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RESEARCH ARTICLE

ANALYSIS OF THE RESULTS OF AIR QUALITY MONITORING IN THE AREA OF THE CITY OF ZENICA

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Abstract

According to the World Health Organization (WHO), air pollution is the largest single environmental risk to public health. According to the latest estimate of this organization, 9 out of 10 people on the planet breathe polluted air. The development of industry in the relatively small Zenica valley reflected on air quality in the city of Zenica. The problem of high air pollution due to emissions of pollutants from industrial sources, traffic, and individual furnaces, burning of environmentally unsuitable fuels containing high sulfur and ash content has been present in the City of Zenica for a long time. In addition, the low wind speed during the year, which ranges up to 1.5 m/s, with unfavorable temperature inversions, causes the concentrations of pollutants in the air to reach alarmingly high values in a short period. In the wider area of the City of Zenica, air quality has been monitored since 1978 in the network of stationary stations. The paper presents results of air quality monitoring which are analyzed at the Institute "Kemal Kapetanovic" in Zenica for the sampling period from 01.01.2019. to 31.12.2020. years. Air quality monitoring included sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and particulate matter (PM_{10}) at three locations in the wider area of the city of Zenica. In the wider area of the City of Zenica, air quality has been monitored since 1978 in the network of stationary stations. The paper presents the processed results of air quality monitoring which are analyzed at the Institute "Kemal Kapetanovic" in Zenica for the sampling period from 01.01.2019 to 31.12.2020. The measured concentrations of pollutants in the ambient air indicate that during the heating season, i.e. the winter months, the air quality in the urban and suburban areas of the city of Zenica is very poor. The data show that the highest hourly concentration of sulfur dioxide was recorded in December at the measuring station AMS Tetovo in the amount of 1100.59 µg/m^3, which is located in the settlement next to the metallurgical facilities of the industrial zone Zenica.

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Introduction:-

Air pollutants released in one location can reach another location through the atmosphere, where they can cause deterioration ofair quality. Sulfur dioxide, particulate matter, and nitrogen dioxide are today considered to be the pollutants that have the greatest impact on human health. Human body reacts differently to certain pollutants. The toxic effect of a pollutant can be shown after a few days or weeks or after prolonged and repeated exposure, while some substances cause a very serious problem already at the first exposure. Harmful substances from the atmosphere can disrupt growth, development, or shortening of life, up to disruption of important physiological functions (lung ventilation, oxygen transfer, sensory work) and a feeling of discomfort and accumulation of pollution in the body, and even death. The percentage depends on the value of the concentration, the duration of the action of the pollution, its physicochemical properties, the place of action, and the health condition of the organism. Studies [1, 2, 3, 4, 5, 6, 7], which have been conducted in the past, have shown that a large number of diseases and deaths can be associated with air pollution.

Air pollutants are substances (chemical elements and compounds) or groups of substances that are toxic, prone to bioaccumulation, and other substances or groups of substances that adversely affect human health. Pollutants from the air enter the body mostly through the respiratory system, skin, and digestive system. Various organic liquids, gaseous, and even solids can pass through undamaged skin. Solids can be taken through the lungs or can be transferred from the hands to food and thus reach the digestive system. However, the most exposed and at the same time the most sensitive organ are the lungs, in which exchange of matter is performed on over a 15 m^2 of alveolar membrane between blood and air. Particularly dangerous are particles with a diameter of less than 2.5 μm, which can pass all the barriers of the upper respiratory tract and enter deep into the lungs. Particles smaller than 1 μm can enter the bloodstream directly. A study conducted by C. Arden Pope 3rd et al [8] shows that exposure to combustion-related particles, whose diameter is generally below 2.5 μm, is a very significant factor in the occurrence of lung cancer.

Air quality monitoring in the area of the city of Zenica

The most common air pollutants that affect the health of the population are sulfur dioxide (SO_2), particulate matter (PM), nitrogen oxides (NOx), ozone (O_3), and carbon monoxide (CO). Harmful substances are often interconnected and it is difficult to separate their impact on the health of the population. In addition, interactions between different pollutants make it difficult to determine the effects of the action of each pollutant individually.

Air quality monitoring and monitoring methods are regulated by the Regulatin on the manner of air quality monitoring and defining the types of pollutants, limit values, and other air quality standards of the FBiH. According to the provisions of this Regulation, air quality is monitored by measuring the concentrations of sulfur dioxide, nitrogen oxides, carbon monoxide, ground-level ozone, suspended particles PM_{10} and $PM_{2.5}$, and lead, arsenic, cadmium, and nickel, as well as benzene and benzo-a-pyrene using automatic measurement or analysis of samples.

