VINČA
INSTITUTE OF NUCLEAR SCIENCES
University of Belgrade
NATIONAL INSTITUTE OF THE REPUBLIC OF SERBIA

UNDP

Analysis of the correlations between the COVID-19 pandemic and air quality

RESERCH TEAM LEADER:

dr Milena Jovašević-Stojanović, research professor

RESERCH TEAM:

Dr Rastko Jovanović, associate research professor

Dr Miloš Davidović, associate research professor

Dr Maja Jovanovič, research assistant

Dr Ivan Lazović, postdoctoral researcher

[1] **Dr Milena Jovašević-Stojnović, research professor**

1. Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the pathogen of the COVID-19 disease. COVID-19 was initially reported in December 2019 in Wuhan (Hubei Province, China), it then successively spread all over the world. The World Health Organization (WHO) declared COVID-19 a Public Health Emergency of International Concern. It appears that there are remarkable differences in terms of the rate of spread of COVID-19 in different countries of the world. These differences have raised important questions related to the influence of atmospheric factors, such as air pollution, on the spread of COVID-19.

The main aim of this report is to present a short-term correlation between main air pollutants and the number of COVID-19 cases in two different cities, with the highest growth of infected people, Belgrade and Nis, in the Republic of Serbia (RS).

2. Methodology

2.1. *Data collection*

Data about main air pollutant concentrations were collected from the Serbian Environmental Protection Agency (SEPA) monitoring stations. Daily concentrations of five air pollutants were reported, including particles with diameters ≤ 2.5 μm (PM2.5), particles with diameters ≤10 μm (PM10), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2). Maximum daily pollutants' concentrations were calculated taking into account the concentrations of all stations in the city to represent the citywide pollution exposure.

Daily numbers of new COVID-19 cases for both investigated cities were obtained from the Institute of Public Health of Serbia "Dr. Milan Jovanovic Batut", through their open data portal. Daily confirmed new cases were reported for each city between March 1st, 2020, and April 28th, 2020.

The monitoring station positions for both investigated cities are shown in Fig. 1.

Fig. 1 Air monitoring stations positions: a) Belgrade, b) Nis

2.2. *Data analysis*

Preliminary correlation between maximum daily air pollutants' concentrations and increase in the daily number of COVID-19 cases was carried out taking into account a delay time of 7 days, which is the estimated COVID-19 incubation period until symptoms manifestation and diagnosis. The relation between the air pollutants and the increase of COVID-19 infected persons in each city was calculated using standard spreadsheet software.

Polynomial linear regression with cubic spline, which is a form of generalized linear models in regression analysis, was used to estimate the associations between the average concentrations of air pollutants and daily COVID-19 confirmed cases. Regression analysis was conducted using the free open-source statistics calculation package JASP statistics.

3. Conclusions

The obtained results allowed to draw the following conclusions:

- Single pollutant polynomial linear regression models were developed and applied to explore the relationship between main air pollutants and daily COVID-19 confirmed cases in the two most affected cities (Belgrade and Nis) in the Republic of Serbia;
- Short-term exposure to the main air pollutants is correlated with the increase in the number of COVID-19 cases;
- Significantly positive associations of PM2.5, PM10, CO, and NO_2 with COVID-19 confirmed cases were found, while SO_2 was negatively associated with the number of daily confirmed cases;
- The strongest positive association is obtained for particulate matter (PM) air pollutants in both investigated cities, Belgrade and Nis, RS;
- The performed statistical calculations confirmed the hypothesis that SARS-CoV-2 virus, which causes COVID-19 infection, can be transmitted via airborne route;
- This study has significant implications for the control and prevention of COVID-19. First, governments and the public should pay more attention to regions with high concentrations of PM2.5, PM10, CO, and NO_2, since these regions may suffer more serious COVID-19 epidemic;
- Adopting policies for reducing air pollutants could be a useful way to control COVID-19 infection spread;
- The presented results can help in forming social behaviour policies (masks wearing, room ventilation…)
- Further research is necessary to determine the exact air transmission route mechanism and its strength.

4. Results and discussion

The maximum daily values of PM10 concentration and increase in COVID-19 cases in Belgrade are shown in Fig. 2. An increase in COVID-19 cases is presented only for those days when maximum PM10 concentration was higher than the World Health Organization (WHO) recommended value of 50 μg m^{-3} (24-hour mean). The increase in COVID-19 cases was presented accounting for an average incubation period of 7 days, reported by the COVID-19 crisis response team of RS.

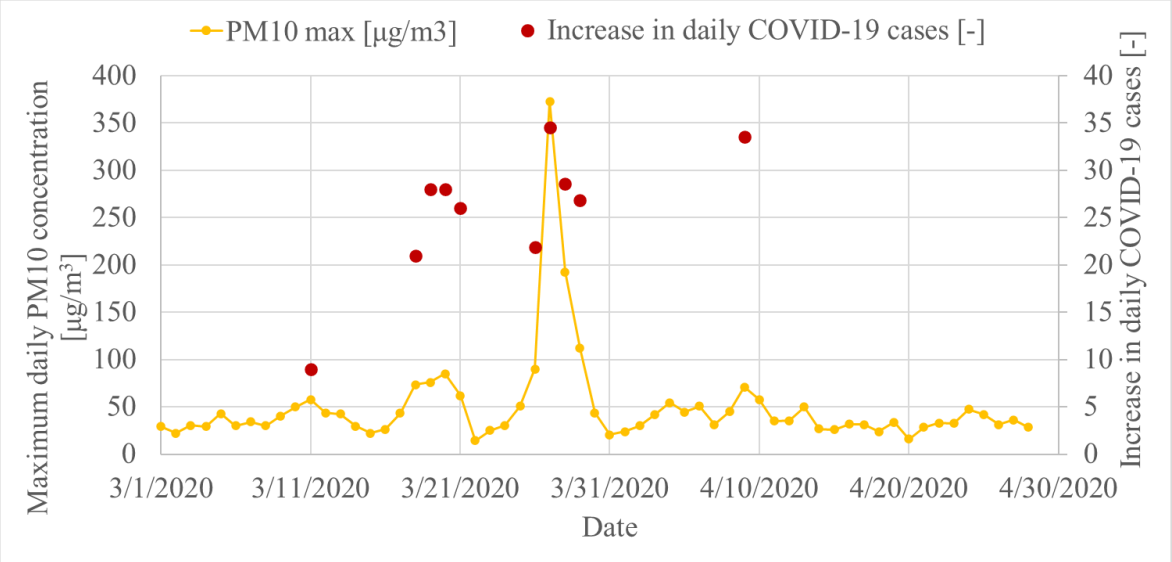

Fig. 2. The maximum PM10 concentrations and an increase in the daily number of COVID-19 cases recorded in Belgrade, Serbia.

The maximum daily values of PM2.5 concentration and increase in COVID-19 cases in Belgrade are shown in Fig. 3. The increase in COVID-19 cases is presented only for those days when maximum PM2.5 concentration was higher than the World Health Organization (WHO) recommended value of 25 μg m^{-3} (24-hour mean).

