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SHORT-TERM HEALTH EFFECTS OF AIR QUALITY CHANGES DURING THE COVID-19 PANDEMIC IN THE CITY OF NOVI SAD, THE REPUBLIC OF SERBIA

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Abstract
Objectives: The objective of this research is to determine the change in outdoor air quality during the COVID-19 related state of emergency resulting in a lockdown and the potential health benefits for the urban population. **Material and Methods:** During 53 days of the COVID-19 related state of emergency with a lockdown (March 15–May 6, 2020) in the Republic of Serbia, as well as in the corresponding periods of 2018 and 2019, data on the daily sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ground-level ozone (O_3) and particulate matter (PM_{10} and $PM_{2.5}$) concentrations were analyzed. The total mortality data were analyzed to estimate the impact of the COVID-19 related lockdown measures on the burden of health in a given population, attributed to the outdoor air quality in the City of Novi Sad, using AirQ+ software. **Results:** The average daily concentrations of $PM_{2.5}$, NO_2, PM_{10} and SO_2 were reduced by 35%, 34%, 23% and 18%, respectively. In contrast, the average daily concentration of O_3 increased by 8%, even if the primary precursors were reducing, thus representing a challenge for air quality management. In the City of Novi Sad, a reduction in the average daily $PM_{2.5}$ concentration of 11.23 μg/m³ was significant, which resulted in a quantified number of avoided deaths. **Conclusions:** Air pollution in the City of Novi Sad had a chance to be improved due to some preventive measures related to the infectious disease (the COVID-19 related lockdown), which in turn was the mitigation measure to air pollution with positive public health effects. The confirmed positive effects of the improved air quality on public health could also include raising collective resistance to mass non-communicable and infectious diseases such as COVID-19 and reducing economic costs. Int J Occup Med Environ Health. 2021;34(2):223–37

Key words:
mortality, air pollution, particulate matter, public health, environment, health impact assessment

INTRODUCTION

Air pollution is recognized as a leading public health problem worldwide [1,2]. It is estimated that 92% of the world's population is exposed to polluted air [3]. Ranking air pollution among the first 10 global human health risk factors [2] suggests that understanding the most effective air pollution control policy remains a significant public health challenge.

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However, the current epidemiological situation related to COVID-19 has raised awareness and brought new questions among scientists and professionals regarding the measures and possibilities of improving outdoor air quality, which can have a significant influence on populations' health outcomes [4].

According to few studies conducted to date, measures taken around the world during the COVID-19 pandemic (the lockdown in particular) have had a positive impact on outdoor air quality [5], suggesting that in the largest epicenters of COVID-19, environmental air pollution is reduced by an average of 20–30% [6,7]. These measures have resulted in a reduction in the number of deaths attributed to the impact of air pollution [8,9].

The impact of measures taken to control the spread of COVID-19 in the Republic of Serbia on the air quality of individual urban areas and their potential health benefits are still unknown.

Objectives

The objective of this research is to determine the change in outdoor air quality during the COVID-19 related state of emergency resulting in a lockdown and the potential health benefits for the urban population. The specific objectives are:

– to determine the outdoor air quality in the City of Novi Sad before and during the COVID-19 related state of emergency resulting in a lockdown, and the quantification of air quality changes,
– to quantify the short-term health effects of air quality changes.

MATERIAL AND METHODS

During 53 days of the COVID-19 related state of emergency with a lockdown (March 15–May 6, 2020) in the Republic of Serbia, as well as in the corresponding periods of 2018 and 2019, data on the daily sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ground-level ozone (O_3) and particulate matter (PM_{10} and $PM_{2.5}$ [except in 2018]) concentrations were analyzed. Briefly speaking, the COVID-19 related state of emergency with lockdown measures included closed schools, decreasing work times in non-essential occupations, doing work from home, and restricted public transportation as well as citizens' movement (especially at weekends).

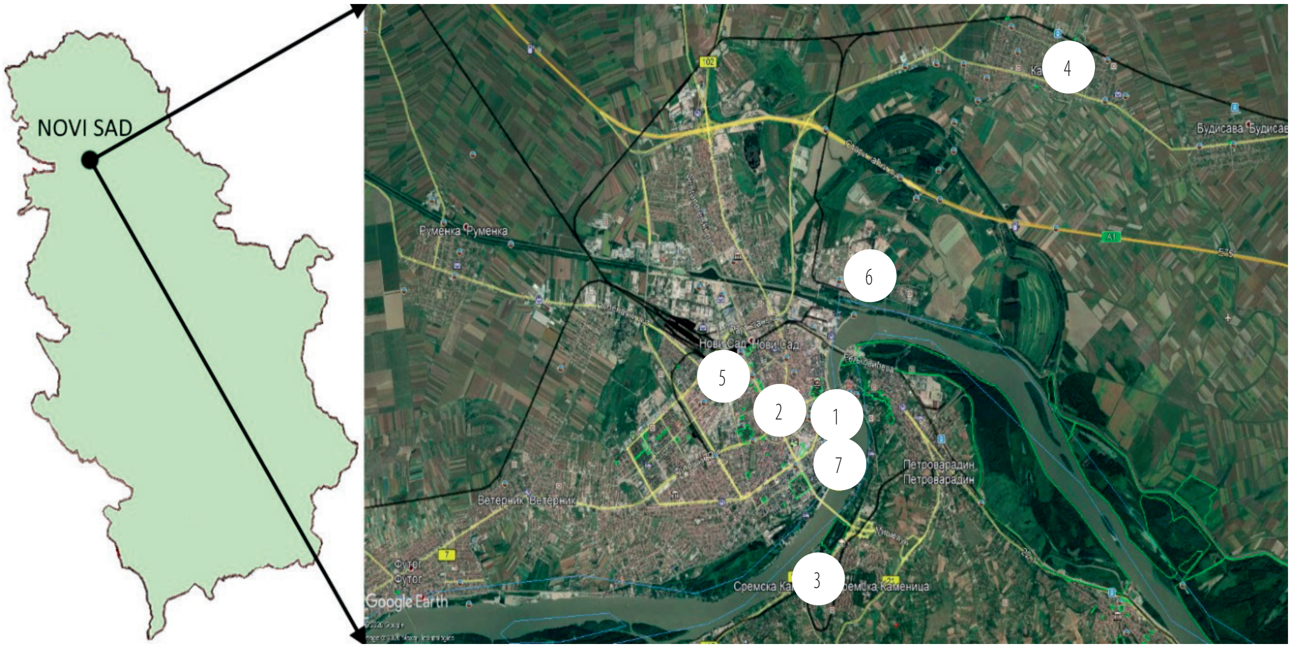
To assess the possible impact of different local air pollution sources, which may be in the function of meteorological conditions (heating vs. non-heating), data obtained in 2020 before the start of the COVID-19 related state of emergency (i.e., regarding the period of January 1–March 14, 2020) were also considered. All publicly available data on air quality for local self-governments are provided by the Institute of Public Health of Vojvodina (IPHV) which, as an authorized and accredited institution for determining outdoor air quality and for assessing the human health impact, performs outdoor air quality monitoring services.