To establish an air quality management system and inform the public about the air quality, a network of air quality monitoring stations has been established in the area ofthe City of Zenica. Together with other stations in the area of Zenica-doboj Canton, they represent the basis for risk assessment of health disorders. The Government of Zenica-Doboj Canton has entrusted the establishment, management, servicing, and calibration of analyzers at automatic measuring stations to the Institute “Kemal Kapetanović” in Zenica, which has been engaged in this business for more than 40 years.

In the area of the City of Zenica, air quality monitoring has been performed since 1978 in the network of stationary manual stations in the wider area of the City of Zenica. Therefore, for the area of Zenica, there are valid data based on which the assessment of air quality is performed to protect the environment and human health.

In the City of Zenica as the largest economic center of Zenica-Doboj Canton, where air pollution is a long-standing problem, air quality monitoring is performedin the network of stationary manual stations. Starting from 2013, air quality monitoring is being established using automatic measuring stations to be able to declare episodic air quality conditions, because data from manual stations are only available the next day. Now the network of measuring stations in the city of Zenica consists of 3 automatic measuring stations managed by the Center for Environmental Monitoring of Zenica-Doboj Canton, which are positioned in following places:

- AMS Centar - Department Store "Bosanka" (urban part of the city),
- AMS Radakovo - Elementary school "Skender Kulenovic" (settlement Radakovo) and

- AMS Tetovo - Suburban settlement Tetovo,
which are used to monitor the air quality of air pollutants, namely: SO_2, NO_2, CO, and PM_{10}.

Figure 1 shows the position of automatic measuring stations in the City of Zenica.

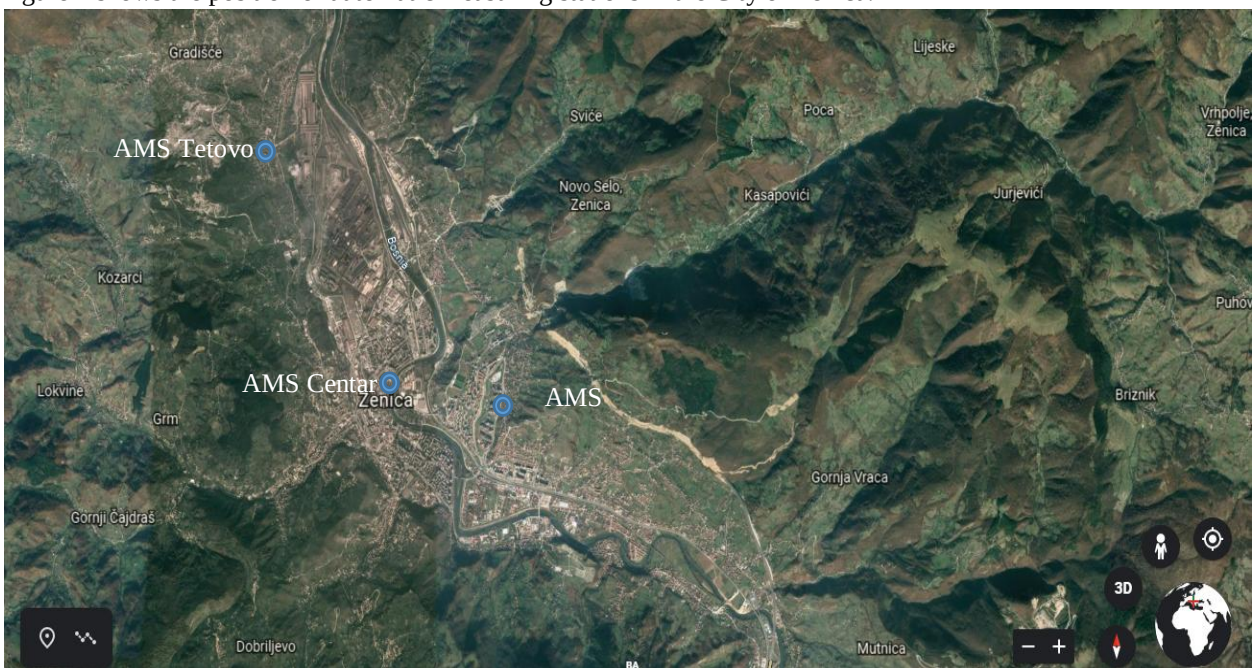


Figure 1:- The area of the City of Zenica with the indicated location of automatic measuring stations (AMS) of the Cantonal Network for Continuous Air Quality Monitoring.