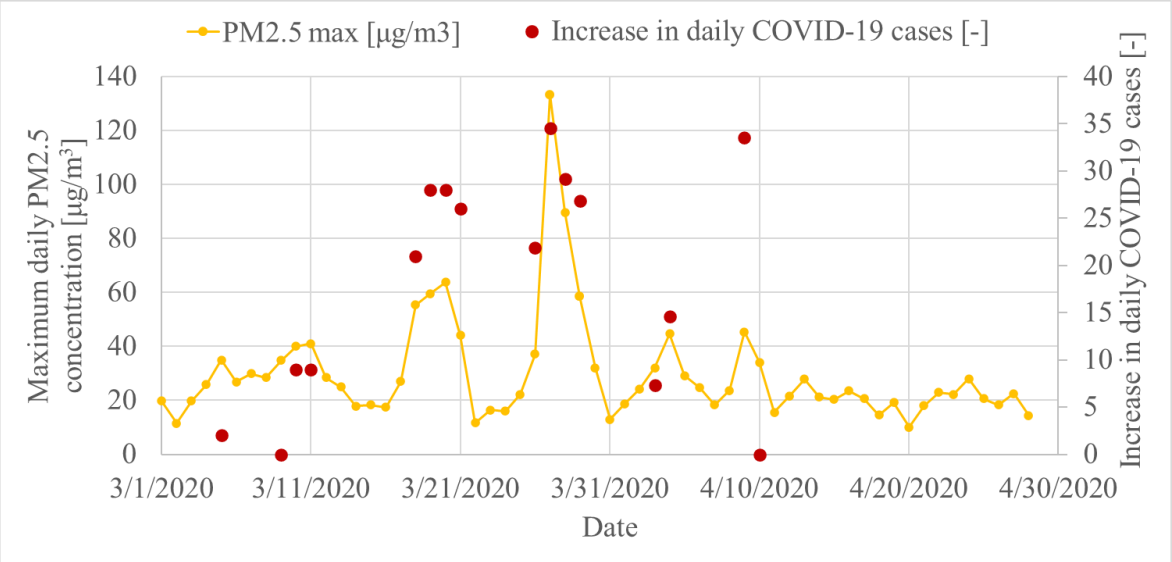

Fig. 3. The maximum PM2.5 concentrations and an increase in the daily number of COVID-19 cases recorded in Belgrade, Serbia.

5

The WHO 24-hour mean guideline values are not provided for all main air pollutants. Thus, it was decided to report values of increase in COVID-19 cases only for those days when PM2.5 maximum daily concentration was exceeded for all presented cases (air pollutants). This was decided to take into account the fact that PM2.5 pollution is the main driver for the air COVID-19 infection route.

Relations between maximum NO_2, CO, and SO_2 daily values and increase in COVID-19 cases are presented in Figs. 4-6, respectively. The high values of all main air pollutants, except for SO_2, are positively correlated with an increase in daily COVID-19 cases. Negative SO_2 correlation with an increase in COVID-19 cases can be explained by its virucidal nature.

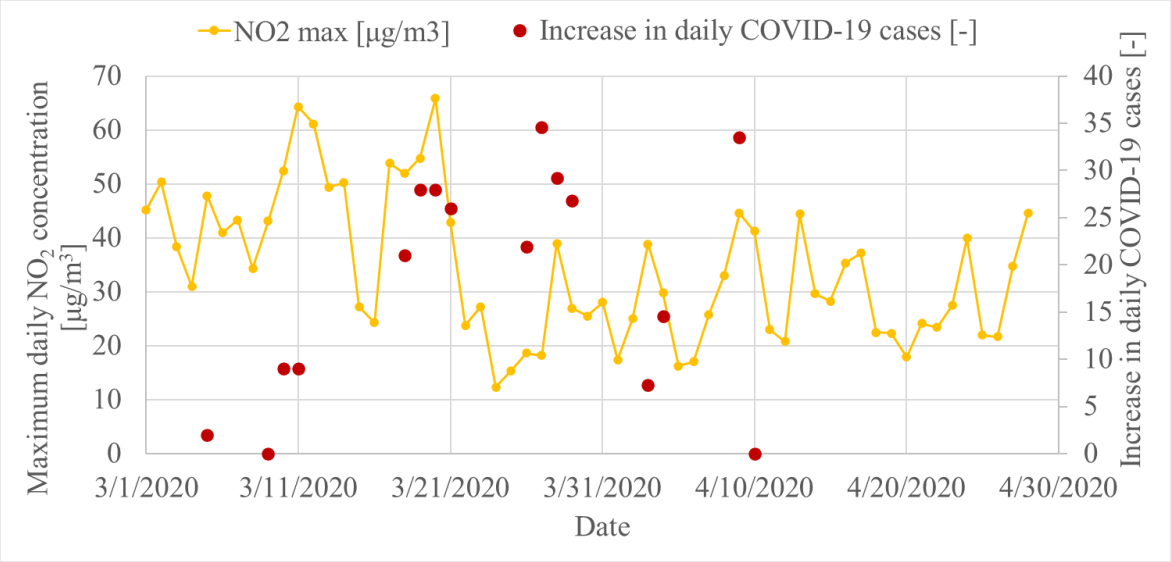

Fig. 4. The maximum NO_2 concentrations and an increase in the daily number of COVID-19 cases recorded in Belgrade, Serbia.

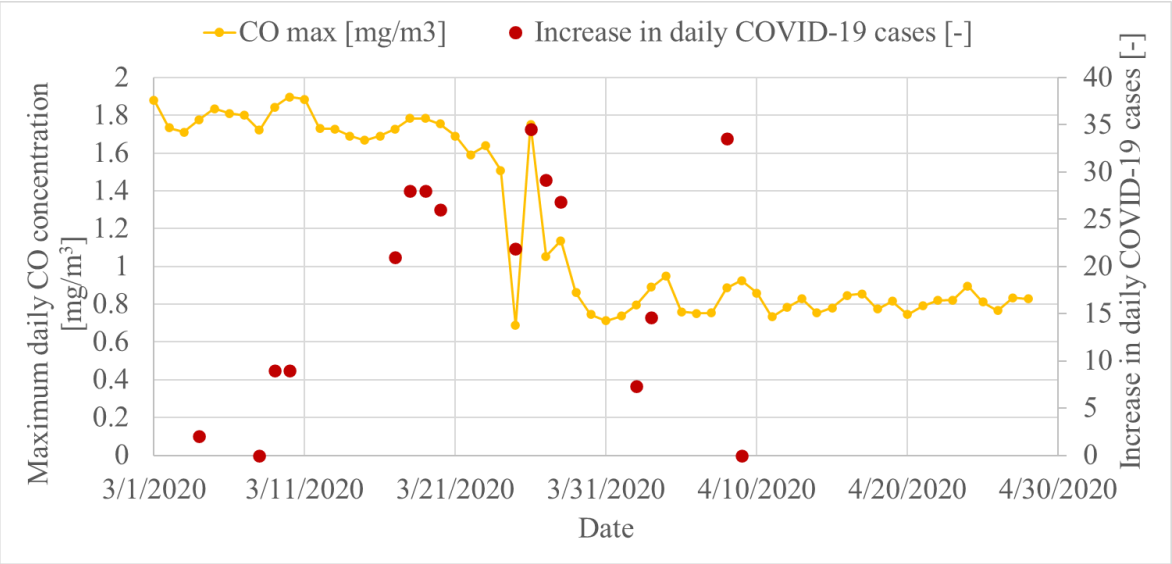

Fig. 5. The maximum CO concentrations and an increase in the daily number of COVID-19 cases recorded in Belgrade, Serbia.

