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Research Paper

Air Pollution Analysis in the Republic of North Macedonia

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Abstract: The Republic of North Macedonia for many years is among countries with high pollution rates of the atmosphere. Based on that fact, the purpose of this paper is to ascertain which are the polluting substances, why is this concerning, what are the consequences of the pollution and what actions have to be taken to improve this situation. Our research is based on data analysis collected from Automatic Monitoring System for air pollutants, that function within the Ministry of Environment and Physical Planning. Initially, we have found the average of monthly and annual values and compared them to the limited values allowed per year. We have also analysed how these values have changed during winter and summer seasons, comparing with the level of pollution that was present at the time the Jugokrom Ferroalloys plant was working. The results show that since 2012 we have been constantly polluted with PM_{10} and $PM_{2.5}$ particles on levels many times higher than allowed. Whereas, in times when the plant has not worked, there has been a decrease in the level of pollution for several times. We can conclude that the environmental pollution is strongly impacted by the use of different types of fuel combustion during which PM_{10} and $PM_{2.5}$ particles are released, which according to the WHO are classified among the first group of carcinogenic particles. This has led to increased diseases and cancer mortality.

Keywords: *air pollution, combustion fuels, PM_{10} and $PM_{2,5}$ particles, average values, pollution monitoring*.

Introduction

In today's world, human society is facing problems of various natures. One of the problems developing countries are facing, including the Republic of North Macedonia, is air pollution. According to data from various relevant institutions in the world, respectively according to a study conducted by the World Bank, it has been found that in the RNM 1350 people die every year as a result of air pollution and economic losses from the pollution consequences are around 3% of Gross Domestic Product. Also, according to the European Environment Agency's numerous reports of consecutive years, including the last year, indicate that RNM, specifically many of the cities such as Tetovo, Skopje, Kumanovo and Bitola are among the cities with the most polluted air. According to Pollution Index by City 2020 Mid-Year (URL.01) and WHO (URL.02) Tetovo is ranked in the first place in the world as the most polluted city with PM_{10} and $PM_{2.5}$ particles. According to the WHO, these particles are classified in the first group of carcinogenic particles, namely particles with a strong carcinogenic action. If the level of PM_{10} and $PM_{2.5}$ particles increases by 10 $\mu g/m^3$ above the Permitted Limit Values, carcinogenic diseases increase by 22% and 36%, respectively. According to WHO, mortality worldwide caused by air pollution is 22%, while in the city of Tetovo it is 38% according to relevant health institutions and doctors of this hospital (URL.03). The Ministry of Environment and Physical Planning in cooperation with UNDP and the City of Skopje, in January 2017 conducted a comprehensive study on the way of heating in Skopje, which included 5044 households in all 17 urban and rural municipalities of the city. According to a report from this research it results that 47% of households use solid fuel for heating (wood, coal, pellets, briquettes, or other), 31% use electricity and 21% are connected to the central heating system. The same study shows that wood as a fuel for household heating participates with 28.2% in urban areas and 85.7% in rural ones (Dimitrovski & Dzambaska, 2017).

Materials and Methods

Measurement of air parameters by automatic monitoring system

Air pollution research will be based on data collected from the automatic monitoring system. This system makes permanent measurements of air quality 24 hours a day and throughout the year. In the

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RNM such systems are located in 12 cities. The data are sent to the central system and are transparent at any time within the Ministry of Environment and Physical Planning. Mostly, the measured air pollutant parameters are: CO, NO_2, O_3, SO_2, and PM_{10} particles, while $PM_{2.5}$ particles are measured only in the cities of Skopje (in three locations), Tetovo, Bitola and Kumanovo. The measurement of PM_{10} particles in Skopje is done in five, namely six locations, where one location in Butel has a mobile monitoring system, in two places in Bitola and in other cities only by one monitoring system. According to the Law on Environmental Air Quality the Permitted Limit Values for Pollutants in the RNM from 2012 are presented in the table below.

