Long-term changes in air quality. The case of Pristina (Kosovo)

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Abstract: Rapid socio-economic development and urbanization have contributed to the serious deterioration of air quality in many world cities including Pristina, the capital of Kosovo. Through a data-driven analysis of regulatory intervention, this study attempts to examine the effectiveness of air pollution control regulations that have been implemented in Kosovo between 2010–2021. Our results show that the measures enforced during this 10-year period in Kosovo, and particularly in the capital city, have resulted in the reduction of pollution. The applied methods for this research are the standard ones of the Instituti Hidrometeorologjik i Kosovës (Hydrometeorological Institute of Kosovo). All results showed a decrease of each pollutant over the ten years. These changes strongly indicated that the origin of the pollution was traffic and anthropogenic activity, while the power plant was considered to be a less significant source of pollution. The basic pollutants of air quality in Pristina are particulate matters ($PM_{2.5}$ and PM_{10}), ozone and nitrogen oxide.

Keywords: airborne pollutants, urban environment, long lasting changes, Kosovo

INTRODUCTION

Air pollution resulting from human activities is one of the greatest threats to human and animal health worldwide. Many studies have shown that air pollution causes a wide variety of diseases, mainly of the respiratory and cardiovascular systems (e.g., Kampa & Castanas 2008, EEA 2018, Manisalidis et al. 2020, Bălă et al. 2021). Exposure is particularly evident in areas with well-developed industrial capacities and high levels of urbanization. Children, older people and those with pre-existing medical conditions are more sensitive to health effects (EEA 2018, Wahab 2021). It is estimated that poor air quality is responsible for approximately eight million deaths annually and almost the entire of the global population breathes air that exceeds the limits set by the World Health Organization guidelines (WHO n.d.).

Particulate matter (PM) in the air is a considerable problem, especially in developing countries (Manucci & Franchini 2017). PM contains small liquid or solid droplets which can cause serious health effects if inhaled (Cheung et al. 2011, Manisalidis et al. 2020). The coarse dust particles (PM_{10}) mainly affect the upper respiratory system, while the finer particles ($PM_{2.5}$) can penetrate the lung barrier and enter the blood system, causing heart attacks, strokes, asthma and bronchitis, as well as premature death from cancer. Research also shows that the longer exposure to high concentrations of $PM_{2.5}$ can impair brain development in children and have reproductive effects, such as infant mortality and low birth weight (Gao et al. 2014, Schwela 2000, Health Effects Institute 2020, Manisalidis et al. 2020). Also important is the fact that the particles can have toxic effects according to their chemical compounds, primarily metals (Cheung et al. 2011).

A similar situation is in the case of nitrogen oxides (NO_x) which are an irritant of the respiratory system. Breathing air with high levels of them may cause the development of asthma and bronchitis and even pulmonary oedema. They may also lead to an increased risk of heart disease (Schwela 2000, Chen et al 2007, Gao et al. 2014, Manisalidis et al. 2020). The main health problems associated with sulphur dioxide (SO_2), apart from respiratory irritation, bronchitis, and the fact that it exacerbates asthma, are skin redness, eye irritation and cardiovascular disease (Chen et al. 2007).

A very high risk, especially in closed rooms, is the increased content of carbon monoxide. Binding of CO in the lungs with haemoglobin in the blood forms carboxyhaemoglobin, which impairs the transport of oxygen. The first symptoms of poisoning due to inhaling CO include headache, dizziness, weakness and nausea. Finally, it could lead to loss of consciousness. Due to the loss of oxygen, hypoxia, neurological deficits and neurobehavioral changes as well as ischemia, and cardiovascular disease are observed (Schwela 2000, Manisalidis et al. 2020).

Ground-level ozone (O_3) is uptake usually by inhalation. If we consider, short-term exposure can cause chest pain, coughing and throat irritation. O_3 affects the upper layers of the skin and the tear ducts. Due to the low water-solubility of ozone, it can penetrate deep into the lungs. Long-term may lead to decreased lung function and cause chronic obstructive pulmonary disease (Schwela 2000, Health Effects Institute 2020, Manisalidis et al. 2020).

These pollutants can also cause considerable long-term changes in the environment including climate changes. Therefore, it is very important to constantly monitor the air quality, as well as identify sources of pollution and strive to reduce and preferably eliminate them. For this, appropriate legal regulations are necessary.

The majority of cities in the western Balkans are known for their poor air quality levels (Belis at al. 2019, Banja at al. 2020). Pristina, the capital city of Kosovo, is especially identified as a city with high concentration of gaseous and dust pollutants and this situation is associated with several possible sources. The first is the city's proximity to a coal-fired power plant, the second is the busy traffic around the city, while the third possible source is domestic heating, usually by means of wood and coal (Bajçinovci 2017, Bajçinovci B. & Bajçinovci M. 2020). This fact is also confirmed by the official published monitoring reports of 43 capitals of different countries, including Pristina. These reports focused primarily on three potential sources of air pollution in the city, namely biomass burning, coal combustion and power plant operation (Dhammapala 2019).

After the end of the war in Kosovo (1999), Pristina was intensively involved in the illegal construction of private houses damaged from the war and most of them have been shown to have had a negative impact on agricultural land (Dobruna 2009). Official United Nations Environment Programme (UNEP) reports on air monitoring, particularly of particulate matter (PM) in several countries around the world and Pristina as a capital, indicate that PM_{10} levels were exceeded 61-fold in 2017 (UNEP 2021). Although the official air monitoring conducted by the Kosovo Hydrometeorological Institute began in 2010, there are no scientific articles on the state of the air and its changes in Pristina. Nevertheless, there are several reports about air quality and its health impact including DNA blood cells observations of people of different ages and genders in Kosovo. Highly negative effects on humans have been detected, especially DNA damage in comparisons of people from two different regions, polluted and unpolluted. The study shows that significant DNA damage in people from polluted regions were higher and it is strongly recommended that Kosovo adapt its legislation in accordance with European legislation. This includes removing old cars, increasing green areas and the application of a permanent biomonitoring system (Ukëhaxhaj et al. 2013, Alija et al. 2016).