Measuring station AMS Center - is located on the roof of the department store "Bosanka", which is located in the center of Zenica. Measuring station AMS Radakovo - is located on the roof of the Elementary School "Skender Kulenovic" in Radakovo. The measuring stations Centar and Radakovo are set at about 20 m above ground level, which allows unobstructed airflow in the sampling zone and is a good choice for assessing the background concentrations of the urban area ofthe city of Zenica. The measuring station AMS Tetovo is located in the suburban settlement of Tetovo in the street Tetovska bb, near the industrial zone where the metallurgical facilities are located. All three stationary automatic stations have been in operation since 01.01.2013. and are primarily intended for monitoring the level of air pollution in the urban environment of the city of Zenica. All stations are equipped with devices for measuring the concentrations of 6 pollutants in the air, a system for sampling ambient air for its chemical analysis, and devices for measuring meteorological parameters.

The following table shows the limit and tolerance values, upper and lower limit of air pollutant concentrations for air quality assessment, warning, and alert thresholds, as well as the minimum number of available data for individual air pollutants for 2019 and 2020 according to the Regulation on emission limit values for air pollutants in the FBiH.

Table 1:- Limit, tolerance, and values of warning and alert thresholds for pollutants prescribed by the Regulation on the manner of conducting air quality monitoring and defining the types of pollutants, limit values, and other air quality standards ("Official Gazette of FBiH", No. 1/12).

Pollutant	Limit value				Tolerance value				Warning threshold	Threshold alert
	1h	8h	24	year	1h	8h	24	year	1h	1h
Sulfur dioxide SO_2 (µg/m_3)	350	-	125	50	380-2019 365-2020	-	125	50	380-2019 365-2020	500
Nitrogen dioxide NO_2 (µg m_3)	200	-	85	40	220-2019 210-2020	-	93-2019 89-2020	44-2019 42-2020	220-2019 210-2020	400

Carbon monoxide CO (µg/m_3)	-	10	5	3		10-2016	5-2016	3	-	-
Floating particles PM_{10} (µg/m_3)				40				42-2019 41,5-2020	-	-

Table 2 gives the values of air quality parameters for episodic situations.

Table 2:- Determined air quality values for episodic situations (values missing in the table are not prescribed by the Federal Ordinance).

	Determined hourly values (µg/m^3)		
	For a standby episode	For a standby episode	For an alarming episode
Sulfur dioxide (SO_2)	350	380	500
Nitrogen dioxide (NO_2)	200	220	400
Ozone (O_3)	-	180	240

Air quality monitoring results

The results of monitoring the concentrations of pollutants in the air show the presence and exceeding of limit and tolerant concentrations, especially in the winter months. Figure 2 shows the measured average monthly SO_2 concentrations in the period 2019-2020.

