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ORIGINAL SCIENTIFIC PAPER

The Influence of Meteorological Parameters and Traffic Flows on the Concentration of Ozone (O_3) in Urban Areas in Brcko

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Abstract: Meteorological parameters and traffic flows have a direct impact on air quality in large urban areas, and hence on the quality of life in them. A large number of done surveys confirmed the great dependence of the concentration of ground-level ozone (O_3) upon meteorological parameters and the size, structure and imbalances of traffic flows. As part of the research conducted in the period from November 5th to December 8th 2014 in Brcko in Muderis Ibrahimbegic St concentrations of ground-level ozone (O_3) were measured, meteorological parameters (temperature, humidity, wind speed and intensity of solar radiation) and characteristics of traffic flow of road motor vehicles. The maximum concentrations of ground-level ozone (O_3) in the measurement period was 106.54μg/m³, while the minimum concentration was 4.794μg/m³. By analyzing the results of measurements the high coefficient of correlation between wind speed, air temperature and humidity was established. The correlation coefficient between the traffic flows on the one hand and the concentration of ground-level ozone (O_3), on the other hand is very low and does not exceed the value of 0.301. A negative correlation coefficient between traffic flows and concentrations of ground-level ozone (O_3) is also observed in the certain time of the day.

Keywords: Ozone (O_3), meteorological parameters, traffic flow.

INTRODUCTION

Ozone (O_3) is a blue, reactive, explosive gas that occurs in both the upper and the lower parts of the atmosphere. In the stratosphere it is located about 90% of total ozone (O_3), which is located in the atmosphere. While in the upper atmosphere-the stratosphere, the presence of high concentration ozone (O_3) is preferable, because of its protective role, the presence of ozone (O_3), especially high concentrations in the terrestrial parts of the atmosphere-troposphere, is undesirable.

In many countries, the transport sector has been identified as a major source of ground-level ozone (O_3). The emergence of ground-level ozone (O_3) is related to the photochemical reaction between nitrogen oxides (NOx) and volatile organic compounds (VOC) in the presence of light. (*1*) The concentration of ground-level ozone (O_3) is determined by chemical reactions between the precursors of ozone (O_3), which originate from natural and anthropogenic sources, advection caused by the horizontal air flow and vertical movement of air masses .

Establishing relations between pollutants generated in the process of traffic and meteorological parameters (temperature, intensity of solar radiation, relative humidity, wind direction and speed, etc.) is related to the improvement of information on the state of ambient air quality. Air temperature and ozone (O_3) have a positive correlation coefficient and with increasing temperature comes the increase of the concentration of ground-level ozone (O_3). (*2*) The increase in the intensity of solar radiation leads to increased concentrations of ground-level ozone (O_3). High relative humidity, wet and rainy weather are connected with a low concentration of ozone (O_3) due to reduced efficiency and increased photochemical ozone deposition on water droplets. Relative humidity is negatively correlated with temperature, which is considered one of the primary indicators of ground-level ozone (O_3). (*3*) Between the concentration of ozone (O_3) and wind speed there is a negative correlation coefficient. Large wind speed allows transport of ozone (O_3). (*4*)

Increased concentrations of ozone (O_3) have a negative impact on human health, flora and construction. Inhalation of ozone (O_3) causes serious irritation and headaches. Ozone (O_3) irritates the eyes, the upper respiratory tract and lungs. Inhalation of ozone (O_3) can sometimes cause the formation of pulmonary edema fluid which accumulates in the tissues of the lungs. (*5*) In addition, increased concentrations of ozone (O_3) can decrease the lung capacity and weaken the immune system. The impact of ground-level ozone (O_3) on vegetation is manifested by the changes on the leaf of plants, which leads to faster aging and reducing the process of photosynthesis. (*6*) Ozone (O_3) has a strong influence on the metals, transforming them into corresponding oxides and organic products which are destroyable. (*7*) In addition, ozone (O_3) is a gas that can lead to an increase in air temperature by keeping the infrared radiation emitted from the Earth's surface. (*3*)

The main objective of the work is the ground-level ozone (O_3) concentration establishment (O_3) as a function of traffic and meteorological parameters. The starting point in determining the above depends on the gathering and analysis of data on the characteristics of the traffic flow (intensity, structure and weather unevenness) and basic meteorological parameters (temperature, humidity, atmospheric pressure, wind speed and wind direction, solar radiation). The significance of the work lies in its originality of the issues presented in the given area. Researches related to the determination of dependence between the concentration of ground-level ozone (O_3) and meteorological parameters and traffic flows on the territory of the Brcko District have never been done until now.

