DOES THE COVID-19 PANDEMIC HELP WITH IDENTIFYING MEASURES TO REDUCE ATMOSPHERIC POLLUTION?

VAI COVID-19 PANDĒMIJA PALĪDZ APZINĀT DARBĪBAS ATMOSFĒRAS PIESĀRŅOJUMA SAMAZINĀŠANAI?

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Abstract

This article analyses the variability of gas and aerosol pollution levels in Riga (Latvia) over different periods associated with Covid-19 restrictions. The variability of atmospheric pollution levels is described from a relative point of view; the effects of meteorological parameters were assessed using Pearson's correlation factor and statistical significance. To assess whether changes were statistically relevant during the various assessment periods, the analysis was performed using the ANOVA dispersion test and the post-hoc Tukey test. Major changes have been identified in the case of gaseous atmospheric pollution.

Keywords: air pollution, Covid-19, Riga, gaseous pollutants, particulate matter

Introduction

Various publications and national reports, including digital media, increasingly show information on the reduction of atmospheric pollution due to the limited economic activity imposed by the COVID-19 pandemic restrictions, such as the reduction of nitrogen dioxide (NO_2) concentrations in atmospheric air in Europe, the USA, Malaysia and other countries (Berman & Ebisu 2020; Othman & Latif 2021). The European Environment Agency has also reported that the most significant reduction in air pollution during the Covid-19 pandemic is particularly observed in case of nitrogen dioxide (NO_2) pollution, but other air pollutants have decreased less (EEA 2020).

The global Covid-19 pandemic started in the city of Wuhan in Hubei province in China. The novel Coronavirus (SARS-CoV-2) is an infectious disease affecting the airways and is more contagious than previous strains of the virus (SARS and MERS), with needle-shaped spikes and protein mutations that increase the spread of the virus. Similar local outbreaks with similar symptoms to the new SARS-CoV-2 virus (Platto et al. 2020) were have been detected at the end of 2019 (October–December). In January 2020, the virus became an epidemic in China, after which it spread elsewhere in the world. By 11 March 2020, SARS-CoV-2 had become a global pandemic, and within a few weeks, the Covid-19 virus had become the most dominant variant of the virus around the world (Platto et al. 2020).

As the virus spread across Europe, in March 2020 most European countries started to introduce economic and movement-restrictive measures to reduce the number of infections. Measures introduced in different countries included partial or total closure of national and international borders, travel restrictions, the closure of educational institutions, restrictions on local mobility and others. These activities, which are intended to limit the spread of the virus, have at the same time significantly reduced the activity of atmospheric pollutants, particularly in the road and aviation sectors. Several researchers have analysed the reduction of direct emissions in the atmosphere (e.g. Guevara et al. 2021), concluding that in 30 countries in Europe (EU-27, the United Kingdom, Norway and Switzerland) the average reduction in NO_x emissions was 33%; in NMVOCs, 8%; and SOx and $PM_{2.5}$, 7%. For pollutants as a whole, with the exception of SO_x, 85% of the reduction was attributable to road transport. There is an unclear situation at concentration levels where a reduction in NO_x concentrations is observed in several European cities including Brussels, Madrid, Milan, Paris; statistically significant changes in $PM_{2.5}$ cannot be confirmed in relation to the complex $PM_{2.5}$ formation mechanism (Dobson & Semple 2020; Fu et al. 2020; Kumar et al. 2020; Lee et al. 2020).

In Latvia, there has been a long-term increase in atmospheric pollution in Riga, and effective measures, whose introduction is widely anticipated and problematic, are being sought to improve the situation. In analysing the results of long-term monitoring, it is not possible to unambiguously identify the impacts of individual pollutants, which makes it difficult to assess the effectiveness of measures to reduce atmospheric pollution. In the case of Covid-19, the extent of the effects of the restrictions on mobility on atmospheric pollution can be used as a unique situation in which it can be assessed whether, in the case of Riga, such measures to limit mobility would be effective. The study carried out an analysis of concentrations of pollutants in Riga before the Covid-19 pandemic and during periods of lockdown.