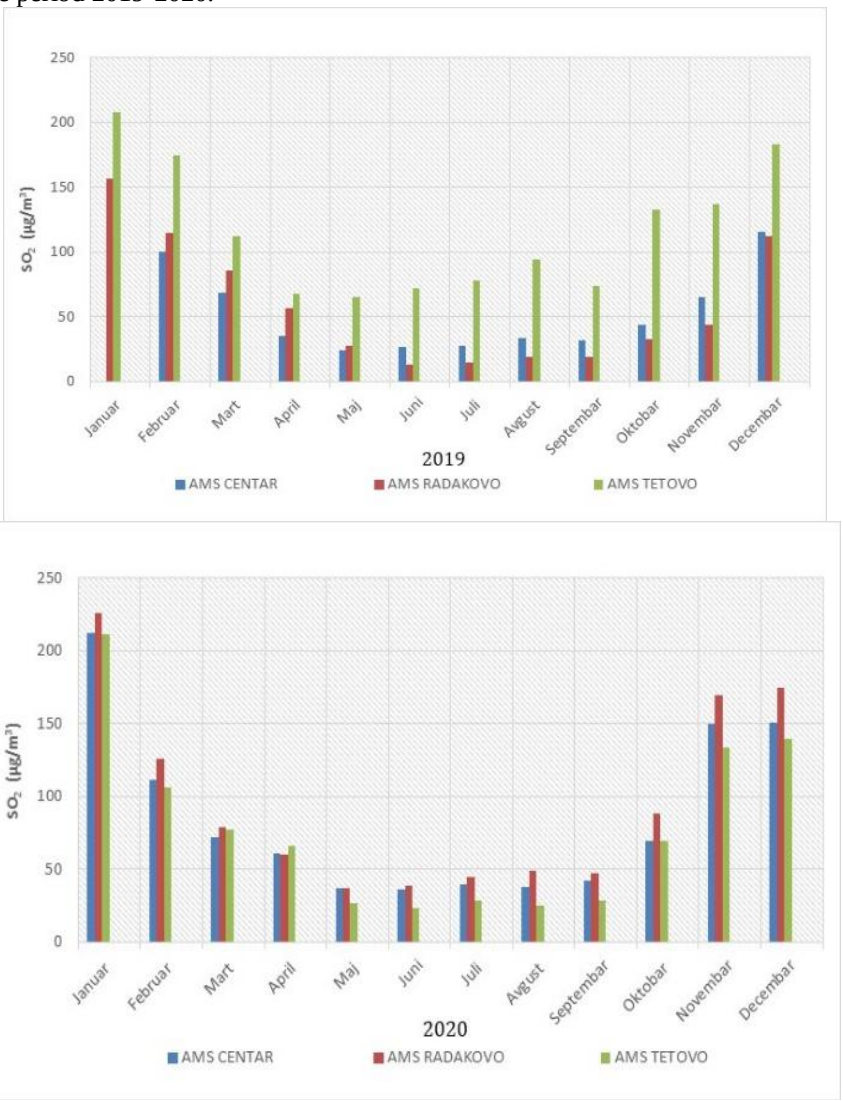


Figure 2:- Mean monthly SO_2 concentrations at measuring stations in Zenica for 2019 and 2020.

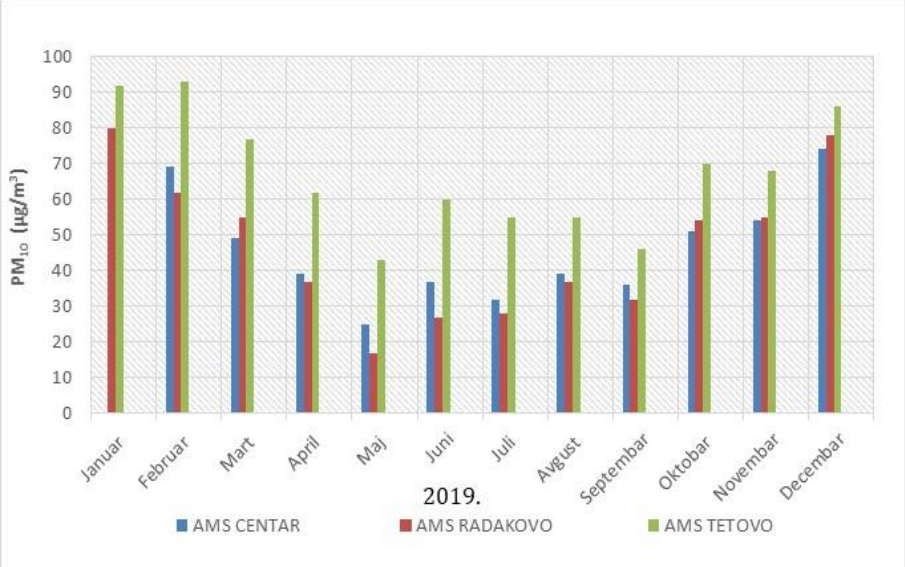
The measured values of concentrations show frequent exceedances of monthly concentrations of SO_2 in the winter, and the month with the maximum concentration is January 2020, when the average monthly concentrations of sulfur dioxide at all three stations were above 200 μg/m^3. The maximum permitted concentrations of SO_2 at the annual level (50 μg/m^3) were exceeded in both years in the periods January - April, and October - December, with the largest exceedances being registered in January and December. It can be seen from the diagram that in the periods with the largest exceedances of sulfur dioxide concentration all stations record almost the same concentrations because in that period inverse atmospheres occur which represent unfavorable conditions for dispersion of pollutants in air and pollutants accumulate below the inverse layer. in the entire Zenica valley. In addition, in the mentioned period, the highest hourly value of SO2 concentration of 1101 μg/m^{3}was registeredat the Tetovo station in January 2019. The following table provides a summary of sulfur dioxide concentrations and the number of exceedances of the limit daily and hourly sulfur dioxide concentrations in 2019 and 2020.