MATERIALS AND METHODS

Description Area

Brcko District is located in the north-eastern, lowland part of Bosnia and Herzegovina. In the southwest it borders with Srebrenik municipality in the southeast with municipalities Lopare and Čelić, in the west with the municipality of Gradacac, in the east with the municipality of Bijeljina and the northwest with the municipality of Orašje. The northern border of Brcko District of Bosnia and Herzegovina with the Republic of Croatia is the River Sava. The administrative center of the District is the town itself (44°53'0''N, 18°49'0''E), located in the northern part of the district on the right bank of the River Sava area which includes 183km^2. The town lies at the confluence of the River Brka, at an altitude of 96m, and it is a very important transit center. Brcko connects the western and eastern part of the Republic of Srpska, and moreover represents an important link between Bosnia and Herzegovina and Croatia, that is the European Union. Figure 1 is represents traffic position of Brcko District. According to preliminary results of the Census of Population, households and residences in BiH in 2013, the total population on the territory of the Brcko District is 93028, while in the city there are 43859 inhabitants.

Figure 1. Traffic position of Brcko District of BiH

Brcko is a single-center organized so that almost all the administrative, commercial and other major attractions are concentrated in the city center, which has developed along the River Sava. Road network is irregular and it generally has a profile which doesn't allow building highly capacitive roads. The position of the border crossing with the Republic of Croatia and the customs terminal, which is located near the city center, as well as ports and railways which are located in the wider central zone, greatly complicate the traffic situation. In the framework of the existing road network in Brcko, traffic is mainly in two-ways. One-way traffic is taking place in 14 streets with total length of 2.78km. There are two main roads in Brcko M-14.1 with 31.75km length and M-1.8 with 5.3km length. The main road M-14.1 goes through the town in length of 9km. Also, two regional roads pass through the town R-460 with 23.2km length and R-458 with 13.6km length. Both regional road pass through the town, R-460 with 3.3km length, and the regional road R-458 with 3.6km length. The total length of the street network is about 85km. In 2014 in Brcko a total of 39982 road motor vehicles were registered. Out of the total number of registered vehicles, passenger cars were 82.82%, trucks 8.49%, motorcycles 2.47%, while other vehicles (mopeds, machinery, tractors, tricycles, motorcycles) were 6.22%. The vehicle fleet age of the Brcko District is extremely unfavorable. The fleet in 2014 prevailed vehicles older than 10 years and such vehicles were 29.21%. After this group of vehicles come vehicles whose age is more than 25 years, or vehicles aged between 26 and 35 years and these vehicles were a total of 24.19%. Vehicles age to 10 years, or between 0 and 5 years and vehicles from 6 to 10 years were only 9.23% of the fleet of the Brcko District. Out of the total number of registered vehicles, nearly 2/3 of the vehicles, or 64.66% of them had powertrains using diesel fuel, 31.69% use gasoline, while only 3.65% of the vehicles have generators using gasoline and LPG. The most recent engines, which meet Euro 5 and Euro 6 standards were located in 4.33% of vehicles, while the largest number of vehicles owned conventional engines 41.94%. Vehicles with catalyst formed the fleet structure of Brcko District with 51.14%, while vehicles without catalyst formed 48.86% of the vehicles. (*8*)

Location sampling has been selected in accordance with the source of emissions, safety, access, availability of electricity, visibility of the site in relation to the environment, safety of the public, the possibilities of determining sampling points for different pollutants at the same location and the requirements of spatial planning. Measuring the concentrations of ground-level ozone (O_3) and traffic counting were done within the Fifth Primary

School (44°52›24.8››N, 18°47›26.3››E) which is positioned in the residential area of the city, intended solely for individual housing, near the transit road connecting the eastern and western part of the Republic of Serbia. Figure 2 shows the micro location of sampling pollutants.

