

Has the COVID-19 pandemic affected the air pollution trends in Warsaw agglomeration?

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Introduction

The pandemic of COVID-19 forced Polish government to introduce numerous preventive measures to manage the epidemiological situation. Since the first lockdown in Spring 2020, the closure of educational institutions and transition to home office resulted in significant traffic reduction in Polish cities. The aim of this study is to investigate whether the administrative measures, that limited citizens mobility and economic activity, had impact on the air quality in Warsaw agglomeration. The main focus is on two transport-related pollutants - NOx and PM2.5, although the main source of the latter is in fact non-industrial combustion processes.

Study area and materials

We used hourly data on the particulate matter (PM2.5) and nitrogen oxides (NOx) mass concentrations from the three Chief Inspectorate of Environmental Protection (GIOŚ) air monitoring stations – Legionowo (LEG), Niepodległości Avenue (NIE) and Wokalna Street (WOK) (Fig. 1). The station in Legionowo, at 38 Zegrzyńska St. is located on the outskirts of Warsaw, next to the busy transit road. The measuring point at 227/233 Niepodległości Av. is located in the city center and represents the traffic type of monitoring station. The station on 1 Wokalna St. is located in the southern part of the city, in the Ursynów district, on a grassy square within a large housing estate.

In order to present a broader context of the air pollution variability, we focused not only on the data from the recent months, covering the period from the beginning of the pandemic in March 2020, but also extended the analysis to the 5-year period (2015-2019) preceding the COVID-19 pandemic outbreak.



Fig. 1. The location of air quality monitoring stations

Covid-19 pandemic in Warsaw agglomeration and its phases

The first coronavirus infection in Poland was confirmed on March 4, 2020. Since March 16, the government announced an epidemic emergency state, but in fact the first lockdown began on March 12, with the closure of schools, kindergartens and universities. By the end of April 2021, a total of 2.79 million confirmed cases and more than 67,000 deaths due to COVID-19 were recorded in Poland. Fig. 2 presents the excess mortality in the Warszawski stoleczny region (PL-91) which corresponds well with the successive epidemic waves in the whole country. Along with the changing incidence and death rates, the state authorities have introduced many restrictions over the past months, that periodically limited the mobility of Warsaw agglomeration inhabitants, leading to significant traffic reduction.

The Covid-19 pandemic in Poland can be divided into the following phases:

- I – pre-pandemic period with first confirmed cases in Poland at the end
- II – first lockdown (since 12.03.2020)
- III – gradual loosening restrictions (20.04.2020)
- IV – removing most of the restrictions (6.06.2020)
- V – introduction of the restrictions (24.10.2020)
- VI – second lockdown (9.11.2020)
- VII – gradual loosening restrictions, restoration of full-time teaching in grades 1-3 (18.01.2021)
- VIII – third lockdown (27.03-18.04.2021)

