). In this paper, SO_2 and NO_2 emissions are monitored continuously, to obtain information on the concentration of selected gases during the year at selected measuring points, depending on local weather conditions.

Allowable concentrations of SO_2 and NO_2 in European countries were given by Directive 2008/50/EC (Directive 2008/50/EC), which was also accepted by the Republic of Srpska government (Regulation, 124/12). Allowable concentrations of SO_2 and NO_2 in ambient air on an hourly, daily, and annual basis in Republic of Srpska are 350 µg/m^3 and 150 µg/m^3 (1-hour mean), 125 µg/m^3 and 85 µg/m^3 (24-hour mean) and 50 µg/m^3 and 40 µg/m^3 (annual mean), respectively. Concentrations of SO_2 and NO_2 dangerous to human health are 500 µg/m^3 and 400 µg/m^3, respectively (Regulation, 124/12). The latest WHO guideline value for SO_2 is 40 µg/m^3 24-hour mean. WHO guideline values for NO_2 are 25 µg/m3 24-hour mean and 10 µg/m^3 (annual mean) (for protecting the public from the health effects of gaseous NO_2) (www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health).

This paper aims to assess the air quality in Bijeljina based on monitoring the content of SO_2 and NO_2 in the air, identifying sources and causes of increasing pollutant concentrations during the year, and determining the correlation between pollutants and meteorological parameters.

MATERIALS AND METHODS

Location

Air quality testing was performed at locations marked „Center" and „Heating Plant" in Bijeljina. The test was performed according to the principle of 24-hour sampling, from January 2019 to the end of 2020 at the planned measuring points. The location marked „Center" is located in the city center (Karađorđeva street, 44° 45´ 24,43´´ N, 19° 13´ 6,53´´ E). The nearby area includes busy streets, service facilities (city administration, banks, shopping malls, and restaurants), cultural and educational facilities (Semberija Museum, schools), religious buildings, residential buildings, and a bus station. Traffic is the predominant source of emissions. The location marked as „Heating plant" is located in the industrial zone, in Sremska street 44° 45´ 41,88´´ N, 19° 12´ 21,28´´ E. The close vicinity of this location includes busy streets, shopping malls, a gas station, service, and residential buildings so that the predominant sources of emissions can be identified as heating plants and traffic.

Figure 1. Location "Center" (source: Google Earth)

Figure 2. Location "Heating plant" (source: Google Earth)

The heating plant has a heat source of 2 boilers with a capacity of 3.8 MW, which gives 7.6 MW (Work plan, 2017). By calculation, it can be obtained that for the heating season from October to March, for boilers with a total capacity of 7.6 MW, 4000 t of coal are needed. According to 2019 data, slightly more than 4,000 tons of coal were procured, as follows: separated cube 500 t, separated walnut 500 t, coal cubes 3,000 t, lignite coal 150 t, and brown coal cube 250 t (Procurement plan, 2019).

Analytical procedure

Teledyne Advanced Pollution Instrumentation, Inc. (TAPI) Sad Diego, California, United States, model T100 (UV Fluorescence SO_2 Analyzer) of the range 0-200 ppb, has been used for measuring SO_2 concentrations and Model T200 (Chemiluminescence $NO/NO_2/NO_x$ Analyzer) for NO_2, of the range 0-50 ppb. Monitoring of SO_2 was performed following standard BAS EN 14212, as the reference method and BAS EN 14211 for NO_2 (BAS EN 14212). Presented data were recorded under the ambient temperature, where simultaneously have been measured meteorological parameters: air pressure, wind speed and relative humidity. At the meteorological monitoring site along the border of the city every day during the research period meteorological parameters have been recorded. The measured concentration of pollutants was compared with actual values, defined by regulations regarding air quality, issues on pollution and air quality control. Based on both data along with Regulation on air quality values (Regulation, 124/12), Directive 2008/50/EC on ambient air quality and cleaner air for Europe (2008/50/EC) as well as standards recommended by WHO and EU countries, an assessment of the current state will be given. The present study gives a review of the existing conditions via representing relevant parameters and discusses the position of their amount in the range of recommended as well as limit values specified by the mentioned legislation.

Statistical analysis

For the determination of the interdependence and relationship between SO_2 and NO_2 of air quality, the Excel 2016, JASP Computer software (JASP, 2021), and Wessa Statistics Software 1.2.1 were used (Wessa, 2021) for statistical data processing. Descriptive statistical operations like mean, median, mode, standard deviation (SD), variance, minimal (min) and maximal (max). Skewness, Kurtosis and Shapiro-Wilk test value have been applied to analyse the measured data. Also, correlation analysis was performed and the bagplots are shown.