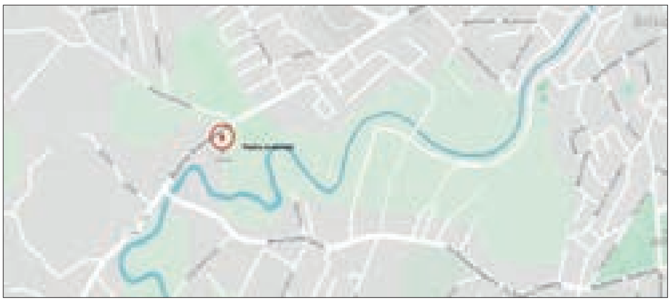

Figure 2. Micro location sampling of pollutants

Collection of ambient air quality and traffic data

Measuring the concentrations of pollutants in ambient air and traffic counting were done in the period from November 5th (from 6 pm) until December 8th 2014 (to 10am), the 784-hour interval. Data about measured concentrations of pollutants and meteorological parameters are automatically recorded in digital form. The values control is subsequently performed and also the validation of measured pollutants parameters. Measuring the concentrations of ground-level ozone (O_3) is performed using ambient O_3 monitor APOA-370. The principles of operation of the analyzer is in accordance with the requirements of the EU Directive 2008/50/EU on ambient air quality and cleaner air for Europe as well as with the requirements of Directive 2004/108 /EC. (*9*) Measurement of concentrations using APOA-370 is based on the principle of non-dispersive ultraviolet absorption, which is prescribed by the international standard ISO 13964. The measuring range of devices is 0 to 0.1/0.2/0.5/1.00ppm. For the concentration of 0.2ppm or less, the sensitivity is 0.5ppb, and for the concentration of>0.2ppm, the sensitivity is 0.5%(2σ). Data about the intensity, structure and timing of uneven traffic flow were obtained after visual process of digital camera. The flows of passenger vehicles (PV), light vehicles (LV), medium heavy vehicles (MHV), heavy vehicles (HV), car trains (CT) and buses (BUS) were recorded.

RESULTS

By Regulations on limit and target values for air quality, information and alert thresholds Brcko defined threshold value of ozone (O_3), which is 120μg/m³ for the sampling period of 8 hours, and a limit value for the protection of ecosystems is 18000μg/m³ for the period of 5 years. Within the Regulations the threshold of information is defined 180μg/m³ or alert threshold of 240**μg/m**³ for the sampling period of 1hour. (*10*) The ratio of measured concentrations of ground-level ozone (O_3) and limit values, threshold information and alert threshold is presented in Figure 3a and 3b.

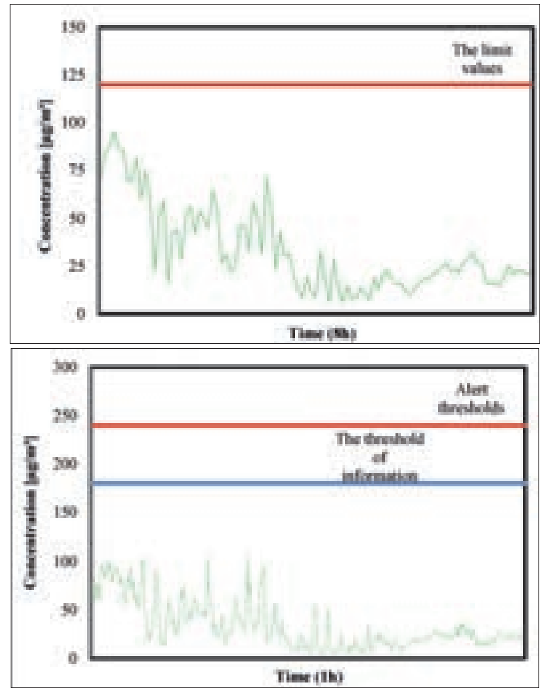

Figure 3A and 3B. The ratio of measured concentrations of ground-level ozone (O_3), the limit values, the threshold of information and alert thresholds

Measuring the concentrations of ground-level ozone (O_3) and meteorological parameters of traffic flows were done in a time series of 784 hours over a period from November 5th (06.00pm) to December 8th 2014 (10.00am). Results of measuring the concentrations of ozone (O_3) and meteorological parameters are shown in Table 1.