The network of air quality measurement stations in the City of Novi Sad, regarding the monitoring of air pollutants, is presented in Figure 1.

Data of measuring stations for selected pollutants (SO_2, NO_2, O_3) and particles (PM_{10} and $PM_{2.5}$) during the following 4 defined periods: March 15–May 6, 2018, March 15–May 6, 2019, January 1–March 14, 2020, and March 15–May 6, 2020, are shown in Table 1.

Considering that the number and spatial distribution of measuring stations for monitoring the daily concentrations of SO_2, NO_2, O_3, and PM_{10} and $PM_{2.5}$ changed from year to year, the assessment of air quality for the 4 defined periods was performed based on the average daily concentrations for the analyzed air pollutants from all (available) monitoring stations.

The availability of daily data for outdoor air quality assessment during the defined periods was 100% for SO_2 and NO_2, 91.84% for O_3, and 89.27% for PM_{10} and $PM_{2.5}$ (in 2019 and 2020).



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Measurement stations: 1 – urban traffic (45°14’54.75”N/19°49’4.72”E); 2 – urban traffic (45°15’14.40”N/19°50’13.03”E); 3 – suburban background (45°13’31.41”N/19°50’42.69”E); 4 – suburban traffic (45°17’58.73”N/19°56’25.92”E); 5 – urban traffic (45°15’45.56”N/19°49’8.98”E); 6 – suburban industrial (45°16’20.7”N/19°52’24.57”E); 7 – urban background (45°14’29.38”N/19°51’9.26”E).

Figure 1. A network of air quality measurement stations in the City of Novi Sad during the analyzed periods of 2018, 2019 and 2020

During the 2 defined periods (53 days in 2020 and 2019) data regarding meteorological parameters (air temperature, relative humidity, atmospheric pressure, and wind velocity) were also processed. The meteorological data were provided from the IPHV automatic stations located at suburban background places in the City of Novi Sad (45°13'31.41"/19°50'42.69"E).

Total mortality data were analyzed to estimate the impact of the COVID-19 related lockdown measures on the burden of health in a given population attributed to the ambient air quality of the City of Novi Sad. To recognize the possible health benefits of air quality changes, the IPHV provided data on mortality from all causes for the analyzed period in 2019 (March 15–May 6, 2019) and the population data for 2019, with similar methods being previously used by other authors [10].

Statistical processing

The statistical processing of collected data during the defined periods included:

– a comparative analysis of the daily concentrations of selected air pollutants as well as meteorological parameters using descriptive statistics, an independent t-test and the analysis of variance (ANOVA adjusted for multiple comparisons between years with the Bonferroni *post hoc* test); the average daily concentrations of the analyzed air pollutants were compared also regarding the daily EU limit value [11] (similar to the national limit values, because EU Directive 2008/50/EC has been transposed into the national legislation) and the recommended WHO guidelines for $PM_{2.5}$ particles [12];
– an estimation of the number of deaths attributed to air pollution using AirQ+ software created by WHO [13].

Table 1. Measurement stations in the City of Novi Sad in the defined periods of 2018, 2019, and 2020 for analyzed air pollutants, the Republic of Serbia

Measurement station*	Observed period			
	March 15–May 6, 2018	March 15–May 6, 2019	January 1–March 14, 2020	March 15–May 6, 2020
Sulfur dioxide (SO_2)				
urban traffic (1)	+			
urban traffic (2)	+			
suburban background (3)		+	+	+
suburban traffic (4)		+	+	+
urban traffic (5)		+		
Nitrogen dioxide (NO_2)				
suburban industrial (6)	+			
urban traffic (2)	+			
suburban background (3)		+	+	+
suburban traffic (4)		+	+	+
Ground-level ozone (O_3)				
urban traffic (2)	+			
suburban background (3)		+	+	+
Particulate matter (PM_{10} and $PM_{2.5}$)				
suburban industrial (6)	+			
urban traffic (2)	+			
suburban background (3)			+	+
suburban traffic (4)		+	+	+
urban traffic (5)		+	+	+
urban background (7)		+	+	+

* The numbers in brackets next to measurement stations are only labeled to indicate the corresponding measurement stations as shown in Figure 1.
"+" – corresponding to the station and the period during which the air pollutant monitoring was performed.

