AIR QUALITY IN TUZLA

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City of Tuzla, among the other cities in Bosnia and Herzegovina as well, is recording degradation in air quality, especially during winter months. The largest air pollutants are exhaust fumes from furnaces, cars and industries. Considering that Tuzla is located in a valley, in periods of unfavorable climate conditions, this area is naturally predisposed to air pollution. In this paper, an analysis and assessment of air quality in Tuzla was made, based on data of the average annual and monthly values of concentration of pollutants emission with automated stationary stations for monitoring of air quality in the period of 2004-2013. Also, the analysis of the air quality state of the Tuzla urban system in 1991 was made, in order to identify certain trends or concentrations of the certain pollutants and a comparison among those periods was also made.

Key words: *air quality, air pollution, temperature inversions, air pollutants, Tuzla.*

INTRODUCTION

With the rise in energy production and consumption, economic recovery, and increasing number of cars on the roads and a large number of households and businesses in need of heating and electricity, the adverse impact on the environment is increasing too. In the area of Tuzla, in addition to a series of geoecological problems, the most important are the degradation of agricultural land, water pollution, landslides and the air pollution.

Although this is a very current topic, to this date there is a small number of published scientific papers that accurately describe the air quality in Tuzla. The study of air quality in the area of Tuzla, whose results, as the base were used in this work, dealt with S. Begic (1997, 2000). Today, a very valuable and important data about the air pollutants are overload are published by the Ministry of spatial planning and environmental protection of Tuzla Canton in their daily, monthly and annual reports on air quality. Also, the certain information on this issue can be found in numerous documents of the Centre for ecology and energy Tuzla, as well as in the Local environmental action plan for environmental protection (LEAP) for the Municipality of Tuzla.

Last researches on the state of air quality and the impact of energetics were made by S. Gutić, co-author of this paper, for the purpose of a master's thesis on the topic "Geoecological aspects of the production process in the PP "Tuzla" in order to improve the air quality". For the purposes of the mentioned research, the data base with the average, maximum and minimum monthly and annual values of pollutants imission and daily, monthly and annual values of important meteorological elements (air temperature, precipitation, cloudiness, relative humidity and air circulation) was formed. The database contains all stored and published data to 1992. and monitoring of air quality for the period 2004-2014.

The subject of research is the analysis and evaluation of the air quality in the Tuzla's city area, which was conducted by comparing the situation in 1991. with annual values from the period 2004-2013. The task of the research is to determine the level of air pollution by individual pollutants and their comparison with the allowed concentrations and limit values. The fact is that the air quality in Tuzla is not at a satisfying level, but exceeding the limit values for most pollutants is characteristic only for the winter season, so this research seeks to register the pollutants to make recommendations and to propose measures that would lead to improved air quality in Tuzla.

It was presumed that the air quality in Tuzla is improving, and that only in the winter the air quality is not at a satisfaying level and that the current situation, beside the expressed anthropogenic influence, is conditioned by the physical geographical characteristics of the area. Considering the complexity of the case studies, many scientific methods were used. A statistical method is used to process the data obtained by the established monitoring of air quality in Tuzla.

The comparative method was used when comparing air quality data measured at measuring stations, when comparing condition of earlier periods and new values and comparing those values with the legal permitted values. Field observations have been made and a large amount of information was obtained by the method of direct observation. In addition, there were used some other scientific methods such as analytical, deductive, inductive, descriptive, empirical, etc., which depended on the current research.

THE STATE OF AIR QUALITY IN TUZLA

The Tuzla city area is located in the basin of Jala river, in the region of Northern Bosnia, specifically in the sub-region of Spreča - Majevica with Semberija, in the northeast of Bosnia and Herzegovina (Ahmetbegovic, S., Stjepić Srkalović, Ž., Gutić, S. 2015). In geomorphological terms, the city area of Tuzla is located in relief basin, elongated in the west-east direction. South Majevica hills that is neotectonicly rising at the edges of the basin, borders the area from the north, east and south sides, while in the west Tuzla basin opens to Spreča tectonic depression. Contact position of Tuzla basin, between the Pannonian plain in the north and Dinara mountain system in the south, along with other climate modifiers, influenced the climatic features of the area.

The geographical location of Tuzla, together with weather conditions and morphological characteristics, are important factors of air quality. The content of pollutants in the air belongs to instrumental monitoring, which includes the measurement and monitoring of the content of harmful air admixtures (Spahic, M. 2016). It's necessary to select the locations of the monitoring network stations so they provide high-quality and representative data on the air quality of the selected area. It depends on several factors such as: the emitter of pollutants, the type and quantity of emitted pollutants, physical-geographical features of the area, monitoring purpose, etc. Selection of the monitored pollutants from the monitoring network depends solely on the pollutant emission such is concentration levels of those pollutants that are emissioned in the greatest volume and have, directly or indirectly, the impact on the biosphere and human health (Đuković, J., Bojanić, V. 2000).