RESULTS AND DISCUSSION

The mean annual value of SO_2 concentration in order to preserv human health amounts 50 μg/m^3 (2008/50/EC; Regulation, 124/12) (Table 1). Measured average values of SO_2 are shown in Table 1, together with maximal and minimal values, median, mode, standard deviation and variance. In a research field, it did not exceed and amounts 19.39 μg/m^3 (locality Center) and 25.06 μg/m^3 (locality Heating plant) (Table 1). The usual values of SO_2 in urban areas usually range from 20 to 100 μg/m^3 (Ilić et al., 2008; Ilić & Janjuš, 2008; Ilić, 2009; Ilić et al., 2010), while in areas far from any human activity the natural level of SO_2 is below 5 μg/m^3 (Jablanović et al., 2003). Daily and hourly concentrations in urban areas, as in the case of Bijeljina, are higher than the usual average of 20-50 μg/m^3. Considering that there are no published publications from the previous period, a comparison was made with the values from Banja Luka City. Measurements in Banja Luka are performed at similar locations as in Bijeljina, in the center next to the busy road, near the City Heating Plant, so the sources of pollution in both cities are similar. Research conducted in the area of Banja Luka, in terms of SO_2 content in the air, showed that Banja Luka is a zone with slightly polluted and unpolluted air. There is no significant impact on people, flora, fauna, and natural and material goods (Ilić et al., 2009), with an average annual SO_2 value of 10.14 µg/m^3. This indicates that the investigated area in Banja Luka is not overburdened with this pollutant, and the values are below the limits that most often occur in the urban area (Ilić et al., 2008; Ilić & Janjuš, 2008; Ilić, 2009; Ilić et al., 2010). Higher values were measured during later research and the annual value is 21.81 µg/m^3 (Ilić, et al., 2018), whereas the prime cause is the increase in the number of vehicles in the city. As in the case of Bijeljina, in the case of Banja Luka, the highest concentrations were recorded during the winter period, due to intensive combustion of sulfur-containing fuels and traffic (Ilić et al., 2008), while during the summer period an extremely low average monthly value was recorded. Daily variations are directly connected to the regime and intensity of traffic and using fossil fuels. During a day, population activities such as traffic frequency increase, and this causes the concentration of polluting substance SO_2 to grow, but probably and sulfur trioxide and 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•) (Ilić et al., 2018).

The mean annual value of NO_2 concentration in order to preserve human health amounts 40 µg/m^3 (2008/50/EC; Regulation, 124/12). Measured average values of NO_2 at measuring points in Bijeljina are shown in Table 1, together with maximal and minimal values, median, mode, standard deviation and variance. In a research field, average values are 45.04 µg/m^3 (locality Center) and 55.62 µg/m^3 (locality Heating plant). Measured NO_2 concentrations, with annual mean concentrations above 18.82 µg/m^3, which is the case in Bijeljina, indicate the dominance of traffic and urban sources in air pollution (RoTAP, 2012). During the research in the area of Banja Luka, the average annual value for NO_2 was 46.08 µg/m^3 (Ilić, 2009, Preradović et al., 2010), indicating polluted air, similar to Bijeljina. The value of NO_2 concentration in the air was exceeded in 2007, when the average annual value was 63.09 µg/m^3 (Erić et al., 2008). A lower average annual value was recorded during 2015-2017, which amounted to 28.23 µg/m^3 (Ilić et al., 2019). Comparing the results of measured values of SO_2 and NO_2 in Bijeljina, with the results obtained for measurements conducted in Banja Luka (Ilić et al., 2009), it is clear that the air quality in Bijeljina is worse. This indicates that in the measuring areas in Bijeljina there are significant sources of pollution, such as heating plants, individual combustion plants that use coal of poorer quality as fuel and the proximity of busy roads. Multiple increases in the concentration of SO_2 and NO_2 in Bijeljina during the winter months can be attributed to the direct impact of increased combustion of fossil fuels during the heating season, as is the case in Banja Luka.

Table 1. Statistical summary of SO_2 and NO_2 and meteorological variables in localities Center and Heating plant in Bijeljina City (2019-2020)

	Center SO_2	Heating plant SO_2	Center NO_2	Heating plant NO_2	Center VW m/s	Heating plant VW m/s	Center P bar	Heating plant P bar	Center T (0C)	Heating plant T (0C)	Center RH%	Heating plant RH%
Valid	730	732	730	732	731	731	731	731	731	731	731	731
Mean	28.431	23.770	47.256	46.656	1.567	1.597	975.881	993.570	10.009	13.773	86.484	87.624
Median	19.395	25.061	45.038	55.624	1.200	1.210	973.736	994.123	9.907	11.690	89.989	90.516
Mode	8.839	26.421	17.237	14.130	1.220	0.600	24.245	990.160	-10.38	99.900	99.900	99.900
Std. Deviation	22.033	7.053	21.866	23.057	1.244	1.242	38.210	10.076	9.654	17.325	35.987	12.887
Variance	485.444	49.739	478.112	531.639	1.547	1.543	1459.968	101.532	93.201	300.173	1295.060	166.083
Skewness	2.318	-0.031	0.075	-0.168	2.058	2.062	-21.147	-0.102	0.186	3.052	19.827	-1.182
Kurtosis	7.040	0.422	-1.809	-0.572	5.137	5.147	528.497	0.730	-0.017	11.403	485.374	1.400
Shapiro-Wilk	0.751	0.959	0.812	0.884	0.791	0.790	0.230	0.990	0.956	0.674	0.260	0.864
Minimum	8.839	8.062	17.237	7.780	0.230	0.250	24.245	960.517	-10.38	-8.568	25.649	29.790
Maximum	180.039	55.014	80.922	146.803	8.400	8.420	1026.347	1028.928	63.781	99.900	99.987	99.900