All air contaminants can be absorbed from airborne particles and can cause different health effects, as has been reported in different regions of Kosovo, and possibility to occur in Pristina it is real (Kastury et al. 2017, Zuśka et al. 2019). In recent years, the government of Kosovo has approved several legislative regulations aimed at the reduction of the normal limit of exhaust gases emissions (UNEP 2021). Considering that the ash waste near the power plant was identified as the second source of particles, the government enforced and implemented a covering of this surface to reduce emissions of contaminants (ZRRE 2012). Lastly, the power plant was identified as the one of sources of gas emissions, thus a filter with the highest emission prevention capacity was installed (KEK 2013).

The main objectives of the present study are the determination of the long-term changes of air pollution in the Pristina region and the identification of significant pollutants and their sources. It is considered the contamination of particulate matter (PM_{10} & $PM_{2.5}$), ground-level ozone (O_3), carbon monoxide (CO), sulfur (SO_2) and nitrogen oxides (NO_x), which according to the World Health Organization (WHO 2021) are the main air pollutants. An important aspect was to show how changes in the law and modernizations in industrial plants can change the degree of air pollution and the reference to the Kosovo Air Quality Index, which clearly indicates the health effects of high concentrations of the analyzed indicators.

MATERIALS AND METHODS

In order to assess air quality changes, the results of the measurements obtained by the Instituti Hidrometeorologjik i Kosovës – IHMK (Hydrometeorological Institute of Kosovo) in Pristina in 2010–2020 were monitored. The data were collected from up to five monitoring stations located in the city (Fig. 1, Tab. 1). The measurement results have been published on the institute's website since 2017 (IHMK 2020), and information on pollutant concentrations from 2010 until 2017 were taken from IHMK reports (AMMK 2010–2020).

The following pollutants measured by the IHMK were investigated in the present study:

- carbon monoxide (CO) acc. to EN 14626 – spectroscopy infrared (infra-red) no dispersive,
- nitrogen oxide IV (NO_2) and NO_x acc. to EN 14211 – chemiluminescence,
- sulphur dioxide (SO_2) acc. to EN 14212 – ultraviolet fluorescence,
- ozone (O_3) acc. to EN 1462 – photometric ultraviolet,
- particulate matters PM_{10} and $PM_{2.5}$ acc. to EN 12341 – beta attenuation (Sharp) and optical measures (Grimm M180),
- PM_{10} acc. to EN 12341 – gravimetric method.

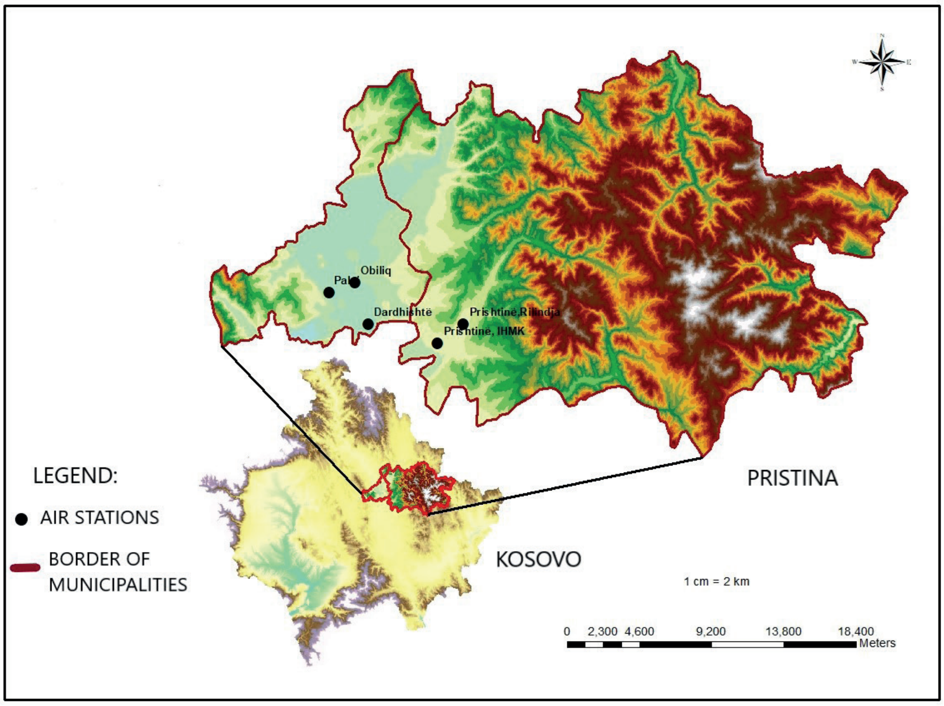

Fig. 1. *Location of the research area and air monitoring stations in Pristina*

Table 1
Description of air monitoring stations operated by the Kosovo Hydrometeorological Institute in Pristina