Analysis and evaluation of air quality in the area of Tuzla, was carried out by comparing the available data of air quality in 1991 with the data of air quality in the period of 2004-2013.

The state of air quality in Tuzla in 1991.

The period up to 1992. can be characterized as a period of the most intense air pollution in Tuzla, primarily because the industrial capacities, located in the western part of the town, worked at full installed capacity. This also applies to the PP "Tuzla", considered the biggest polluter in Tuzla, northeastern Bosnia and wider, that before the war (1992-1995) worked with all the installed blocks, with total power 779 MW, and largely influenced the atmosphere of the area. Also, big part of the town has not yet been connected to the district heating system, so there was a greater number of individual furnaces which further caused the increased value of pollutants and their accumulation in the lower troposphere.

The ecology team of Technology Faculty in Tuzla in 1991. monitored the quality of air at several locations in the city. These are, unfortunately the only available data on air quality in Tuzla before the war and were related to the concentration of sulfur dioxide (SO_2), smoke or soot, ammonia (NH_3), nitrogen oxides (NO_x), hydrogen sulfide (H_2S), suspended particles, chlorine (Cl_2) and sedimentary materials. Location of measuring stations are selected in accordance with the methodology and recommendations of the World Health Organization (Begic, S. 1997) in that period, and there were four measuring stations. For the purposes of this paper the monthly and annual concentrations of sulfur dioxide, nitrogen oxides and smoke was analyzed by measuring stations at four locations: near the former Grafičar, at the Municipality building, at the Technology Faculty and at the Brčanska Malta.

In Table 1 are presented the average monthly concentrations of SO_2 in Tuzla in 1991. According to the measurement results shown in Table 1 and Figure 1, it can be concluded that the average annual concentrations of SO_2, especially at measuring stations no. 2 and 4, were very high and exceeded then permissible value of 110 $\mu g/m^3$.

Table 1: Average monthly sulfur dioxide (SO_2) concentrations in Tuzla 1991. ($\mu g/m^3$)

Month	MS-1 Grafičar	MS-2 Technological faculty	MS-3 Municipality building	MS-4 Brčanska malta
I	55.3	170.6	118.9	197.3
II	112.7	135.3	148.4	153.7
III	172.9	125.9	79.1	176.2
IV	116.4	117.3	56.0	259.2
V	156.4	116.7	34.3	156.2
VI	35.3	96.8	23.3	100.0
VII	-	-	18.5	-
VIII	-	-	20.5	-
IX	7.2	227.6	21.1	58.2
X	42.4	203.2	25.8	393.0
XI	49.6	203.1	120.0	488.0
XII	-	362.1	178.7	-
Ann. average	**83.1**	**175.8**	**70.4**	**220.2**

Data source: Begić, S. (1997), p. 8.

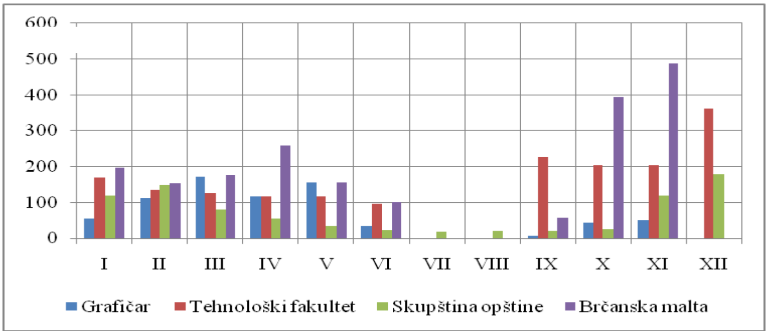

Fig. 1: Average monthly sulfur dioxide (SO_2) concentrations in Tuzla 1991. (µg/m^3)

The high content of this pollutant is observed in the colder period of the year in the heating season. Average monthly values of SO_2 in these months is several times higher than the permissible norms. Maximum average monthly value was recorded in November at the measuring station no. 4 (488 µg/m^3), which with the high average annual value (220.2 µg/m^3) indicates that this part of town had extremely polluted air. There was no better condition on the measuring station no. 2, where the SO_2 concentration of 362.1 µg/m^3 was recorded in December.

Table 2 shows the results of the average monthly concentration of NO_x in 1991. at measuring stations. Although no data were available for July, August and September, we can assume that at the measuring point no. 1 "Grafičar" the NO_x concentrations in the winter and summer months were at a similar level.