Data and methods

Changes to the structure of air quality data were studied as data changes over specific periods. The following periods for analyses were set, corresponding to specific lockdown periods regulated by legislation in Latvia: (1) 12.03.2019–31.12.2019 (the pre-Covid-19 period); (2) 12.03.2020.– 9.06.2020 (the first Covid-19 lockdown period); (3) 10.06.2020–8.11.2020 (the period between lockdowns); (4) 12.03.2021–30.04.2021 (the second Covid-19 lockdown period). All changes in concentrations of pollutants were analysed, taking into account meteorological parameters, as their impact on concentrations are well-known. All the data included in the analysis were obtained from the official database operated from the Latvian Environmental, Geology and Meteorology Centre. In the case of gaseous pollutants and meteorological data, hourly values were analysed, while in the case of particle pollution, 24-hour agglomerated data were used. A detailed description of monitoring sites is given in Table 1.

Table 1. **Information about monitoring points and gathered data**

Monitoring point	Station type	Geographical coordinates	Parameter
Kengarags	City background station	56.935928 N 24.156786 E	SO_2, NO_2, O_3, benzene, toluene
Parks	City background station	56.950606 N 24.115872 E	SO_2, NO_2, O_3, benzene, toluene
Brivibas	Traffic pollution station	56.958914 N 24.125775 E	PM_{10}
Kronvalda	City background station	56.954847 N 24.104756 E	$PM_{2.5}$, PM_{10}
Riga-University	Meteorological station	56.954797 N 24.104686 E	pressure, air temperature, precipitation, wind speed, wind direction

The data analysis was carried out using the the programme JASP 0.14.1.0. The following methods of analysis were applied as part of the work:

(1) a descriptive statistical analysis to give an idea of the variation of parameters over the periods defined above
(2) correlations analysis – in order to assess the impact of individual meteorological parameters on concentrations of pollutants, with a view to excluding the effects of these parameters from further analysis
(3) analysis of dispersions (ANOVA) and post-hoc analysis to compare differences between each Covid-19 period, excluding the effects of statistically relevant meteorological parameters

Results

As a reference period, a sufficiently long period has been selected to reflect the situation of atmospheric pollution before the introduction of the Covid-19 restrictions, it has also been considered to ensure that, as far as possible, data are collected throughout the seasons. It appears that the average and median concentrations of all observation stations do not exceed the air quality standards, but it is apparent that very high-pollution episodes have also been observed, particularly in the case of particulate pollution (see page Table 2).

Table 2. **Overview of pollutant concentrations for pre-Covid-19 period included in data analysis (12.03.2019.–31.12.2019.)** (authors' elaboration based on Latvian Environmental, Geology and Meteorology Centre data)

Pollutant, site	Median concentration, ug/m³	Mean concentration, ug/m³	Minimum concentration, ug/m³	Maximum concentration, ug/m³
$PM_{2.5}$, Kronvalda	9.9	12.018	0.2	67.1
PM_{10}, Kronvalda	17.5	20.62	1.1	85.5
PM_{10}, Brivibas	34.6	35.756	11	94
SO_2, Parks	2.383	2.284	0.279	3.953
NO_2, Parks	19.493	20.977	3.463	69.276
O_3, Parks	30.237	32.845	3.867	87.237
C_6H_6, Parks	2.35	2.542	1.102	5.912
Toluene, Parks	7.273	7.641	2.97	14.918
SO_2, Kengarags	1.474	1.646	0.763	4.681
NO_2, Kengarags	23.843	24.761	3.23	61.717
O_3, Kengarags	51.364	53.933	26.535	93.55
C_6H_6, Kengarags	1.563	1.65	0.68	3.6
Toluene, Kengarags	7.12	7.749	2.502	36.21

Concentrations of substances vary very much over the prescribed periods, depending on the specific pollutants and inherent concentrations in the environment. Therefore, in order to assess the intensity of these changes, the variability of concentrations is described as relative values as a percentage relative to the pre-Covid-19 period; negative values indicate a decrease in concentrations, while positive values indicate an increase in concentrations.