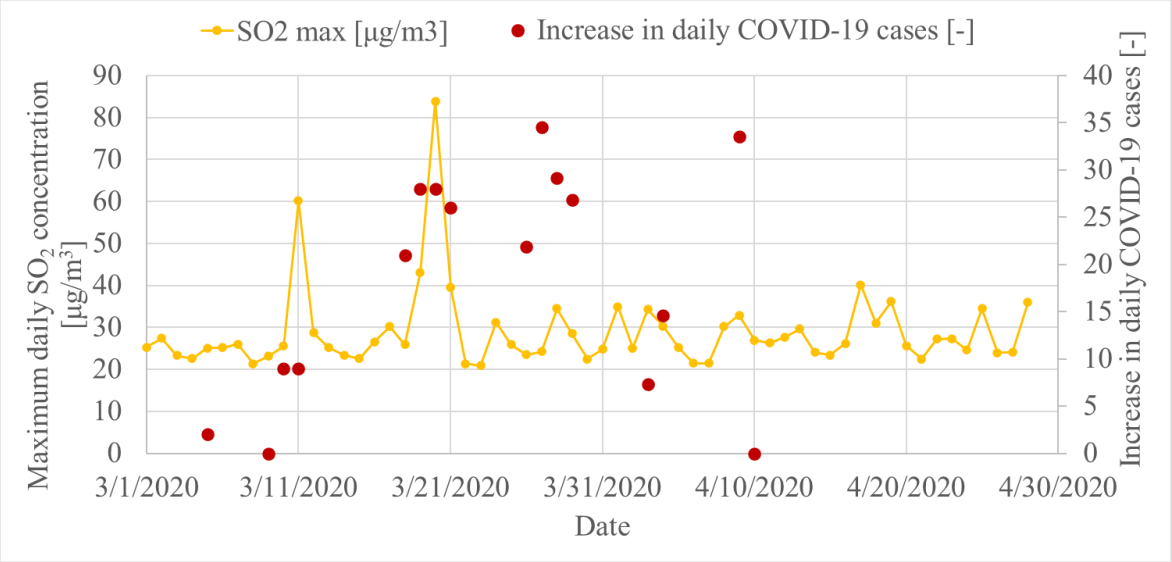

Fig. 6. The maximum SO_2 concentrations and an increase in the daily number of COVID-19 cases recorded in Belgrade, Serbia.

Maximum daily PM10 concentration and an increase in daily numbers of COVID-19 cases in Nis, RS are shown in Fig. 7. It can be observed that growth in daily COVID-19 cases is positively correlated with high PM10 air pollution.

7

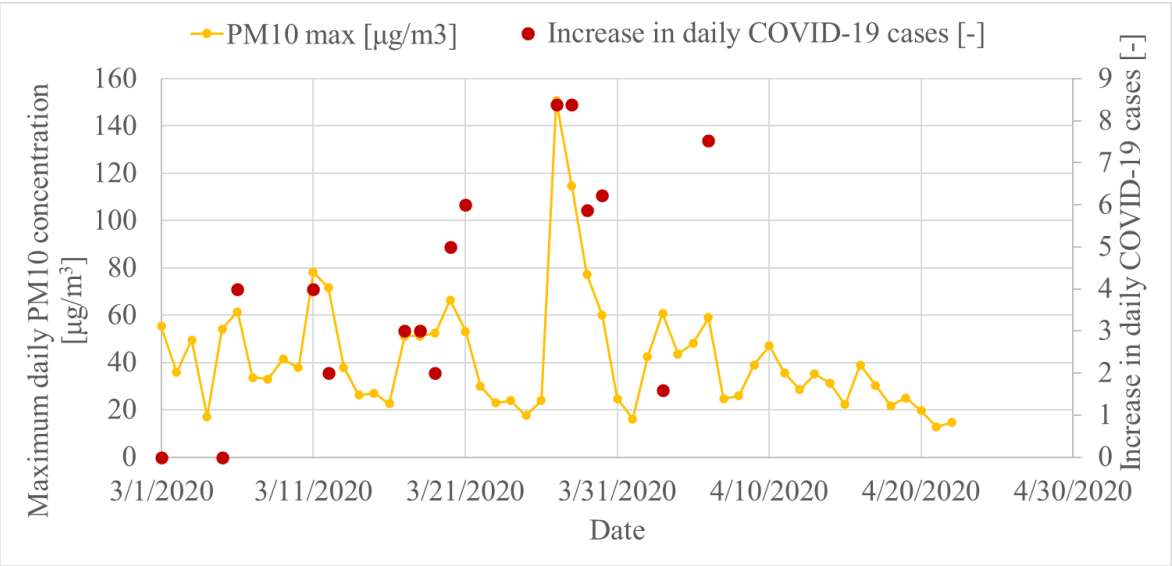

Fig. 7. The maximum PM10 concentrations and an increase in the daily number of COVID-19 cases recorded in Nis, Serbia.

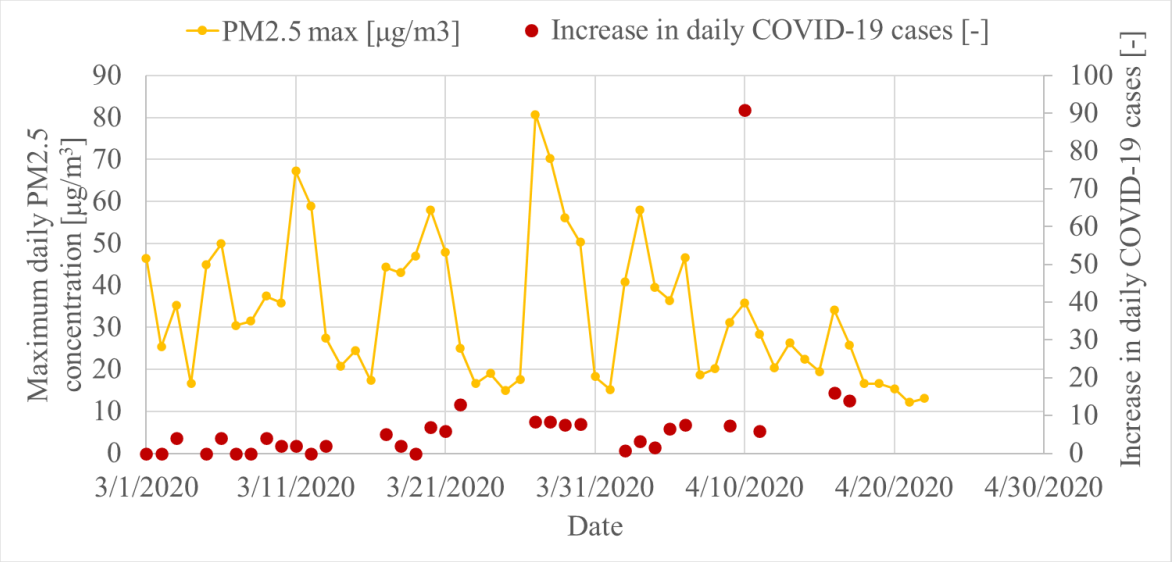

Fig. 8. The maximum PM2.5 concentrations and an increase in the daily number of COVID-19 cases recorded in Nis, Serbia.

Maximum daily PM2.5 concentration and an increase in daily numbers of COVID-19 cases in Nis, RS are shown in Fig. 8. Again, as in the case of PM10 pollution, it can be observed that growth in daily COVID-19 cases is positively correlated with high PM2.5 air pollution.

