FACTA UNIVERSITATIS
Series: **Working and Living Environmental Protection** Vol. 16, N° 1, 2019, pp. 25 - 36
https://doi.org/10.22190/FUWLEP1901025P

THE RESULTS ANALYSIS OF AIR QUALITY MONITORING IN THE MUNICIPALITY OF TRSTENIK

UDC 504.5(497.11Trstenik)

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Abstract. *Economic and social development of cities, as well as the development of transport, yield great benefits to the inhabitants, but also have rather negative impact on the environment. The paper analyzes the results of environmental monitoring of air quality in the municipality of Trstenik for 2017, based on the assessment report done by the Public Health Institute Kruševac (an accredited testing laboratory of the municipal administration of Trstenik). Sampling was performed at a measuring site in Trstenik over a 24-hour period. Afterwards, an analysis of the obtained measurement results was carried out, followed by a conclusion on air pollution values, and a proposal for improvement measures.*

Key words: *air pollution, air pollution monitoring, living environment*

1. INTRODUCTION

From the beginning of the first human communities, man has been adjusting the environment to himself and to his needs. The development of modern cities, industrialization, and urbanization have improved the quality of life; however, in the meantime, they developed negative impacts on the quality of the environment. The environment refers to a space or the surroundings in which a person lives, i.e. everything beyond the organism (definition in the British vocabulary of environmental terms) [1]. The environment is a set of natural and created values whose complex interrelationships make up the environment, i.e., the space and the conditions of life [2]. Environmental pollution is the release of polluting substances into the environment, caused by human activity or natural processes, which may have consequences to the environment and human health.

Today, traffic is considered as one of the largest environmental polluters. In the middle of the twentieth century, when the expansion of car began, about 2.6 billion people lived on planet Earth and they owned around 50.000.000 cars. In the new millennium, people have over 500.000.000 cars (with freight vehicles and motorcycles, even more than 800 million). During

Received March 22, 2019 / Accepted April 22, 2019
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this period, the population has grown more than twice, while the number of cars has increased 10 times. Bearing in mind that around 50 million vehicles are produced annually in the world, it is expected that there will be around two billion passenger vehicles in two decades [3, 4].

Nowadays, without traffic, the activities in cities would be almost impossible. However, despite numerous positive effects on social, economic, cultural, sports and overall development, traffic has a very negative effect on the environment and the sustainable development of the city [5]. These negative effects are mainly related to traffic accidents, congestion, soil, air and water pollution, noise generated by transport, and the use of energy, land and other natural resources in vehicle production [6].

2. AIR POLLUTION INFLUENCE

At present, air pollution is an important risk factor for human health. Global Burden of Disease [7] shows that air pollution is one of the ten major global health risk factors. For example, according to data and estimations of the World Health Organization for 2012, it was predicted that approximately 7 million deaths can be attributed to total air pollution in 2012. Even more, about 3.7 million deaths are caused by ambient air pollution. According to data for Europe, 400.000 people per year suffer from premature deaths due to polluted air in European Union countries (EU) [8]. The Organization of Economic Co-operation and Development (OECD) predicts that in 2050 global pollution of external air will be the biggest cause of death related to environmental conditions [9].

Air pollution is actually the release of harmful natural and synthetic substances into the atmosphere as a direct or indirect consequence of human activities (Law on Environmental Protection, 2016). The basic pollutants found in the environment are: sulfur dioxide, suspended particles, nitrogen oxides, tropospheric ozone, lead, etc. [10].

The percentage of European people living in cities increased from 71% in 2000 to 73% in 2010. With such a direction of development, it is expected that this value will reach 82% until 2050 [11]. The biggest disturbance to life in cities is air pollution, whereas noise and traffic are the greatest source of air pollution in the urban environment. Research shows that traffic contributes to over 50% of total atmospheric pollution [3]. Road traffic (passenger and freight) affects pollution to the largest extent. If we observe all traffic congestion (not including air and sea), overall traffic volumes are as follows: road passenger transport (19.5%), freight transport (70.4%), rail transport (2.4%) and river traffic (7.4%) [12].