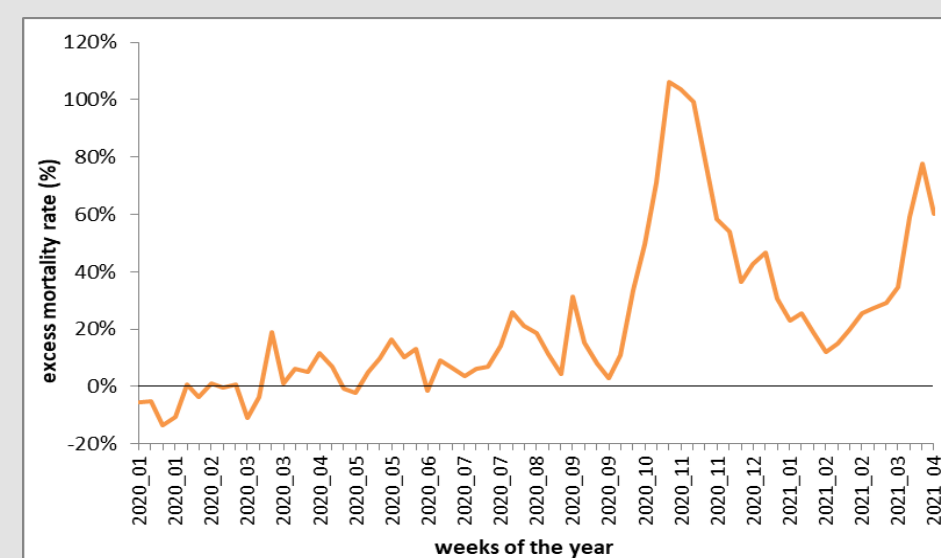


Fig. 2. The excess mortality* (%) in Warszawski stoleczny NUTS3 region from the beginning of the year 2020

* The weekly excess mortality indicator is expressed as the percentage rate of additional deaths in a week, compared to a baseline period 2015-2019.

NOx and PM2.5 concentrations during COVID-19 pandemic

The most significant impact of traffic reduction due to COVID-19 pandemic has been noted for NOx concentration downtown (NIE) - an average decrease of 34.9% (Fig. 3), whereas the least visible differences between pre-pandemic period and the pandemic were in the outskirts of Warsaw (LEG), next to the exit road with transit traffic. In residential district (WOK) at the beginning of the pandemic in April 2020 NOx concentration even exceeded long-term average (31%), but since October 2020 when the second COVID-19 wave started, NOx has been remaining at a slightly lower level than in previous years. From the beginning of the pandemic, mean concentration of PM2.5 in Warsaw agglomeration has been slightly lower to the long-term average level (from 18,9% at WOK to 24,6% at LEG). However, at all spots the largest reductions in PM2.5 concentrations took place at the beginning of 2020, before the introduction of restrictions. This may be partially explained by meteorological conditions, specifically anomalously warm January and February in 2020 ($t_{II} = 3.2^{\circ}\text{C}$), what resulted in lower heating demand and better air quality.