As input data, the authors used the average daily $PM_{2.5}$ concentrations on 53 days in 2020, the number of a given population (N = 360 925), the total number of deaths (N = 556), and the number of deaths per 100 000 population (N = 154) in the corresponding period of 2019, as well as the relative risk (RR) values recommended by WHO for short-term exposure (for $PM_{2.5}$ RR = 1.0123, 95% CI: 1.0045–1.0201 per 10 μg/m^3) [14]. The authors used 0 as the cut-off value because the health effects of air quality differences were calculated between 2 periods (2019 vs. 2020). It was also considered appropriate to use the same cut-off values for other periods, regarding the arguments that there is no safe level for the adverse effects of $PM_{2.5}$ [15]. The results of attributed and avoided deaths were expressed as an attributable proportion (AP), while the total number of attributed and

Table 2. Daily concentrations of air pollutants during the COVID-19 related state of emergency in 2020, and the corresponding periods in 2019 and 2018, in the City of Novi Sad, the Republic of Serbia

Air pollutants	Daily concentration [μg/m³]			p*
	M	SD	min.–max	
SO_2				<0.05
March 15–May 6, 2018	6.25	3.14	1.85–15.50	
March 15–May 6, 2019	8.93	5.06	2.40–23.33	
March 15–May 6, 2020	7.32	2.93	2.70–18.50	
air quality change** [μg/m³ (%)]	1.61 (–18)			
NO_2				<0.05
March 15–May 6, 2018	17.34	7.98	3.90–43.15	
March 15–May 6, 2019	20.20	8.48	6.00–39.80	
March 15–May 6, 2020	13.33	5.78	6.10–31.00	
air quality change** [μg/m³ (%)]	6.87 (–34)			
O_3				<0.05
March 15–May 6, 2018	77.78	14.86	48.80–106.00	
March 15–May 6, 2019	79.96	19.94	30.80–122.80	
March 15–May 6, 2020	86.18	14.67	46.10–117.10	
air quality change** [μg/m³ (%)]	6.22 (+8)			
PM_{10}				>0.05
March 15–May 6, 2019	41.34	14.32	10.33–71.00	
March 15–May 6, 2020	31.90	36.45	9.45–223.67	
air quality change** [μg/m³ (%)]	9.44 (–23)			
$PM_{2.5}$				<0.05
March 15–May 6, 2019	31.89	11.06	7.93–54.43	
March 15–May 6, 2020	20.66	23.97	5.33–145.52	
air quality change** [μg/m³ (%)]	11.23 (–35)			

* For SO_2 the p-values of <0.05 were considered to indicate statistically significant differences between 2019 vs. 2018, for NO_2 between 2020 vs. 2019, and 2020 vs. 2018, for O_3 between 2020 vs. 2018 in ANOVA analyses adjusted for multiple comparisons between years with the Bonferroni *post hoc* test: for PM_{10} and $PM_{2.5}$ the p-value was taken from the t-test.
** A comparison between the defined periods in 2019 and 2020.

avoided deaths was calculated as the AP multiplied by the total number of deaths. Avoided deaths were estimated based on air quality changes ($PM_{2.5}$ levels in 2019 vs. 2020).

The statistical analysis was performed using SPSS software, v. 21, while graphs were created in Excel. All statistical analyses with the p-value of <0.05. were interpreted as statistically significant.

RESULTS

During the 3 defined periods of 2018, 2019, and 2020, the average daily concentration of SO_2 was the highest (8.93 μg/m³) in the period of March 15–May 6, 2019, and the lowest (6.25 μg/m³) in the period of March 15–May 6, 2018. Differences in the average daily concentrations of SO_2 between the 2 years (2019 vs. 2018) were statistically significant ($p < 0.05$) (Table 2). The limit