Air pollution sources are mainly the result of human activities and are divided into three groups: stationary sources, mobile sources, and pollution sources from enclosed spaces. Mobile sources include any form of a motor vehicle with internal combustion, e.g. light vehicles that use petrol, light and heavy vehicles that use diesel, motorcycles, and planes. The exhaust engine gases contain many harmful substances: carbon monoxide, non-combustible hydrocarbons and partly burnt materials, nitrogen oxides, sulfur oxides, lead compounds, solid and liquid smoke components and these substances are released during the combustion of various fuels in engines. Carbon monoxide (CO) is highly poisonous gas, without color, odor, and taste. The CO concentration of 1% in the air is deadly. Emitted acidic substances, such as sulfur dioxide (SO_2) and nitrogen dioxide (NO_2), can stay in the atmosphere for up to a few days. Also, passenger cars emit a higher amount of CO_2 during their exploitation if they are not properly/timely maintained [13].

Owing to the introduction of new standards and limitations, the emissions from automotive engines have been reduced significantly; however, engines are still the largest source of carbon monoxide and non-methane hydrocarbons. Engines are, also, the largest source of energy nitrogen oxides (35-40% of total emissions). About 60% amount of air pollutants in urban environments comes from internal combustion engines, regardless of whether they are powered by petrol or diesel [4].

The level of air pollution caused by traffic is influenced by:

- the age and the quality of vehicles
- the fuel quality
- the way traffic is organized in a particular city
- the position of the city on a map and the meteorological situation, etc.

The age of motor vehicles has a major impact on different types of emissions. In Serbia, the average age of the car is 15 years, according to the poll of the website www. *polovniautomobili.com*, conducted from February to September 2018, in which 31.988 registered site users took part. More than 40% of them said that the vehicle had been produced between 2001 and 2005. Fuel quality also plays an important role in the emissions of gases. According to the aforementioned survey, diesel fuel is convincingly in the first place. Even 54.99% of respondents said they were driving a diesel engine, 24.56% petrol engine, while 12.7% of the respondents were driving cars with a combination of petrol and gas [14].

There are other sources of pollution that are related to traffic. A large amount of particles is created by friction and wear between car tires and road surfaces. It can be said that traffic is the biggest source of air pollution in the world′s most developed countries. For this reason, during the last decades, lot of has been done in order to reduce emission of pollutants.

Air is the most indispensable natural source of life. By protecting the air we are protecting the human organism from introducing substances that are harmful to human health. The presence of harmful pollutants in the air not only reduces the air quality but also increases potential hazards to human health. The most vulnerable are sensitive groups: children, the elderly and chronic patients. A study conducted in 10 European cities shows that about 14% of chronic asthma cases occur in children due to traffic contamination, which, as estimated by the World Health Organization, is as harmful as passive smoking [15].

The Serbian Environmental Protection Agency implements operative monitoring of the air quality through the network of automatic stations for the air quality monitoring. In accordance with *The Regulation for establishing a program for control the air quality in the state network* [16], this network is, actually, the state network for monitoring the air quality. Based on the monitoring results, with the fulfillment of availability more than 90% of valid hourly values, the report on the air quality in the Republic of Serbia state level can be prepared. The report on the air quality also contains an assessment of the situation, which according to the *Law on Air Protection* represents the official assessment of the air quality in agglomerations and zones [17].

The Law on Air Protection comprehensively regulates air quality management, determines the measures, the organization and the implementation of the control process and air quality improvement. The Law states that mobile sources of pollution can be used and put into circulation if the pollutants in the exhaust gases from these sources do not exceed the emission limits determined by the technical regulations. Pollution emissions from mobile

sources are controlled during regular, occasional and control technical inspections, in accordance with the relevant technical regulation and with the law that regulates traffic safety.

Serbia implements *International Agreements for the Adoption of Uniform Technical Regulations* for vehicles with wheels, equipment, and parts that can be fitted and/or used on wheeled vehicles and conditions for mutual recognition of approvals based on these Regulations. The Traffic Safety Agency is responsible for the implementation of the above Agreement, in order to respect the UN / ECE regulations relating to the emission of harmful gases from road vehicles. The quality of gasoline and liquid fuels is regulated by the Ordinance on technical and other requirements for liquid petroleum fuels [18] adopted on the basis of the Law on Technical Requirements for Products and Conformity Assessment [19, 15].

On the basis of the Law on Air Protection, the categorization of air quality in relation to the limit and tolerance values as follows:

- The first category - pure or slightly polluted air where the limit values in case of one pollutant are not exceeded.
- The second category - moderately polluted air where the level limit values for one or more pollutants are exceeded, but no permissible values of any pollutant are exceeded.
- The third category - excessively polluted air where permissible values for one or more pollutants are exceeded.