8

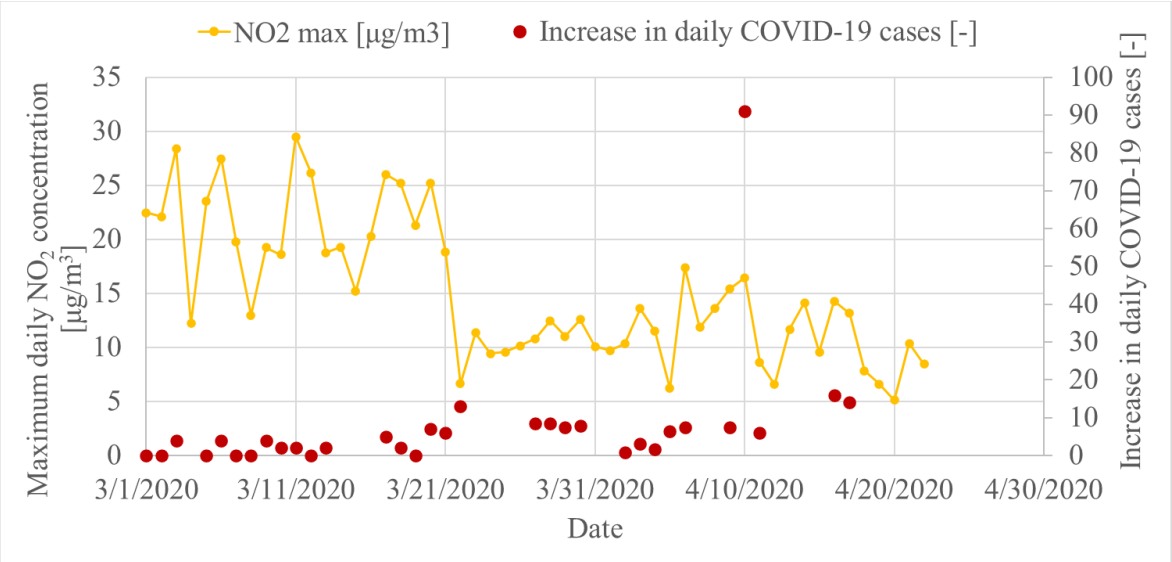

Fig. 9. The maximum NO_2 concentrations and an increase in the daily number of COVID-19 cases recorded in Nis, Serbia.

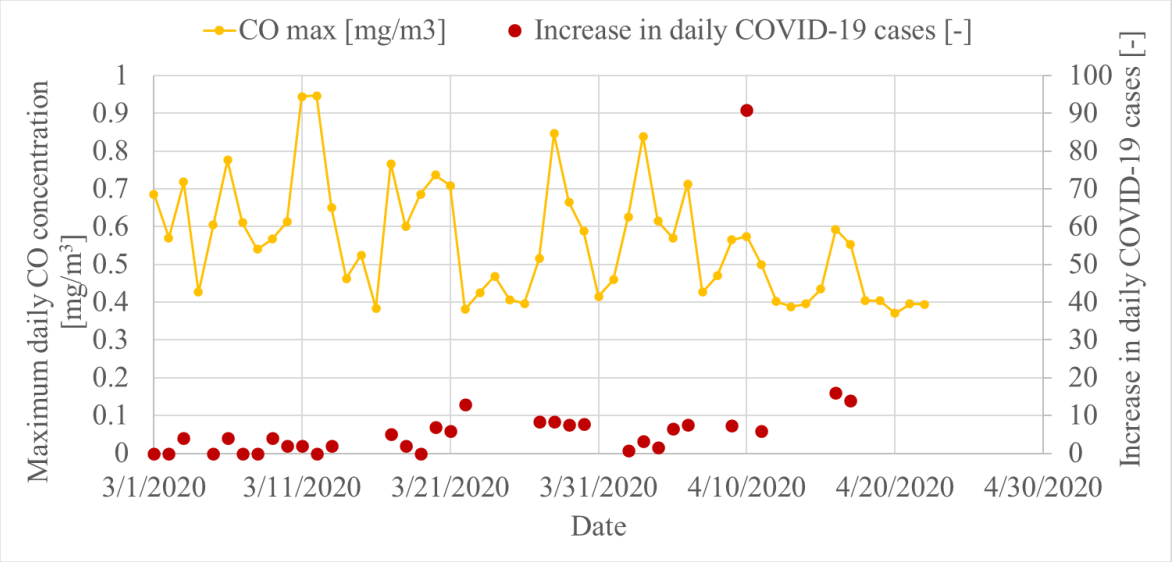

Fig. 10. The maximum CO concentrations and an increase in the daily number of COVID-19 cases recorded in Nis, Serbia.

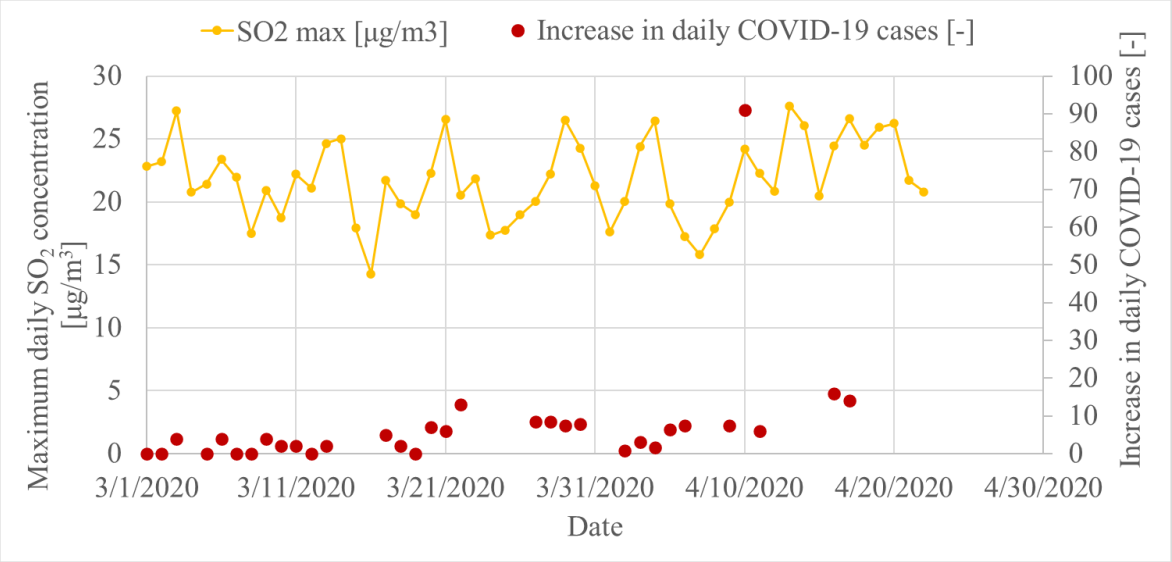

Fig. 11. The maximum SO_2 concentrations and an increase in the daily number of COVID-19 cases recorded in Nis, Serbia.

Associations between all other main air pollutants, NO_2, CO, and SO_2, maximum daily concentrations, and corresponding daily increase in COVID-19 cases in Nis, RS are presented in Figs. 9-11, respectively. The same trends, like those present in Belgrade, apply in Nis. Namely, all main air pollutants except SO_2, are positively correlated with growth in COVID-19 cases.

The obtained results were the motivation for more in-depth statistical analysis. Polynomial linear regression was used to develop single-pollutant models. Each regression model has one predictor (air pollutant) variable and one dependent variable – log-transformed

number of daily COVID 19 cases. The cubic spline was used as a polynomial function for all predictor variables.