Table 1. Permitted Limit Values (PLV) for air pollutants (Ministry of Environment and Physical Planning of Republic of Macedonia, 2013-2018)

Pollutants	Evaluation Time	Limit Value	Allowed days of exceedance per year	The year by which the limit value should be reached	Informing and Alarming Limit	
					Period	Threshold Value
SO_2	1 hour	350 µg/m^3	24	2012	3 hours	**500 µg/m^3 ****
	24 hours	125 µg/m^3	3			
NO_2	1 hour	200 µg/m^3	18	2012	3 hours	**400 µg/m^3 ****
	1 year	40 µg/m^3	0			
PM_{10}	**24 hours**	**50 µg/m^3**	**35**	**2012**	2 days	**100 µg/m^3** stable conditions *
Particles	**1 year**	**40 µg/m^3**	**0**		2 days	**200 µg/m^3** stable conditions ** From 01.01.2022 it is going to be 150 µg/m^3
$PM_{2.5}$ Particles	1 year	**25 µg/m^3**	0	**2020**		
		20 µg/m^3	0	2025		
Pb	1 year	0.5 µg/m^3	0	2012		
Benzene C_6H_6	1 year	5 µg/m^3	0	2012		
CO	Average Daily Value during 8 hours	10 mg/m^3	0	2012		
O_3	Max. Daily	120 µg/m^3	25	120 µg/m^3	1 hour	**180 µg/m^3***

* *Informing limit, ** alarming limit*

From Table 1 we see that according to the ***Law on Environmental Air*** from 2012 the Permitted Limit Values apply as shown in the table above. This means that any excess of these values of air pollutants represents air pollution. Therefore, we will analyse data from the automatic monitoring system starting from 2012 until 2019, where we will see which of the pollutants were above the Permitted Limit Values, in which year, in what season and what were the Average Monthly and Annual Values above the allowed limit.

Considering that the monitoring system provides daily average of data, for our needs and further analysis we will find/present with tables the ***Average Monthly and Annual Values*** for particle pollutants, for each year and for each measuring location in order to analyse and compare pollution in the ***Winter*** season (October, November, December, January, February, March) and ***Summer*** season (April, May, June, July, August, September).

From the tabular data, we will draw conclusions about:

- *What were the Average Monthly Values in each measuring location?*
- *What were the Average Monthly Values in the Winter and Summer seasons?*
- *Have there been any air quality improvements from 2012 to 2019 or not, and*
- *How were the Average Annual Values in different settlements in relation to the Permitted Limit Values?*

Due to a large number of tables for Average Monthly Values for each year, in the following table we will present only the Average Annual Values (AAVs) for PM_{10} and $PM_{2.5}$ pollutants, separated according to the seasons from 2012 to 2019.

Analysing the annual reports on the quality of the environment from 2012 to 2019, specifically on the air quality monitored by the automatic monitoring system, which as mentioned above monitors pollutants as: SO_2, NO_2, CO, O_3, and PM_{10} and $PM_{2.5}$ particles, we have ascertained which of these pollutants was above the permitted values. From the analysed reports we conclude that:

- *There was no excess of air pollution with **SO_2** and **NO_2** in any year.*
- *Partly, in some years and some cities we have an excess of pollutants such as **CO** and **O_3**, at very low levels above the permitted values, and*
- *Throughout the years, starting from 2012 to 2019 there is an excess of the PLV or pollution of the atmosphere with **PM_{10}** and **$PM_{2.5}$** particles.*

Results and Discussions

Analysis of annual reports on the quality of the environment

Considering that the air pollution is mainly caused by **PM_{10}** and **$PM_{2.5}$** particles, we have analysed only these pollutants. Since data from the monitoring system is provided daily throughout the year, we have found the Average Monthly Values to analyse the pollution by seasons and the Average Annual Values to compare with the Annual Permitted Limit Values.

