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Impact of COVID-19 Restrictions on Air Quality Levels in Samsun, Turkey †

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Abstract: The outbreak of the novel coronavirus SARS-CoV-2 (hereafter COVID-19) has changed the daily routines of people around the world. The first case of COVID-19 was confirmed in December 2019, whilst it was confirmed on 11 March 2020 in Turkey. After the number of cases reached 4500 per day by 10 April, the government declared more restrictive lockdown measures for 31 metropolitan cities, which were implemented for the following weekends and national and religious holidays. The changes in the concentrations of CO, NO_x, NO_2 and PM_{10} during the period of these measures with respect to the pre-lockdown period and for different levels of measures for Samsun, the biggest city of the Karadeniz region, were investigated in this study. The daily mean concentrations of CO, NO_x, NO_2 and PM_{10} were obtained from Tekkekoy station due to it having data completeness greater than 95% for all pollutants. The average CO, NO_x and NO_2 concentrations during the lockdown period declined with respect to the pre-lockdown period, whilst PM_{10} increased by 3%. The average concentrations of all the pollutants decreased when the level of restrictions increased during the COVID-19 lockdown period. The number of days exceeding the WHO limit for PM_{10} was decreased during the lockdown period to 16 days with respect to the pre-lockdown period at 19 days. There was only a positive weak relationship between the mobility decrease rate and NO_2 concentrations.

Keywords: COVID-19; air pollution; Turkey; Samsun

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1. Introduction

The first positive case of SARS-CoV-2 (hereinafter COVID-19) was detected in Turkey on 11 March 2020. After the confirmation of the first case, some measures such as a stay-at-home order and restrictions on airway transportation were implemented by the Turkish government. However, the number of cases reached 4500 on 10 April. Then, more strict measures were applied for 30 crowded cities including Samsun. These measures were lockdown on the weekends, cancellation of intercity travel, etc.

Several studies declared an improvement in air quality due to the partial and total lockdowns related to COVID-19 [1–7]. The work of [4] showed that the improvement in air quality in Barcelona was related to the quarantine measures. The study of [6] investigated the improvement in ozone levels in Rio de Janeiro, Brazil. The work of [7] showed an increase in air quality in terms of the reduction in the concentrations of $PM_{2.5}$, PM_{10}, SO_2, CO and NO_2 in China. Moreover, Ref. [6] discussed the impact of the partial lockdown on the ozone levels in the city of Rio de Janeiro, Brazil. Additionally, the study of [4] showed that the quarantine measures led to an improvement in air quality in Barcelona. Studies in several European cities such as Barcelona, Istanbul, Madrid, Milan and Munich also reported an improvement in air quality. The work of [5] reported reductions in PM_{10} (32–43%), $PM_{2.5}$ (19–47%), NO_2 (29–44%), CO (40–58%) and SO_2 (34–69%) in Istanbul, a megacity in Turkey.

Meanwhile, a few studies included mobility to understand the effect of traffic on air quality during the COVID-19 measures [8,9]. The work of [8] found a significant correlation

between mobility and trends of $PM_{2.5}$ and NO_2 for Singapore. The study of [9] declared that mobility and airborne particulate matter have an impact on the risk of COVID-19 transmission.

Samsun, located in the central part of the Black Sea Region of Turkey, is the most crowded and developed city of the region. In this study, the change in air pollutant concentrations during the lockdown in Turkey was investigated. The effect of mobility was considered as well.

2. Materials and Methods

Samsun, located in the central part of the Black Sea Region of Turkey, is the most crowded and developed city of the region (Figure 1). Its population was 1,356,000 by the end of 2020 [10], and it is the 16th crowded city of Turkey. It is surrounded by the Black Sea in the north, Ordu city in the east, Tokat and Amasya in the south and Sinop and Çorum cities in the west. The city has an area of about 9725 km^2, and 45% of this area is mountains, 37% plateaus and 18% plains.

Figure 1. Samsun and its location in Turkey.