No.		1	2	3	4	5
Station name		Prishtinë, IHMK	Prishtinë, Rilindja	Palaj	Obiliq	Dardhishtë
Latitude		42.6488	42.6596	42.6777	42.6839	42.6597
Longitude		21.1371	21.1573	21.0526	21.0733	21.0833
Station type		city	city, roadside	urban and industrial district		
Purpose		protecting human health & public exposure assessment				
Measurement method		automatic				
Measured compounds	**PM_{10}**	+	+	+	+	+
	$PM_{2.5}$	+	+	+	+	+
	SO_2	+	+	+	+	+
	NO_2	+	+	+	+	+
	NO	+	+	+	+	+
	NO_x	+	+	+	+	+
	O_3	+	+	+	+	+
	CO	+	+	+	+	+
Parameters	**wind speed**	+	+	+	+	+
	wind direction	+	+	+	+	+
	temperature	+	+	+	+	+
	humidity	+	+	+	+	+
	pressure	+	+	+	+	+

ASSESMENT OF AIR QUALITY

The results from the Hydrometeorological Institute of Kosovo concerning the air quality in Pristina were compared to the level of permissible contaminants in the air according to the Regulation of the Ministry of Environmental Protection on the normal level of substances in the air (QRK 2011, IHMK 2019). They also were compared to the Kosovo Air Quality Index (AQI) (Tab. 2).

Corresponding health recommendations are presented in Table 3.

Table 2
Ranges of the concentrations in the Kosovo Air Quality Index (AQI) for selected pollutants (EEA n.d., QRK 2011)

AQI	SO_2* [µg/m³]	NO_2* [µg/m³]	CO** [mg/m³]	PM_{10}*** [µg/m³]	$PM_{2.5}$*** [µg/m³]	O_3* [µg/m³]
Good	0–100	0–40	0.0–4.5	0–20	0–10	0–50
Moderate	100–200	40–90	4.5–9.5	20–40	10–20	50–100
Unhealthy for sensitive groups	200–350	90–120	9.5–12.5	40–50	20–25	100–130
Unhealthy	350–500	120–230	12.5–15.5	50–100	25–50	130–240
Very unhealthy	500–750	230–340	15.5–30.5	100–150	50–75	240–380
Hazardous	750–1250	340–1000	30.5–50.5	150–1200	75–800	380–800

* The hourly concentrations.
** Not offered for Kosovo in AQI – calculated acc. to EPA (2018).
*** Based on 24-hour running means.

Table 3
The Kosovo AQI and the corresponding health recommendations for residents (acc. to: AMMK n.d., EEA n.d., IQAir n.d., QRK 2011)

AQI	Health recommendations
Good	It's a beautiful day to be active outside as well.
Moderate	Good air quality. Air pollution poses a minimum threat to those at risk. Very good conditions for outdoor activities.
Unhealthy for sensitive groups	Sensitive groups: You should reduce long-term or tedious activities. It's okay to be active even outside, but take more breaks and perform activities with less intensity. Be careful with symptoms such as coughing, shortness of breath during respiratory processes. People with asthma: You should adhere to their asthma action plans and have with them quick-relief medications for rapid release of respiratory airways. People with heart disease: Symptoms like rapid heartbeat, shortness of breath or unusual fatigue may indicate serious problems. If you have any of these symptoms, contact your healthcare provider.
Unhealthy	Sensitive groups: You should avoid heavy or prolonged exertion. Try to do the activities inside or postpone them to a time when the air quality is better. Everyone: You should avoid long and strenuous activities. Take longer breaks during activities outside.
Very unhealthy	Sensitive groups: You should avoid all physical activities outside. Try to carry activities inside or reschedule them to a time when air quality is better. Everyone: Avoid strenuous and long activities. Try to do activities inside or postpone them to a time when air quality is better.
Hazardous	Sensitive groups: Remain indoors and keep activities at low levels. Everyone: Avoid all physical activity out.

RESULTS AND DISCUSSION

The current air quality investigation in the Pristina region is based on the monitoring of particulate matter (PM_{10} & $PM_{2.5}$), ground-level ozone, carbon monoxide, sulfur and nitrogen oxides changes. This monitoring has its limitations and mistake probabilities because actual trends are strongly dependent on atmospheric and topographic conditions (Chalvatzaki et al. 2019).

In Table 4, the changes of six monitored parameters over the last 10 years are presented. A decreasing trend of changes can be seen only for PM_{10} and $PM_{2.5}$. This can be explained by the following reasons: the increase of fuel quality control, especially the level of sulphur in fuel, as well as the implementation of ecological technology in the power plant which took place mainly in 2014, and when among others a new electrostatic precipitator was installed (AMMK 2015a). Other possible causes are the cover of the ash waste and greening the entire surface, as well as the regeneration of car fleets with other new cars producing lower emissions. Other air pollutants increased and this tendency appears normal for O_3. However, for the other three parameters (SO_2, NO_2 and CO) this increasing level is surprising and unexpected. This can be explained by the fact that the improvements in the power plant in the form of the filter only influenced the decrease of particle matter in the air, not the gaseous pollutants.