Although extremely high levels of SO_2 and NO_2 have not been recorded during the investigated period, humidity during the analyzed period of 86.49% (locality Center) and 87.62% (locality Heating plant). Due to several chemical reactions in which SO_2 and NO_2 are converted into sulfur and nitrogen acid, it can affect the increase in harmful effects caused by the action of SO_2 and NO_2.

Figures 3 and 4 show the trend of the presence of SO_2 pollutants by months for both years of research. The level of SO_2 concentration is significantly higher in the winter compared to the summer months, which confirms that the use of fossil fuels is a significant source of this pollutant. The concentration of SO_2 in the area of the heating plant during the heating season is significantly higher compared to the measured concentration at the measuring point Center. That can be attributed to the direct impact of the heating plant on air quality. During the rest of the year, the concentrations of SO_2 at both measuring points are equal, as the seasonal sources of pollution (heating plants and individual furnaces) are not operative. The levels of SO_2 at both measuring points during the summer season (April-September) are even, which indicates that the predominant sources of air pollution in that interval are the exhaust gases of motor vehicles.

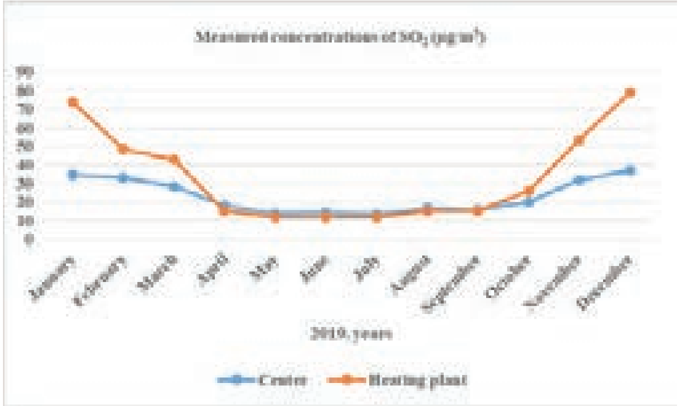

Figure 3. Graphic representation of measured SO_2 concentrations (µg/m^3) in 2019

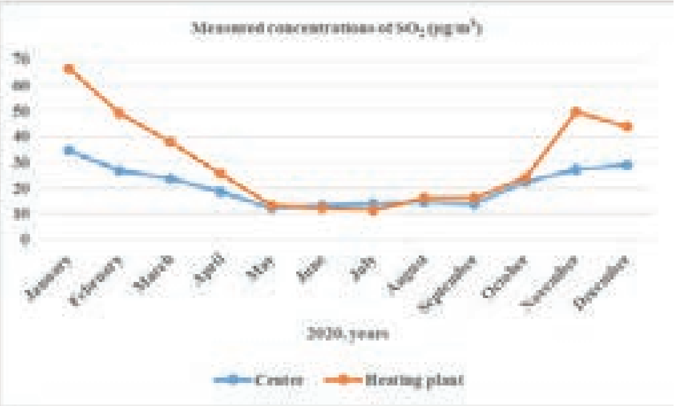

Figure 4. Graphic representation of measured SO_2 concentrations (µg/m^3) in 2020

Figures 5 and 6 show the trend of NO_2 presence by months for both years of the study. The level of NO_2 concentration is uniform during winter and summer periods, which indicates that the source of this pollutant is related to human activities, primarily related to traffic. NO_x concentrations are in a wide concentration range, depending on geographical areas. Nitric oxide content in urban areas is high compared to non-urban areas. These concentrations, which vary depending on the region, regarding the emission intensity, also vary during the day. Variations in NO_2 levels predominantly depend on human activity during the day, month, and meteorological conditions. Thus, for example, nitric oxide concentrations in the early morning hours without solar insolation are generally constant. As the activity of the population changes during the day, the frequency of traffic increases, and the concentration of NO, as the primary pollutant, increases (Thomas & St. John, 1958; Ilić & Preradović, 2009; Ilić & Maksimović, 2021). The concentration of NO_2 at both measuring points is uniform throughout the year, with the measured concentrations at the measuring station of the Heating plant being higher concerning the location of the Center, which supports the claim that that location is an additional source of pollution of Heating plant.

