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EFFECTS OF METEOROLOGICAL VARIABLES ON NITROGEN DIOXIDE VARIATION

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ABSTRACT

The study presents results of the measurements of the atmospheric nitrogen dioxide concentration and simultaneous meteorological variables: average temperature, air pressure, and relative humidity, speed and wind direction. The data were collected from July 2015 to June 2017 at stations located in Banja Luka (locality Centre). Nitrogen dioxide is one of the major environmental pollutants which has negative impact on plants growth, atmospheric chemistry and climate change. Levels of nitrogen dioxide in air samples and meteorological variables from urban zone of Banja Luka were determined at locality, which is highly populated area, with intensive traffic. The study presents average measured values of nitrogen dioxide, together with maximal and minimal values and relationship between nitrogen dioxide and meteorological variables, i. e. for pollution modelling together with meteorological variables. Statistical analysis confirms string of rolls, which shows directional connection between nitrogen dioxide and meteorological variables. Correlation between nitrogen dioxide and temperature (r= -0.207), wind speed (r= -0.130) and relative humidity (r= -0.048) was negative and significant during the measurement period.

Keywords: *air pollution, Banja Luka, monitoring, nitrogen dioxide (NO_2), urban zone*

INTRODUCTION

Nitrogen dioxide (NO_2) is one of relatively stable nitrogen oxides in atmosphere [1] and one of the major environmental pollutants, which belongs to the family of nitrogen oxides (NO_X) [2]. Among the various nitrogen oxides emitted from stationary combustion; nitrogen oxide (NO), nitrous oxide (N_2O), and nitrogen dioxide (NO_2) are stable while NO predominates (over 90%) [3]. Nitrogen (NO_X) and sulfur (SO_X) oxides emissions are primary contributors to acid rain, which is associated with a number of effects including acidification of lakes and streams, accelerated corrosion of buildings, and visibility impairment.

In health effects, NO_2 can irritate the lungs and lower resistance to respiratory infection and has negative impact on plants growth, atmospheric chemistry and climate change. In the area of ozone nonattainment, NO_X and volatile organic compounds (VOCs) react in the atmosphere to form ozone, a photochemical oxidant and a major component of smog. Atmospheric ozone can cause respiratory problems by damaging lung tissue and reducing lung function. There is a significant influence to tropospheric NO_2 concentration because of the human activity and land cover change near ground [1, 4, 5, 2]. It is generally believed that over 80% of the total NO_X emitted to the atmosphere originate at sources where fossil fuels and industrial wastes are burned [2]. Air pollution in big cities is produced in a significant level by road vehicle emissions, with the modifying influence of meteorological agents [6]. High NO_2 levels, combined with ultrafine particles and other oxidants, have become one of the major air pollution problems in urban areas all over the world. Nitrogen oxides are one of the main components of the mixture of pollutants classically referred to as photochemical smog [7]. At higher concentrations, its presence has been implicated in the corrosion of electrical components, as well as vegetation damage [2].

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 [8, 9]. On the other hand, there is significant amount of published research in the field of air pollution [10, 11, 12, 13, 14, 15, 16, 8, 9, 17]. The present study investigates the relationship between the concentration of NO_2 and meteorological variables, over the period from July 2015 – June 2017 in Banja Luka, Republic of Srpska, Bosnia and Herzegovina (BiH). This subject has not been yet studied in this region, although the recent scientific methodology suggests there is a correlation between these data in other parts of the world, as already cited above.

Air pollutant agents come from different sources: industry, agriculture and livestock farming, road and air traffic, forest fires, natural sources like volcanoes or particles drawn by wind, among others. Also, a wide variety of elements modify the concentration of different pollutants, mainly meteorological agents, but also topography, tree and shrub presence, building distribution or water streams like rivers [6].

A small number of local communities in Republic of Srpska perform the control of air pollution, while monitoring of emissions is not represented to the extent necessary [17]. Numerous studies analysed the impact of meteorological variables and air quality parameters [18, 19, 20, 21, 22, 23], and results were often uncoordinated or even contradictory.

For example, by examining the effect of air temperature on the concentration PM10, Kassomenos et al. [24] they get positive correlation values, and Giri et al. [25] obtained negative correlation values. One of the explanations for these differences could be the difference in locations of research studies, timing and similar factors.

It is necessary to take urgent measures in order to detect pollutants and take actions to improve air quality in considered areas, primarily to protect health of people inhabit here [26].