Table 2. Average Annual Values of PM_{10} and $PM_{2.5}$ particles

No.	City	Year	2012		2013		2014		2015		2016		2017		2018		2019	
		Location	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5
		PLV µg/m³	40	25	40	25	40	25	40	25	40	25	40	25	40	25	40	25
1	SKOPJE	*Center*	85	53	73	40	64	50	70	39	63	27	57	38	54	28	46	34
		Karposh	75	52	68	32	61	41	64	50	61	52	64	48	54	39	45	42
		Lisiche	122		85		90		88		78		76		57		55	
		Gazi Baba	116		61		84		79		78		73		49		42	
		Rektorat	86		69		68		67		71		82		73		58	
		Butel													44	34	48	48
		AAV	97	53	71	36	73	46	74	45	70	40	70	43	55	34	48	32
2	TETOVA	AAV	157		150		134		147		97		59	44	50	42	63*	50
3	MANAST.	Manastir 1	74		73		54		54		48		48		45		47	
		Manastir 2	155		0		0		68		58		59	32	47	35	54	
		AAV	115		73		54		61		53		54	32	46	35	52	44
4	KUMAN.	AAV									64		67	38	52	37	54	38
5	ILINDEN	AAV	50		47		50		41		44		54		50		46	
6	VELES	AAV	69		51		61		51		41		40		61		*50	
7	KAVADA.	AAV			111*		81		56		47		62		56		66	
8	KOCHANI	AAV	116*		59		46		50		44		41		40		38	
9	KICHEVO	AAV	207*		79		77		80		61		48		42		71	
10	LAZAR.	AAV	14		20		24		15		11		10		12		15	
11	GOSTIVAR	AAV													49		40	
12	STRUMICA	AAV													52		52	

* During 2012, the measurement was made only in December

Table 2 shows the Average Annual Values of PM_{10} and $PM_{2.5}$ particles in all measuring locations of all respective cities where measurements are performed.

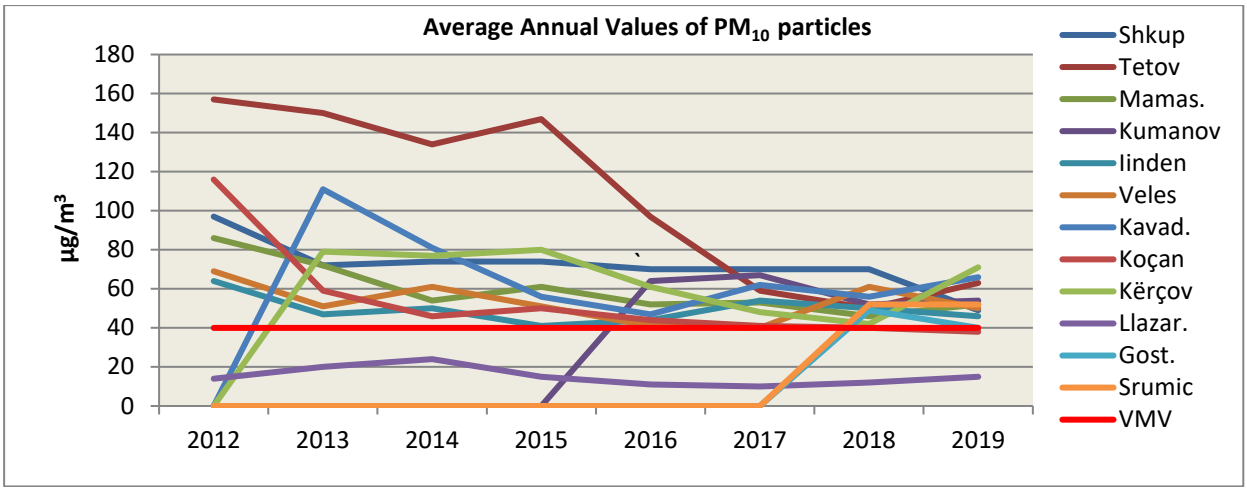

Figure 1. Average Annual Values for PM_{10} particles for the period 2012 - 2019

Table 3. Average Annual Values for PM_{10} particles by season, for the period 2012 – 2019.