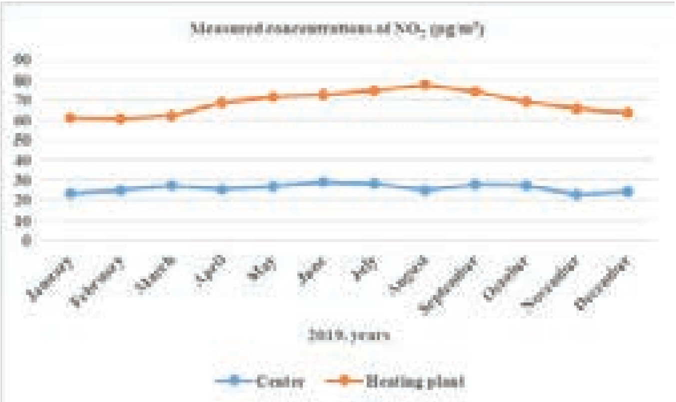

Figure 5. Graphic representation of measured NO_2 concentrations (µg/m³) in 2019

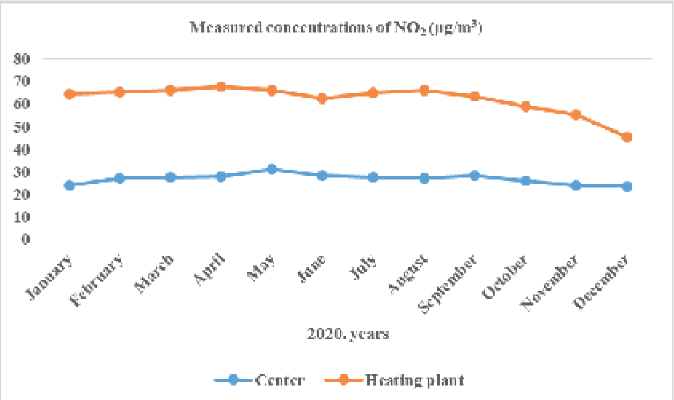

Figure 6. Graphic representation of measured NO_2 concentrations (µg/m³) in 2020

Each meteorological factor plays a unique role in explaining variations of pollutants through its particular response or effect (Vasiliauskienė et al., 2016). The influence of meteorological parameters on ambient air quality is significant (Gong et al., 2015). The relationship between SO_2 and NO_2 concentrations and meteorological factors for two included locations in the City of Bijeljina was analyzed using the correlation technique. The results of the correlation analysis between the SO_2 and NO_2 concentration and meteorological parameters are shown for the level of significance $p < 0.001$ and $p < 0.01$ (Table 2). Temperature, air pressure and relative humidity are meteorological factors with the strongest impact on the SO_2 and NO_2 concentration level (Zhang, et al., 2015; Jayamurugan et al., 2013; Liu et al., 2020).

Table 2. Correlation coefficients between SO_2 and NO_2 concentrations and meteorological variables

				Pearson			Spearman			Kendall	
			r		p	rho		p	tau B		p
Centar SO_2	-	Centar NO_2	0.110	**	0.003	-0.275	***	0.001	-0.171	***	0.001
Centar SO_2	-	Centar VW m/s	-0.014		0.713	-0.038		0.306	-0.019		0.453
Centar SO_2	-	Centar P bar	0.131	***	0.001	0.192	***	0.001	0.130	***	0.001
Center SO_2	-	Center T (⁰C)	-0.639	***	0.001	-0.737	***	0.001	-0.505	***	0.001
Centaer SO_2	-	Center RH%	0.162	***	0.001	0.520	***	0.001	0.357	***	0.001
Center SO_2	-	Toplana SO_2	0.164	***	0.001	0.109	**	0.003	0.078	**	0.002
Center NO_2	-	Center VW m/s	0.565	***	0.001	0.650	***	0.001	0.442	***	0.001
Center NO_2	-	Center P bar	0.128	***	0.001	0.249	***	0.001	0.151	***	0.001
Center NO_2	-	Center T (⁰C)	-0.031		0.400	0.107	**	0.004	0.093	***	0.001
Center NO_2	-	Center RH%	-0.062		0.093	-0.127	***	0.001	-0.083	**	0.001
Center NO_2	-	Heating plant SO_2	0.398	***	0.001	0.327	***	0.001	0.240	***	0.001
Center NO_2	-	Heating plant NO_2	0.662	***	0.001	0.544	***	0.001	0.372	***	0.001
Heating plant SO_2	-	Heating plant NO_2	0.801	***	0.001	0.737	***	0.001	0.547	***	0.001
Heating plant SO_2	-	Heating plant VW m/s	0.399	***	0.001	0.534	***	0.001	0.387	***	0.001
Heating plant SO_2	-	Heating plant P bar	-0.014		0.708	-0.019		0.603	-0.013		0.595
Heating plant SO_2	-	Heating plant T (⁰C)	-0.067		0.071	-0.230	***	0.001	-0.154	***	0.001
Heating plant SO_2	-	Heating plant RH%	0.051		0.168	0.037		0.314	0.029		0.246
Heating plant NO_2	-	Heating plant VW m/s	0.455	***	0.001	0.614	***	0.001	0.437	***	0.001
Heating plant NO_2	-	Heating plant P bar	-0.055		0.137	-0.101	**	0.006	-0.064	**	0.010
Heating plant NO_2	-	Heating plant T (⁰C)	-0.034		0.358	-0.160	***	0.001	-0.105	***	0.001
Heating plant NO_2		Heating plant RH%	-0.039		0.295	-0.060		0.107	-0.033		0.195