MATERIALS AND METHODS

Location

Monitoring of NO_2 concentration pollution along with meteorological variables at locality Center in Banja Luka is topic of the presented research. The measurements were made in the periods of intensive traffic and high population in the city, from July 1, 2015 to June 30, 2017. As an administrative centre of the Republic of Srpska in BiH, Banja Luka is densely populated and found to be a worst case scenario location suitable for investigation. It is the second largest city in BiH, after Sarajevo. Typical sources of air pollution are: heating plants, traffic, foundries, metal-processing and chemical industry, and fireboxes in households, municipal waste, etc.

Analytical procedure

Teledyne Advanced Pollution Instrumentation, Inc. (TAPI) Sad Diego, California, United States, model T 200 (*Chemiluminescence* $NO/NO_2/NO_X$*Analyzer*) of the range 0-50 ppb / 0-20 ppm, has been used for measuring of NO_2 concentrations. Monitoring of NO_2 was performed in accordance with standard BAS EN 14211, as reference method for the measurement of this oxide [27]. The Model T 200 uses the proven chemiluminescence detection principle, coupled with state-of-the-art electronics, allowing accurate and dependable low level measurements for use as an ambient analyzer or dilution CEMS monitor.

Picture 1. Research site (locality Center in Banja Luka)

Presented data were recorded at the ambiance temperature. Simultaneously, the air pressure, wind speed and direction and relative humidity were recorded at the meteorological monitoring site at the outer rim of the inner city every day during the study. Results of polluting particles concentration, obtained during monitoring, were compared with current values defined by 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. Present study determines if the measured values satisfy recommended and limit values specified by the mentioned legislation.

Statistical analysis

For determination of the interdependence and relationship between nitrogen dioxide of air quality and meteorological variables, i.e. for pollution modelling together with meteorological variables, the EXCEL, JASP Computer software [30] and Free Statistics Software were used [31] for statistical data processing. Descriptive statistical operations like mean, median, mode, standard deviation (SD), variance, minimum (min) and maximum (max) have been applied into analysing of the measured data. Correlation analysis was performed and the bagplots are shown.

RESULTS AND DISCUSSION

Average values of measured NO_2 are shown in Table 1, together with maximal and minimal values, median, mode, standard deviation and variance. Mean annual value with the aim of protection of human health for NO_2, during the sampling period of 1 hour is 150 $\mu g/m^3$, period of 24 hours is 85 $\mu g/m^3$ and period 1 year is 40 $\mu g/m^3$ [29], as prescribed and Directive 2008/50/EC [30]. In a research field, it did not exceeded and is 28.23 $\mu g/m^3$ (Table 1).

Although high levels of NO_2 have not been recorded during the investigated period, humidity during the analysed period of 68.70%, due to a number of chemical reactions in which NO_2 is converted into nitrogen acid, can affect the increase in harmful effects caused by the action of NO_2.

Table 1. Statistical summary of NO_2 and meteorological variables

	NO_2 μg/m^3	VW m/s	DW (Å)	P Pa	T (^{0}C)	RH %
Mean	28.23	0.3855	148.3	1000	13.13	68.70
Std. Error of Mean	0.2182	0.003907	1.087	0.07512	0.08771	0.1667
Median	21.47	0.2700	79.94	999.4	13.39	72.96
Mode	6.610	0.06000	45.00	998.2	8.240	83.64
Std. Deviation	23.96	0.4291	119.4	8.250	9.634	18.31
Variance	574.1	0.1841	1.425e+4	68.07	92.81	335.3
Minimum	0.2000	0.000	0.01000	971.9	-14.04	4.800
Maximum	325.7	5.320	359.9	1021	38.90	97.90