Table 1. Results of Measuring The Concentration of Ground-Level Ozone (O_3) And Meteorological Parameters

	Time (h)	Maximum	Minimum	The medium value	The standard deviation
Concentration (μg/m³)	784	106.54	4.794	33.587	24.117
Wind speed (m/s)	784	3.611	0.146	1.154	0.655
Temperature(°C)	784	22.84	-2.139	7.33	5.027
Humidity (%)	784	99.85	42.85	92.29	10.713
Sunlight (W/m²)	784	409.9	5.195	42.741	72.068

The maximum measured concentration of ground-level ozone (O_3) was 106.54 (μg/m³) and measured on November 14th in the time period from 01.00pm to 02.00pm. At the time when the maximum concentration was measured, wind speed was 1.06m s, the air temperature 14.06°C, humidity 84.41%, while the intensity of sunlight was 155.80W/m². Minimum measured concentrations of ground-level ozone (O_3) was measured on November 23th from 07.00 to 08.00am and it was 4.794 (μg/m^3). During that period, the calm weather prevailed, with winds of 0.61m/s, the low temperature of -2.09°C, humidity of 99.54% and low intensity sunlight of 8.15W/m^2. The medium value of measured concentrations of ground-level ozone (O_3) is 33.587μg/m^3, while the standard deviation was 24.117μg/m^3. The approximate three-dimensional function of distribution of the concentration of ozone (O_3) in day function of the week and hour of the day is shown in Picture 4. The convex feature of graphic functions with maximum concentrations of ozone (O_3) is located around the coordinates on Thursday in the daily interval from 12.00 to 06.00pm.

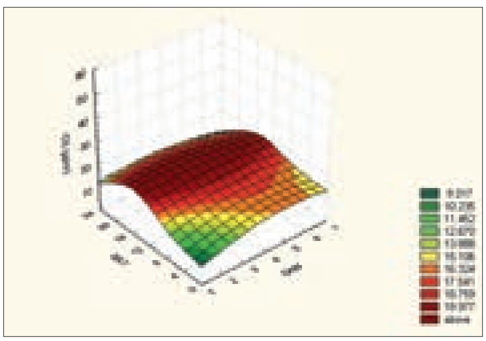

Figure 4. The approximate three-dimensional function of distribution of the concentration of ozone (O_3) in day function of the week and particular hour of the day

Analysis of variance of medium concentrations by a factor of the day of the week highlights the concentration of ozone (O_3) on Thursdays with a significant maximum of 38.33μg/m^3. The value of medium concentrations of ozone (O_3) on Thursdays is significantly higher than the minimum value on Tuesdays (30.35μg/m^3), but the same it does not apply in the remaining days. Between the value of concentrations of ozone (O_3), which are measured every other day, there were no significant differences. Analysis of variance of average concentrations of ozone (O_3) by a factor of hour in the day indicates the existence of two complementary periods. Period with a high concentration starts at 12.00pm and ends at 6.00pm, the value in this period is over 40μg/m^3 with a maximum value in the period from 03.00pm to 04.00pm with a value of 47.58μg/m^3. In the period from 06.00pm to 12.00pm concentration value does not exceed 40μg/m^3, and the minimum was established in the early morning hours in the interval from 08.00am to 09.00am and has a value of 25.96 μg/m^3. In these periods there are no significant differences in the intensity, and between these periods there are marked differences. Dependence of the concentration of ground-level ozone (O_3) as a function of meteorological parameters is shown in Figures 5A-5D.