Table 2: Average monthly nitrogen oxide (NO_x) concentrations in Tuzla 1991. (µg/m^3)

Month	MS-1 Grafičar	MS-2 Technological faculty	MS-4 Brčanska malta
I	25.6	111.9	35.8
II	35.4	136.6	59.0
III	33.0	72.8	103.5
IV	28.2	73.3	80.9
V	20.7	51.7	89.7
VI	31.0	23.4	-
VII	-	23.0	-
VIII	-	23.9	-
IX	-	30.2	-
X	28.4	38.2	43.7
XI	28.6	100.8	49.2
XII	30.5	113.4	-
Ann. average	**29.0**	**66.6**	**65.9**

Data source: Begić, S. (1997), p. 8.

At the measuring point no. 2 the values of this pollutant were elevated in the winter months. The greatest average concentrations have been recorded in February (136.6 µg/m^3), December (113.4 µg/m^3) and January (111.9 µg/m^3). At the MS-2 the average value of NO_x during the winter (December-January-February) amounted to 120.6 µg/m^3, in autumn (September-October- November) 56.4 µg/m^3, spring (March-April-May) 65.9 µg/m^3 and summer (June-July-August) 23.4 µg/m^3. At the MS - 4 data are available for a total of five months, which makes up over 40% of the data. However, we can conclude that at the measuring point during 1991. the NO_x concentrations were rising in the spring, with the largest average value in March from 103.5 $\mu g/m^3$. The content of nitrogen oxides in the air of Tuzla area, in 1991. belonged to the second category of air quality.

Table 3: Average monthly concentrations of smoke (soot) in Tuzla 1991. ($\mu g/m^3$)

Month	MS-1 Grafičar	MS-2 Technological faculty	MS-4 Brčanska malta
I	40.9	62.1	77.1
II	39.6	81.1	72.2
III	23.2	64.1	42.8
IV	8.7	51.5	42.7
V	13.4	13.7	30.9
VI	12.9	7.3	25.1
VII	-	-	-
VIII	-	-	-
IX	24.2	1.7	16.5
X	19.0	54.1	80.2
XI	143.0	139.4	50.5
XII	-	149.4	-
Ann. average	**36.1**	**62.4**	**48.6**

Data source: Begić, S. (1997), p. 8.

Content of smoke in Tuzla in 1991., similar to the content of SO_2, had a regular annual movement of a concentration levels. It was high during the winter and low in summer. Microparticles of soot due to air from car engines and furnaces where combustion of oil, its derivatives and coal. The highest average annual concentration was in the MS-2 and exceeded the value of 60 $\mu g/m^3$. The monthly values of smoke are exceeded 100 $\mu g/m^3$ in the MS-2 in November (139.4 $\mu g/m^3$) and December (149.4 $\mu g/m^3$) and the MS-1 in November (143.0 $\mu g/m^3$).

During the war (1992-1995) there was a drastic reduction of industrial pollution due to delays or partial engagement of industrial capacity. In the same period, the PP "Tuzla" worked with a capacity of up to 20%. The blocks with a less installed capacity were in operation (unit 1, 2 and 3), and units 4, 5 and 6 were temporarily out of work. Although during this period there is no data for air quality, because of the reasons stated above, it can be assumed that the state of the environment in terms of industrial pollution were significantly more favorable in relation to state in 1991.

The state of air quality in Tuzla in period of 2004-2013.

In the period of post-war reconstruction the air become loaded with pollutants again. Continuous monitoring of air quality, which is under the Ministry of spatial planning and environmental protection of Tuzla Canton, started in 2003 by installing of stationary emission measuring stations at five locations, including: MS-1 "Square", MS-2 "BKC", MS-3 "Bukinje“, MS-4 "Bektići" and MS-5 "Cerik". At these measuring stations values of sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3) and deposited dust ($PM_{2,5}$) are monitored and also some stations perform measurements of basic meteorological elements, such as: air temperature, wind speed and direction, air pressure, solar radiation and precipitation.

Table 4: Mathematical-geographical location of air quality measuring stations in Tuzla municipality

Meassurment stations	Latitude	Longitude	Elevation (meters)	Geographical location in relation to PP "Tuzla"
Skver	44°30´23″ N	18°36´16″ E	234	7 km east
BKC	44°31´55″ N	18°39´17″ E	232	2,5 km east
Bukinje	44°31´25″ N	18°36´01″ E	216	300 m north
Bektići	44°31´20″ N	18°34´51″ E	259	2,5 km west
Cerik	44°30´23″ N	18°36´16″ E	286	2,2 km south

Data source: Ministry of spatial planning and environmental protection of Tuzla Canton, 2014.; independent calculations.

It is important to note that for a few years and for a few measuring stations the data are not available because of equipment servicing, interruptions in communication between the measuring stations and the center, and other reasons. This particularly applies to the year 2007. for which does not exist monitoring data. It can be considered that the monitoring program is adequately balanced if each calendar quarter containing less than 20% of the total number of observations that are made during the year.