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We found a negative correlation between SO_2 in locality Center and temperature (r = -0.639), which implies the significant use of fossil fuels at low temperatures in individual furnaces. At the location of the Center, the correlation was not confirmed, which indicates the dominant influence of traffic and constant pollution, regardless of the meteorological parameters. The statistical analysis confirms that when the temperature drops, there is an increase in pollution, as there is increased consumption of fossil fuels, which is the cause of enlargement in the concentration of SO_2. Temperature decrease is followed by rises of the SO_2 concentration values, i.e. and vice versa. Correlation between temperature and SO_2 concentration in location Center is confirmed by the Pearson's, Spearman's and Kendall's Rank Correlation Coefficient and presented in Table 2; Fig. 7. Positive correlation of SO_2 concentrations with the wind speed is significant in locality Heating plant (r = 0.399, Table 2, Fig. 8). The wind speed increase is followed by rises of the SO_2 concentration valuesand vice versa. This indicates that the source of pollution is probably from other areas, more precisely from urban settlements with individual fireboxes.

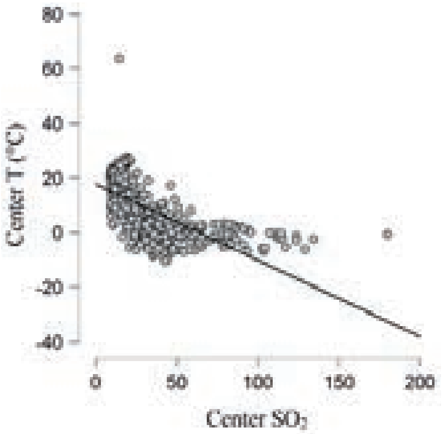

Figure 7. Correlation between SO_2 concentrations and temperature in location Center

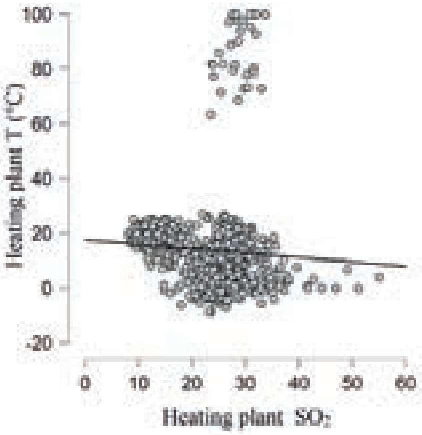

Figure 8. Correlation between SO_2 concentrations and temperature in location Heating plant

Correlation between SO_2 and relative humidity was found to be positive (r = 0.162, Table 2), which implies that increasing of the SO_2 concentration is followed by increasing of relative humidity, and vice versa. From the data collected during the study period, SO_2 concentration dependence on the relative humidity is obtained and shown in Fig. 9 and 10. The correlation was also confirmed by the Pearson's, Spearman's and Kendall's Rank Correlation Coefficient and given in Table 2. The humidity level is highest in the winter. At the same time, there is the highest consumption of fossil fuels, as well as the highest emissions of pollutants.

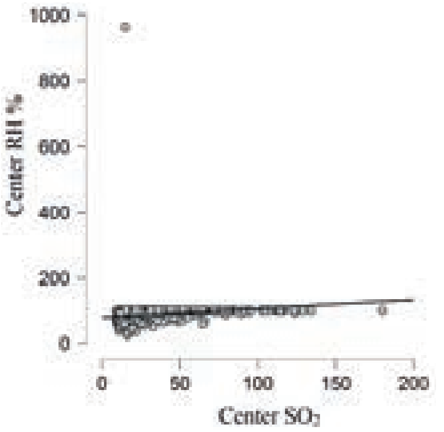

Figure 9. Correlation between SO_2 concentrations and relative humidity in location Center

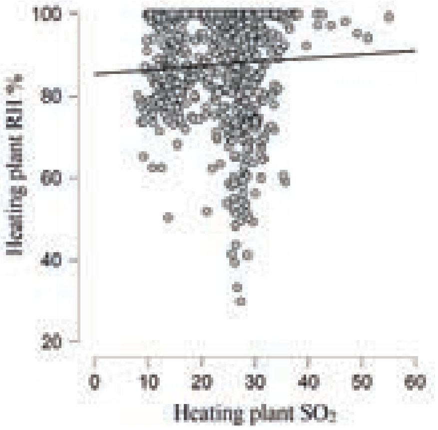

Figure 10. Correlation between SO_2 concentrations and relative humidity in location Heating plant

Relative humidity was found as animportant parameter with a strong impact on the reactivity of the system, by affecting the production of wet aerosols, which in turn affect the ultraviolet actinic flux. It can be a restrictive factor in the disposition of NO_2 because high percentages of humidity favor the reaction of NO_2 with particles of Sodium chloride (Dueñas et al., 2002). Correlation between NO_2 and relative humidity was found to be negative in locality Center (r = - 0.062, Table 7), which implies that lowering of the NO_2 concentration is followed by the increase of relative humidity and vice versa. From the data collected during the study period, NO_2 concentration dependence on the relative humidity is obtained and shown in Fig. 11. Negative correlation was also confirmed by the Pearson's, Spearman's and Kendall's Rank Correlation Coefficient and given in Table 2. In locality Heating plant correlation was not confirmed (Fig. 12).