No.	City	Particles	PLV	2012			2013			2014			2015			2016			2017			2018			2019		
			µg/m3	Winter	Summer	AAV	Winter	Summer	AAV	Winter	Summer	AAV	Winter	Summer	AAV	Winter	Summer	AAV	Winter	Summer	AAV	Winter	Summer	AAV	Winter	Summer	AAV
1	Skopje	PM10	40	142	51	97	101	44	72	103	44	74	106	42	74	100	39	70	103	37	70	76	38	55	64	31	49
2	Tetova	PM10	40	272	88	*157	212	89	*150	191	77	*134	213	81	*147	120	74	97	80	38	59	71	29	50	74	30	63*
3	Manastir	PM10	40	133	39	115	83	64	73	68	40	54	88	33	61	71	33	53	70	35	53	63	31	46	53	28	52
4	Kuman.	PM10	40													91	42	64	94	40	67	71	33	52	66	31	54
5	Ilinden	PM10	40	83	38	64	56	38	47	64	36	50	53	29	41	59	29	44	76	32	54	66	35	50	62	30	46
6	Veles	PM10	40	99	44	69	60	45	51	76	46	61	69	34	51	59	24	41	51	29	40	81	45	61	50	0	*50
7	Kavadar	PM10	40				102	125	111*	90	55	81	75	38	56	64	29	47	79	45	62	73	40	56	69	55	66
8	Kochani	PM10	40	116	0	116*	59	0	59	60	37	46	65	35	50	54	33	44	51	31	41	50	31	40	46	30	38
9	Kichevo	PM10	40	207	0	207*	114	44	79	110	43	77	119	40	80	85	36	61	69	27	48	61	23	42	85	42	71
10	Lazarop.	PM10	40	20	11	14	15	22	20	28	20	24	11	16	15	6	14	11	7	13	10	10	15	12	11	18	15
11	Gostivar	PM10	40																			63	37	49	64	21	40
12	Strumica	PM10	40																			75	33	52	78	27	52

Table 3 presents the Average Annual Values of PM_{10} particles for the Winter and Summer season.