According to a quantitative representation and noxiousness, the SO_2 is the biggest air polluter of and therefore its concentration is taken as a reference parameter for the assessment of the quality or level of air pollution. Table 5 presents the available data on the average annual SO_2 concentrations in Tuzla by the measuring stations in the period 2004-2013. It should be noted that the MS-4 Bektići data are available only for three years of measurements of this pollutant.

Table 5: Average annualy concentrations of SO_2 in Tuzla in period of 2004-2013. (µg/m^3)

Year	MS-1 Skver	MS-2 BKC	MS-3 Bukinje	MS-4 Bektići	MS-5 Cerik
2004.	35.10	39.70	52.20	38.60	31.60
2005.	57.80	73.30	47.80	46.10	32.10
2006.	-	62.00	19.30	-	57.50
2007.	-	-	-	-	-
2008.	112.10	59.10	47.80	-	-
2009.	58.60	69.70	55.60	-	48.10
2010.	74.60	73.10	57.20	-	52.10
2011.	116.36	-	59.26	-	58.20
2012.	54.54	56.95	57.96	-	43.51
2013.	62.20	84.15	83.58	57.16	69.90

Data source: Ministry of spatial planning and environmental protection of Tuzla Canton, 2014.

By determining the average annual value for SO_2 in Tuzla it is obvious that concentrations of this pollutant generally exceed statutory annual limit value of 50 µg/m^3. Following the movement of this pollutant it is noticable that it alternates from year to year, noting increases and reductions. Very high average annual values of SO_2 were determined at MS-1 for 2008. (112.10 µg/m^3) and for 2011. (116.36 µg/m^3), and at the MS-2 for 2013. (84.15 µg/m^3), which indicates that the city center is highly contaminated by this pollutant.

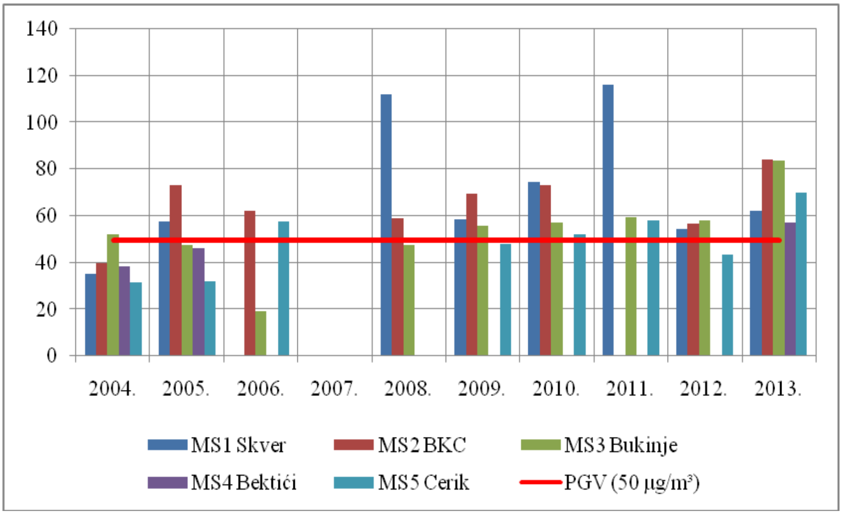

Fig. 2: Average annually concentrations of SO_2 in Tuzla in period of 2004-2013. (μg/m^3)

The analysis of available data, it can be concluded that the value of this pollutant often exceeded the thresholds warning and threshold alerts. Number of exceeding coincides with the highest annual average concentrations of SO_2. In the following table the data of the number of hourly intervals when SO_2 concentrations exceed 500 μg/m^3 are presented.

Table 6: Overview of the number of exceedances of alert for SO_2 in Tuzla in period of 2004-2013. (hour intervals)

Year	MS-1 Skver	MS-2 BKC	MS-3 Bukinje	MS-4 Bektići	MS-5 Cerik
2004.	10	20	34	12	12
2005.	39	45	29	23	20
2006.	-	38	3	-	34
2007.	-	-	-	-	-
2008.	111	10	33	-	-
2009.	34	41	29	-	13
2010.	35	10	38	-	8
2011.	88	-	60	-	26
2012.	5	24	13	-	17
2013.	36	78	65	39	58
Total	309	266	304	74	188

Data source: Ministry of spatial planning and environmental protection of Tuzla Canton, 2014.

If we follow the average value per month, it can be concluded that in Tuzla the SO_2 concentrations are increased during the colder periods of the year, during the heating season when domestic furnaces, which mostly use coal (lignite and brown coal), emit large quantities of this pollutant.