Air protection is performed by systematic monitoring of air quality, reducing cut-off values of air polluting substances below prescribed limit values, undertaking technical, technological and other necessary measures for emission reduction, as well as by monitoring the impact of polluted air on human health and the environment. [10].

3. DATA AND METHODOLOGY

At the state level, the Republic of Serbia, as well as the units of local self-government, provides continuous control and monitoring of the state of the environment, in accordance with the Law on Environmental Protection. Monitoring is an integral part of the unique information system of the environment. Monitoring is carried out by systematic tracking of negative impacts on the environment, environmental conditions, measures and activities undertaken in order to reduce the negative impacts and raise the quality of the environment. The criteria for determining the number and layout of measuring points, the measuring network location, the extent and frequency of measurement, the classification of the phenomena to be monitored, the methodology and indicators of environmental pollution and their monitoring, the deadlines and manner of data delivery are prescribed by various laws [20] .

The minimum number of measuring points and sampling locations for the measurement of the concentration of sulfur dioxide, nitrogen dioxide, suspended particles, lead, benzene and carbon monoxide in the air is defined in accordance with Annex I, which is an integral part of the Regulation. The sampling procedure involves the preparation, sampling, storage and transportation of samples to an authorized laboratory. The procedure for analyzing air samples includes a laboratory test of air samples or their chemical and physical analysis. The results of the measurement of pollutant concentrations are compared with the prescribed

limit, allowable and limit values of air pollutants in order to determine the level of air pollution [20].

The Republic of Serbia has adopted 47 European standards dealing with air quality while 19 are currently being harmonized. There are several standards on the methods for pollutant assessments referred to in the Decree on the emission limit values for air pollutants:

- SRPS EN 14211: 2008 - Ambient air quality – The standard method for measuring the concentration of nitrogen dioxide and nitrogen monoxide based on hemiluminescence.
- SRPS EN 14212: 2008 - Ambient air quality – The standard method for the measurement of sulfur dioxide concentration based on ultraviolet fluorescence.
- SRPS EN 14902: 2008 - Ambient air quality – The standard method for the determination of Pb, Cd, As and Ni in the PM 10 fraction of suspended particles [21].

In this paper, we used the data from the Test Report No. I 25-36 / 17 of the Public Health Institute Krusevac Republic of Serbia are used [23]. This is a report on the state of air quality in the Municipality of Trstenik for 2017. The Municipality of Trstenik spans on the fertile valley of the Western Morava, on the slopes of Gledić Mountains (922 m) and Goč (992 m). On an area of 448 km^2, in 51 settlements there are nearly 50 000 inhabitants. The city itself is located on the right bank of the West Morava, at 172 m above sea level. About 17,000 inhabitants live in the city and suburbs. Trstenik is located in the central part of Serbia, West Pomoravlje (Latitude: 43.5° N. Geographical length: 21° E. District: Rasinski). The ratio between the plain and mountainous terrain is 30:70%, whereas the climate is moderate-continental. Average population density is 95.95 people / km^2. The number of rural settlements is 50. The number of urban settlements is 1. Total length of roads is 266 km. Agricultural area is about 28,144 ha and area covered by forests is about 12 583 ha [22].

The type of sample is air, more exactly aero-sediments. Air sampling was carried out in accordance with *The Instructions for Air Sampling.* The method of analyzing monitoring results is based on the criteria from the *Regulation on conditions for monitoring and air quality requirements*. The tests comprise of chemical analysis. The measurement of substances in the air is continuously carried out at the Public Health Institute in Kruševac. During 2017, the Institute monitored the following parameters in the municipality of Trstenik: sulfur dioxide, nitrogen dioxide, soot, total precipitants, and heavy metals in precipitants (lead, cadmium and zinc). The sampling and measurement principle for analyzing the content of sulfur dioxide and nitrogen dioxide is 24 hour sampling, where the sample analysis was performed in the laboratory using spectrophotometry. For analyzing the contents of the soot it was necessary to conduct 24 hours sampling and provide sample analysis in the laboratory with reflectometry.

The Auto-Moto Association Trstenik was the location point for measurements. After determining the statistical parameters, the mean value, the median, the minimum and the maximum value, the exact moment (day) when the concentrations were above the limits, we managed to obtain the annual results of the air quality.