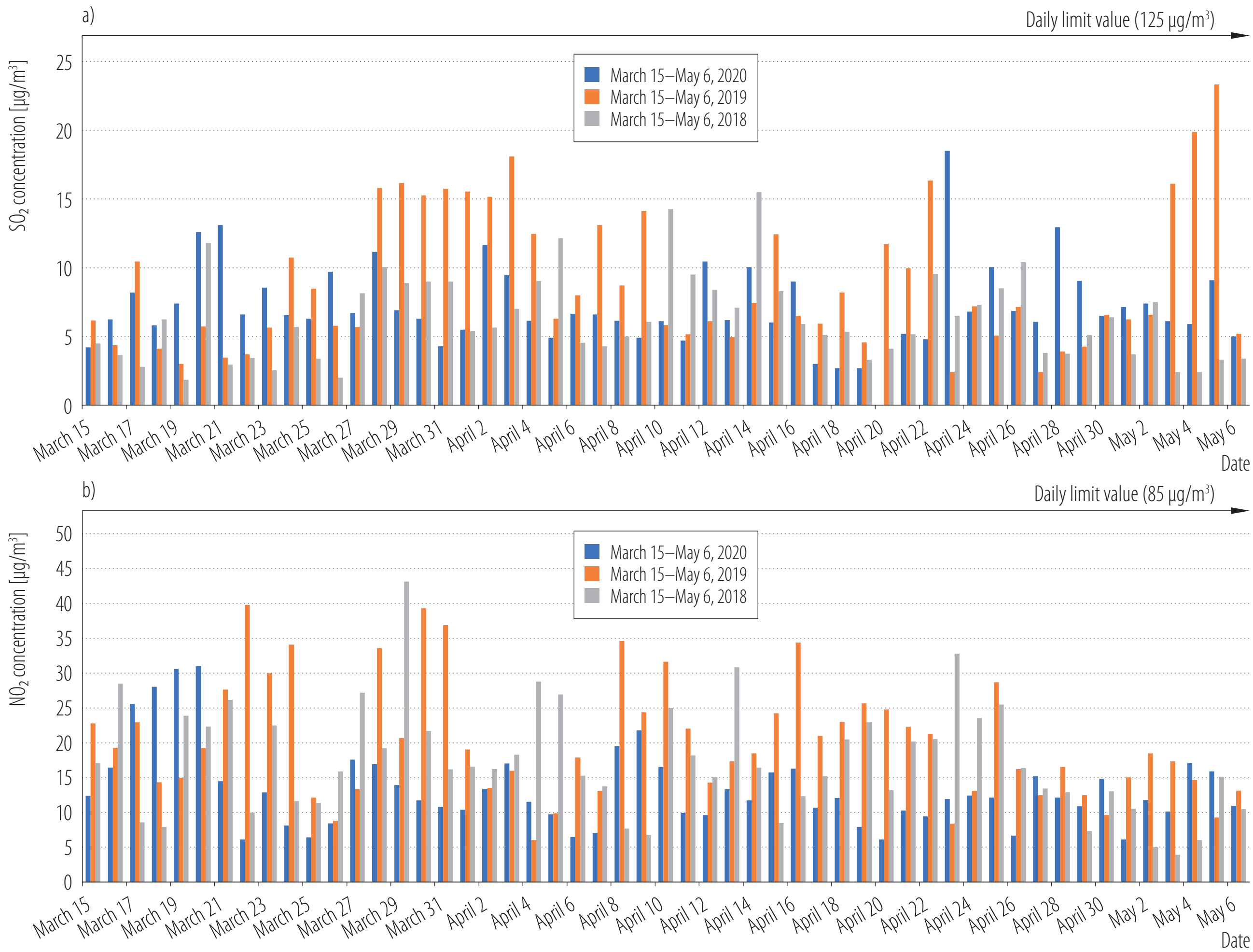

Figure 2. Average daily concentrations of a) SO_2 and b) NO_2 during the COVID-19 related state of emergency in 2020, and the corresponding periods of 2019 and 2018, in the City of Novi Sad, the Republic of Serbia

value of 125 μg/m³ was not exceeded during the observed periods (Figure 2).

During the 3 defined periods of 2018, 2019, and 2020, the average daily concentration of NO_2 was the highest (20.20 μg/m³) in the period of March 15–May 6, 2019, and the lowest (13.33 μg/m³) in the period of March 15–May 6, 2020. Differences in the average daily concentrations between 2 years (2020 vs. 2019, and 2020 vs. 2018) were statistically significant ($p < 0.05$) (Table 2). There was no exceedance of the limit value of 85 μg/m³ in the observed periods (Figure 2).

During the corresponding periods of 2018, 2019, and 2020, the daily maximum 8-hour average concentration of O_3 was the highest (86.18 μg/m³) in the period of March 15–May 6, 2020, and the lowest (77.78 μg/m³) in the period of March 15–May 6, 2018. There was a statistical difference in the daily maximum 8-hour average concentrations of O_3 between 2 years (2020 vs. 2018) ($p < 0.05$) (Table 2). A daily target value for O_3 of 120 μg/m³ was exceeded only once in the period of March 15–May 6, 2019 (Figure 3).

The average daily concentrations of suspended PM_{10} particles amounted to 41.34 μg/m³ in the period of March 15–May 6, 2019, and to 31.90 μg/m³ in the period of March 15–May 6, 2020. There was no statistical difference between the average daily concentrations in these 2 years ($p > 0.05$)

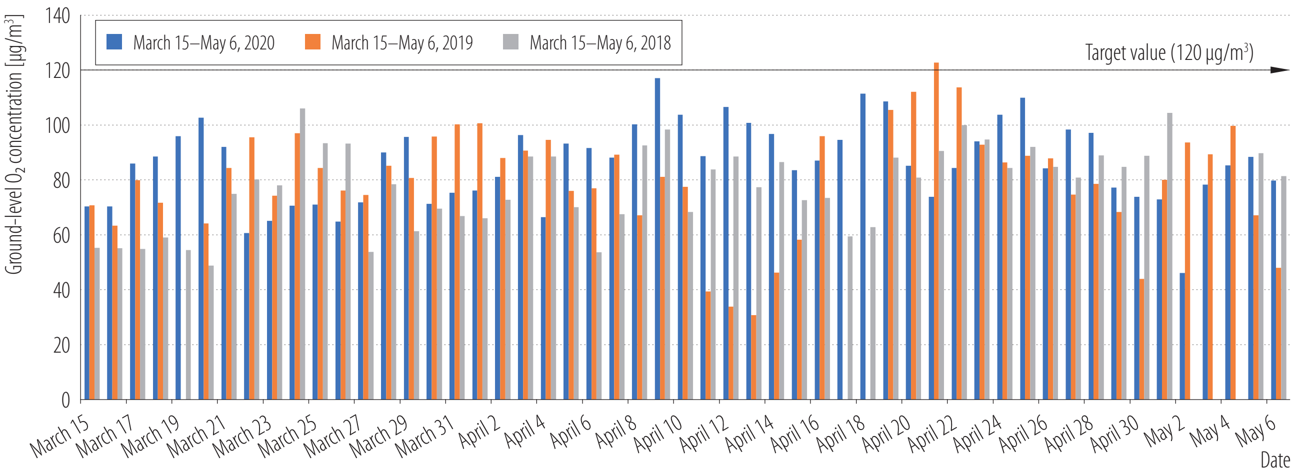

Figure 3. The average daily maximum 8-hour concentrations of ground-level O_3 during the COVID-19 related state of emergency in 2020, and the corresponding periods of 2019 and 2018, in the City of Novi Sad, the Republic of Serbia

(Table 2). The daily PM_{10} concentrations exceeded 50 μg/m^3 on 11 days in 2019 and on 3 days in 2020 (Figure 4).