Concentrations of ground-level ozone (O_3) is a high correlation coefficient or coefficient of determination of wind speed, temperature and air humidity. The correlation coefficient between the concentration of ground-level ozone (O_3) and specified meteorological parameters ranges in the interval $0.46<r<0.91$. The intensity of solar radiation and concentrations of ground-level ozone (O_3) are in a weak dependence and in this case the correlation coefficient is $r<0.29$. Concentrations of ground-level ozone (O_3) at the beginning of the measurements are considerably higher than at the end of the measurements, which is visible from Figure 3a and 3b. In addition, at the beginning of the measurements were significantly greater fluctuations in the concentrations than at the end, which is caused primarily by larger fluctuations in temperature. In contrast to the foregoing, the percentage differences in the concentration of ground-level ozone (O_3) are significantly higher at the end of the measurement, than at the beginning.

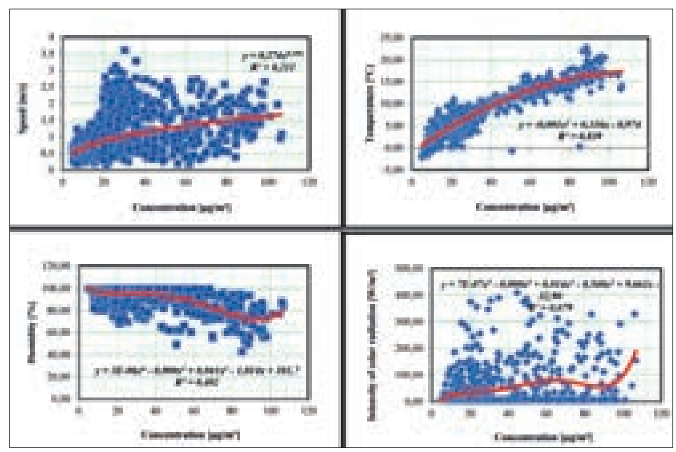

Figure 5A – 5D. Dependence of the concentrations of ground-level ozone (O_3) as a function of meteorological parameters

Results in recording traffic flows (PV, LV, MHV, HV, CT and BUS) indicate significant disparities of all traffic flows at the days of the week and hours of the day. Results measurement of traffic flow are presented in Table 2.

Table 2. Results of Measurement of Traffic Flow Characteristics

	Time (h)	Maximum	Minimum	The average number of vehicles	Standard deviation
PV	784	962	7	406.83	302.672
LV	784	27	0	5.662	6.149
MHV	784	21	0	2.512	3.078
HV	784	28	0	5.977	6.739
CT	784	54	0	12.205	10.337
BUS	784	18	0	5.343	3.991

From the analysis of variance of medium values of PV flows by a factor of the day of the week indicates the maximum value flows of PV on Fridays which is 451.90PV/day and on Sundays with a minimum value of 297.33PV/day. For LV traffic flows by the analysis of variance by a factor of the day of the week the maximum is established on Thursdays (7.12LV/day) and minimum on Sundays from 1.925LV/day, a maximum of MHV on Thursdays is 3.28MHV/day, a minimum on Sundays from 0.558MHV/day, for HV the maximum on Tuesdays is 7.558HV/day , and the minimum with PV, LV, MHV on Sundays is 1.35HV/day. The analysis of variance by a factor of the day of the week established for CT flows and BUS, minimum is on Sundays and for CT 4.308PCT/day, respectively BUS is 3.983BUS/day while the maximum for CT and BUS on Wednesdays is 15.525CT/day or 6.317BUS/day . Maximum values of concentrations of ground- level ozone (O_3) occurs at the end of the working week (Thursday and Friday), while the minimum values are measured at the end of the week (Sunday).