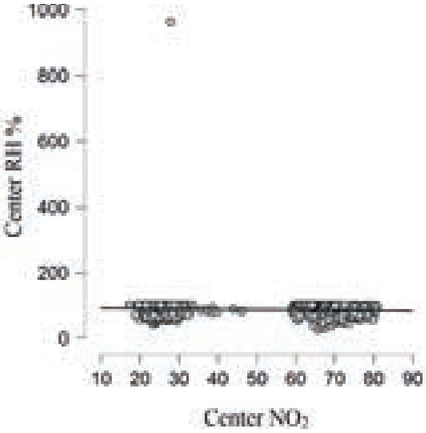

Figure 11. Correlation between NO_2 concentrations and relative humidity in location Center

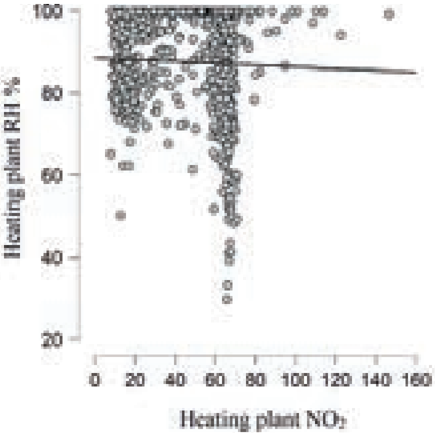

Figure 12. Correlation between NO_2 concentrations and relative humidity in location Heating plant

Correlation NO_2 with temperature was not confirmed in both localities (Fig. 13 and 14).

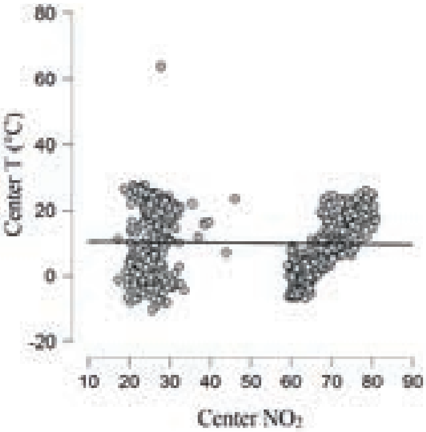

Figure 13. Correlation between NO_2 concentrations and temperature in location Center

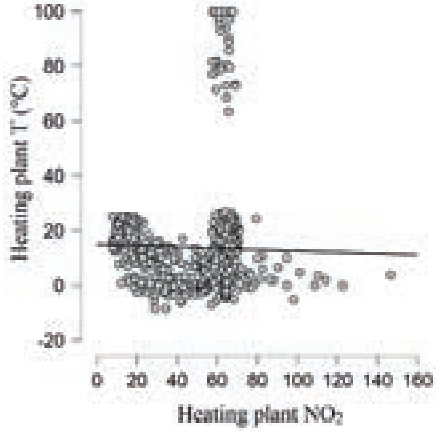

Figure 14. Correlation between NO_2 concentrations and temperature in location Heating plant

The positive correlation of NO_2 concentrations with the wind speed is significant in both localities Center (r = 0.565) Heating plant (r = 0.455) (Table 2). The wind speed increase is followed by rises of the NO_2 concentration values and vice versa.

There are very significant deviations regarding the correlation analysis at the location of the Heating plant concerning the location Center. The reason may be the existence of different dominant sources of pollution at the sites in question. At the Center location, traffic is the predominant source of pollution, while at the Heating plant location, the most important source of pollution is coal combustion in the Heating plant.

CONCLUSION

This paper presents results of simultaneous measurement of SO_2, NO_2 and meteorological parameters at locality "Center" and "Heating plant" in the City of Bijeljina.

The mean annual value for two-year sampling periods for SO_2 in a research field is 19.39 µg/m^3 (locality Center) and 25.06 µg/m^3 (locality Heating plant). The results obtained for SO_2 were below regulatory limits. Measured average values of NO_2 at measuring points in Bijeljina are average values are 45.04 µg/m^3 (locality Center) and 55.62 µg/m^3 (locality Heating plant).

Dominant sources of pollution are traffic and coal combustion in the heating plant, which is especially noticeable in the winter when there is a significant increase in the concentrations of SO_2. Statistical analysis confirms directional connection between SO_2 and NO_2 and meteorological parameters, specially temperature in locality Center (r = - 0.639), wind speed in locality Heating plant (r = 0.399) and relative humidity (r = 0.162). The correlation of NO_2 with temperature was not confirmed in both localities. Speed of wind increase is followed by rises of the NO_2 concentration values and vice versa. Correlation NO_2 with pressure is confirmed in locality Center (r = 0.128) and not confirmed in the locality Heating plant. Correlation between NO_2 and relative humidity was found to be negative in locality Center (r = - 0.062). These parameters are the most important meteorological factors influencing the variation in SO_2 and NO_2 levels during the research. Depending on the obtained correlation, meteorological parameters had a positive or negative impact on air pollution.