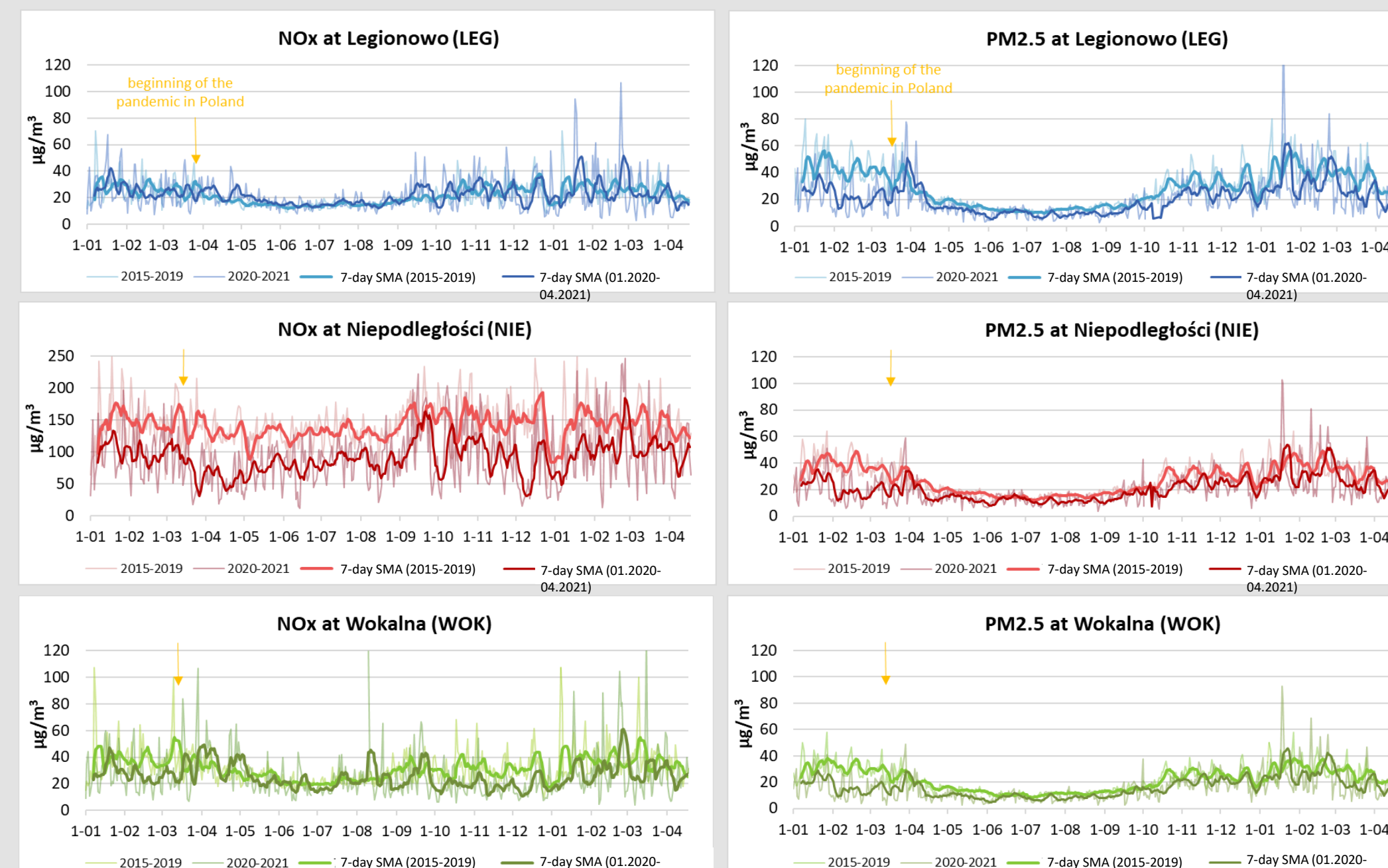


Fig. 3. Course of daily averages and 7-day moving averages (SMA) of daily NOx and PM2.5 concentrations in the Warsaw agglomeration from the beginning of 2020 against the corresponding averages for the 5-year period 2015-2019

Changes of air pollution in particular phases of the pandemic

During first lockdown in Spring 2020 the reduction of NOx concentration was observed only downtown (NIE) (Fig. 4a), while in other spots small increase in NOx levels occurred. With the next two lockdowns in November 2020 and at the end of March 2021 NOx concentrations were lower than the long-term average, although in residential district (WOK) the reduction effect was noted already with the introduction of the first restrictions in the pandemic phase V.

PM2.5 levels were lower than long-term averages in all analysed places, regardless of the pandemic phase (Fig. 4b). The highest percentage decrease in PM2.5 concentration (by 39%) was observed in the housing estate (WOK) during phase III, despite the gradual loosening of the restrictions at that time. Therefore, it can be concluded that the reduction of PM2.5 level was also influenced by other factors, not necessarily related to the limitation of traffic.