By the analysis of variance on the average number of PV by a factor of hours of the day is the maximum established in 11.00am and is 794.3PV/h, and a minimum of 24.84PV/h at 03.00am. For LV flows from the analysis of variance the maximum is visible at 07.00 pm (13.03LV/h) and a minimum at 11.00pm (0.03LV/h), a maximum of MHV is at 11.00pm (6.218MHV/h), and the minimum is at 02.00am (0.121MHV/h), a maximum of HV at 01.00pm (15.40HV/h) and a minimum at 01.00am (0.121HV/h). The maximum values for the CT and BUS flows are at 01.00pm 27.15CT/h, respectively 11.43BUS/h, while the CT minimum at 03.00am is 1.909CT/h, and BUS flows at 04.00am 0.505BUS/ h. To establish the correlation between the time series of the intensity of the traffic flow of vehicles (PV, LV, MHV, HV, CT and BUS) and time series of concentrations of ground-level ozone (O_3), the coefficients of linear correlation are calculated between the intensity of flows for each hour phase shift from + 1h. Time series of concentrations of ground-level ozone (O_3) have been moved in stages. Table 3 provides an overview of the calculated coefficients of linear correlation of PV, LV, MHV, HV, CT and BUS flows and total flows.

Table 3. Summary of The Linear Correlation Coefficient For Flows PV, LV, MHV, HV, CT And BUS And Total Flows

Coefficient	Maximum (sati)	Minimum (sati)
PV	0.250 (21)	-0.237 (10)
LV	0.253 (20)	-0.130 (8)
MHV	0.301 (21)	-0.018 (8)
HV	0.249 (21)	-0.188 (8)
CT	0.249 (23)	-0.121(11)
BUS	0.134 (21)	-0.143 (10)
Σ	0.253.(21)	-0.231 (10)

The maximum values of the correlation coefficient for PV flow was established at 09.00pm (r_{max}=0.250), while the minimum was established on 10.00pm (r_{min}=-0.237) for LV flow maximum is at 08.00pm (r_{max}=0.253), and the minimum at 08.00am (r_{min}=-0.130), for MHV flow maximum is at 09.00pm (r_{max}=0.301) and a minimum at 08.00am (r_{min}=-0.018), for HV flows maximum is established at 09.00pm (r_{max}=0.249), and minimum at 08.00am (r_{min}=-0188), for CT flow maximum is established at 11.00pm (r_{max}=0.249), and the minimum at 11.00am (r_{min}=-0121) and for BUS flow maximum is established at 9.00pm (r_{max}=0.134), and the minimum at 10.00am (r_{min}=-0.143). For total traffic flow, maximum is identified at 09.00pm (r_{max}=0.253), and the minimum at 10.00am (r_{min}=-0.231).

DISCUSSION

The measured values of the concentration of ground-level ozone (O_3) are extremely high, but there are within the permissible limits. The time at which the measurement was done was characterized by large fluctuations in temperature (-2.139<t <22.84°C), cold weather with an average temperature of 7.33°C and the low intensity of solar radiation (mean 42.741W/m^2) and high relative humidity (mean 92.29%). Because the formation of ground-level ozone (O_3) is related to the photochemical reaction between nitrogen oxides (NOx) and volatile organic compounds (VOC) in the presence of light, the intensity of solar radiation during the entire study period was very low, with a maximum value of 409.90W/m^2. In addition to low solar radiation, the period of intense solar radiation in the period when the measurement was performed is very short. High concentrations of ozone (O_3) occur at extremely windy weather, wind occurs when there are areas of low pressure and low pressure causes the cyclone (movement of air masses in the zone of low pressure). From the analysis of variance of the average concentrations of ground-level ozone (O_3) and traffic flows (PV, LV, MHV, HV, CT, BUS) it is evident that the maximum average values occur at the end of the week, roughly on Thursdays or Fridays, while the minimum value for flows occur on Sundays, for ground-level ozone (O_3) on Mondays and Tuesdays. Analysis of variance average concentrations of ground-level ozone (O_3) and traffic flows (PV, LV, MHV, HV, CT, BUS) by a factor of hour in a day show becoming two distinct periods - the period of minimum and maximum values. The maximum values of average concentrations of ground-level ozone (O_3) appear in the afternoon (maximum value measured in the period between 03.00pm and 04.00pm), while the medium maximum intensity flows for most vehicles is around noon. Minimum values of average concentrations of ground-level ozone (O_3) was established in the early morning hours in the interval from 08.00 to 09.00am and has a value of 25.96μg/m^3, while the minimum average values of traffic flows occur in the early morning, roughly around 04.00am. This ratio clearly indicates the dependence of the concentration of ground-level ozone (O_3) on traffic flows. The correlation coefficient between the traffic flow of vehicles and the concentration of ground-level ozone (O_3) is very small, and the emergence of negative correlation coefficient is visible.