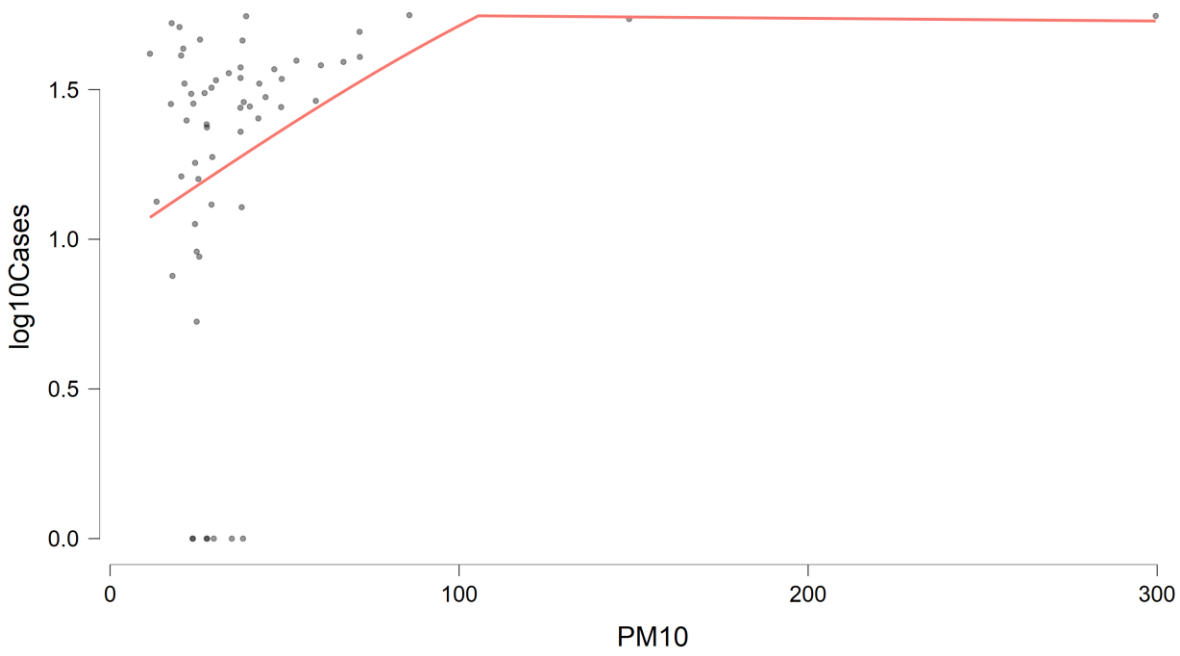

Fig. 12. The correlation between PM10 average daily concentrations and logarithmized number of daily COVID-19 cases in Belgrade, Serbia.

10

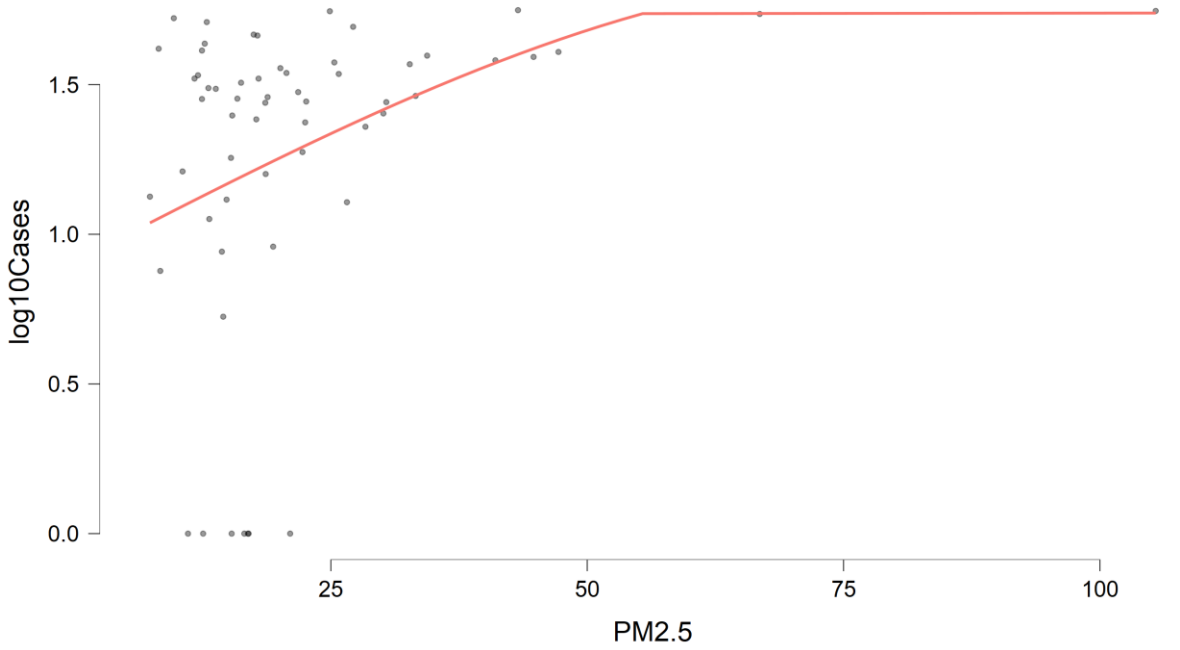

Fig. 13. The correlation between PM2.5 average daily concentrations and logarithmized number of daily COVID-19 cases in Belgrade, Serbia.

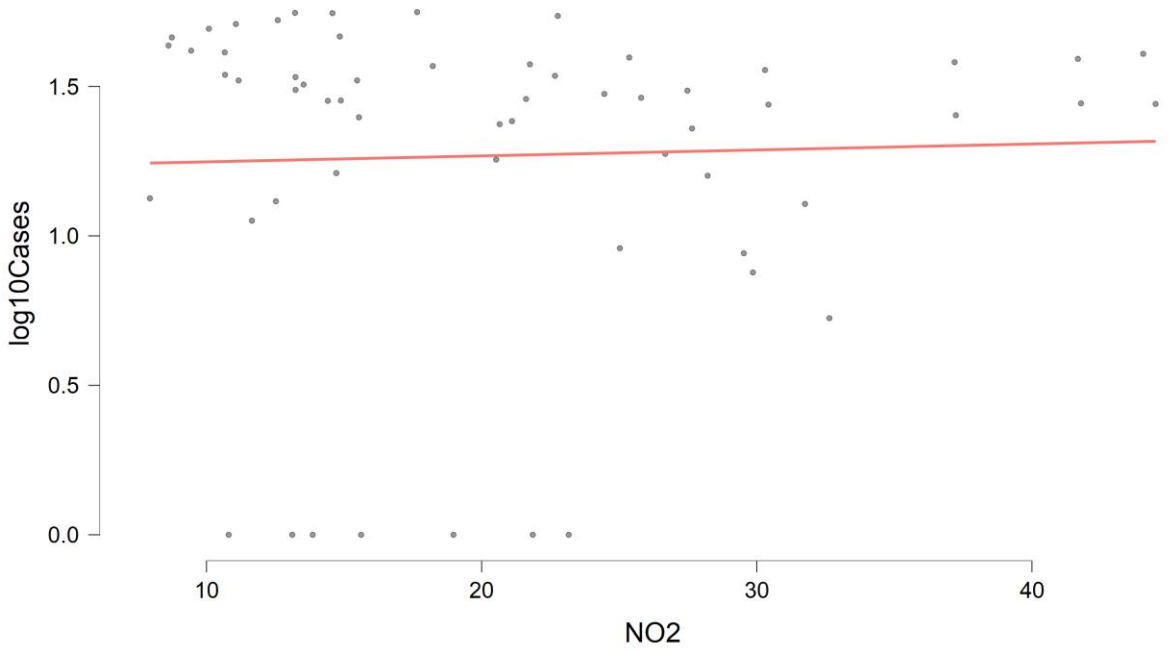

Fig. 14. The correlation between NO_2 average daily concentrations and logarithmized number of daily COVID-19 cases in Belgrade, Serbia.