The average daily concentrations of $PM_{2.5}$ particles were significantly lower in the period of March 15–May 6, 2020 (20.66 μg/m^3) compared to the concentrations in the corresponding period of 2019 (31.89 μg/m^3) ($p < 0.05$) (Table 2, Figure 4). The WHO average daily 24-hour guideline value of 25 μg/m^3 was exceeded on 35 days in the period of March 15–May 6, 2019, and on 9 days during the lockdown period in 2020.

Even though the average daily concentrations of SO_2, PM_{10}, and $PM_{2,5}$ were higher in the period of January 1–March 14, 2020 compared to the period of March 15–May 6, 2020, the difference was not significant (Table 3, Figure 5). The daily limit for PM_{10} particles of 50 μg/m^3 was exceeded on 16 days in 2020 before the COVID-19 related state of emergency, and on 3 days during the COVID-19 related state of emergency (Figure 5). The WHO average daily 24-hour guideline value of 25 μg/m^3 was exceeded on 26 days in the period before the COVID-19 related state of emergency, compared to 9 days during the COVID-19 related state of emergency in 2020 (Figure 5). There was no exceedance of the average daily concentrations of SO_2 above 125 μg/m^3 in the defined periods of 2020 (Figure 5).

The average daily concentrations of NO_2 were significantly lower during the period of March 15–May 6, 2020 compared to the period of January 1–March 14, 2020 (Table 7, Figure 5). The average daily concentrations of O_3 were significantly higher in the second observed period (March 15 – May 6, 2020) (Table 3, Figure 5).

The daily limit concentration value for NO_2 of 85 μg/m^3 and the target value of 120 μg/m^3 for O_3 were not reached at all during both the observed periods (Figure 5).

Weather conditions during the analyzed 53 days of the state of emergency in the City of Novi Sad, as well as during the corresponding period of the year before (2019) are presented in Table 4. The average values of air temperature, atmospheric pressure, and wind velocity did not change significantly ($p > 0.05$), while the value of relative humidity was statically significant ($p < 0.05$).

Using AirQ+ software, the authors estimated that, during 53 days in 2019, a total of 21 (95% CI: 8–34, AP 1.36%) premature deaths were attributable to short-term (daily) exposure to the average daily $PM_{2.5}$ levels of 30.88 μg/m^3 (Table 5). Using the same baseline number of all causes of deaths, during the 53 days in 2020 when measures for the current epidemiological situation were taken, a total