Table 4
Annual pollutant concentration changes in air in Pristina, 2010–2020 (AMMK 2010–2020, IHMK 2020)

Year	SO_2 [µg/m³]	NO_2 [µg/m³]	CO [mg/m³]	PM_{10} [µg/m³]	$PM_{2.5}$ [µg/m³]	O_3 [µg/m³]
2013	7.9	10.9	0.6	51.4	37.2	48.3
2014	16.7	17.1	0.7	43.6	36.1	39.4
2015	9.4	21.7	2.3	43.5	35.3	41.8
2016	15.7	18.4	3.1	31.5	22.8	39.7
2017	15.6	40.8	1.4	37.1	29.3	30.7
2018	33.5	26.9	2.1	36.5	29.6	49.9
2019	11.3	26.9	1.5	28.6	19.7	49.2
2020	13.3	16.6	1.4	29.6	20.4	43.3
Minimum	7.9	10.9	0.6	28.6	19.7	30.7
Maximum	33.5	40.8	3.1	51.4	37.2	49.9

The same parameters were monitored during the twelve months of 2019 to show the variation by month during the year (Tab. 5). Generally, their highest content can be observed in the winter season. This difference can be explained due to the overload of anthropogenic activity in the winter, especially the heating of flats and workplaces, compared with the summer when schools do not work, traffic is reduced and people spend their summer holidays away. This is also due to the fact that inversions of temperature are more frequent in these periods and this may affect the presence of smog. This is a trend seen in other countries with a winter period often called as the heating season (Chen et al. 2015, Cichowicz et al. 2017, Bodor et al. 2020, Traczyk & Gruszecka-Kosowska 2020). It can also be dependent on meteorological parameters such as air temperature, humidity and wind speed (Cichowicz et al. 2017).

Table 5
Changes in the average monthly air pollutants content in 2019 in Pristina; average values from all the monitoring stations with classification according to Kosovo AQI (AMMK 2010–2020, IHMK 2020)

Month	SO_2 [µg/m³]	NO_2 [µg/m³]	CO [mg/m³]	PM_{10} [µg/m³]	$PM_{2.5}$ [µg/m³]	O_3 [µg/m³]
January	17.2	56.5	2.2	57.5	54.2	64.5
February	11.5	31.8	2.0	42.4	31.0	45.7
March	11.9	31.4	1.9	35.0	21.7	64.5
April	11.9	23.1	1.0	29.8	17.9	48.7
May	5.8	17.1	0.6	12.9	6.7	49.6
June	7.7	16.0	0.4	16.1	8.4	55.9
July	15.5	20.4	1.0	15.5	7.7	65.2
August	19.0	18.4	1.4	20.7	9.0	69.7
September	8.1	32.1	1.2	19.6	10.1	46.6
October	11.1	30.4	1.6	35.3	24.0	32.0
November	7.7	21.1	1.9	23.2	17.4	25.5
December	10.2	23.0	2.8	34.9	28.3	22.8
Minimum	5.8	16.0	0.4	12.9	6.7	22.8
Maximum	19.0	56.5	2.8	57.5	54.2	69.7
Arithmetic mean	11.5	26.8	1.5	28.6	19.7	49.2
Median	11.3	23.1	1.5	26.5	17.7	49.2
SD	4.0	11.1	0.7	13.1	13.7	15.8

The colors acc. to the Kosovo AQI (see Tab. 3); SD – standard deviation.

The SO_2 level was unexpectedly high in July and August, although this can be partly attributed to the burning of grass (Chen et al. 2017, Li et al. 2017), which usually occurs at this time of the year. The level of O_3 is higher during summer compared with winter. The reason for this is more intensive insolation in summer, which becomes the main source of increasing the level of this pollutant in the air (Song et al. 2011, Yin et al. 2019). In the case of NO_2, it can be noticed that concentration is usually higher in winter than in summer. These differences could be explained by the fact that the main source of emission of this gas is road traffic, but also the operation of the power plant. During winter and cold periods, people have a greater need to move and use more cars than public transport.

The period of the pandemic associated with the SARS-CoV-2 virus was also a time of restrictions and limited movement of people. This undoubtedly affected the quality of the environment (Rodríguez-Urrego D. & Rodríguez-Urrego L. 2020, Gope et al. 2021, Sarmadi et al. 2021, Saxena & Raj 2021), therefore based on the presented results at this period of year, the air quality is better than before.

Particular attention was paid to the initial spread of the SARS-CoV-2 virus. The air monitoring results obtained for the period from March to early June 2020 were analyzed. All pollutants in this period show a decreasing tendency (Tab. 6). The usually detected level of pollutants originates from the emissions of the power plant and other anthropogenic activity.

Table 6
Changes in monthly air pollutant contents in 2020 in Pristina; average values of all the monitoring stations with classification acc. to Kosovo AQI (AMMK 2010–2020, IHMK 2020)

Month	SO_2 [µg/m³]	NO_2 [µg/m³]	CO [mg/m³]	PM_{10} [µg/m³]	$PM_{2.5}$ [µg/m³]	O_3 [µg/m³]
January	15.4	29.6	3.4	56.1	45.6	23.3
February	11.7	23.5	2.2	37.7	26.9	38.8
March	12.2	17.0	1.5	34.7	22.3	51.6
April	12.3	12.3	1.9	26.6	16.2	62.0
May	22.1	13.2	1.1	22.6	11.3	51.9
June	12.2	12.4	0.9	15.7	8.4	54.7
July	13.8	10.7	0.8	16.2	9.2	60.8
August	13.8	13.6	0.8	17.6	10.7	54.1
September	12.8	13.4	0.6	18.7	9.7	55.1
October	9.1	17.9	0.7	27.7	18.4	30.3
November	12.4	19.4	1.3	50.2	40.5	15.7
December	12.2	16.6	1.1	31.6	26.0	21.5
Minimum	9.1	10.7	0.6	15.7	8.4	15.7
Maximum	22.1	29.6	3.4	56.1	45.6	62.0
Arithmetic mean	13.3	16.6	1.4	29.6	20.4	43.3
Median	12.4	15.1	1.1	27.2	17.3	51.8
SD	3.1	5.5	0.8	13.2	12.4	16.5

The colors acc. to the Kosovo AQI (see Tab. 3); SD – standard deviation.