Table 3:- Aggregate data of sulfur dioxide concentrations of SO_2 during 2020 at measuring stations in the City of Zenica.

Air quality monitoring station	Number of valid daily averages	Percentage of valid measure-ments (%)	Number of days with daily concGV (>125 ug/m^3)	Highest daily conc. during the year	Number of hours with concentration (>350 ug/m^3)	Average annual concentration	Highest hourly value ug/m^3
2019							
AMS CENTAR	357	98	42	360	26	60	814
AMS RADAKOVO	356	98	44	367	17	58	672
AMS TETOVO	359	98	117	575	156	116	1101
2020							
AMS CENTAR	360	99	75	473	48	86	857
AMS RADAKOVO	348	97	78	633	46	92	928
AMS TETOVO	363	99	66	512	85	78	944

Sulfur dioxide can affect the respiratory system causing coughing, secretion, increasing asthma, and chronic bronchitis. Research [9] has shown that exposure to increased concentrations of sulfur dioxide increases mortality, especially in the part of the population with heart and lung diseases.

Figure 3 shows the average monthly concentration of suspended particles below 10 μm (PM_{10}). Based on the data obtained from the measuring stations, it can be noticed that the average monthly values exceed the annual limit values in the periods January - April, and October - December at all measuring stations. This exceedance was registered at the measuring station Tetovo throughout 2019. The highest concentrations of PM_{10}have been recorded in January 2020 at the measuring station Tetovo.



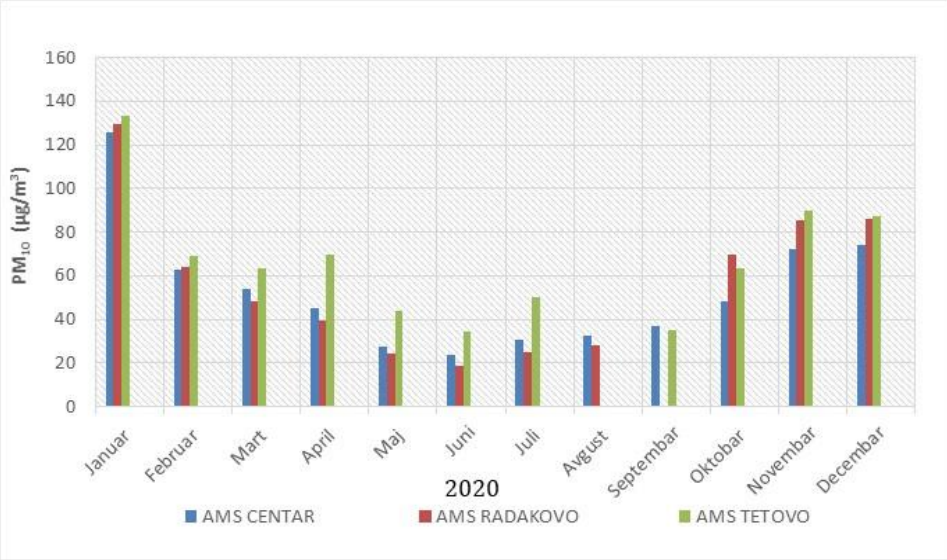


Figure 3:- Average monthly PM_{10} concentrations at measuring stations in Zenica for 2019 and 2020.

Based on the data on the values of PM_{10} concentrations registered at the measuring stations for air quality monitoring in the city of Zenica, it was determined that the annuallytolerable concentration of PM_{10} was exceeded in January, February, March, November, and December at all three measuring stations. Maximum concentration of $PM_{10}$was measured at the AMS Tetovo station in January 2020 with value of 133.5 $\mu g/m^3$. From Figure 3 it can be seen that the concentrations of PM_{10} at the Tetovo station are higher than the concentrations registered at the other two stations and that concentrations exceed the allowed annual average even in the summerdue to the proximity of metallurgical plants.

The following table provides a summary of the concentrations of PM_{10} suspended particles and the number of exceedances of the permitted daily and hourly PM_{10} concentrations in 2019 and 2020.

Table 4:- Aggregate data on the concentration of sulfur dioxide PM_{10} during 2020 at measuring stations in the City of Zenica.