High average values of SO_2 were recorded in the MS-1 "Skver" and MS-2 "BKC". It's shown in the table 7 in which the top ten average concentrations of this pollutant in the period 2004-2013 were presented. These two measuring stations had the highest average values of SO_2 in the winter that are regularly amounted to over 130 μg/m^3, while at the other measuring stations values were below 100 μg/m^3. The highest daily maximum concentrations were recorded in November 2011. at the MS-2 (952.8 μg/m^3) and MS-1

(890.1 μg/m^3), which indicates that the center of the city of Tuzla is very threatened by this pollutant.

Fig. 3: Air pollution from domestic furnaces in the Kula settlement

Fig. 4: Air pollution from domestic furnaces in the Brčanska Malta settlement

Table 7: The highest average concentrations of SO_2 in Tuzla in period of 2004-2013. (μg/m^3)

Ord. No.	Year	Month	Measuring station	Value
1.	2013.	December	BKC	291.1
2.	2008.	January	Skver	285.8
3.	2013.	December	Skver	234.0
4.	2011.	January	Skver	189.4
5.	2006.	January	BKC	187.8
6.	2011.	November	BKC	185.4
7.	2008.	January	BKC	184.5
8.	2011.	November	Skver	183.9
9.	2008.	February	Skver	183.7
10.	2010.	February	Skver	174.7

Data source: Ministry of spatial planning and environmental protection of Tuzla Canton, 2014.

The main source of pollution by nitrogen oxides in Tuzla is traffic. Emissions caused by traffic are the greatest in the center of the city of Tuzla, near the main roads, where the speed of the cars is reduced. However, the average annual NO_2 concentrations in Tuzla are below the allowed annual limit (40 μg/m^3). Compared to 1991., the concentrations of NO_2 in Tuzla are far lower.

Table 8: Average annual concentrations of NO_2 in Tuzla in period of 2004-2013. (μg/m^3)

Year	MS-1 Skver	MS-2 BKC	MS-3 Bukinje	MS-4 Bektići	MS-5 Cerik
2004.	31.70	21.90	18.20	8.30	11.30
2005.	35.50	39.40	26.40	-	9.20
2006.	21.80	33.30	15.40	-	15.50
2007.	-	-	-	-	-
2008.	6.90	-	2.90	-	-
2009.	25.00	27.40	17.80	-	12.90
2010.	18.20	29.80	15.50	-	12.20
2011.	-	36.60	25.28	-	37.21
2012.	38.81	34.28	21.67	-	39.76
2013.	27.16	29.14	18.43	14.25	29.54

Data source: Ministry of spatial planning and environmental protection of Tuzla Canton, 2014.

The concentrations of this pollutant, similar to values of SO_2 increases during the colder periods of the year, ie from October to April. The highest average (82.0 µg/m^3) and maximum (195.4 µg/m^3) value of this pollutant was recorded in February 2012. at the MS Skver.

If we observe the daily movement of NO_2 concentrations, it is evident that, regardless of the season, the values of this pollutant were increasing in the morning and afternoon hours, which can be attributed to the increased traffic, when residents go to to work or are returning from work. On weekends, the NO_2 concentrations are increased in the late afternoon and evening hours, what again can be associated with increased frequency of traffic.

Some pollutants that are emitted from the primary pollutants are resulting in photochemical processes in the atmosphere, which are known as photochemical oxidants. The main pollutant in this category is ozone. Average annual concentrations of ozone in Tuzla for the period 2004-2013. are shown in Table 9.

Table 9: Average annual concentration of O_3 in Tuzla in period of 2004-2013. (µg/m^3)

Year	MS-1 Skver	MS-2 BKC	MS-3 Bukinje	MS-4 Bektići	MS-5 Cerik
2004.	47.30	39.90	39.90	28.00	55.20
2005.	42.90	40.90	38.00	49.60	54.90
2006.	37.10	23.40	41.90	44.60	21.00
2007.	-	-	-	-	-
2008.	41.10	32.50	40.60	-	61.20
2009.	32.40	29.90	43.20	-	40.80
2010.	-	17.30	39.30	-	24.80
2011.	-	17.20	26.80	-	23.00
2012.	-	-	21.90	-	13.39
2013.	-	30.94	35.13	-	42.43

Data source: Ministry of spatial planning and environmental protection of Tuzla Canton, 2014.

The average annual values of O_3 are ranging from 13.39 µg/m^3 in 2012. to 61.20 µg/m^3 in 2008 which is recorded on the MS-5. Analyzing the data in Table 9 it's evident that the values of this pollutants were generally declined from 2008. to 2012., followed by an increase in 2013.

Unlike other pollutants, O_3 values has increased in the spring and summer months, because the concentration of O_3 is directly related to solar radiation.