There are 6 air quality monitoring stations in the city operated by the Central Black Sea Clean Air Center. However, only Tekkekoy station has data completeness greater than 95% during the period of the COVID-19 lockdown measures. PM_{10}, CO, NO_x and NO_2 are monitored at Tekkekoy station. The information about Tekkekoy station is presented in Table 1. The change in the concentrations of air pollutants during the period of the COVID-19 lockdown measures and the number of exceedances of the limit values according to the World Health Organization [11] were calculated. According to the WHO guidelines, the limit for PM_{10} for 24 h is 50 $\mu g/m^3$, while the NO_2 limit for 1 h is 200 $\mu g/m^3$. Therefore, only the exceedance numbers for PM_{10} and NO_2 were calculated.

Table 1. Description of the air pollutants at Tekkekoy station.

Station	PM_{10}	CO	NO_x	NO_2
Tekkekoy	2019–2020	2019–2020	2019–2020	2019–2020

Some periods were defined according to the COVID-19 measures in order to conduct the comparison of air pollutant concentrations. Some periods were chosen to perform the comparisons of the pollutant concentrations. The period from 1 January to 17 March 2020 was defined as pre-lockdown, and the period from 18 March to 1 June 2020 was defined

as lockdown. The changes in the concentrations of pollutants were analyzed for three different steps. Firstly, the change in concentrations and the exceedance numbers during the lockdown with respect to the pre-lockdown were investigated.

Secondly, the change in the concentration levels of air pollutants during the lockdown was investigated by dividing the lockdown period into two parts: the first one covers the dates where full lockdown measures were applied for metropolitan cities, and the second covers the remaining lockdown days. Thirdly, the concentrations during the lockdown were compared to the same period in the previous year.

In the last part of the study, mobility data of [12] were used to analyze the effect of mobility on the air quality. These data are represented as the percent change from a baseline in six categories. The baseline is the median value of mobility data covering the period from 3 January to 6 February 2020. The mobility data are explained in six different categories as introduced by [12], but only workplace mobility data were used to represent the traffic change.

3. Results

3.1. Comparison of Lockdown and Pre-Lockdown Periods

The daily concentrations of CO, NO_2, NO_x and PM_{10} for the period from 1 January to 1 June 2020 are shown in Figure 2. The decline in the concentrations of CO, NO_2 and NO_x are clear, while the change in the concentration of PM10 is not clear. The mean concentrations before the lockdown and during the lockdown are shown in Table 2. As shown in Table 2, the mean concentrations of CO, NO_2 and NO_x declined by 72, 37 and 35%, while the mean concentration of PM_{10} increased by 3% during the lockdown according to the period before the lockdown.