REFERENCES

Abbasi, S., Jansson, A., Sellgren, U., & Olofsson, U. (2013). Particle emissions from rail traffic: A literature review. *Critical reviews in environmental science and technology*, *43* (23), 2511-2544.

Barbosa, P., Camia, A., Kucera, J., Liberta, G., Palumbo, I., San-Miguel-Ayanz, J., & Schmuck, G. (2008). Assessment of forest fire impacts and emissions in the European Union based on the European Forest Fire Information System. *Developments in Environmental Science*, *8*, 197-208.

BAS EN 14211 (2013). Ambient air - Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence

BAS EN 14212 (2013) Ambient air - Standard method for the measurement of the concentration of sulfur dioxide by ultraviolet fluorescence

Cardu, M., & Baica, M. (2005). Regarding the relation between the NOx content and CO content in thermo power plants flue gases. *Energy conversion and management*, *46* (1), 47-59.

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 [Internet]. Off. J. Eur. Union. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0050&from=en

Dueñas, C., Fernández, M. C., Cañete, S., Carretero, J., & Liger, E. (2002). Assessment of ozone variations and meteorological effects in an urban area in the Mediterranean Coast. *Science of the Total Environment*, *299* (1-3), 97-113.

Đuković, J., Bojanić, V. (2000). Air pollution - idea, condition, sources, control and technological solutions. Institute of Protection and Ecology, Banja Luka.

Erić, Lj., Tepić, S., Ilić, P., Račić-Milišić, S., Tubin, B. (2008). Presence of NO_2 and NO_X at the Center site in Banja Luka. 5th Symposium "Chemistry and Environmental Protection" with international participation. Tara, Serbian Chemical Society. Beograd.

Fino, A. (2019). Air Quality Legislation, Encyclopedia of Environmental Health (Second Edition), 61-70.

Ge, S., Xu, X., Chow, J. C., Watson, J., Sheng, Q., Liu, W., ... & Zhang, J. (2004). Emissions of air pollutants from household stoves: honeycomb coal versus coal cake. *Environmental science & technology*, *38* (17), 4612-4618.

Gong J, Hu Y, Liu M, et al. (2015). Characterization of Air Pollution Index and its affecting factors in industrial urban areas in Northeastern China. *Pol. J. Environ. Stud.* 24 (4), 1579–1592.

Grennfelt, P., Engleryd, A., Forsius, M., Hov, Ø., Rodhe, H., & Cowling, E. (2020). Acid rain and air pollution: 50 years of progress in environmental science and policy. *Ambio*, *49* (4), 849-864.

Hesterberg, T. W., Bunn III, W. B., Chase, G. R., Valberg, P. A., Slavin, T. J., Lapin, C. A., & Hart, G. A. (2006). A critical assessment of studies on the carcinogenic potential of diesel exhaust. *Critical reviews in toxicology*, *36* (9), 727-776.

Ilić, P. & Maksimović, T. (2021). Air pollution and biodiversity. Pan-European University Apeiron, Banja Luka.

Ilić, P. (2009). Quality control and research of air pollution influence in function of protection and environmental improvement in Banja Luka. Doctoral dissertation, ACIMSI, University of Novi Sad.

Ilić, P. (2015). Pollution and control of air quality in the function of environment protection. Independent University, Banja Luka

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, 14-15. November 2008, Institute for Protection and Ecology, Banja Luka*, 281-290.

Ilić, P., Lakić., N., Tubin, B., Janjuš, Z. (2008). Monitoring of sulfur dioxide at locality center in Banja Luka. *Second international congress ''Ecology, health, work, sport", Banja Luka.*

Ilić, P., Markić, D. N., & Bjelić, L. S. (2018). Variation concentration of sulfur dioxide and correlation with meteorological parameters. *Archives for Technical Sciences*, 18 (1), 81-88

Ilić, P., Marković, S., Janjuš, Z. (2009). Air pollution and its influence on ecosystems and vegetation. Conference: International Conference Evaluation and preservation potential of the Danube region, Banja Luka, Republic of Srpska, Bosnia and Herzegovina, 168-182.

Ilić, P., Popović, Z., Gotovac-Atlagić, S. (2019). Effects of meteorological variables on nitrogen dioxide variation. *Archives for Technical Sciences*, *20* (1), 65-72.

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

Ilić, P., Preradović, Lj., Dejanović, R., Marković, S., Janjuš, Z. (2010). Using the factor analysis in monitoring of air pollution and meteorological parameters, Conference: 54th ETRAN Conference, Donji Milanovac, RT5.5-1-4

Jablanović, M., Jakšić, P., Kosanović, K. (2003). Introduction to ecotoxicology. University of Priština, Faculty of Science, Kosovska Mitrovica.