The main gaseous pollutant with a communication origin is nitrogen oxide; therefore, we focused on monitoring this element. This period is compared with the same time length – between the months of March – April of 2019 when the movement of people was not limited. A sizable difference can be observed from March 21, 2020, just five days after the prohibition of free movement (Fig. 2). This trend continued even in the subsequent months of 2020 (April, May and June) (Figs. 3–5). This may indicate that most of the nitrogen oxide comes from traffic emissions and is related to the burning of fuel, something also confirmed in studies conducted in other cities with urban environments (Anttila at al. 2010, Kurtenbach et al. 2012, Smith et al. 2015, Lorente et al. 2019, Kamińska et al. 2020). In 2019, only two days of May (May 7 and May 26), and at the beginning of June, concentrations of nitrogen oxides were at the same low level as in 2020. This was most likely due to the rainy weather, which was monitored during this period (Chalvatzaki et al. 2019).

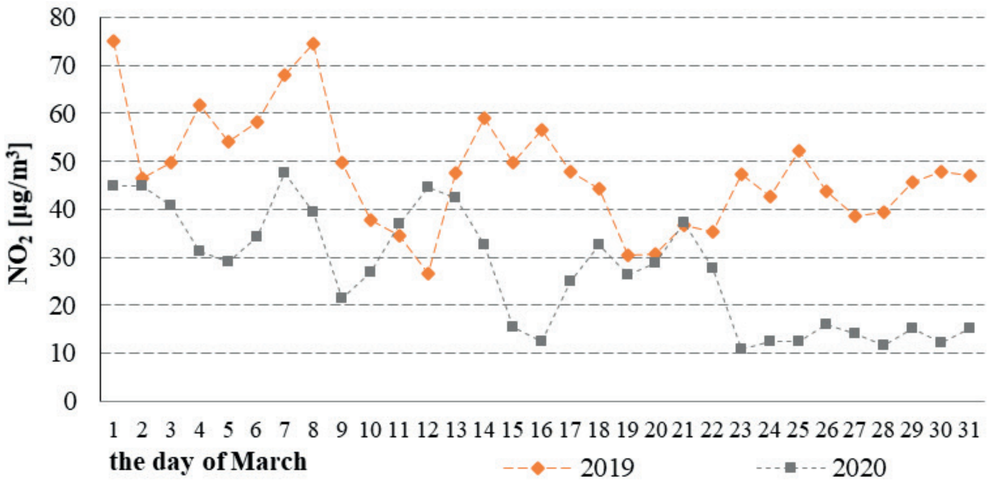

Fig. 2. *Comparison of monthly changes of NO$_2$ [µg/m^3] concentration during March 2019 and 2020*

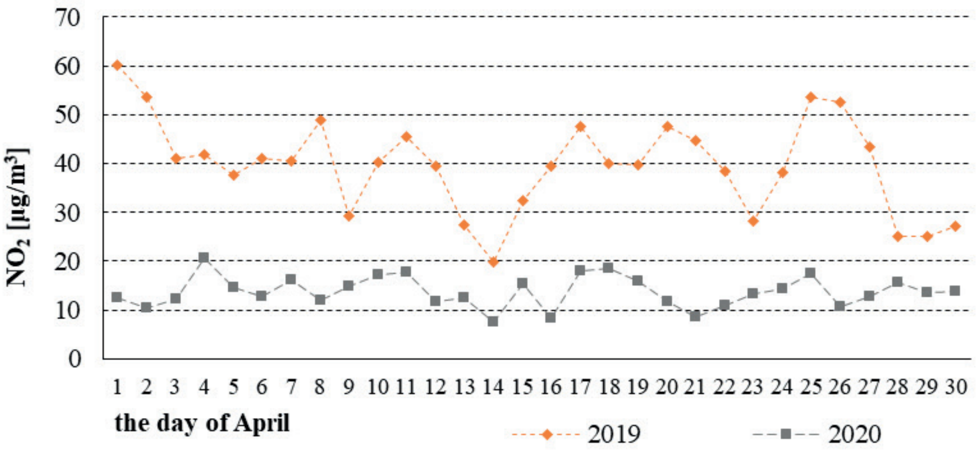

Fig. 3. *Comparison of monthly changes of NO$_2$ concentrations [µg/m^3] during April 2019 and 2020*

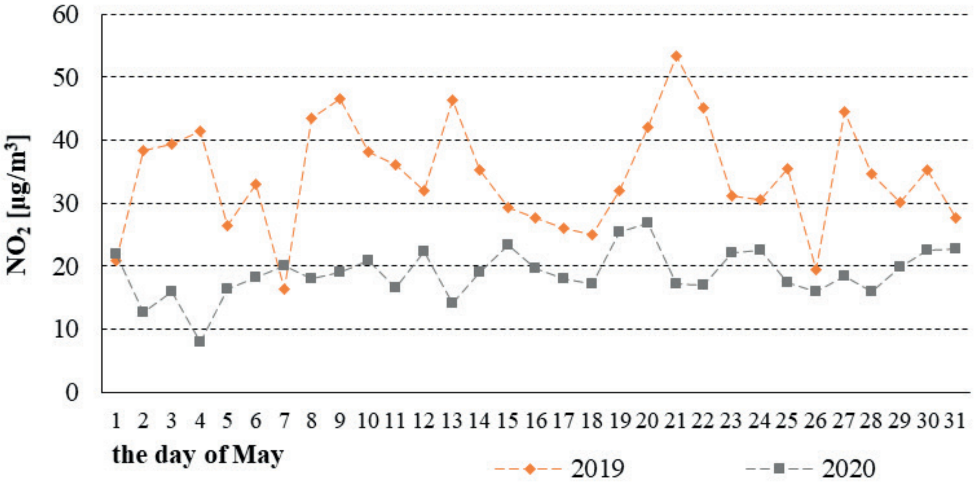

Fig. 4. *Comparison of monthly changes of NO$_2$ concentrations [µg/m^3] during May 2019 and 2020*