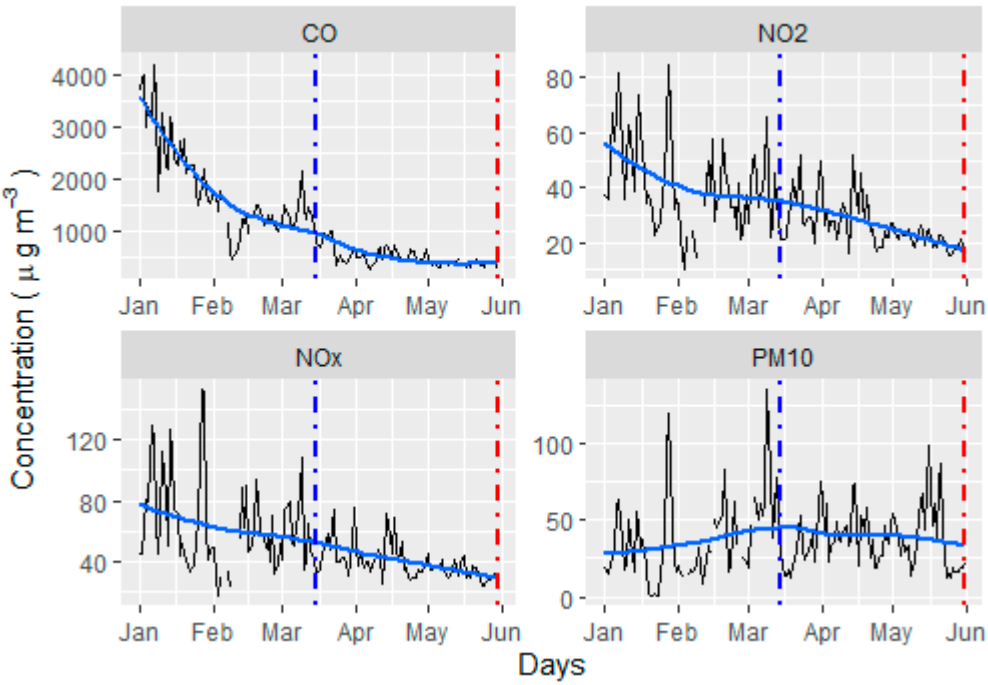

Figure 2. The daily mean concentration of air pollutants from 1 January to 1 June 2020. The blue dashed vertical line represents the start of the measures, and the red dashed vertical line represents the end of the measures.

Table 2. The mean concentrations before and during the lockdown and percent change.

Pollutant	Before Lockdown (μg/m^3)	Lockdown (μg/m^3)	Change (%)
CO	1807	496	−73
NO_2	41	26	−37
NO_x	62	40	−35
PM_{10}	37	38	+3

The numbers of exceedances for NO_2 and PM_{10} are shown in Table 3. NO_2 did not exceed the WHO limits for both the pre-lockdown and lockdown periods. PM_{10} concentrations exceeded the WHO limits 19 times before the lockdown and 16 times during the lockdown, although the mean concentrations of PM_{10} increased during the lockdown according to the pre-lockdown period. The days that exceeded the WHO limits decreased by 16% during the lockdown with respect to the pre-lockdown period.

Table 3. Number of exceedances for NO_2 and PM_{10}.

Pollutant	Before Lockdown	Lockdown	Change (%)
NO_2	0	0	-
PM_{10}	19	16	−16

3.2. Comparison of Sub-Periods in Lockdown Period

The mean concentrations of air pollutants during the period of the full lockdown measures and the remaining days and the percent change during the full lockdown days with respect to the remaining days are shown in Table 4. As shown in Table 4, the concentration of all the pollutants decreased. The CO concentration decreased just 1% during the period of the full lockdown measures with respect to the remaining days of the lockdown. NO_2, NO_x and PM_{10} decreased by 25, 20 and 18%, respectively.

Table 4. The mean concentrations during the period of the full lockdown measures and the remaining days, and percent change.

Pollutant	Full Lockdown Days (μg/m^3)	Remaining Days (μg/m^3)	Change (%)
CO	497	491	−1
NO_2	28	21	−25
NO_x	41	33	−20
PM_{10}	40	31	−18

3.3. Comparison of the Lockdown Concentrations with the Same Period of 2019

The mean concentrations of the air pollutants during the lockdown period and the same period in 2019 are shown in Table 5. NO_2 concentrations did not change during the lockdown with respect to 2019. CO and NO_x increased by 4 and 2.5%, respectively, whilst PM_{10} decreased by 21%.

Table 5. The average pollutant concentrations during the lockdown and the same period of the previous year.

Pollutant	2019 (μg/m^3)	2020 (μg/m^3)	Change (%)
CO	474	496	+4
NO_2	26	26	0
NO_x	39	40	+2.5
PM_{10}	48	38	−21

3.4. Relationship between Mobility and Air Pollution

The time series of the mobility data and daily average NO_x, NO_2 and PM_{10} concentrations during the lockdown period is shown in Figure 3. The CO concentrations are not plotted due to the greater values of CO. As shown in Figure 3, the overall average of work mobility change in Samsun was 49%. The peak mobility values in the figure represent the full lockdown measures applied for metropolitan cities. During these peaks, declines in the mean concentration of the air pollutants are obvious.