4. Results and Discussion

According to the objectives of the test, air monitoring in the Municipality of Trstenik determined: the number and the arrangement of measuring points, the parameters of testing, testing period, the frequency of sampling, data processing, and reporting elements. The measuring point near the Auto-Moto Association of Serbia (AMSS) was located at the

intersection of the Kneginje Milice and Sveti Sava streets (coordinates 43°36′59.1"; 36'59.1"; 21°0'46.35"). The location of this measuring point is shown in Figure 1.

Fig. 1 Measuring point- AMSS Trstenik

The test parameters were: sulfur dioxide, nitrogen dioxide, soot, total precipitants, and heavy metals in precipitants (lead, cadmium and zinc). The sampling and measurement principle for content analysis is 24-hour sampling, from the beginning to the end of 2017, followed by sample analysis in the laboratory and corresponding chemical analysis. The equipment for the sampling of sulfur dioxide, nitrogen dioxide and soot, sedimentation and the appearance of the measuring spot is shown in Figure 2.

Fig. 2 Measuring point -AMSS Trstenik, equipment for sampling SO_2, NO_2 and soot (left), sediments (right)

Air sampling and laboratory testing were carried out by accredited methods, and the results of the tests were interpreted in accordance with *The Law on Air Protection and the Regulation on conditions for monitoring and air quality requirements*. Quality measurement testing, method of processing and display of results and assessment of their reliability and credibility shall be carried out according to the prescribed measurement methods and requirements of the SRPS ISO / IEC 17025 standard.

The assessment of air quality (the level of pollutants) is done on the basis of prescribed measurement methods and the requirements from the same standard and the prescribed numerical values. The results obtained are shown in Tables 1 and 2. According to the Regulation on monitoring conditions and air quality requirements, for a 24 hour sampling period, the sulfur dioxide limit value is 125μg/m^3. For the same sampling period, the maximum allowed value for the soot is 50μg/m^3, and for nitrogen dioxide it is 85μg/m^3.

After assessing the obtained results of the air quality control of the communal environment of Trstenik in the period from January-December 2017, we have reached certain conclusions.

Sulfur dioxide was continuously measured at one measuring point. The average annual value was 10.7 μg/m^3 and it was below the limit value. There were no days with values above the limit value. The soot was also continuously measured at the same measuring point. The measured average annual soot content was 12.5 μg/m^3 and was below the limit value. During this period, increased daily concentrations of soot were measured for 7 days in January. Moreover, the nitrogen oxides measured at this measuring site had an average annual value of 15.6 μg/m^3 and their concentration was below the limit value. However, during this period, increased daily concentrations were not measured.

According to the Regulation on conditions for monitoring and air quality requirements, the maximum allowable value for total precipitants on a monthly level is 450 mg / m^2 /24 h. The total precipitates were systematically measured at one measuring spot in the communal environment of Trstenik and the obtained values range from 55.7 mg /m^2 /24h to 244.2 mg / m^2 / 24h. Comparing the obtained results with the prescribed values, no higher values of total precipitants were recorded on a monthly basis. The quantity of heavy metals (lead, cadmium and zinc) was determined in the field of precipitations at this measuring site. However, recorded zinc concentrations are slightly lower than last year, while the concentrations of lead and cadmium in all samples are below the limit.

The annual report on air quality in the Republic of Serbia is prepared and published annually by the Environmental Protection Agency in line with the Law on Air Protection. The competent bodies of local self-government units and authorized legal entities are obliged to submit data on air quality obtained by air quality control from the state and local network, as well as the results of the other measurements [25].

According to the data, the average annual value of sulfur dioxide concentrations above the limit value (50μg/m^3) was not recorded in 2017. The annual limit value for nitrogen dioxide of 40 μg/m^3 is exceeded in Belgrade and Užice. The overall assessment of air quality for 2017 is as follows: in the zone of Serbia, in the cities of Valjevo, Kraljevo and Kragujevac, air quality was of the 1st category (clean or slightly polluted air). Similarly to the previous case, the air in Vojvodina was also ranked in the 1st category, except in Subotica town. *The air is heavily polluted in Belgrade, Niš, Pančevo, and Užice (*air quality is in the 3rd category). In agglomerations Novi Sad and Bor, the air was considered clean or slightly polluted. In the agglomerations of Smederevo and Kosjerić, due to the insufficient measurement, the air quality could not be estimated. In the territory of the towns Valjevo,

Kraljevo, Kragujevac and Subotica, the air was in the 3rd category, which means it was excessively polluted (see Figure 3) [24].