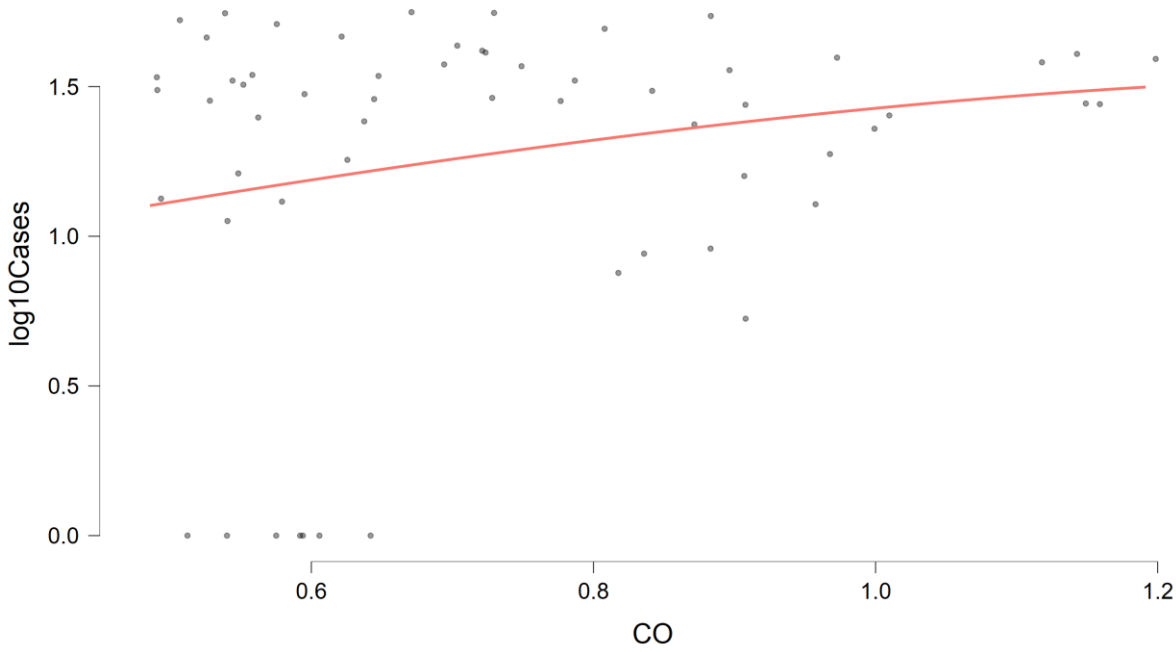

Fig. 15. The correlation between CO average daily concentrations and logarithmized number of daily COVID-19 cases in Belgrade, Serbia.

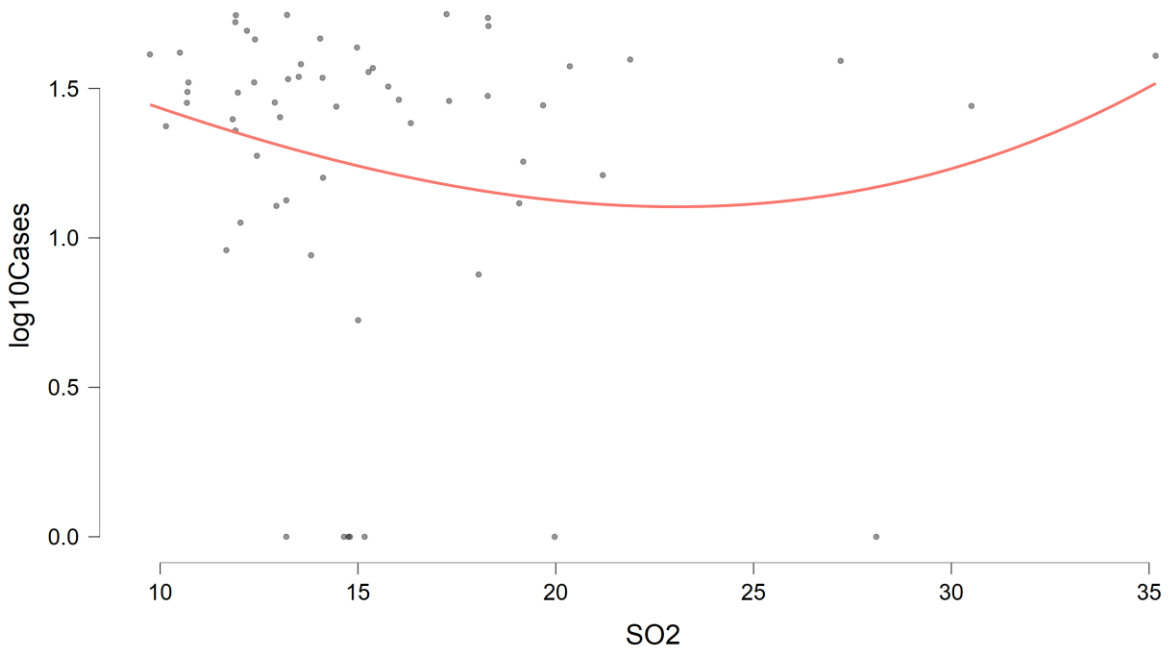

Fig. 16. The correlation between SO_2 average daily concentrations and logarithmized number of daily COVID-19 cases in Belgrade, Serbia.

Correlation curves between main air pollutants (PM10, PM2.5, NO_2, CO, and SO_2) maximum daily concentration values and logarithmized number of daily COVID-19 cases in Belgrade, RS have the following standardized slope coefficients: 0.613[PM10] - 0.407[PM10]^3, 0.527[PM2.5] - 0.264[PM2.5]^3, 0.037[NO_2], 0.326[CO] - 0.108[CO]^3, and -0.529[SO_2] + 0.474[SO_2]^3. The correlation curves are shown in Figs. 12-16. Based on these values, it can be concluded that the strongest positive correlation is established between particulate matter (PM) and log-transformed COVID-19 cases. In the case with CO as a predictor, the correlation is somewhat weaker, and the weakest correlation is obtained when NO_2 is used as a predictor in the regression model. The negative correlation is obtained when SO_2 is used as a predictor variable, as already explained.

Correlation curves between main air pollutants (PM10, PM2.5, NO_2, CO, and SO_2) maximum daily concentration values and logarithmized number of daily COVID-19 cases in Nis, RS have the following standardized slope coefficients: 0.641[PM10] - 0.372[PM10]^3, 0.639[PM2.5] - 0.315[PM2.5]^3, 0.785[NO_2]-0.707[NO_2]^3, 0.761[CO] - 0.509[CO]^3, and -0.664[SO_2] + 0.394[SO_2]^3. The correlation curves are shown in Figs. 17-21. It can be seen that the model predicted trends for Nis are similar to those predicted in Belgrade, with a somewhat stronger correlation in regression models with CO and NO_2 as predictors.