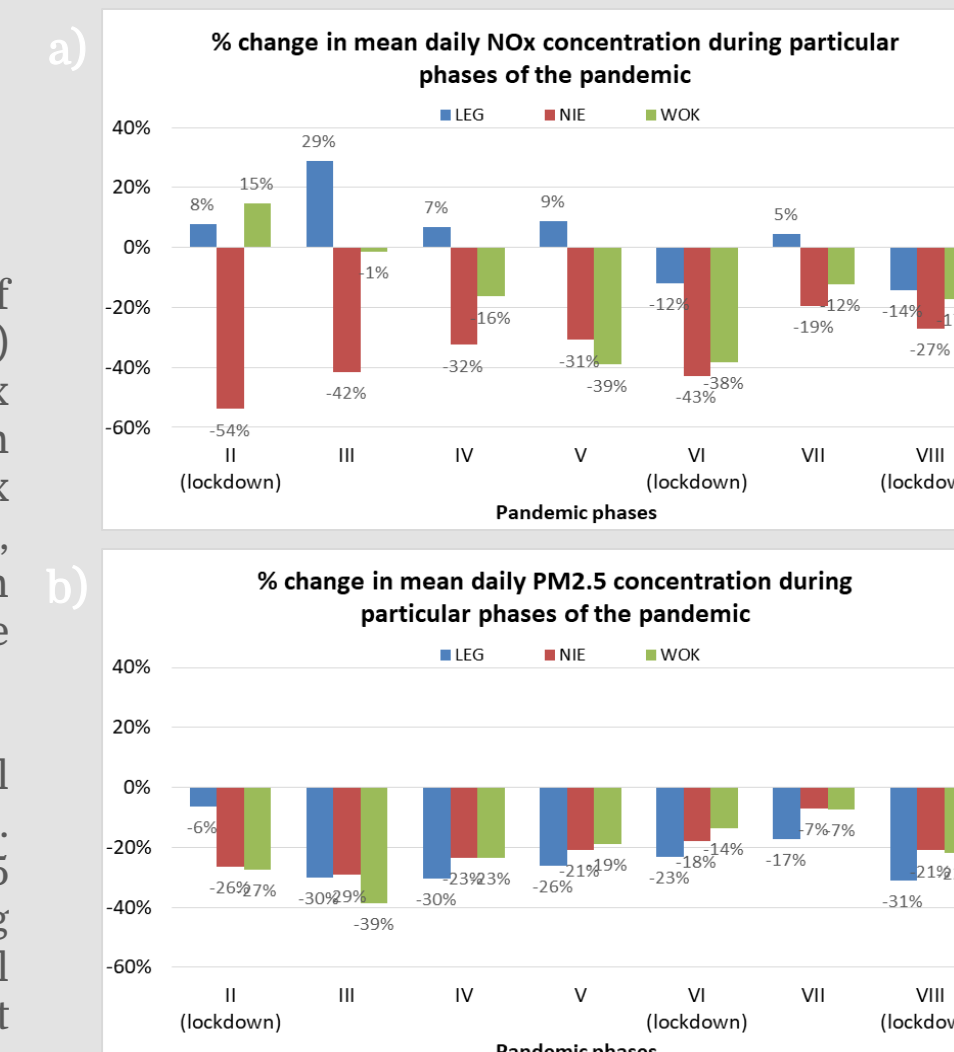


Fig. 4. Relative change (%) in mean daily a) NOx and b) PM2.5 concentration during particular phases of the pandemic with respect to daily averages for corresponding periods in years 2015-2019

Changes in weekly and daily pollutant concentration trends

Significant changes in daily and weekly pollutant concentration trends were observed. During last 14 months NOx levels have been lower than long-term average on every day of the week in NIE and WOK, with the maximum effect on Fridays (Fig. 5), while on the contrary in the outskirts (LEG) NOx concentrations raised from Monday to Thursday in comparison to the pre-pandemic period. Since the beginning of the pandemic the PM2.5 pollution levels have dropped at all stations, but the greatest decrease was also observed at the end of the week, from Friday to Saturday, which may be the result of combining remote work with trips outside the city for "extended weekends".

NOx hourly levels decreased the most during morning and evening rush hours at NIE, located in the city center (of 34% and 38.3% respectively) (Fig. 6). Maximum values of NOx related to rush hours fall at the same time, as before COVID-19, but the afternoon peak has clearly flattened. In the other locations the reduction effect in the morning was not observed, but the maximum NOx values occurred an hour later than in the pre-pandemic period, which suggests the growing importance of local traffic within the closest neighborhood. Since the beginning of pandemic mean hourly concentrations of PM2.5 have decreased for the whole day, but the reduction was the most significant in the late evening and at night.