In accordance with the Article 5 the Law on Air Protection, the Regulation about the zones and agglomerations determination [26], there were three zones and eight agglomerations on the territory of the Republic of Serbia where the measurements were carried out. The assessment of air quality, based on the measured concentrations of air pollutants, is carried out using the assessment criteria in accordance with the Regulation on the conditions for monitoring and air quality requirements.

National and EU practices in the area of air quality are balanced by the adoption of the Law on Air Protection. EU regulations are summarized in Directive 2008/50, (DIRECTIVE 2008/50 / EC on ambient air quality and cleaner air for Europe), taken over and transposed into domestic regulations. In accordance with these regulations, operational automatic monitoring and air quality assessment in the Republic of Serbia is carried out [27].

The assessment of air quality can be monitored in real time on the website of the Environmental Protection Agency. Bearing in mind that site visitors are primarily interested in the quality of the air, and only after that the numerical values of individual parameters, on the home page (called MAPA) are presented the air quality estimates, based on the last 24-hour values of pollutants concentrations of pollutant. The SAQI_11 Index is determining for each pollutant and the worst pollutant is displayed.

Table 1 Basic air pollutants

Parameter		Month												Average annual value	Annual total number of days with value above LV/MAC	LV/ MAC
		January	February	March	April	May	June	July	August	September	October	November	December			
Content of sulphur dioxide	Measurement unit	mg/m^3														
	Method	VMI 25														
	Average Montly Concentration	16.7	15.2	11.2	8.8	9.5	8.2	9.8	6.6	10.5	12.0	12.4	7.0	10.7	0	125
	Number of days with value above LV*	0	0	0	0	0	0	0	0	0	0	0	0			
Content of soot	Measurement unit	mg/m^3														
	Method	VMI 43														
	Average monthly concentration	34.1	21.0	12.8	8.4	6.0	7.1	6.8	6.9	7.0	9.1	13.9	16.8	12.5	7	50
	Number of days with value above LV*	7	0	0	0	0	0	0	0	0	0	0	0			
Content of nitrogen dioxd	Measurement unit	mg/m^3														
	Method	VMI 30														
	Average monthly concentration	30.6	20.0	21.4	14.2	12.4	9.1	8.4	10.9	7.8	12.3	20.8	19.4	15.6	0	85
	Number of days with value above LV*	0	0	0	0	0	0	0	0	0	0	0	0			

** In Table 1 and 2: LV- limit value, MAC – max allowable concentrations*

The site visitor is provided with complete information and the possibility of insight into the estimates for all available measurements, as well as insight into the numerical values of the measurements. Given that there is no uniquely defined AQI in the EU regulations, which is introduced into national regulations, the Environmental Protection Agency SAQI_11 has been defined in the Environmental Protection Agency. In the SAQI_11 index indication, the part of the "AQI" tag is the usual indication for the air quality index, "S" indicates the national, Serbian, version, and "_11" indicates the year when it is defined. The air quality index SAQI_11 has 5 classes depending on the concentration of certain pollutants: excellent, good, acceptable, contaminated and highly contaminated [27].

The Air Quality Report in Europe provides information on the concentrations of most air pollutants at the state level for 33 EEA countries (the European Environment Agency) and 6 associates including Serbia. The 2018 report presents the data for 2016. This is followed by European air quality standards for health protection, as set out in the Ambient Air Quality Directives (EU, 2004, 2008), and the reference levels of pollutants prescribed by the World Health Organization (WHO), whose requirements are more stringent [28].

Table 2 Precipitation substances (results of chemical analysis)

Parameter	Measurement unit	Method	MAC*	1	2	3	4	5	6	7	8	9	10	11	12
Total sedimentary matter	mg/m^2/day	VM24	450	96.1	78.9	55.7	193.0	192.3	118.9	111.0	188.6	244.2	207.9	144.0	84.9
Zinc		VM23a	/	72.6	142.1	84.6	122.3	100.1	102.8	57.7	94.4	261.4	108.1	115.4	79.9
Lead	μg/m^2/day	VM23a	/	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Cadmium		VM23a	/	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