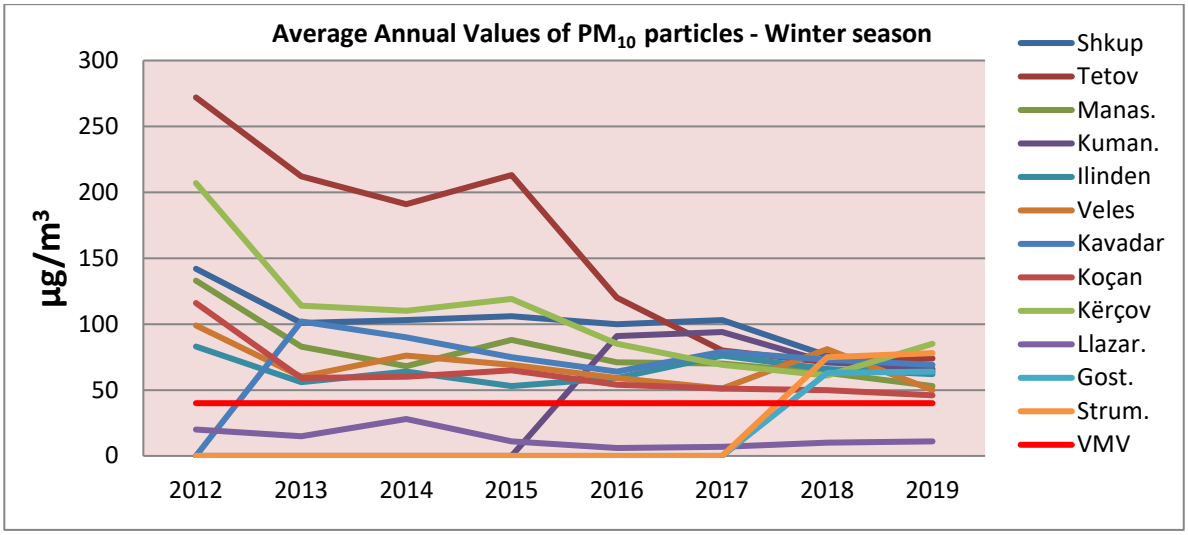

Figure 2. Average Annual Values of PM_{10} particles during Winter season

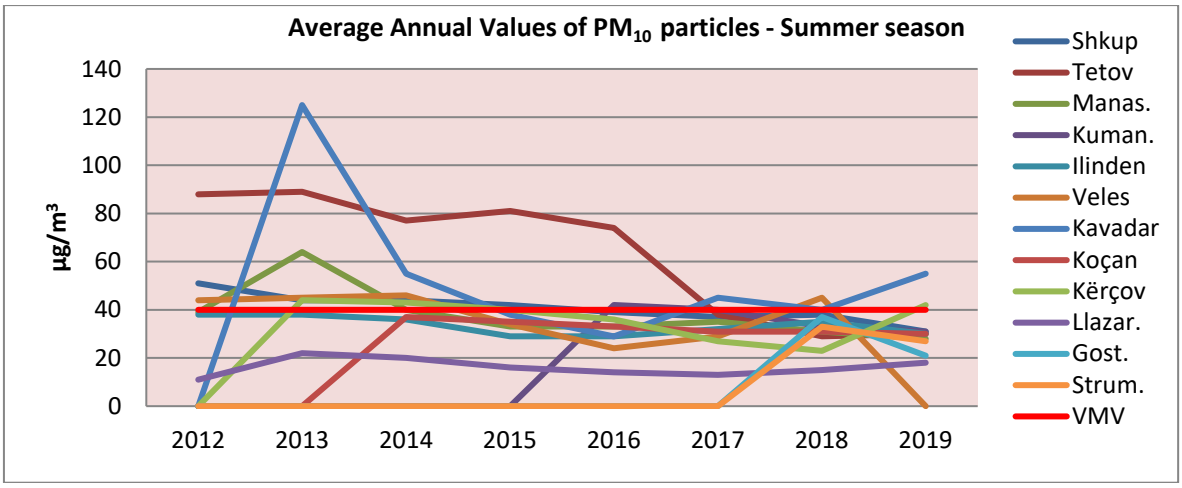

Figure 3. Average Annual Values of PM_{10} particles during Summer season

Table 4. Average Annual Values for $PM_{2.5}$ particles by season, for the period 2012 – 2019

No.	City	Particles	PLV	2012			2013			2014			2015			2016			2017			2018			2019		
			µg/m3	Winter	Summer	AAV	Winter	Summer	AAV	Winter	Summer	AAV	Winter	Summer	AAV	Winter	Summer	AAV	Winter	Summer	AAV	Winter	Summer	AAV	Winter	Summer	AAV
1	Skopje	PM2.5	25	79	26	53	55	20	36	51	32	40	64	25	45	59	20	39	63	23	43	47	22	34	41	23	33
2	Tetova	PM2.5	25																60	20	43	66	19	42	61	19	50
3	Manastir	PM2.5	25																43	15	32	56	17	35	50	10	44
4	Kuman.	PM2.5	25																53	17	38	56	19	37	48	18	38

In Table 4 we have presented the data on the Average Annual Values for $PM_{2.5}$ particles for the entire year as well as divided into Winter and Summer seasons.