Air quality monitoring station	Number of valid daily averages	Percentage of valid measurements (%)	Highest daily conc. during the year $\mu g/m^3$	Number of days with concentration (>50 $\mu g/m^3$)	Mean annual concentration $\mu g/m^3$	Highest hourly value $\mu g/m^3$
2019						
AMS CENTAR	351	96	168	114	49	327
AMS RADAKOVO	331	93	182	82	47	346
AMS TETOVO	296	84	197	152	66	444
2020						
AMS CENTAR	357	98	263	132	53	698
AMS RADAKOVO	308	86	272	125	56	447
AMS TETOVO	207	62	197	133	70	446

An overview of the emission balance in the City of Zenica, according to the Register of air pollution sources in the Zenica-Doboj Canton, shows that sulfur dioxide emissions predominantly come from industrial and energy plants, accounting for about 70% of total emissions in Zenica and small home fireplaces with a share of about 30%.

Suspended PM_{10} particles are very harmful to human health because they can cause blockage and inflammation of the nasal and bronchial passages, and thus cause a series of respiratory disorders that can lead to disease. Particulate matter $PM_{10}$is known to contain a significant proportion of $PM_{2.5}$ and PM_1 fractions. Data from the measuring station Vranduk, located 8 km north of the metallurgical facilities, show that the particulate matter PM_{10} contains about 80% $PM_{2.5}$ and 75% PM_1(research conducted by the Institute "Kemal Kapetanović" in Zenica for 2020 by

simultaneously measuring PM_{10}, $PM_{2.5}$ and PM_1 at the measuring station Vranduk). Exposure to high levels of $PM_{2.5}$ and PM_1 can cause a range of heart disease and cardiovascular disease [10].

The following figure shows the average monthly NOx concentrations (expressed as NO_2) for 2019 and 2020. The picture shows that from September 2019 to February 2020, the annual limit value of NO_2 at the Tetovo measuring station was exceeded. In the period September 2020 - December 2020, exceedances of the allowed annual value were registered at the Radakovo station. The highest NO_2 concentration was registered in the cold part of the year, with the highest hourly concentration recorded at the Tetovo station in December 2020 with value of 186.8 μg/m^3.