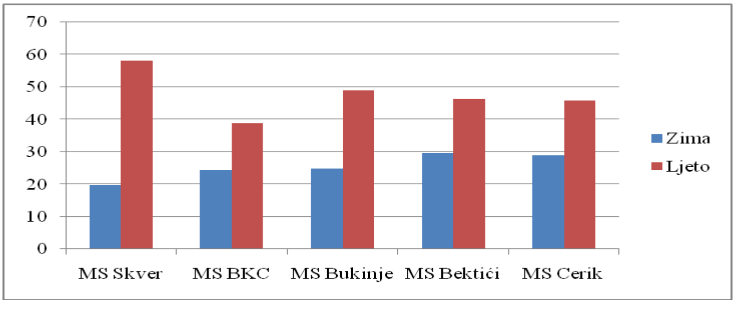

Fig. 5: Average concentrations of O_3 during summer and winter in Tuzla for a period of 2004-2013. (µg/m^3)

Hourly concentrations of ozone in the analyzed period did not exceed the threshold warnings (192.00 μg/m^3) and alert thresholds (240.00 μg/m^3) determined by the Rules on limit values of air quality. The highest average of O_3 concentrations were recorded in March and April 2005., at the MS-5 and amounted to over 80 μg/m^3. That same year and at the same measuring station the daily maximum value of 119.5 μg/m^3 was recorded (12.02.2005). Minimum values range from 0.1 μg/m^3 (recorded in October 2010. at the MS-5) to 48.3 μg/m^3 (April 2004. MS-3).

Carbon monoxide is one of the most common pollutants in the atmosphere. Its average annual values in Tuzla ranges from 0.48 mg/m^3, which is recorded at the MS-5 in 2004., to 1.60 mg/m^3 in 2011. at MS-2. For a few years at the measuring stations were no data, but we assume that the city center is particurarly burdened by this pollutant as a result of large number of cars that are the largest emitters of CO.

Table 10: Average annual concentrations of CO in Tuzla in period of 2004-2013. (mg/m^3)

Year	MS-1 Skver	MS-2 BKC	MS-3 Bukinje	MS-4 Bektići	MS-5 Cerik
2004.	1.24	1.37	0.83	0.68	0.48
2005.	1.30	1.40	0.90	0.80	0.70
2006.	1.30	1.40	0.70	0.60	-
2007.	-	-	-	-	-
2008.	1.10	-	-	0.80	-
2009.	1.40	-	-	0.60	-
2010.	0.96	0.86	-	1.04	-
2011.	-	1.60	-	-	-
2012.	0.80	1.00	-	-	-
2013.	1.20	1.10	0.80	1.30	1.00

Data source: Ministry of spatial planning and environmental protection of Tuzla Canton, 2014.

Observed by the months, it can be clearly seen that the concentrations of this pollutant, as well as most other pollutants, were increasing during the colder periods of the year. The highest average value of CO was recorded in December 2013. at the Skver and it was 4.1 mg/m^3, and the highest maximum concentration was recorded in December 2010. at BKC and amounted to 8.90 mg/m^3 (22.12. 2010.). During the warm period of the year, the value of this pollutant are generally below 1.0 mg/m^3, which is well below the annual limit value (3.0 mg/m^3).

Particulate matter is considered as a key indicator of air quality. The data on the average annual concentrations of dust deposits in Tuzla evidently shows that its value in all years is well above the prescribed annual limit value (25 μg/m^3). The highest average annual concentrations of this pollutant is evidented at the Skver in 2011. and amounted to 86.40 μg/m^3.

From the average annual values of this pollutant, it can be seen that its concentration in the MS-3 Bukinje has declined. Considering that in the vicinity of the measuring station is PP "Tuzla", the evidented decrease is largely a result of the installation of a modern electrostatic filters on chimneys at PP "Tuzla" which significantly reduces the dust emissions. The highest registered values of this pollutant are in the autumn-winter period, ie. during the heating season, which indicates that the main reason for the high content of deposited dust is the emissions from individual furnaces and boiler rooms.

The content of deposited dust is particularly high at BKC and the Skver, where are no industrial facilities. So the highest average concentrations of this pollutant is recorded in January 2008. at the MS-2 BKC (223.0 μg/m^3) and at the same time is recorded and the highest maximum concentration of dust on the Skver (567.0 μg/m^3). During the summer period the value of dust at all measuring stations are mainly below 30 μg/m^3.

Table 11: Average annual concentrations of $PM_{2,5}$ in Tuzla in period of 2004-2013. (μg/m^3)

Year	MS-1 Skver	MS-2 BKC	MS-3 Bukinje	MS-4 Bektići	MS-5 Cerik
2004.	52.40	62.70	68.30	68.30	36.50
2005.	65.60	75.30	68.80	-	41.70
2006.	61.30	-	60.20	-	41.20
2007.	-	-	-	-	-
2008.	58.30	67.80	62.00	-	41.40
2009.	53.50	77.10	50.10	33.30	41.40
2010.	59.60	70.40	52.50	43.20	43.40
2011.	86.40	-	65.80	58.40	65.30
2012.	52.70	39.22	40.99	43.81	-
2013.	53.28	32.89	36.02	39.38	-

Data source: Ministry of spatial planning and environmental protection of Tuzla Canton, 2014.