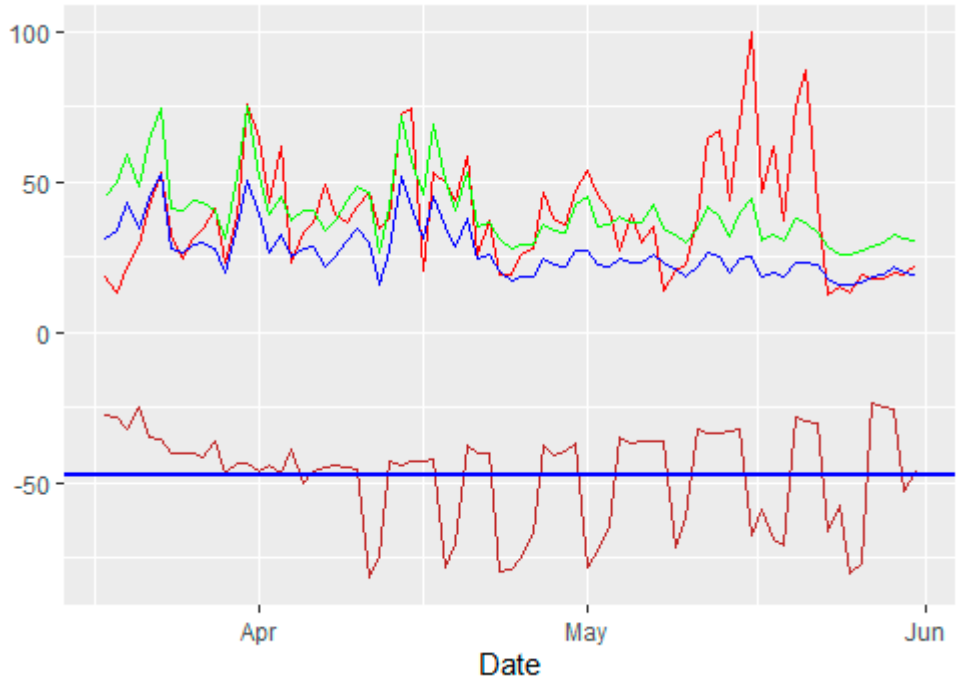

Figure 3. Time series of the mobility during the LDM period with respect to 1 January–16 February 2020 (negative values on y axis, blue line represents the average mobility change during LDM period) and PM_{10} (red), NO_x (green) and NO_2 (blue) concentrations during LDM period (positive values).

The correlation between mobility change and pollutant concentrations was calculated and tested via Pearson's test, and the results are shown in Table 6. The correlation coefficients between mobility and CO, NO_x and PM_{10} were 0.15, 0.27 and 0.08, respectively, and were not statistically significant. The correlation coefficient between mobility and NO_2 was 0.30, and it was statistically significant at the 99% confidence level.

Table 6. Pearson's correlation coefficients between work mobility and pollutant concentrations.

	CO	**NO_x**	**NO_2**	**PM_{10}**
Correlation Coefficient	0.15	0.27	0.30 *	0.08

* denotes the correlation coefficient is statistically significant at 99% level.

4. Conclusions

The daily routines of people in all countries have been changed by COVID-19. In Turkey, after the confirmation of the first case on 11 March 2020, authorities implemented some rules such as shutting down airway transportation and moving to online education. However, by 10 April, the number of cases reached 4500, and more restrictive measures were imposed on 31 major cities including Samsun. The changes in the concentrations of CO, NO_x, NO_2 and PM_{10} in Samsun during the period of these measures and their relationship with the decrease in mobility were investigated in this study. The main findings are as follows:

1. The mean concentrations of CO, NO_2 and NO_x declined by 72, 37 and 35%, while the mean concentration of PM_{10} increased by 3% during the lockdown according to the pre-lockdown period. The PM_{10} concentrations exceeded the WHO limits 19 times before the lockdown and 16 times during the lockdown, although the mean concentrations of PM_{10} increased during the lockdown according to the pre-lockdown period.
2. The mean concentration of all the pollutants decreased during the period of the full lockdown measures compared to the remaining lockdown days at different levels. The CO concentration decreased just 1% during the period of the full lockdown measures with respect to the remaining days of the lockdown. NO_2, NO_x and PM_{10} decreased by 25, 20 and 18%, respectively.
3. NO_2 concentrations did not change during the lockdown with respect to 2019. CO and NO_x increased by 4 and 2.5%, respectively, whilst PM_{10} decreased by 21%.
4. The correlation between mobility change and pollutant concentrations was calculated and tested via Pearson's test. Only the correlation coefficient between mobility and NO_2 was statistically significant at the 99% confidence level, with a value of 0.30.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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