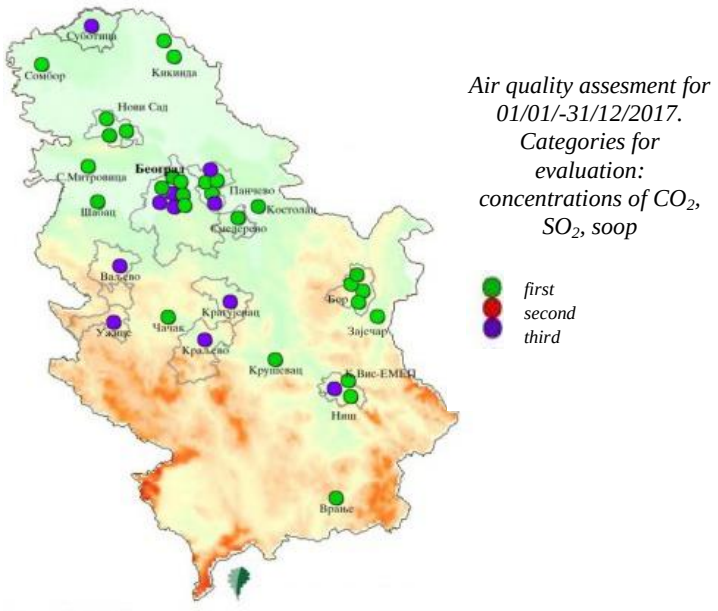

Fig. 3 Categories of air quality 2017 (*Environmental Protection Agency*)

5. THE MEASURES FOR IMPROVEMENT

In order to improve the air quality of the urban environment of Trstenik and to reduce the impact of air pollution on human health, the following measures have been proposed:

- Better regulation of roadway traffic
- Maintenance of municipal hygiene
- Continued construction of traffic bypasses and modernization of existing urban roads, along with the improvement of traffic regulation in the city
- Control of exhaust gases from motor vehicles during vehicle inspection
- Increased number of streets that will be regularly cleaned and washed
- Maintenance of green areas and trees in the city and creating protective green belts between industrial zones and the city area
- Prohibiting the transport of waste materials in the city streets
- Monitoring the impact of air pollution on human health and the environment

6. CONCLUSION

Air pollution is an ongoing topic, especially in cities where there are numerous sources of pollution, such as energy sources, traffic and industry. That way, primary pollutants like sulfur dioxide, nitrogen dioxide, carbon monoxide, particles soot, and other (related to the industrial processes in the observed area) can be found in the air. Also, traffic is a serious environmental threat. Moreover, it is directly related to air pollution which is responsible for negative impact on human health.

Air quality in Trstenik is mostly affected by soot. According to the measurements, soot is the pollutant with the limit values near the allowable ones (its values were above the limits during a 7-day period in 2017). However, all measured values of air pollutants are below the allowed values, so we can conclude that the quality of air in Trstenik for 2017 was good and that there was no pollution. To support this claim, even the zinc concentrations were slightly lower than during 2016.

In addition to the short-term measures for improving the air quality, which have already been mentioned, long-term measures should also be implemented. They must include the improvement of air monitoring programs, the accreditation of laboratories, the harmonization between national and European standards, the implementation of the air quality strategy, and the necessity of cooperation between all relevant institutions. To sum up, the development and implementation of environmental policies in the city of Trstenik, with the application of legal regulations and the integrated approach of all influential factors, can significantly improve ecological parameters.

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ANALIZA REZULTATA MONITORINGA KVALITETA VAZDUHA U OPŠTINI TRSTENIK

Privredni i društveni razvoj gradova, razvoj saobraćaja, donosi velike dobrobiti stanovnicima tih gradova ali, sa druge strane, negativno utiče na životnu sredinu. U radu je urađena analiza rezultata monitoringa kvaliteta vazduha u životnoj sredini u opštini Trstenik, za 2017. godinu, na osnovu izveštaja o ispitivanju Zavoda za javno zdravlje Kruševac, kao akreditovane laboratorije za ispitivanje, za korisnika opštinsku upravu Trstenik. Uzorkovanje je sprovedeno na jednom mernom mestu u Trsteniku, u toku 24 časa. Zatim je izvršena analiza dobijenih rezultata merenja, izveden zaključak o svim vrednostima zagađujućih materija i dat predlog mera za poboljšanje.

Ključne reči: *zagađenje vazduha, monitoring kvaliteta vazduha, životna sredina*