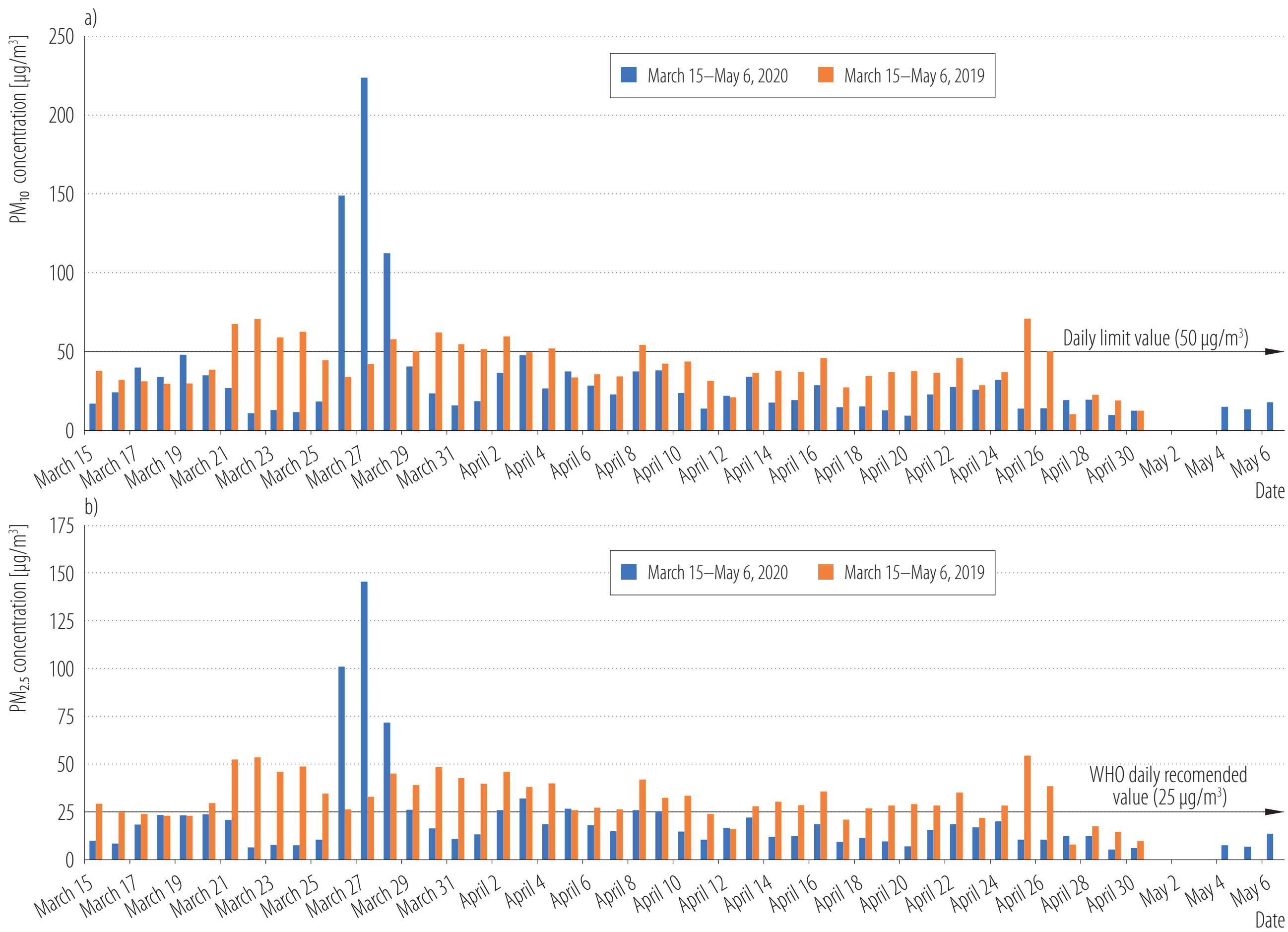

Figure 4. Average daily concentrations of particles a) PM_{10} and b) $PM_{2.5}$ during the COVID-19 related state of emergency in 2020 and the corresponding period of 2019 in the City of Novi Sad, the Republic of Serbia

Table 3. Daily concentrations of air pollutants in the City of Novi Sad during 2 periods in 2020 (before and during the COVID-19 related state of emergency), the Republic of Serbia

Period	Air pollutants [µg/m³] (M)				
	SO_2 ($p^* > 0.05$)	NO_2 ($p^* < 0.05$)	O_3 $p^* < 0.05$	PM_{10} ($p^* > 0.05$)	$PM_{2.5}$ ($p^* > 0.05$)
January 1–March 14, 2020	7.36	21.99	46.93	39.88	27.36
March 15–May 6, 2020	7.32	13.34	86.17	31.91	20.66

* The p-values of <0.05 were considered statistically significant.

of 14 (95% CI: 5–22) premature deaths were attributable to short-term exposure to the average daily $PM_{2.5}$ levels of 20.66 µg/m³. Considering the determined reduction (–11.23 µg/m³) in the average daily $PM_{2.5}$ levels in the City of Novi Sad, a total of 8 (95% CI: 3–12) premature deaths could be avoided (Table 5).

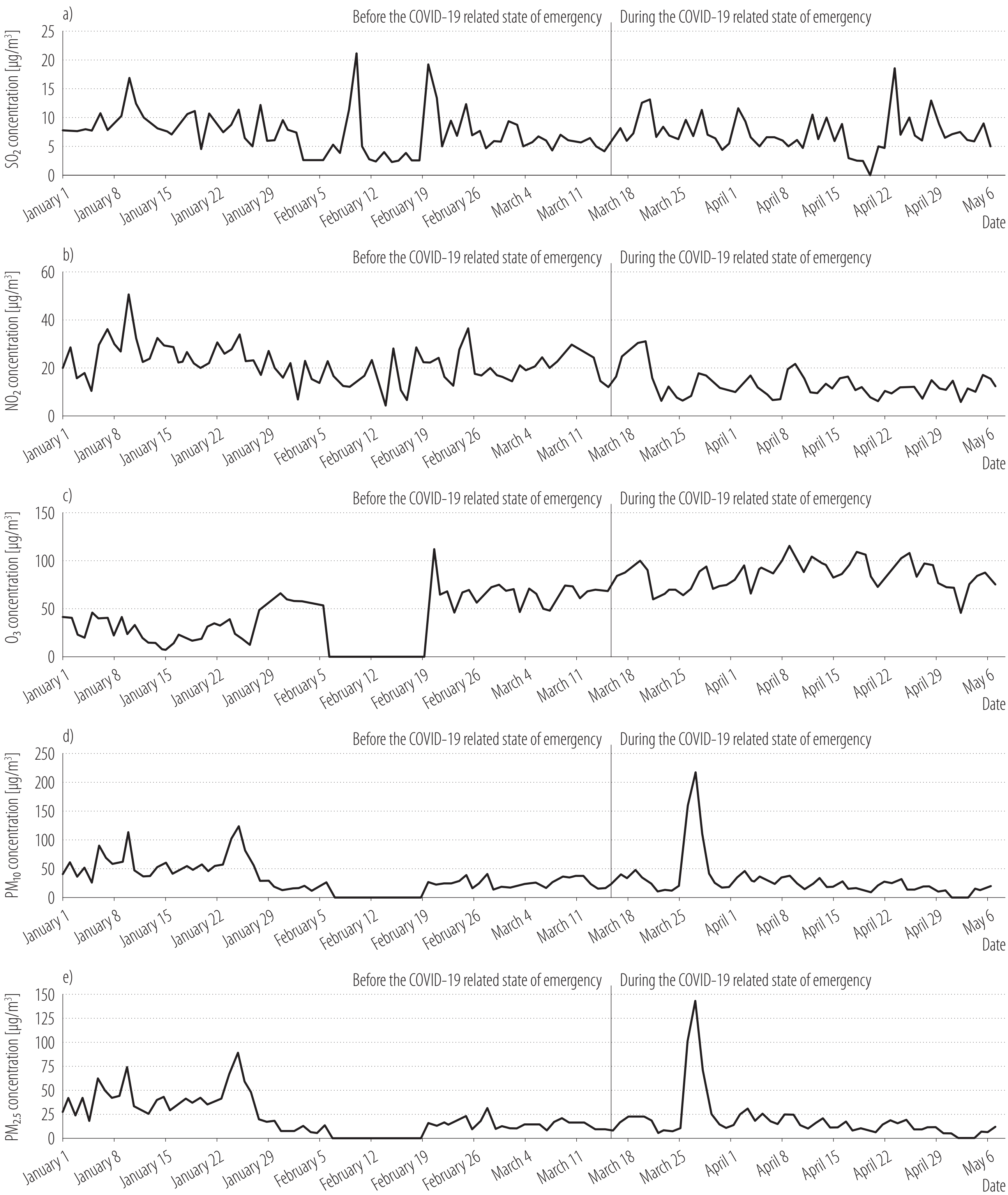

Figure 5. Average daily concentrations of a) SO_2, b) NO_2, c) O_3, d) PM_{10} and e) $PM_{2.5}$ before and during the COVID-19 related state of emergency in 2020 in the City of Novi Sad, the Republic of Serbia