Temperature inversions and air pollution

In the stable atmospheric conditions the state when the lower layer of air is colder compared to the higher layers, ie., the warmer air is above the cooler can be often formed. This state of the atmosphere is called the temperature inversion (Spahic, M. 2002). It's conditioned with relief and microclimate characteristics of the area, and it is common in Tuzla basin and linked mainly to the winter period. From the aspect of air pollution, it is the most difficult situation because there can not be more significant distribution of pollutants.

Intromissioned, very harmful pollutants in the inversion layer arise only to a certain height and stay there or return to the ground. If inversion lasts longer, pollutants accumulate and their concentration reaches such proportions which are dangerous to human health (Spahic, M. 1999).

Terrestrial radiational or orographic inversion, characteristic for the Tuzla basin, mainly follows the appearance of a dense fog, which with pollutants form smog. Smog rises to the height of the inversion layer and makes the smoke curtain or "cap" over urban areas. It is generated through the combustion of fossil fuels and from air pollutants and other particles contained in the atmosphere. Fog is a aggravating factor in the vertical expansion of the air and other harmful pollutants particles that are dissolved in droplets of mist from the city atmosphere. By a field research, on the vertical profile from the bottom of the Tuzla basin to Majevica orographic structure, a height of radiation inversion layer is noticable at about 290 m (Figure 6). Capacity of atmospheric complex of Tuzla basin, according to the opening in Spreča tectonic basin, in the village Bukinje and up to 300 m above sea level is only 1.59 km^3 (1.595.200.000 m^3). Due to the small capacity of atmospheric complex, which is further reduced by the infrastructure facilities, the value of distributed polutants exceed the capacity of natural self-regulatory processes in the basin.

The height of the inversion layer is essential in determining of the dimensions of industrial and other chimneys. Today, the height of the chimneys is adjusted to the height of the inversion layer, so the emitted gases, vapors and particles could scatter out at a larger area (Matas, M. 2001). According to available data, all chimneys of PP "Tuzla" are exceeding the height of inversion layer, which is from the air pollution aspect positive, because in these conditions the released pollutants do not stay in the lower layers. In such condition, the biggest polluters in Tuzla are individual heating units, traffic and industrial capacities that haven't adapted their production to physical-geographical (relief and microclimate) conditions of space.