It is important to underline that the performed work was limited to the derivation of correlations between main air pollutants concentrations and an increase in the daily number of COVID-19 cases. However, derived correlation coefficients do not imply causality between predictor variables (air pollutants) and dependent variable (daily number of COVID-19 cases). Causality investigation was beyond the scope of this report due to several limitations. First, it was possible to perform analysis for only two cities (Belgrade and Nis) in the Republic of Serbia, which had a statistically significant number of COVID-19 infected individuals. Second,

open data at the city level were not reported during the whole COVID-19 outbreak period, and thus they were estimated using the described interpolation procedure. Third, open data did not include gender- or age-specific confirmed cases, so it was not possible to conduct subgroup analyses.

To extend the applicability of this study to identify causality factors it would be necessary to establish a unique open database with daily observations (minimum required time-resolution level) of main air pollutants and the number of COVID-19 cases at national, regional, and local scales during lockdown period. If the above-mentioned limitations are overcome in the future, it will be possible to perform a more detailed study about the association between air pollution and the number of COVID-19 cases in the period of lock-down for the whole territory of the Republic of Serbia. It is expected that such a study, combined with an ongoing global investigation about the SARS-Cov-2 virus mechanism of infection, would be able to determine causal relations between air pollution and intensity in the COVID-19 outbreak.

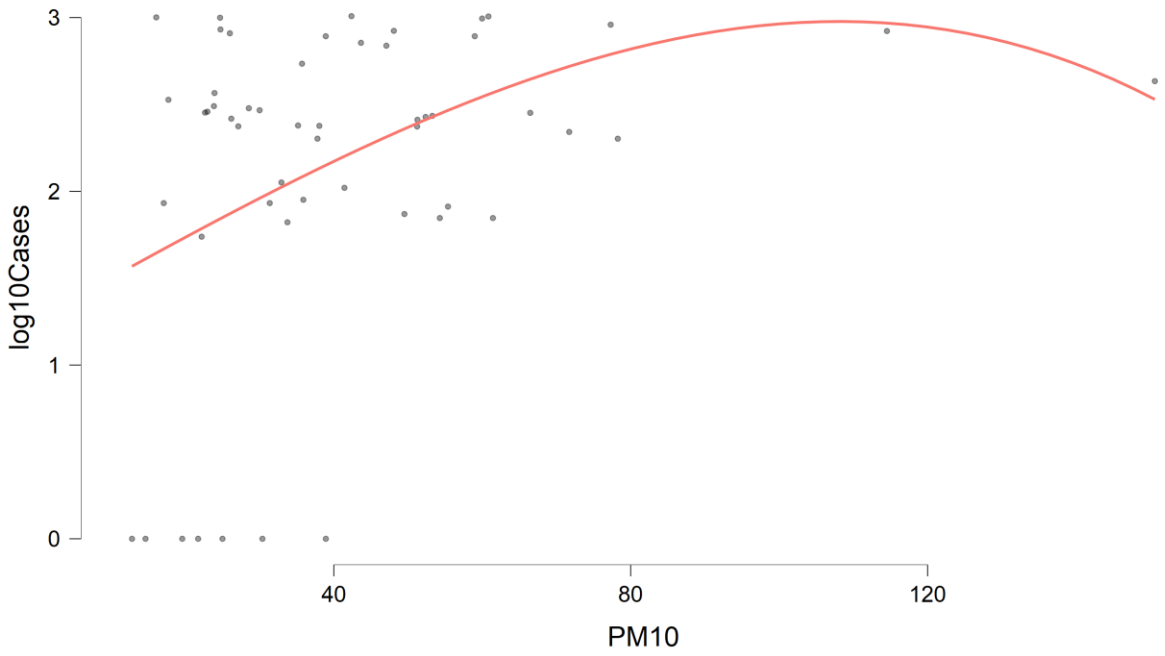

Fig. 17. The correlation between PM10 average daily concentrations and logarithmized number of daily COVID-19 cases in Nis, Serbia.

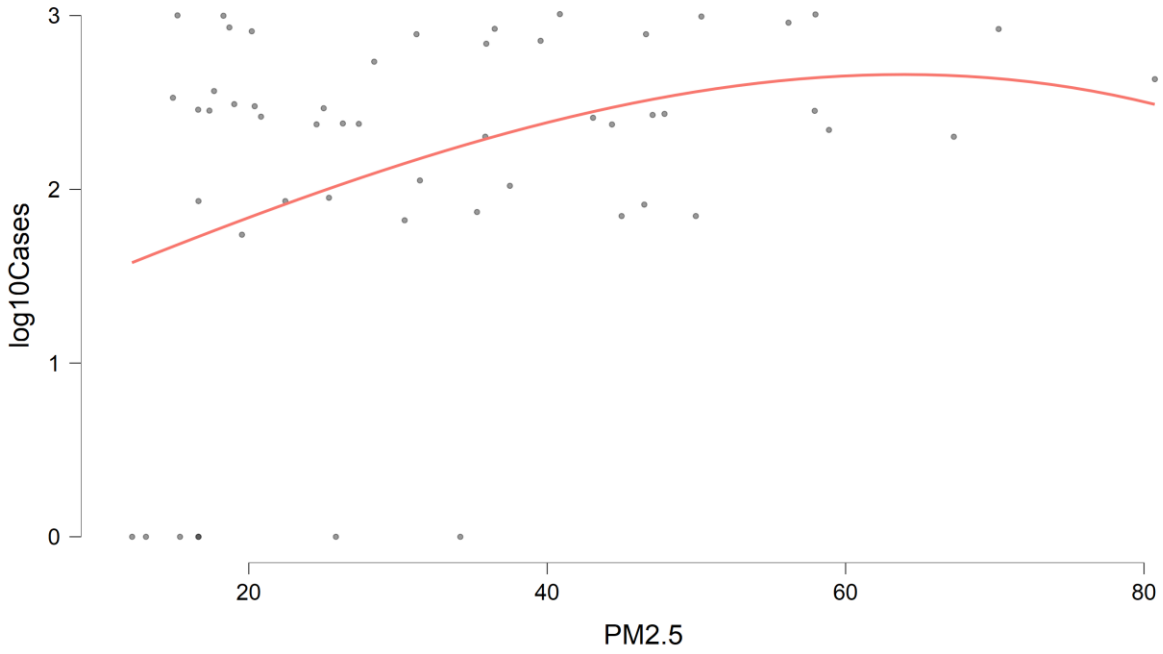

Fig. 18. The correlation between PM2.5 average daily concentrations and logarithmized number of daily COVID-19 cases in Nis, Serbia.