In general, it can be argued that nitrogen dioxide concentrations have decreased during the Covid-19 periods with specified operational and displacement limits, which has contributed to increasing ozone concentrations in the atmosphere as a result of photochemical processes. In the case of sulphur dioxide, the situation is not clear: there was a decrease in concentrations at Parks station and an increase at Kengarags station. A similar situation was observed with toluene and benzene contamination, which could potentially indicate specific, very local sources of pollution. In the case of coarse particulate matter (PM_{10}), atmospheric pollution levels have only increased, while in the case of smaller particulate matter ($PM_{2.5}$), the situation has improved over the Covid-19 periods. This reduction of concentrations could be explained by changes in the level of contamination of other concentrations, as part of $PM_{2.5}$ is secondary aerosols produced in response to volatile organic compounds and nitrogen dioxide.

Detailed changes to pollution levels for all substances and all monitoring stations are given in Figure 1.

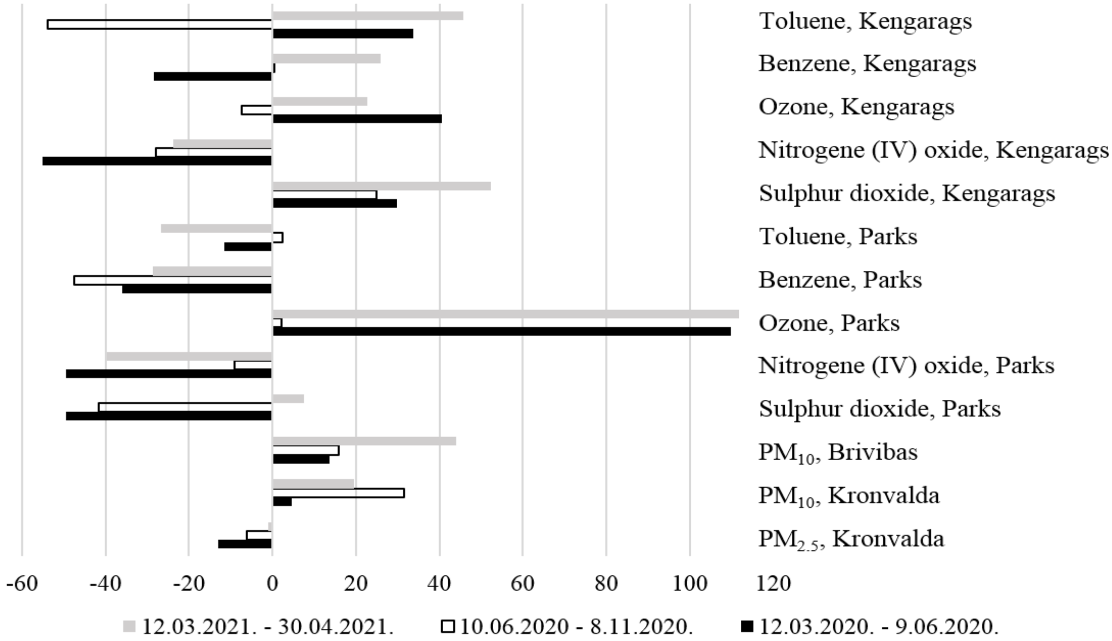

Figure 1. **Relative changes (%) in concentrations; base period is pre-Covid-19 period (12.03.2019. - 31.12.2019.)** (authors' elaboration based on Latvian Environmental, Geology and Meteorology Centre data)

At the Park station there has been found to be a particularly high increase in ozone concentrations, which may initially seem extremely dangerous. However, it should be noted that in urban areas nitrogen dioxide concentrations are close but reversible, related to ozone concentrations. Due to photochemical reactions in the atmosphere, when ozone molecules are split in sunlight, oxygen in the atomic form reacts with nitrogen (II) oxide emitted in the results of incomplete combustion, and a result of this reaction is nitrogen (IV) dioxide. Comparing concentrations between pollutants is difficult not only because of different periods of time but because, as is known, atmospheric pollution is heavily affected by meteorological conditions. Wind speed, wind direction, precipitation, atmospheric temperature and atmospheric pressure are generally considered to be the most significant weather conditions. A correlation analysis has been carried out to assess the magnitude of the effects of particular circumstances, which which eliminates statistical relevance and correlations.