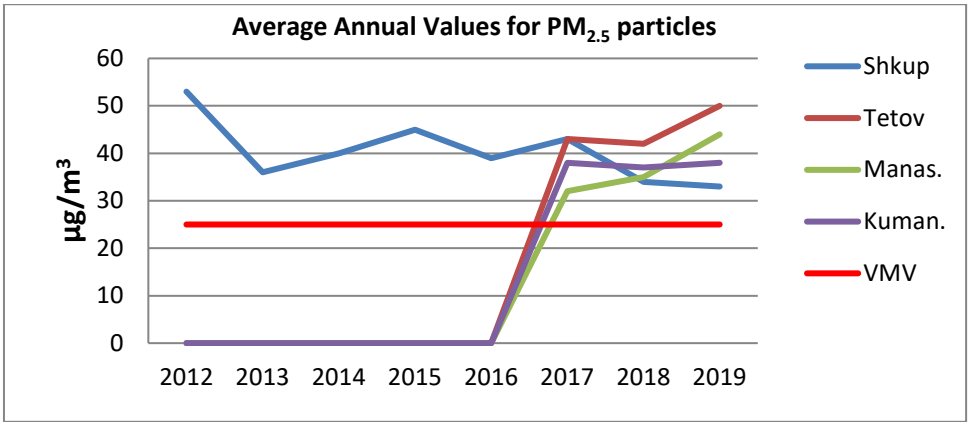

Figure 4. Average Annual Values of $PM_{2.5}$ particles

Analysis of PM_{10} particles

The Annual Permitted Limit Value of PM_{10} particles as shown in Table 1 is 40 µg/m^3. The measurement of PM_{10} particles in North Macedonia as shown in Table 2, is done in 5 locations - municipalities of Skopje and in a mobile station in two measuring locations in the city of Bitola and in 10 other cities of the country. The measurement of particles in these settlements has started since 2012, but often times in different settlements these stations did not work during the year. In the last two settlements the measurement has started from 2018. As seen from Table 2, but also from the graph in Figure 1, the lowest Average Annual Values have been measured in Lazaropole throughout the years from 2012 to 2019. Only in the cities of Veles in 2017 and Kocani in 2018 the Average Annual Values were 40 µg/m^3 and 38 µg/m^3, in 2019 the city of Gostivar was 40 µg/m^3, which are equal to the Permitted Limit Values. Whereas the Average Annual Values were higher than the Permitted Limit Values in all

other cities from 2012 to 2019. Based on the measured results, we can say that these higher values were in the city of Skopje, Tetovo, Bitola and Kumanovo. But, above all, the highest rate of pollution was registered in the city of Tetovo from 2012 to 2016, starting from 157, 150, 134, 147 to 97 μg/m^3.

Analysing Table 3 and the diagrams in Figures 2 and 3, we can see that there is a big difference between the winter and summer seasons. The only city during the winter season where the Average Annual Values of PM_{10} particles are below the Permitted Limit Values is Lazaropole, while in all other cities the AAVs of PM10 particles are higher than the Permitted Limit Values. While, during the summer season the AAVs in almost all measuring locations have been below or very little above the Permitted Limit Value. Only in the city of Tetovo as seen from the diagram in Figure 3, the AAVs from 2012 to 2017 were higher than the Permitted Limit Value.

Analysis of $PM_{2.5}$ particles

The Permitted Limit Value for $PM_{2.5}$ particles as shown in Table 1 is **25 μg/m^3**, and this is approved since January 2020. According to this, the Average Annual Values for $PM_{2.5}$ particles for the years before 2020 that have been higher are not considered as excess/pollution of the environment. The measurement of these particles from the monitoring system started in 2012 in two locations in Skopje, while from 2017 the measurement of $PM_{2.5}$ particles has started in the following cities: Tetovo, Bitola and Kumanovo. Table 4 shows the Average Annual Values of $PM_{2.5}$ particles. Although we mentioned that the Permitted Limit Value for these particles was approved by law in the RNM in January 2020, this does not mean that they have not been harmful to people's health. Based on Table 4 and the diagram in Figure 4, it can be seen that these values have been below the Permitted Limit Value during the summer season, while during the winter season these values of $PM_{2.5}$ particles have been above the Permitted Limit Value in all measuring locations.

Analysis of pollutants for the city of Tetovo

Considering the fact that of all the measuring locations, the largest scale of pollution has been recorded in the city of Tetovo, we will continue to further analyse the pollution in this city. Below we have presented a table with the days of exceeding the allowed pollution during the year, for the period from 2012 to 2019, the number of days that the monitoring system hasn't been working, as well as the Average Annual Values for each year. We will also provide some important data which will serve us to analyse the pollution of the city's atmosphere. What is thought to have affected the air pollution in Tetovo is the working of the metallurgical plant in the village of Jegunovce. Therefore, we will analyse the work of this plant from 2012.

- From 2012 - 2015, the plant has worked continuously at full capacity
- In 2016, in the months of January, February and November, December it stopped working
- From 2017 onwards, it has not worked at all.