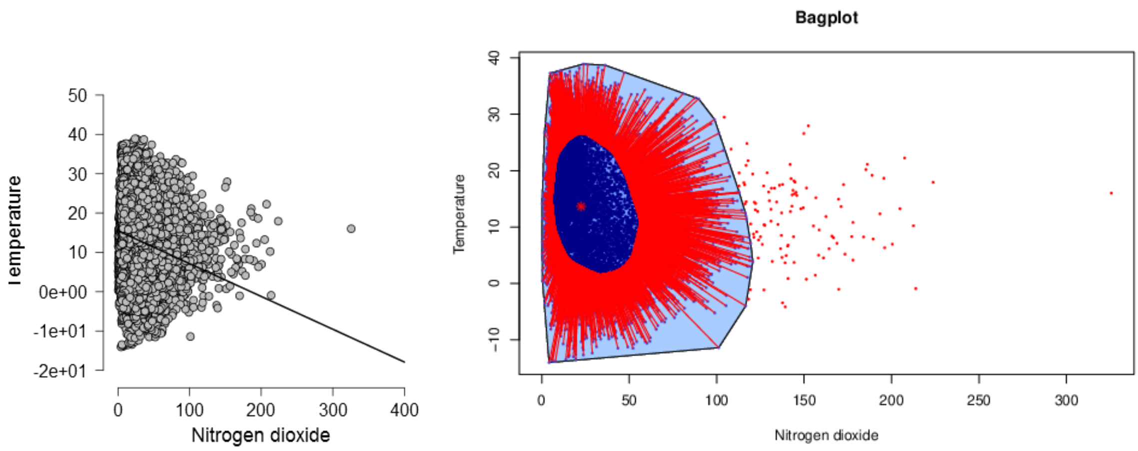
The relationship between NO_2 concentrations and other meteorological variables in the study area was analysed using correlation analysis. The results of the correlation analysis between the NO_2 concentration and at the same time meteorological variables are shown for the level of significance $p < .05$, $p < .01$ and $p < .001$ (Table 2). Between the meteorological variables of relative humidity and temperature there is a significant negative correlation (r = -0.610), respectively a significant negative correlation between the temperature and pressure (r = -0.379). By increasing the relative humidity, the temperature values were reduced, i.e. by reducing pressure, the temperature has grown. The increase in temperature has caused the reduction in value of pressure, and vice versa during the study period.

Table 2. Correlation coefficients between NO_2 concentrations and meteorological variables

		NO_2 μg/m^3	VW m/s	DW (Å)	P Pa	T (^{0}C)	RH %
NO_2 μg/m^3	Pearson's r	—					
	p-value	—					
	Spearman's rho	—					
	p-value	—					
VW m/s	Pearson's r	-0.130 ***	—				
	p-value	< .001	—				
	Spearman's rho	-0.100 ***	—				
	p-value	< .001	—				
DW (Å)	Pearson's r	-0.099 ***	-0.026 **	—			
	p-value	< .001	0.004	—			
	Spearman's rho	-0.096 ***	-0.083 ***	—			
	p-value	< .001	< .001	—			
P Pa	Pearson's r	0.020 *	0.009	0.038 ***	—		
	p-value	0.029	0.334	< .001	—		
	Spearman's rho	0.063 ***	-0.024 **	0.021 *	—		
	p-value	< .001	0.010	0.018	—		
T (^{0}C)	Pearson's r	-0.207 ***	0.119 ***	0.065 ***	-0.379 ***	—	
	p-value	< .001	< .001	< .001	< .001	—	
	Spearman's rho	-0.273 ***	0.145 ***	0.028 **	-0.396 ***	—	
	p-value	< .001	< .001	0.002	< .001	—	
RH %	Pearson's r	-0.048 ***	-0.243 ***	-0.019 *	0.185 ***	-0.610 ***	—
	p-value	< .001	< .001	0.040	< .001	< .001	—
	Spearman's rho	-0.060 ***	-0.246 ***	0.013	0.167 ***	-0.576 ***	—
	p-value	< .001	< .001	0.142	< .001	< .001	—

* p < .05, ** p < .01, *** p < .001

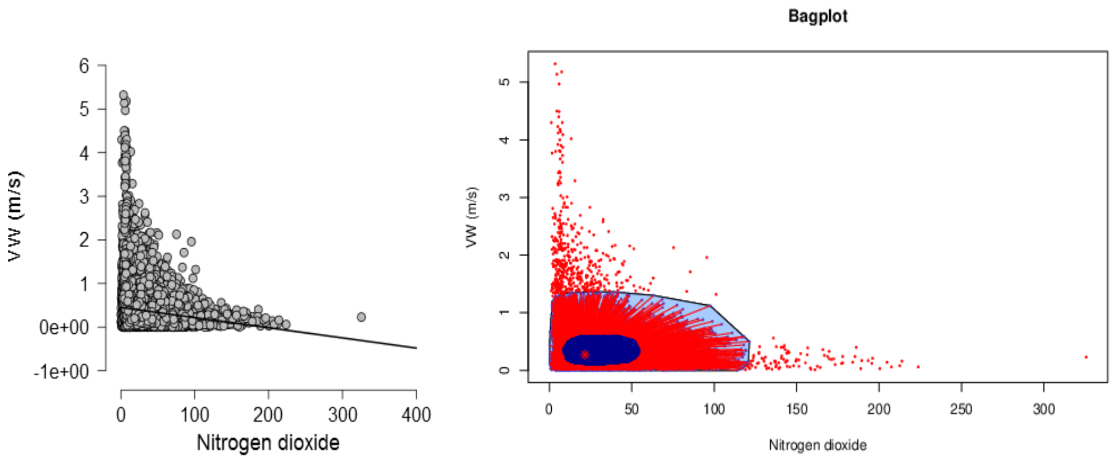
Correlation between NO_2 and temperature was negative and significant during the study period (r= -0.207). Concentration of NO_2 decreasing is followed by temperature increasing, also applies vice versa i.e. the temperature decreasing caused increasing of the NO_2 concentration. The Graph 1 shows the dependence of the concentration of NO_2 on the temperature. Correlation was also confirmed by the Spearman's Rank Correlation Coefficient, during the study period (Table 2; Graph 1).