Table 4. Statistical analysis of metrological conditions during the COVID-19 related state of emergency in the City of Novi Sad, and the corresponding period a year before, 2019–2020, the Republic of Serbia

Meteorological parameters	M	SD	Min.–max	p*
Air temperature [°C]				>0.05
March 15–May 6, 2019	12.26	4.92	0.30–20.40	
March 15–May 6, 2020	13.27	3.48	7.20–23.50	
Relative humidity [%]				<0.05
March 15–May 6, 2019	53.31	13.06	26.90–92.80	
March 15–May 6, 2020	60.42	16.55	36.00–94.00	
Atmospheric pressure [hPa]				>0.05
March 15–May 6, 2019	1009.09	6.44	997.00–1022.75	
March 15–May 6, 2020	1006.30	7.98	992.97–1024.07	
Wind velocity [km/h]				>0.05
March 15–May 6, 2019	0.35	0.21	0.10–1.30	
March 15–May 6, 2020	0.33	0.17	0.10–0.80	

* The p-values of <0.05 obtained from the t-test were considered statistically significant.

Table 5. The estimated attributable proportion and number of attributable cases of short-term exposure to $PM_{2.5}$ particles in the City of Novi Sad during the COVID-19 related state of emergency and the corresponding period a year before

Period	Total mortality (Me (95% CI))	
	attributable proportion [%]	attributable cases [n]
March 15–May 6, 2019	3.82 (1.42–6.15)	21 (8–34)
March 15–May 6, 2020	2.46 (0.92–4.03)	14 (5–22)
Difference (health benefits)	1.36 (0.5–2.21)	8 (3–12)

DISCUSSION

One of the visible signs of the COVID-19 pandemic in the function of the environment is the improvement of air quality. In some cities with the worst air pollution (New Delhi), thanks to protective measures, a significant drop in pollution was observed [16]. According to NASA reports, in the area of Wuhan, where the first human cases of COVID-19 were recorded, an unprecedented decrease in the NO_2 concentration was noticed, which spread very quickly to other areas of China [17], being directly related to the measures taken to prevent the spread of the SARS-CoV-2 virus, i.e., the lockdown. Since then, even in a short time, a large number of studies have been released [6,9,18] also concluding that air pollution has improved due to some measures taken to reduce the spread of the SARS-CoV-2 virus.

During the COVID-19 related lockdown in the City of Novi Sad, air quality was improved with the decreasing levels of $PM_{2.5}$ by 35%, NO_2 by 34%, PM_{10} by 23%, and SO_2 by 18%, compared to the data for the corresponding period a year before (2019). The drop in $PM_{2.5}$ from 30 $\mu g/m^3$ (before the COVID-19 related lockdown) to 20 $\mu g/m^3$ (during the COVID-19 related lockdown) was statistically significant. This also applied to the NO_2 levels where a reduction of approx. 7 $\mu g/m^3$ compared to the corresponding period of 2019, and of approx. 4 $\mu g/m^3$ compared to 2018, was considered significant. These results, along with the significantly increased levels of O_3 during the COVID-19 related lockdown (a rise of 8%), could imply the significant air pollution sources (traffic) in the City of Novi Sad that should be defined as the first target to which air pollution controls should be directed.

The significantly lower concentrations of NO_2, as well as the significantly increased levels of O_3 during the COVID-19 related state of emergency, compared to the previous period at the beginning of 2020, also indicate the importance of the traffic impact on air quality in the City of Novi Sad. The concentrations of PM particles and SO_2, probably originating from the combustion of fossil fuels and mineral dust, did not differ significantly. Persisting activity of these air pollution sources could also be confirmed with the exceeding of the EU daily limit values for PM_{10} particles and the WHO daily recommendation for $PM_{2.5}$ particles during several days. However, a short episode of higher PM_{10} and $PM_{2.5}$ concentrations on 3 days during the COVID-19 lockdown could be explained with some less persistent air pollution sources such as burning waste from landfills. There is a possibility that this kind of a short episode might not have been visible in that way if there had been no reduction in air quality as a consequence of measures taken during the COVID-19 related state of emergency.

In an extensive study covering European cities, similar conclusions were reached by other authors. Namely, in Europe, the reduction in $PM_{2.5}$ was found to be lower than that in NO_2, i.e., it ranged 5–10%. It is believed that this was due to the impact of emissions of primary particles from domestic heating, which were still in use, especially in March [18]. On the other hand, the significant reduction in $PM_{2.5}$ between these 2 periods (i.e., before vs. during the COVID-19 related lockdown) in the City of Novi Sad suggests that the more dominant source of $PM_{2.5}$ is traffic, and also that the contribution of secondary sources (ammonia) was perhaps not present as usually due to the limited citizen movement and opportunities for agricultural activities.

The air quality data analysis for the City of Novi Sad during the period before taking the lockdown measures indicates that there was an upward trend in other air pollutant concentrations, considering that higher concentrations were determined during the defined period in 2019 than in the same period in 2018. These results suggest that, while traffic is regarded as one of the leading sources of pollution in the City of Novi Sad, there are more other anthropogenic sources (power generation, industry and residential energy use [19]), as well as landfill fire, which must go under better air pollution management.