Table 5. Data on pollution in the city of Tetovo

Year	Days with exeeded values	Days when the system did not work	AAV μg/m^3	Decrease %
2012*	**198**	**140**	157	
2013*	**300**	**29**	150	*
2014*	**330**	**0**	134	
2015*	**350**	**0**	146	
2016**	**297**	**6**	97	1. /3
2017	**136**	**37**	59	61%
2018	**134**	**4**	50	
2019	**120**	**151**	63	

** -the years when the plant was operating*
*** -the year when the plant ceased operations for 4 months from 2017 onwards - period when the plant was not operating all year*

From Table 5 we see that the highest Average Annual Values were from 2012, 2013, 2014 and 2015 at 157, 150, 134 and 146 μg/m^3, which means that they were almost four times higher than the Permitted Limit Values (40 μg/m^3). In these years, the number of days with pollution that exceeds the allowed

values is very large, almost all year. We must emphasize that according to the law, the number of days with exceeding pollution of 50 μg/m^3 within 24 hours during a year is 35 days.
In 2016 the Average Annual Value is 97 μg/m^3, so we have a reduction of the pollution rate by approximately 1/3. This reduction in pollution corresponds to the non-operation of the plant for 4 months or 1/3 of the year. From 2017 onwards when the plant is not working at all, we see that the Average Annual Value of air pollution in Tetovo has decreased by 60%. Also, the number of days with excess of pollution is significantly lower, which shows that this is also related to the working activity of the metallurgical plant.

Conclusions

Analysing the data from the monitoring systems presented in tabular form and graphs, we can conclude that the Average Annual Values of pollutants, PM_{10} and $PM_{2.5}$ particles have been higher than the Permitted Limit Values in all measuring locations, except in Lazaropole. Exceeding the Permitted Limit Values has also occurred during the summer season in some cities, where Tetovo is worth mentioning for the period of 2012-2015, specifically 2016. But, the highest rate of pollution-many times higher than the Permitted Limit Values has occurred during the winter season in all settlements except Lazaropole. In some cities such as Tetovo, Skopje, Bitola and Kumanovo the pollution has been very high which has often made these cities to be ranked as the most polluted cities in the world. The main cause of pollution as shown by the study of the Ministry is the use of fossil fuels. But that study conducted in 2017 was focused only on fossil fuels which is used in households and according to it the main cause of air pollution is exactly the use of fuel used for heating in households.

The fact that the cities with the most polluted air are Tetovo, Skopje, Bitola and Kumanovo shows something else. These cities not only have a larger population but in these cities are also located some industrial production capacities which are users of fossil fuels. Therefore, if we find that the source of pollution is fossil fuel, then we must also consider the amount and type of fuel used in these industries. From 2012-2015 the city of Tetovo was the highest polluted city and this corresponds with the fact that during this time the electrometallurgical plant worked at full capacity, which used large quantities of coal and wood fuel, which compared to the quantity of fuel used in Tetovo in all activities is in the ratio 61% to 39% (Idrizi, 2007). Being close to the city and having high chimneys, it is very vulnerable to the wind which is directed towards the city, so all the polluting particles are distributed in the city Tetovo and the surrounding area. From this, it follows that it participates in the same percentage in air pollution. This is best proved by the fact that:

- in 2016, when the plant stopped working for 4 months, which is 1/3 of the year, the Average Annual Values of air pollution decreased to 97 μg/m^3, exactly by 1/3.
- from 2017 onwards when the plant does not work at all, the Average Annual Values of air pollution have decreased to 59, 50, and 63 μg/m^3, or approximately by 60%.

Therefore, based on the pollution analysis for the city of Tetovo where it is very clear how the industry and the use of fuel in industry affects air pollution. The study conducted by the Ministry of Environment and Physical Planning, UNDP and the City of Skopje, cannot determine the main source of pollution in the city of Skopje, as this study did not analyse the amount and type of fossil fuels used in industry, production activities and traffic in the localities where the study was conducted. Also, data on the amount and type of incinerated waste imported from abroad were not taken into account. These activities use a large amount of fuel which in any case affects air pollution.

Also, the other fact why the pollution is greater during the winter season should not be sought only in the use of fuel for heating, but we must keep in mind that at this time atmospheric conditions also affect that these pollutants are not distributed over long distances and remain in the nearby locality where they are created.

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