The correlations analysis confirmed that there was a statistically significant correlation between these meteorological parameters and concentrations of pollutants, a factor of Pearson's correlation rates, often with a rather low correlation. The highest correlation rates for Pearson are obtained for wind direction and wind speed, which is why the effects of these parameters on concentrations are excluded in the subsequent analysis.

All set of Pearson correlation coefficients are given in Table 3, and additionally statistically substantial relations were shown.

Table 3. **Pearson correlation coefficients for the whole period analysed** (authors' elaboration based on Latvian Environmental, Geology and Meteorology Centre data)

Variable	**Atmospheric pressure**	**Air temperature**	**Precipitation**	**Wind speed**	**Wind direction**
$PM_{2.5}$ Kronvalda	0.20***	0.22***	-0.14**	-0.17***	-0.26***
PM_{10} Kronvalda	0.24***	0.22***	-0.17***	-0.14***	-0.25***
PM_{10} Brivibas	0.28***	0.13**	-0.19***	-0.25***	
SO_2 Parks		0.15***			
NO_2 Parks	0.18***	0.11**		-0.55***	-0.22***
O_3 Parks	0.17***	-0.35***	-0.18***	0.34***	0.21***
C_6H_6 Parks		0.15***		-0.08*	
Toluene Parks	0.10**	0.32***		-0.16***	-0.10*
SO_2 Kengarags	0.23***	-0.18***	-0.20***		
NO_2 Kengarags	0.15***	-0.24***		-0.50***	-0.11*
O_3 Kengarags	0.21***		-0.15***	0.24***	0.17***
C_6H_6 Kengarags		-0.17***		-0.13*	
Toluene Kengarags	0.13**	-0.76***	-0.10*	0.16***	0.13**

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

An analysis of the variance of ANOVA, completed by the post-hoc Tukey test, has been prepared following the elimination of the impacts of the major meteorological parameters. In the case of particulate matter contamination, statistically significant changes could not be identified during the various periods, even after the effects of meteorological conditions were excluded. However, the situation is different in the case of gaseous contamination (see Figure 2).