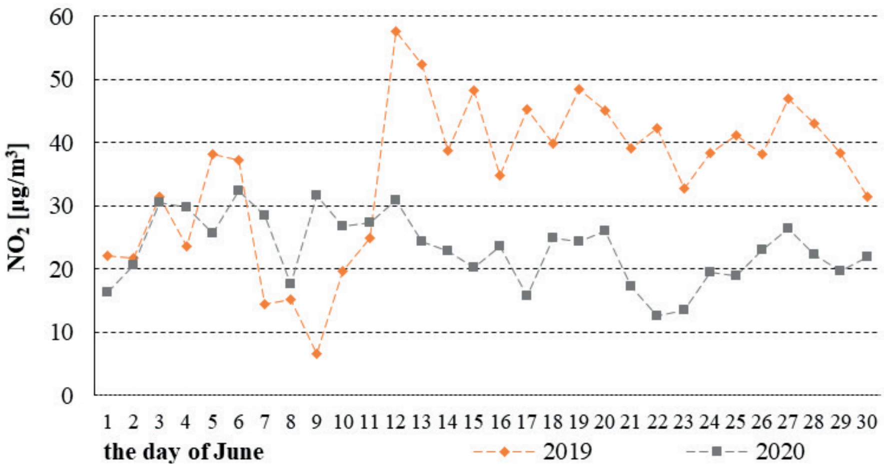

Fig. 5. *Comparison of monthly changes of NO_2 concentrations [μg/m^3] during June 2019 and 2020*

Table 7 and Figures 6–9 show a large difference between the two selected months, both before and after the SARS-CoV-2 crisis. The first one is January, as a cold winter month and the second is July, a hot summer month. In January 2020, data measured from the air quality monitoring system indicated an increase in the concentrations of some air pollutants, especially the concentrations of NO_2, PM_{10} and $PM_{2.5}$ (Figs. 6–8). All these pollutants mainly originate from busy traffic, households, the power plant and other similar activities (Bajçinovci B. & Bajçinovci M. 2020). Moreover, the value of PM_{10} dust concentration was significant and exceeded the normative values for sixteen days during this month based on international normative legislation (QRK 2011).

On days with a high concentration of pollutants, specific weather conditions occurred, i.e., the temperature ranged from –2 to +2°C, there was fog and very low wind speed, close to 0 m/s. Furthermore, there was also no atmospheric precipitation at this time (IHMK n.d.). All these atmospheric conditions favored the accumulation and retention of most air pollutants. In January 2020, only a decrease of O_3 concentration is observed (Fig. 9) because its presence is usually the result of photochemical reaction of nitrogen oxides and hydrocarbons in the atmosphere. These reactions are accelerated by high air temperatures and January temperatures are recorded as low, with a monthly average of around –3°C (IHMK n.d.). Usually, if one of those precursors is not present, then ozone will be at a low level. Comparing the state of air quality in January and July 2020, a reduction of pollution by up to 50% is visible for all monitored parameters, except for ozone. The concentration of O_3 increased by over 60% and this can be explained by summer insolation. Subsequently a low level of ozone was detected for several days. This is completely correlated with weather conditions such as lower temperature, high humidity, and wind speeds from 1.4 to 2.9 m/s (IHMK n.d.).

Table 7
Statistic parameters in daily average air pollutant contents in a selected winter (January) and summer (July) months of 2020 for Pristina (AMMK 2010–2020, IHMK 2020)

Statistic parameter	Month	O_3 [μg/m^3]	SO_2 [μg/m^3]	NO_2 [μg/m^3]	CO [mg/m^3]	PM_{10} [μg/m^3]	$PM_{2.5}$ [μg/m^3]
Minimum	January	1.7	11.6	17.5	2.2	9.5	8.5
	July	42.5	8.6	7.8	0.5	9.7	5.3
Maximum	January	37.2	38.3	51.0	4.4	139.7	114.2
	July	70.9	20.1	21.0	1.0	30.2	21.4
Arithmetic mean	January	15.3	17.3	32.5	3.0	58.4	46.2
	July	57.2	10.0	13.7	0.7	19.7	11.5
Median	January	14.5	15.7	33.8	2.9	50.3	36.7
	July	57.5	9.3	14.0	0.7	19.4	11.7
SD	January	9.0	5.8	9.6	0.5	32.7	27.1
	July	7.8	2.5	3.2	0.2	4.7	2.8