Graph 1. Correlation between NO_2 concentrations and temperature and bagplot

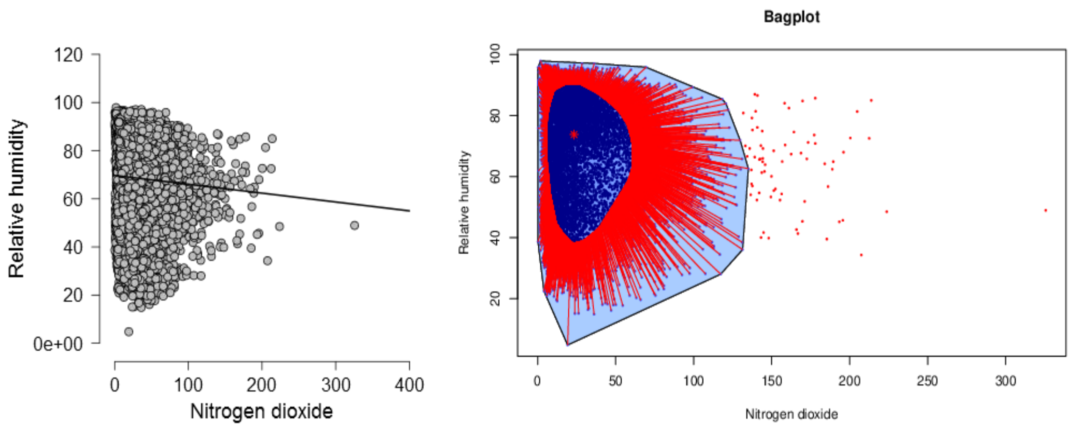
High negative correlation between NO_2 and wind speed was found during the study period (r= -0.130). Increase of the wind speed is followed by decrease in NO_2 concentration, and vice versa, during the study period. The Graph 2 shows the dependence of the concentration of NO_2 on the wind speed.

Correlation was also confirmed by the Spearman's Rank Correlation Coefficient, shown on bagplot. In the bivariate case the box of the boxplot changes to a convex polygon, the bag of bagplot. In the bag are 50 percent of all points. The fence separates points within the fence from points outside. It is computed by increasing the bag (Table 2; Graph 2).



Graph 2. Correlation between NO_2 concentrations and wind speed and bagplot

Correlation between NO_2 and relative humidity was negative during the period of study (r= -0.048). Increasing of relative humidity is followed by lowering of the NO_2 concentration and vice versa. The Graph 3 shows the dependence of the concentration of NO_2 on the atmospheric pressure, during the study period. Correlation was also confirmed by the Spearman's Rank Correlation Coefficient (Table 2; Graph 3).



Graph 3. Correlation between NO_2 concentrations and relative humidity and *bagplot*

24-hour average is recommended from World Health Organization (WHO) for NO_2 is 85 μg/m^3 and period 1 year is 40 μg/m^3 [28, 29], as well as in Republic of Srpska. All over the test area, average annual value is not exceeded.

CONCLUSION

Simultaneous measurements of NO_2 and standard meteorological variables were performed from July 2015 up to June 2017 for one station, located at the locality Centre in Banja Luka (urban location with intensive traffic flow and relative proximity of heating plants and local industry). Mean annual value for NO_2 in a research field and is 28.23 μg/m^3. The results obtained for NO_2 were bellow limits of both national and international Regulation on air quality values. Concentration of NO_2 is found to be dependent on traffic activities. Statistical analysis confirms string of rolls, which shows directional connection between NO_2 and meteorological variables. Correlation between NO_2 and temperature (r= -0.207), wind speed (r= -0.130) and relative humidity (r= -0.048) was negative and significant during the period of study.

Statistical analysis confirms string of rolls which show direct connection between air pollution and meteorological parameters. In winter seasons on lower temperatures, fuel consumption is higher, great amounts of nitrogen dioxide that cause winter smog are created. Winter smog is created by mild air flow and temperature inversion that disables vertical air flow and diluting of pollution materials in lower layer of atmosphere.

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