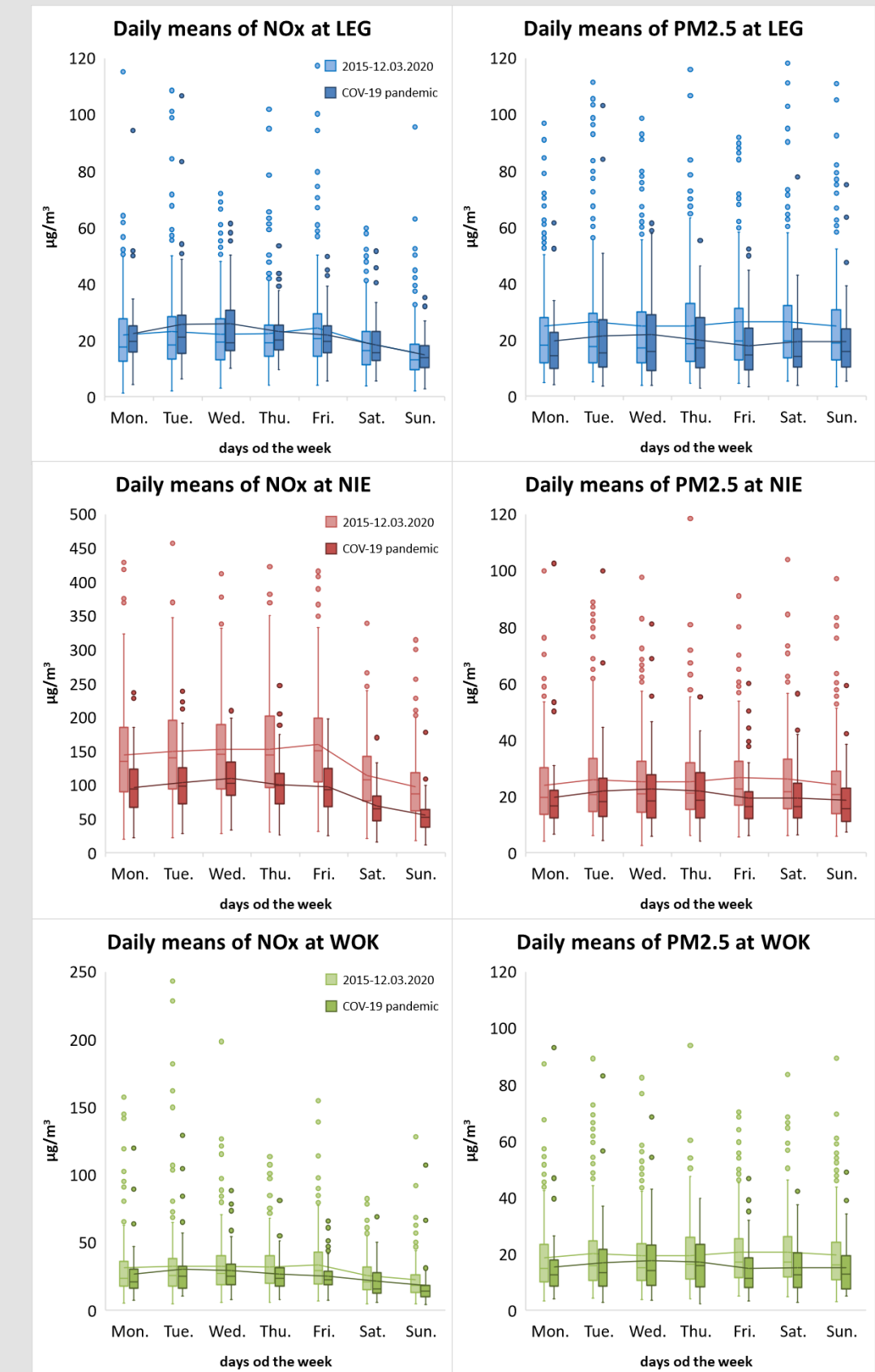


Fig. 5. Weekly distribution of average daily concentrations of NOx and PM2.5 during the COVID-19 pandemic and in the pre-pandemic period 2015-12.03.2020 at LEG, NIE and WOK monitoring stations.