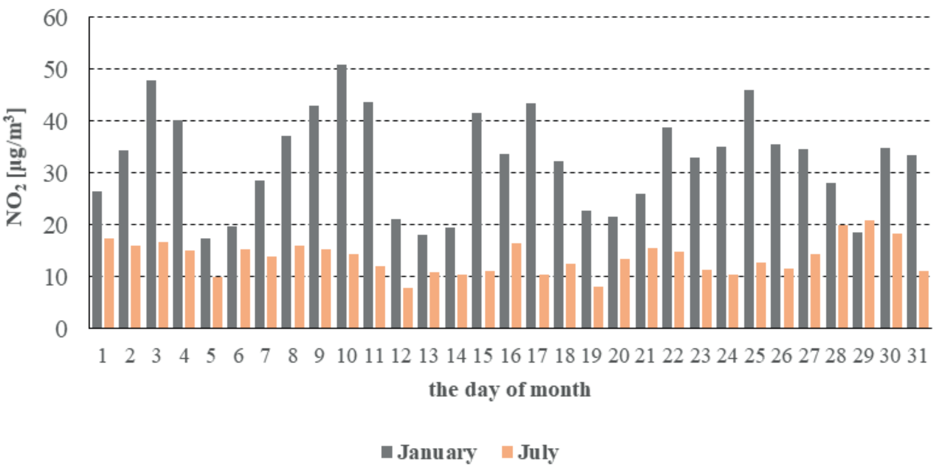

Fig. 6. *Comparison of daily average changes of NO_2 concentrations during selected winter and summer months of 2020 for Pristina (AMMK 2010–2020, IHMK 2020)*

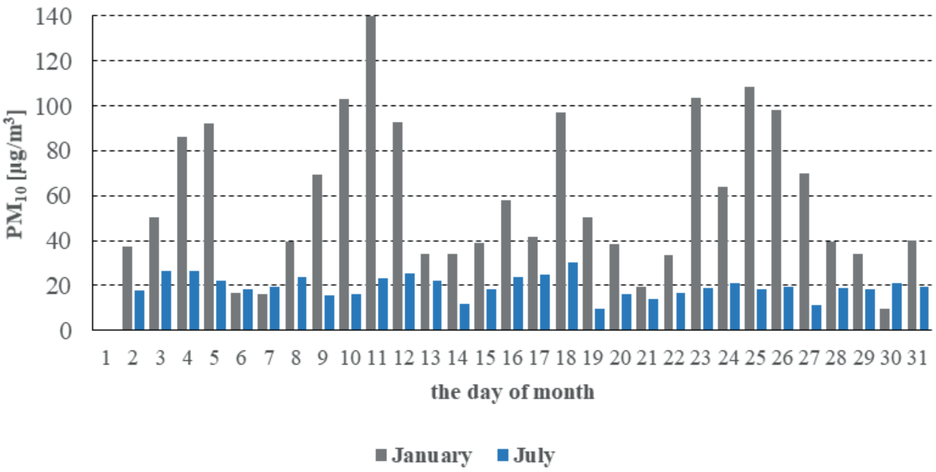

Fig. 7. *Comparison of daily average changes of PM_{10} concentration during selected winter and summer months of 2020 for Pristina (AMMK 2010–2020, IHMK 2020)*

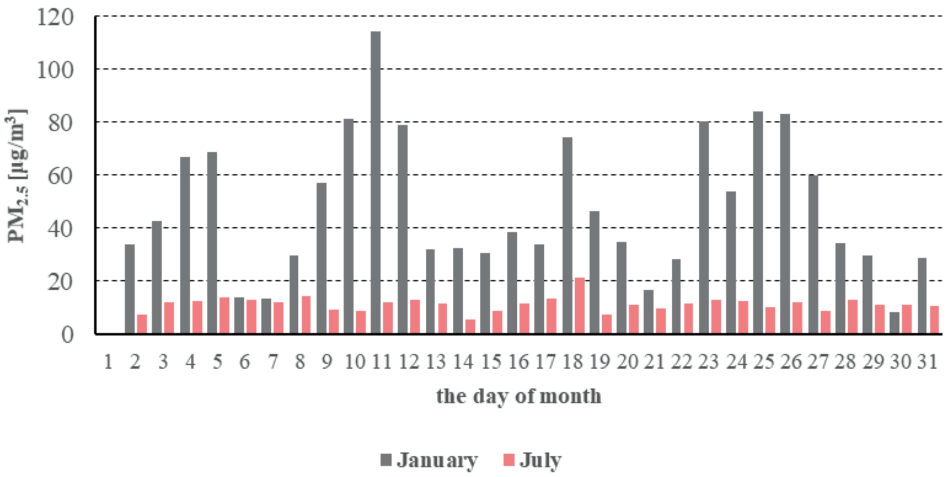

Fig. 8. *Comparison of daily average changes of $PM_{2.5}$ concentration during selected winter and summer months of 2020 for Pristina (AMMK 2010–2020, IHMK 2020)*

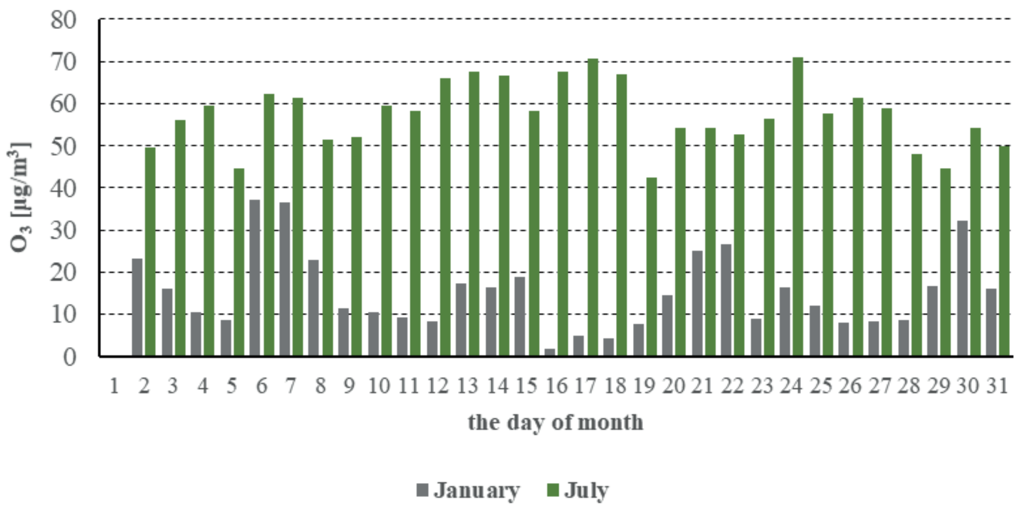

Fig. 9. *Comparison of daily average changes of O_3 concentration during selected winter and summer months of 2020 for Pristina (AMMK 2010–2020, IHMK 2020)*