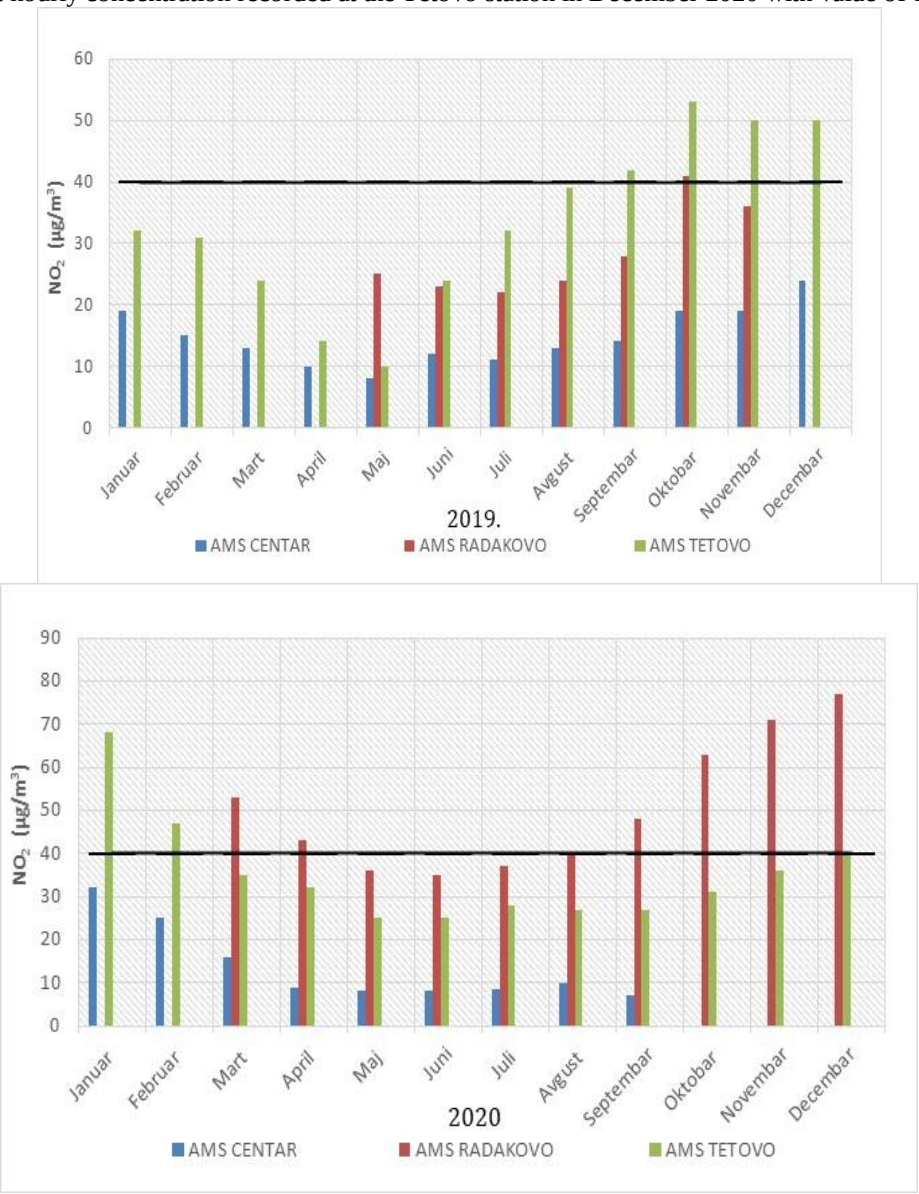


Figure 4:- Average monthly NO_2 concentrations at measuring stations in Zenica for 2019 and 2020.

Based on the processed data on CO concentrations, it was determined that the permitted average value at the annual level was not exceeded. Exceedances of the allowed hourly and eight-hour averages were not recorded in 2019 and 2020. This pollutant very rarely compromises air quality and concentrations remain within the prescribed limit values.

An annual concentration limit for ozone is not prescribed, but a permitted maximum of eight-hour ozone value is prescribed. In 2019, exceeding the eight-hour limit value was recorded at all stations, with the highest eight-hour

value and the largest number of days with an eight-hour average greater than 120 μg/m^3 being registered at the Radakovo measuring station.

Discussion Of Results:-

In the city of Zenica, the biggest airquality problem is pollutants SO_2, PM_{10}, and organic matter caused by the combustion of fossil fuels and low-quality coal in various industrial plants, small home fireplaces, and internal combustion engines. These pollutants mostly cause respiratory health problems in the population.

An overview of the emission balance in the area of the City of Zenica, according to the register of air pollution plants in the Zenica-Doboj Canton, shows that PM_{10} emissions predominantly come from industrial and energy plants, accounting for 62% of total emissions from all sources in Zenica. Therefore, industrial and energy plants in the area of Zenica predominantly pollute the air with PM_{10} particles.

According to the data of the Institute for Health and Food Safety Zenica on the number of diseases of the respiratory system, about 14,500 inhabitants get sick every year. The following table provides data on the number of registered diseases of the respiratory system by age groups for 2018 and 2019. According to the given data, the age group from 20 to 65 suffers the most from diseases of the respiratory system.

Table 5:- Number of registered diseases of the respiratory system by age groups in 2019;

Age	0 - 6	7 - 19	20 - 65	> 65	TOTAL
Number of patients 2018	2673	4264	5262	2378	14577
Number of patients 2019	479	4580	7690	1880	14629

Note: Data for 2020 have not been processed until the publication of this paper.

Conclusion:-

Concentrations of pollutants in the sampling period in 2019 and 2020, measured at three automatic measuring stations in the City of Zenica, exceeded the limit values, especially in the winter. According toRegister of air pollution sources in the Zenica-doboj Canton, the biggest problem of air pollution in the city of Zenica are pollutants caused by the combustion of various fuels from industrial plants and small house stows. A large number of diseases of the respiratory system registered in the areas of the City of Zenica can be associated with excessive air pollution with sulfur dioxide and PM_{10} particles.

Poor air quality in the City of Zenica requires the implementation of planned measures to reduce emissions and improve air quality to protect human health and provide conditions for further development. To improve air quality in the areas of its excessive pollution and protect air quality in the area of the City of Zenica and the entire Zenica-doboj Canton, it is necessary to establish an air quality management system. In that sense, it is necessary to implement all measures related to reducing the emission of pollutants from industrial plants and small house stows. It is estimated that ecologically unsuitable coal with a high content of sulfur and ash will be used in small house stows in the next 10 years.

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