JASP Manual [Internet]; Seton Hall University Department of Psychology; c2021. [cited 12. September 2021]. Available from: https://www.shu.edu/psychology/upload/JASP-Manual_SHU-RD-A_9-1-18.pdf.

Jayamurugan, R., Kumaravel, B., Palanivelraja, S., & Chockalingam, M. P. (2013). Influence of temperature, relative humidity and seasonal variability on ambient air quality in a coastal urban area. *International Journal of Atmospheric Sciences*, *2013*.

Liu, Y., Zhou, Y., & Lu, J. (2020). Exploring the relationship between air pollution and meteorological conditions in China under environmental governance. *Scientific reports*, *10* (1), 1-11.

Maduna, K., & Tomašić, V. (2018). 7. Air pollution engineering. *Environmental Engineering*, 195-240.

Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and health impacts of air pollution: a review. *Frontiers in public health*, *8*, 14.

Mueller, D., Uibel, S., Takemura, M., Klingelhoefer, D., & Groneberg, D. A. (2011). Ships, ports and particulate air pollution-an analysis of recent studies. *Journal of Occupational Medicine and Toxicology*, *6* (1), 1-6.

Pandey, B., Agrawal, M., & Singh, S. (2014). Assessment of air pollution around coal mining area: emphasizing on spatial distributions, seasonal variations and heavy metals, using cluster and principal component analysis. *Atmospheric pollution research*, *5* (1), 79-86.

Prato, D. F., & Huertas, J. I. (2019). Determination of the area affected by agricultural burning. *Atmosphere*, *10* (6), 312.

Preradović, Lj., Ilić, P., Marković, S., Janjuš, Z. (2010). Functional dependences between air pollution and nitrogen dioxide-possibility of data mining application, Conference: 54th ETRAN Conference, Budva, Montenegro, VI2.3-1-4

Procurement plan for 2019, number 125/19, PE "City Heating Plant" d.o.o., City of Bijeljina, January 28, 2019.

Ramanathan, V., & Feng, Y. (2009). Air pollution, greenhouse gases and climate change: Global and regional perspectives. *Atmospheric environment*, *43* (1), 37-50.

Regulation on air quality values [Internet]; "Official Gazette of the Republic of Srpska", No. 124/12; c2012. [cited 11. September 2021]. Available from: https://rzsm.org/tehprop/151-mpuge

RoTAP (2012). Review of Transboundary Air Pollution: Acidification, Eutrophication, Ground Level Ozone and Heavy Metals in the UK*: Summary for Policy Makers*. Centre for Ecology & Hydrology.

Rulebook on measures for prevention and reduction of air pollution and improvement of air quality (Official Gazette of the Republic of Srpska, No. 3/15, 51/15, 47/16 and 16/19)

Stanek, L. W., Brown, J. S. (2019). Air Pollution: Sources, Regulation, and Health Effects. Reference Module in Biomedical Sciences., 1-10.

Thomas, M. D., & St. John, G. A. (1958). Nitric Oxide and Nitrogen Dioxide Concentrations Near the Ground at Menlo Park, California. *Journal of the Air Pollution Control Association*, *8*(3), 234-277.

Vasiliauskienė V, Šerevičienė V, Zigmontienė A. (2016). Spatial and Temporal Variation in Ozone and Nitrogen Dioxide in the Seaside Recreation Area Environment. *Pol. J. Environ. Stud.*, 25 (2), 795–803.

Von Glasow, R., Bobrowski, N., & Kern, C. (2009). The effects of volcanic eruptions on atmospheric chemistry. *Chemical Geology*, *263* (1-4), 131-142.

Warmiński, K., & Bęś, A. (2018). Atmospheric factors affecting a decrease in the night-time concentrations of tropospheric ozone in a low-polluted urban area. *Water, Air, & Soil Pollution*, *229* (11), 1-13.

Wessa, P. (2021), Free Statistics Software, Office for Research Development and Education, version 1.2.1, URL https://www.wessa.net/

Work plan for 2017 PE "City Heating Plant", d.o.o. Bijeljina, City of Bijeljina, March 2017.

www.who.int/health-topics/air-pollution#tab=tab_1

www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

www.who.int/phe/eNews_63.pdf

Yadav, I. C., Devi, N. L. (2019). Biomass Burning, Regional Air Quality, and Climate Change, Encyclopedia of Environmental Health (Second Edition), 386-391.

Zhang, H., Wang, Y., Hu, J., Ying, Q., & Hu, X. M. (2015). Relationships between meteorological parameters and criteria air pollutants in three megacities in China. *Environmental research*, *140*, 242-254. Gvozdić, V., Kovač-Andrić, E., & Brana, J. (2011). Influence of meteorological factors NO_2, SO_2, CO and PM10 on the concentration of O 3 in the urban atmosphere of Eastern Croatia. *Environmental modeling & assessment*, *16* (5), 491-501.

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