However, the obtained results have also revealed a new obstacle that needs to be overcome when managing air quality. Namely, it seems that the reduction of traffic, which was evident during the COVID-19 related state of emergency according to the determined NO_2 values, led to the risk for increased O_3 in the urban centers of the City. Namely, lower concentrations of NO_2 are also conditioned by lower concentrations of precursors (NO), which results in reduced O_3 degradation. Ozone as an extremely irritating gas and the leading risk factor for the development of asthma and the worsening of lung function, especially in people with chronic obstructive pulmonary diseases [20] was characteristic of the predominantly summer months in the City, and mostly in rural areas where traffic is not expected. Similar results are also provided from other studies in Italy [21], as well as other European countries [18].

The results indicate that the unplanned control traffic as an important urban source of air pollution could be the reason to transform a regional air pollutant into a local air pollutant. Although O_3 as a secondary pollutant depends on meteorological conditions, this constatation is based on the results of this study. Namely, meteorological conditions (air temperature, atmospheric pressure, and air velocity) in the City of Novi Sad did not change significantly between the 2 periods (53 days during 2020 and 2019). Even if some authors [22] suggested that the reduction in air quality could not be directly attributed to the lockdown or quarantine because of an important interaction of air pollutants and local weather conditions, these impacts could be excluded in this study, with an exception of relative humidity. Chinese authors [23] also pointed at a limited meteorological influence on air quality changes during the lockdown period.

Taking into account the fact that vulnerability to COVID-19 increased in the countries with worse air quality [24], compared to the results of this study, considering the potential health co-benefit with a more aggressive method for the improved air quality could have an important influence on decision-makers.

The authors found that even a small improvement in air quality ($PM_{2.5}$ particles) could reduce the air pollution induced mortality. Numerous time-series studies, conducted in different areas and using different statistical models, have provided evidence that PM particles and mortality are interrelated [15,25]. Consistent with the availability of air quality data, the original studies used PM_{10} particles as an exposure indicator [15,25]. However, since WHO, in its air quality guidelines of 2006 [12], defined $PM_{2.5}$ particles as an indicator of outdoor air pollution, research with $PM_{2.5}$ particles in focus displays an increasing trend. In this study, exposure to $PM_{2.5}$ particles was also selected as an indicator of air quality changes in the City of Novi Sad, given that it was found that the most significant negative health effects (mortality, cardiovascular and respiratory diseases) are the consequences of exposure to suspended $PM_{2.5}$ particles [26]. Besides, due to the daily exposure of the human population to outdoor air pollution, health impacts are possible at all stages of human life – from conception to old age [26].

Regarding short-term exposure to air pollution, the results of these studies suggested that a reduction in the average daily $PM_{2.5}$ levels by 11.23 μg/m^3 during the COVID-19 related state of emergency in the area of the City of Novi Sad probably saved 8 lives. Similar results were reported for some other individual urban areas, too [27]. In 2 cities in Morocco, Casablanca and Marrakech, it was estimated that the reduction in $PM_{2.5}$ levels contributed to avoiding, respectively, a total of 48 (95% CI: 70–89) and 15 (95% CI: 10–19), deaths related to $PM_{2.5}$ exposure during the quarantine period (32 days) [27]. According to recent research, this situation with the improved air quality in Europe saved about 11 000 lives (95% CI: 7000–21 000) only in 1 month [28]. Similar results came from China, where only 34 days of quarantine improved air pollution contributed to avoiding nearly 9000 NO_2 related deaths, as well as >3000 $PM_{2.5}$ related deaths [29]. Although a direct comparison could only correspond to an attributable fraction because of the sizeable differences in the population number, variance in the results could also have resulted from heterogeneity in air quality during and before the quarantine period. This dissimilarity is explained by some socio-economic factors (a lower income level and a larger population) that could affect air quality changes [10].

The main strength of this study is the fact that it provides an answer to the question of how air quality improvements would affect public health, i.e., mortality reduction in the population of the City of Novi Sad. Although the measures taken during the COVID-19 pandemic were negative from the mental health point of view [30], they provided an unprecedentedly significant opportunity to gain insight into the magnitude and significance of the anthropogenic impact on air quality. In unusual conditions, it served as an important tool for showing the public health importance of improving air quality.

However, this study also has several limitations:

- the likelihood of an exposure measurement error between the analyzed periods because of heterogeneity in the number and distribution of measuring stations;
- an assumption that citizens had the same outdoor exposure although most of them were predominantly exposed to indoor air quality;

- although the authors applied the short-term RR value proposed by WHO, derived from a study covering a wide range of climatic conditions, the possibility of some modificatory factors, such as the city characteristics and socio-demographic characteristics, could not be excluded;
- using the same mortality data (from 2019) for calculating avoided deaths in 2 different observed periods (2020 vs. 2019) although the authors assumed that, in that way, they could avoid misinterpreted results in 2020 because of the rising number of COVID-19 related deaths.

CONCLUSIONS

Air pollution in the City of Novi Sad had a chance to be improved due to some preventive measures related to the infectious disease (the COVID-19 related lockdown), thus acting as a mitigation measure to air pollution. The average daily concentrations of $PM_{2.5}$, NO_2, PM_{10} and SO_2 were reduced. The increased concentration of O_3, even if the primary precursors were reducing, represented a challenge for air quality management. In the City of Novi Sad, a reduction in the $PM_{2.5}$ level was significant, which resulted in a quantified number of avoided deaths. The results of this research represent a scientific basis for the adoption of an adequate public health policy and a strategy for improving air quality at the level of local and wider communities. The confirmed positive effect of the improved air quality on public health could also include raising collective resistance to mass non-communicable and infectious diseases such as COVID-19 and reducing economic costs.

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