When analyzing the results of the 24-hour air quality monitoring, the study only focused on three parameters (NO_2, PM_{10} and $PM_{2.5}$) because the three others did not show any significant changes. It can be noticed that there is a correlation between nitrogen oxide and dust particles (Fig. 10). During the early morning hours, from 1:00 until 5:00 they are usually at a low level and then they increase steadily until noon. This is related to the activity of people in traffic. From 12:00 until 16:00 the level decreased, which is due to the fact that most people are active in closed work zones during this period. However, this changes after the end of the working schedule. Public institutions finish work at 16:00, while the private sector around 17:00, with the result that the concentrations of all three parameters, especially NO_2, begins to increase rapidly. This tendency continues until 22:00, which seems to be in full compliance with the activity of people and traffic when the volume of people's movements definitely decreases (around 22:00) and when pollution rapidly decreases as a result.

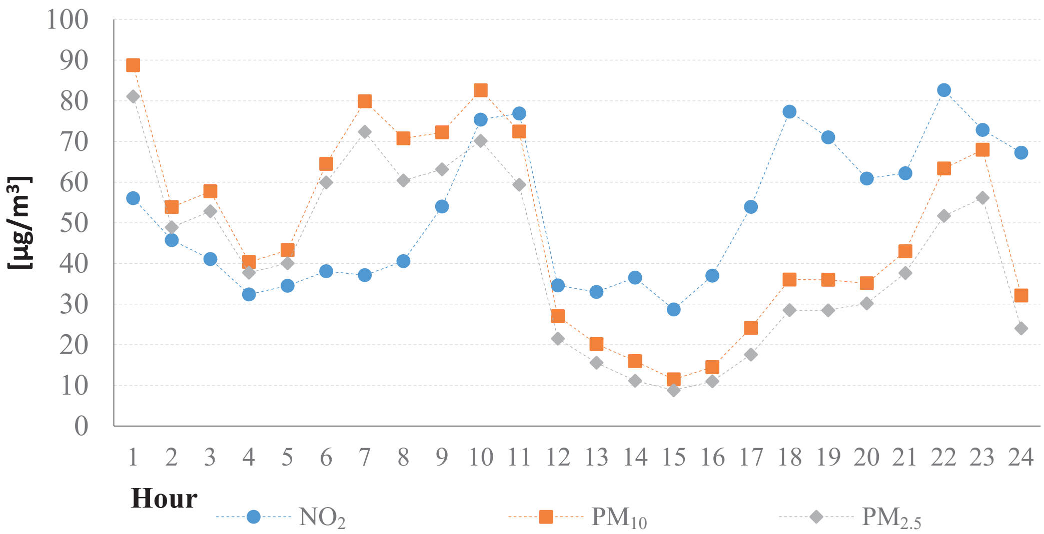

Fig. 10. *Changes in hourly average NO_2, PM_{10}, and $PM_{2.5}$ content for Pristina on January 7, 2020*

Finally, from all our monitoring presented in this research, PM_{10} and $PM_{2.5}$ seem to originate from the power plant, in contrast with gaseous pollutants whose origin is the traffic emissions around Pristina. This has been the goal of this research: to enable the identification of the source of emissions.

Both of these issues have frequently been the subject of discussion at the institutional level, including the obligation to increase the filtration of the thermal power plant. Although this has affected the reduction over the years, apparently even more can be done in this regard.

Concerning traffic pollution, some laws have been issued that aim to remove old vehicles and replace them with newer ones (AMMK 2015b). Yet, as can be seen, this is insufficient because the number of vehicles circulating in the capital is much higher than the size of the capital itself. Therefore, the solution should be aimed at removing vehicle traffic by providing public transport, offering it as a cheaper, more convenient, and faster alternative.

Taking into account the average concentrations of $PM_{2.5}$ in the air in European countries (acc. to IQAir 2020), Kosovo ranks 7th (20 ug/m^3) but the capital is not the most polluted city, a dubious honor held by Vushtrri. Pristina also ranks seventh among the cities in Kosovo. $PM_{2.5}$ concentrations are usually much higher in southern and eastern Europe. This trend is especially pronounced in winter, in countries that use energy based on burning coal and biomass. This is especially discernible in cities in Poland, Bosnia and Herzegovina, Serbia, and Turkey.

SUMMARY AND CONCLUSION

The present study revealed a general decreasing tendency of annual pollutant content (PM, NO_x, SO_2, CO, O_3) in the air in Pristina based on data and available information for the past 10 years. Unfortunately, in those years, all the above-mentioned pollutants exceeded the limit values set out in the national law for Kosovo. These exceedances applied, as in many other countries, especially to the heating season. The bad quality of air is largely due to the use of vehicles that burn poor quality fuel. This is indicated by the large improvement in air quality during the lockdown introduced as a result of the SARS-CoV-2 pandemic. Although some investments have already been started in Pristina to improve air quality, such as the fact that the power plant has introduced an electrostatic precipitator on the air emitter, much more should be done, not only in the capital but nationwide.

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