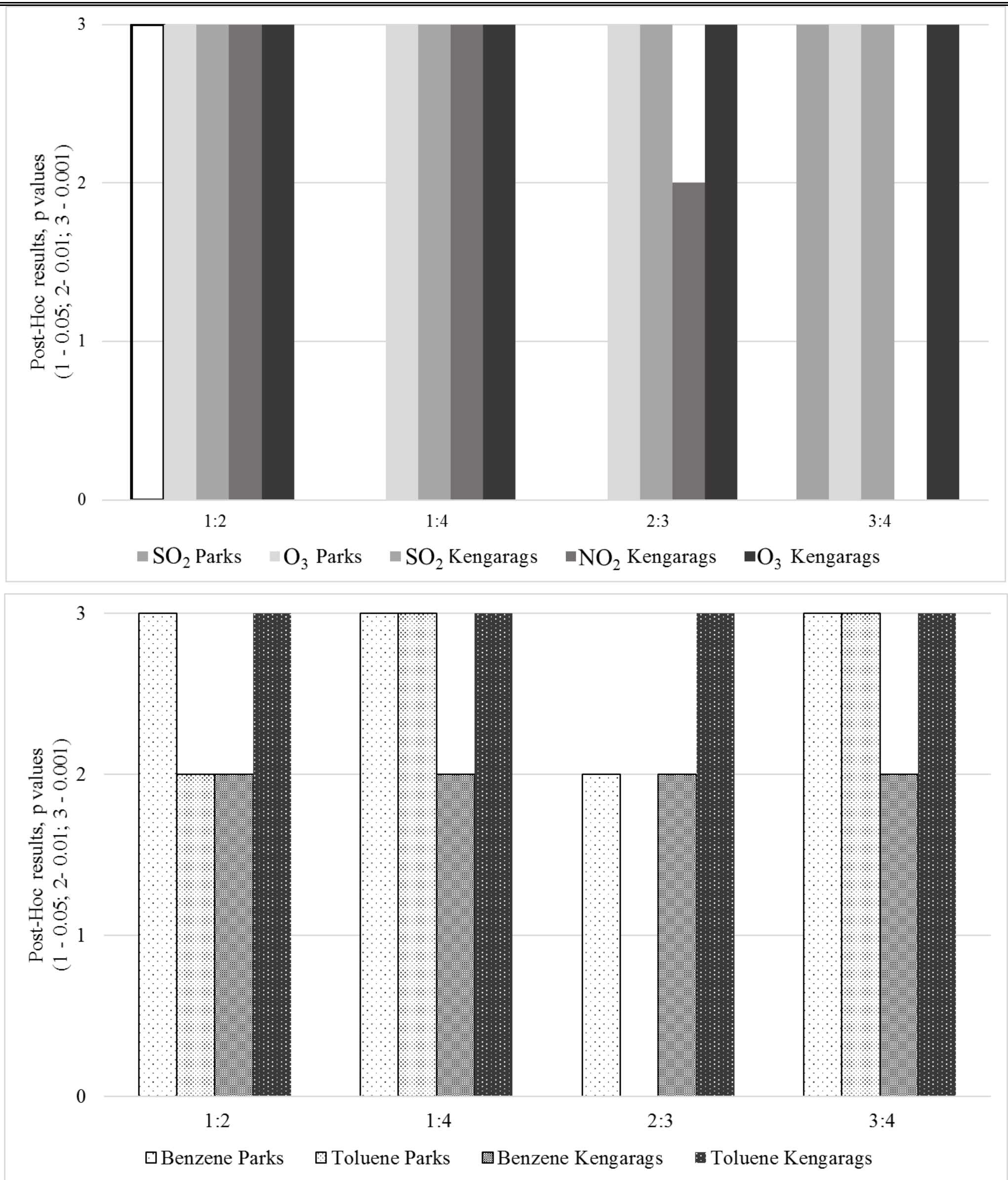

Figure 2. **Grouped post-hoc test results for different periods; example of gaseous pollutants** (authors' figure based on Latvian Environmental, Geology and Meteorology Centre data)

Conclusions

Although the restrictions on movement and economic activity imposed in Latvia during Covid-19 were not as strict as in other countries, there have been statistically significant changes in the field of atmospheric pollution. The results have shown that this situation can be used to predict how pollution could change if the activity of various sources of pollution was limited. The statistically significant reduction in gaseous concentrations observed unfortunately does not solve the major pollution problem in Riga – the pollution of particulate matter PM_{10} – but it has indicated that the occurrence of significant amounts of pollution is not confined to transport and heating pollution. On the other hand, the results of $PM_{2.5}$ have shown that pollution can be reduced by reducing the level of secondary aerosols. Since the reduction of this type of pollution is extremely difficult, the analysis of the results during the above periods indicates that the reduction can be achieved by reducing concentrations of nitrogen dioxide and volatile organic compounds.

Kopsavilkums

Rakstā analizēta gāzveida un aerosolu piesārņojuma līmeņa mainība Rīgā (Latvijā) dažādos ar Covid-19 ierobežojumiem saistītos periodos. Atmosfēras piesārņojuma līmeņa mainība raksturota no relatīvā skatu punkta, meteoroloģisko parametru ietekme novērtēta, izmantojot Pīrsona korelācijas koeficientu un statistisko būtiskumu. Lai novērtētu, vai pārmaiņas dažādos novērtējuma periodos ir statistiski būtiskas, analīze veikta, izmantojot ANOVA dispersijas testu un Poist-Hoc Tukey testu. Būtiskākās pārmaiņas konstatētas gāzveida atmosfēras piesārņojuma gadījumā. Novērotais statistiski būtiskais gāzveida koncentrāciju samazinājums diemžēl neatrisina lielāko piesārņojuma problēmu Rīgā – lielāko cieto daļiņu PM10 piesārņojumu, tomēr tas indikatīvi liecina, ka būtiska piesārņojuma daudzuma rašanās tomēr nav saistīta tikai ar transporta un apkures piesārņojumu. Savukārt iegūtie rezultāti par sīkāko cieto daļiņu PM2.5 koncentrācijas pārmaiņām liecina, ka šo gāzveida piesārņojumu iespējams ierobežot, šādā veidā samazinot sekundāro aerosolu īpatsvaru.

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