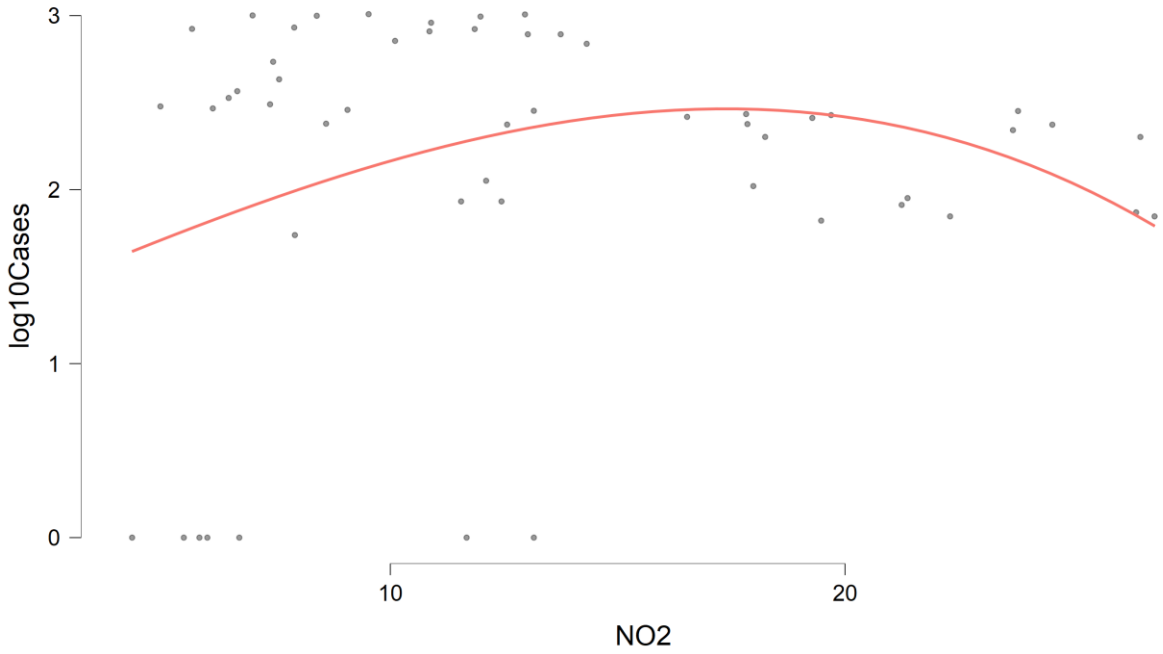

Fig. 19. The correlation between NO_2 average daily concentrations and logarithmized number of daily COVID-19 cases in Nis, Serbia.

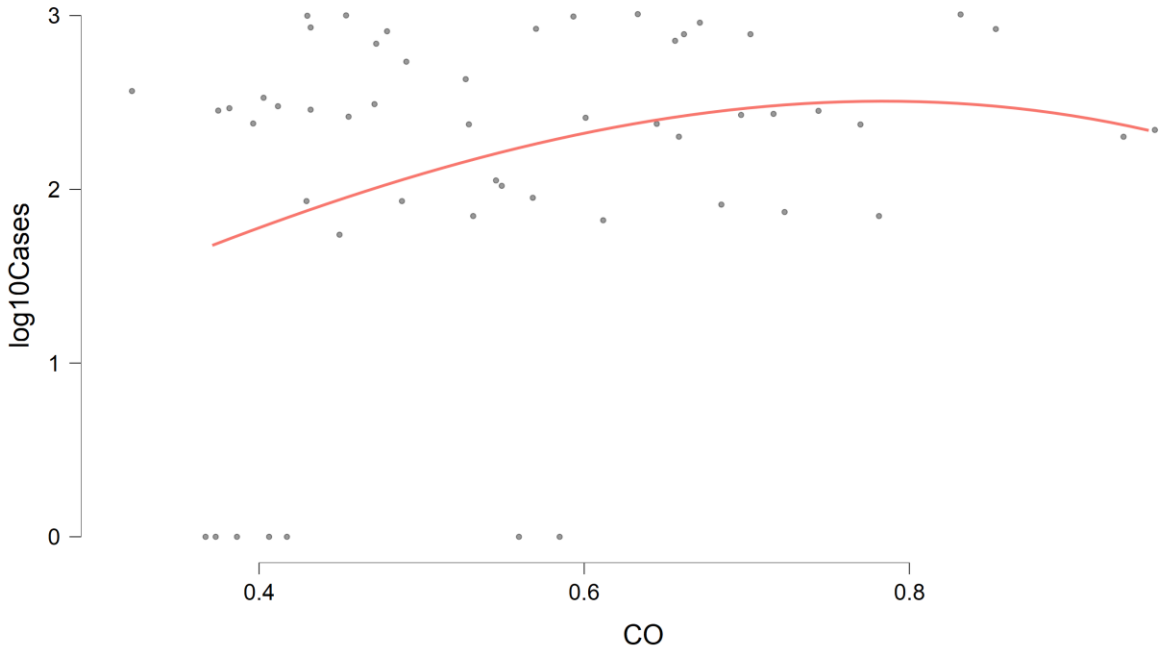

Fig. 20. The correlation between CO average daily concentrations and logarithmized number of daily COVID-19 cases in Nis, Serbia.

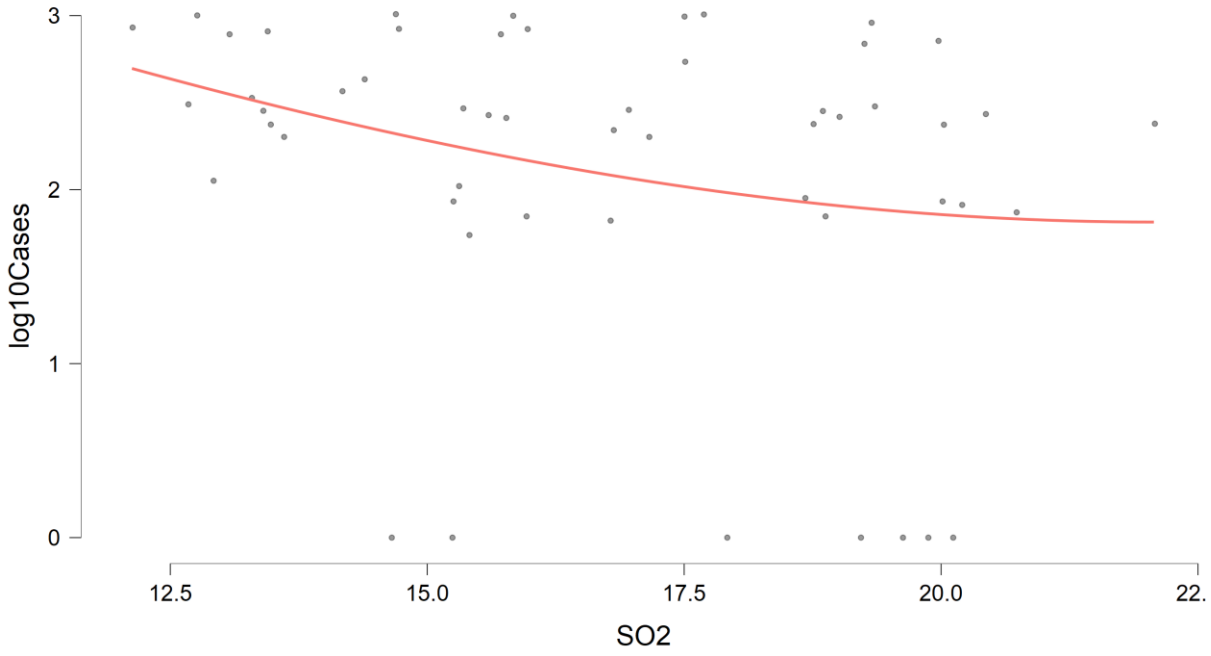

Fig. 21. The correlation between SO_2 average daily concentrations and logarithmized number of daily COVID-19 cases in Nis, Serbia.