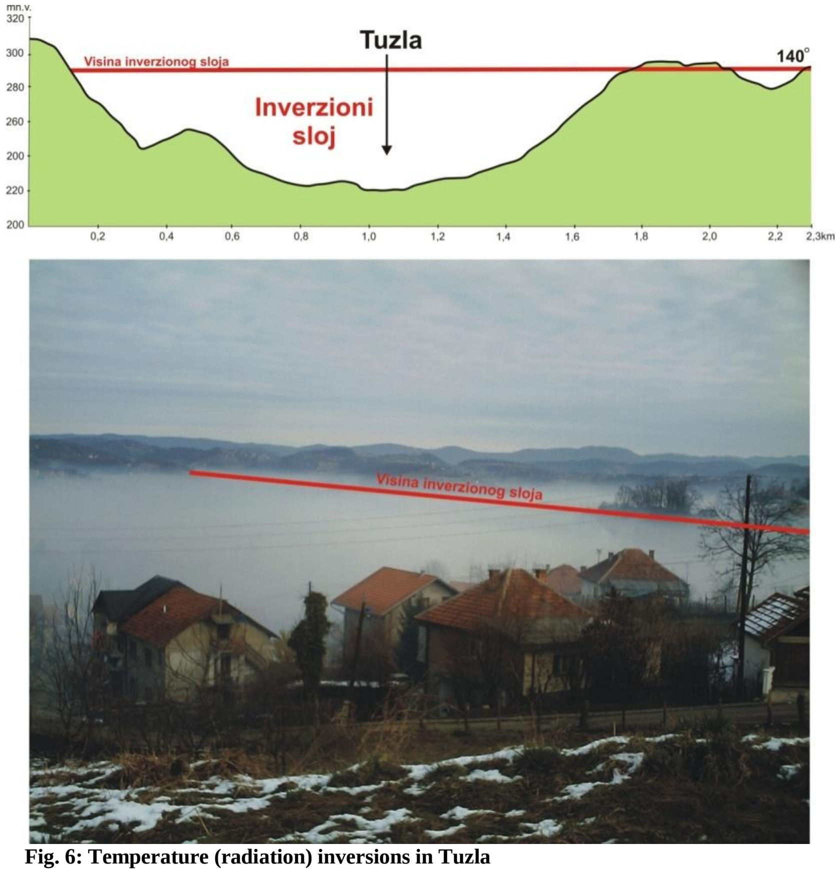

Fig. 6: Temperature (radiation) inversions in Tuzla

CONCLUSION

The fact that Tuzla is under very polluted air and that it is, according to the claims of many, one of the cities with the highest anthropogenic influence on atmospheric complex in Europe. However, the research leads to the data that the state of the air quality in Tuzla is now better than in the period up to 1992., but there hasn't been a significant improvement in the period from 2004. to 2013. Also, the air quality disrupts in the colder part of the year, especially in the anticyclonal weather conditions, where in the frequent occurrence of temperature inversions creates the conditions for the accumulation of pollutants in the lower atmosphere. According to the observed concentrations of sulfur dioxide and dust are often exceeding the thresholds warnings and alerts, which is the biggest problem in atmospheric complex urban system over Tuzla.

Studies have shown that the exceeding of the limit values caused by low capacity of the atmospheric complex in Tuzla Basin, occurres only in the winter period, so it can be concluded that, in addition to industry, energetics and transport sectors, a strong influence on the reduction of air quality has a large number of individual home furnaces. In order to improve the air quality in Tuzla, it is necessary to continue the expansion of district heating network and connection to the existing heating system of the PP "Tuzla", and to take the advantage of the proximity of the thermal power plant in this way, to reduce emissions of harmful pollutants from residential buildings. Establishing the geoecological way of production and adaptation to EU standards, with greater use of thermal energy from the PP "Tuzla", the protection of the environment and reduce the possibility of bigger air pollution of the wider area will be contributed. The construction of the cogeneration unit 7 of PP "Tuzla", will replace the existing dilapidated, less energy and environmentally nonefficient units, which will ensure long-term supply of heating energy, reduce emissions of pollutants and to contribute to the quality of the environment. In parts of the urban area where it is not technically and economically justified to expand the existing district heating system it is necessary to use low-sulfur fuel or some of the renewable energy sources, along with increased inspection control furnaces.

To improve air quality, it is essential to adjust the dimension and height of industrial and other chimney to the inversion layer which is determined in Tuzla basin at an altitude of about 290 m. It is important to continuously develop further the long-established cadastre of air pollutants in Tuzla and the environment, because it is a first and the most important document that registers the sources of pollutant emissions. Regulated legislation and strict control can prevent the emission of pollutants from industrial and other production facilities in the Tuzla area, and it is necessary to reconstruct the transport networks, to stimulate public transport, and to build bicycle paths and pedestrian zones.

Literature and sources

Ahmetbegović, S., Stjepić Srkalović, Ž., Gutić, S. 2015: Poplave i klizišta na području grada Tuzla uzrokovani prirodnim nepogodama u 2014. godini, Acta Geographica Bosniae et Herzegovinae, Vol. 2. Br. 4., Sarajevo, p. 43-54;

Ahmetbegović, S., Gutić, S. 2016: Stanje kvaliteta zraka u Lukavcu, Zbornik radova sa Naučne konferencije "Kulturno-historijsko i prirodno naslijeđe općine Lukavac", JU Javna biblioteka Lukavac i JU Zavod za zaštitu i korištenje kulturno-historijskog i prirodnog naslijeđa Tuzlanskog kantona, Lukavac, p. 644-658;

Begić, S. 1997: Stanje kvaliteta zraka na području Tuzle, Zbornik radova "Zaštita okolice-Tuzla ´97", Ministarstvo za urbanizam, prostorno uređenje i zaštitu okolice, Tuzla, p. 7-10;

Begić, S. 2000: Ekologija (zrak, voda, tlo), Eko-zeleni, Tuzla;

Dokumentacija i podaci Ministarstva za prostorno uređenje i zaštitu okolice Tuzlanskog kantona, 2014;

Đuković, J., Bojanić, V. 2000: Aerozagađenje-pojam, stanje, izvori, kontrola i tehnološka rješenja, Institut zaštite i ekologije, Banja Luka;

Matas, M. 2001: Geografski pristup okolišu, Visoka učiteljska škola, Petrinja;

Spahić, M. 1999: Osnove geoekologije, Harfo-graf, Tuzla;

Spahić, M. 2002: Opća klimatologija, Geografsko društvo Federacije Bosne i Hercegovine, Sarajevo;

Spahić, M. 2016: Magla nije smog, Udruženje geografa u Bosni i Hercegovini – GEOuBiH, http://www.geoubih.ba/index.php/reagovanja/70-reagovanje-o-magli-u-sarajevu-magla-nije-smog-2 (30.05.2016);

Gutić, S. 2015: Geoekološki aspekti upravljanja procesom proizvodnje u TE "Tuzla" u funkciji poboljšanja kvaliteta zraka, Magistarski rad, Prirodno-matematički fakultet, Univerzitet u Tuzli, Tuzla.

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