Given the proven variation of the traffic flows during the months, where November and December are months with extremely low intensity of traffic flows, it is expected that the increase of the correlation coefficient will happen in the months with high intensity flows (July and August). If we take into account the fact that these months are extremely warm, July at the hottest month with average temperatures of 21°C, the concentration of ground-level ozone (O_3) could exceed the authorization of values. In order to create a complete picture of the concentration of ground-level ozone (O_3) in Brcko and the influence of traffic and meteorological parameters on the concentration of the same, it is necessary to do further research in this area. Within the research great attention should be paid, in addition to ozone (O_3) and other pollutants created during the traffic flow, especially volatile organic compounds (VOCs) and nitrogen oxides (NOx). In addition, future researches should be done in a rather long period of time, so time periods with higher air temperature or intensity of solar radiation and lower relative humidity and higher intensity of traffic flows were covered with them. Simultaneously with the above mentioned research, it would be necessary to implement a control research. Control research should include measuring the concentration of ground-level ozone (O_3) and meteorological parameters in a rural part of Brcko, in a location that is not near the road or where there are no local traffic impact. By comparing the results obtained from research in urban and rural areas a complete picture of the impact of meteorological parameters and traffic flows on the concentration of ground-level ozone (O_3) in the urban area of the town of Brcko would be created.

REFERENCES

[1] Wu, Y., Jin, B. and Chan, E. Detection of Changes in Ground-Level Ozone Concentrations via Entropy. *Entropy.* Vol. 17, 2015, pp. 2749-2763.

[2] Munir, S., Habeebullah, M., T., Ropkin, K. and Seroji, R., A. Modelling Ozone-Temperature Slope under Atypically High emperature in Arid Climatic Conditions of Makkah, Saudi Arabia. *Aerosol and Air Quality Research,* Vol. 15, No. 4, 2015, pp. 1281-1290.

[3] De Souza, A., Aristones, F., Pavão, G.H. and Fernandes, A.W. Development of a Short-Term Ozone Prediction Tool in Campo Grande-MS-Brazil Area Based on Meteorological Variables. *Open Journal of Air Pollution*. Vol. 3, 2014, pp. 42-51.

[4] Ocak, S. and Sezer, T.F. Effect of Meteorology on the Atmospheric Concentrations of Traffic-Related Pollutants in Erzurum, Turkey. *Journal of International Environmental Application & Science*, Vol. 3, No. 5, 2008, pp. 325-335.

[5] Mustafa, A.Y. and Mohammed, J.S. Measurement of Ground Level Ozone at Different Locations. *American Journal of Environmental Sciences.* Vol. 8, No. 3, 2012, pp. 311-321.

[6] Pleijel, H. *Ground-level ozone: A problem largely ignored in southern Europe.* Swedish NGO Secretariat on Acid Rain, Goteborg, 2000.

[7] Crnogorac, Č. i Spahić, M. *Osnovi geoekologije.* Artprint, Banja Luka, 2012.

[8] www.iddeea.gov.ba/index.php?option=com_content&view=article&id=607&Itemid=107&lang=sr

[9] 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. Official Journal of the European Union L152/1. http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1458765602820&uri=CELEX:32008L0050

[10] Pravilnik o graničnim i ciljanim vrijednostima kvaliteta vazduha, pragovima informisanja i uzbune. "Službeni glasnik Brčko distrikta BiH", broj 18/2011. http://www.bdcentral.net/index.php/ba/akti-odjeljenja-za-prostorno-planiranje?start=10