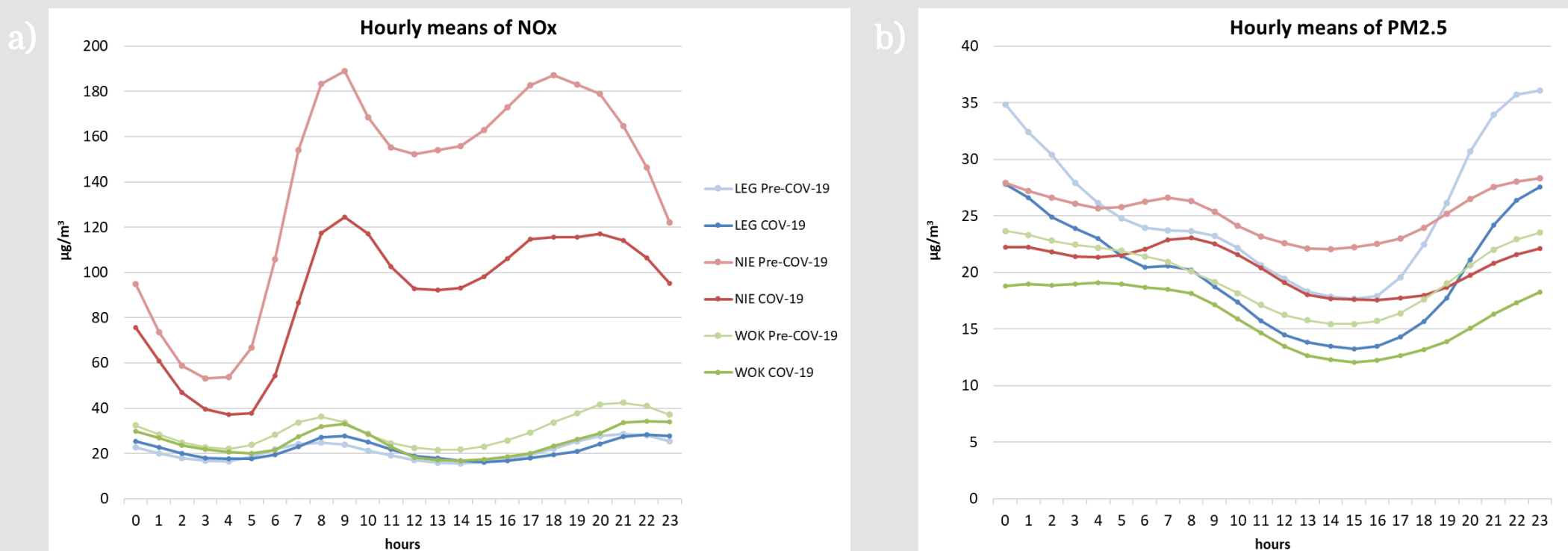


Fig. 6. Course of mean hourly a) NOx and b) PM2.5 concentrations during the COVID-19 pandemic and in the pre-pandemic period 2015-12.03.2020 at LEG, NIE and WOK monitoring stations.

Conclusions

Presented preliminary results of the study demonstrated that COVID-19 pandemic has influenced NOx and PM2.5 concentrations in Warsaw agglomeration, however the effect varied depending on the location within the city and type of the measuring point surroundings. The greatest was the reduction of NOx pollution in the center of Warsaw (at NIE), which was probably the effect of the transition to remote work made in many companies and institutions, resulting in the traffic reduction downtown and thus an improvement of air quality.

The weekly and hourly air pollution trends have changed along with the changing lifestyle- no need to transport children to educational institutions or commuting to work have meant that many residents stopped using cars on a daily basis or even temporarily moved out of Warsaw, from where they can work remotely.

In further stages of this study, the influence of weather conditions as well as the seasonal and long-term air pollution trends in Warsaw will be taken into account.