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HIGHLIGHTS

- Actions taken in COVID-19 pandemic in Turkey produced mixed effects on air quality
- Variable effects observed among cities and among studied stations in a city
- $PM_{2.5}$ and PM_{10} concentrations not significantly affected by curfew policies
- Significant reductions observed in NO, NO_2, and NO_x concentrations
- Excess Risk posed by $PM_{2.5}$ and PM_{10} were slightly decreased

Abstract

The COVID-19 pandemic, which has reached 4 million global cases as of March 10, 2020, has become a worldwide problem. Turkey is one of the most affected (9th in the world) country with 139 771 cases. An intermittent curfew policy that differ for three age groups, and an intercity travel ban varying within the country have been implemented. The effects of changes in social life and industrial activity in terms of environmental pollution are not yet known. The short-term effects on $PM_{2.5}$, PM_{10}, SO_2, NO_2, NO, NO_x, O_3 and CO concentrations measured at 51 air quality measurement stations (AQMS) in 11 cities in March – April period of 2020 were statistically compared with that of the previous year. While $PM_{2.5}$ (9/14 AQMS) and PM_{10} (29/35 AQMS) concentrations were not significantly affected, NO (12/24 AQMS), NO_2 (20/29 AQMS), NO_X (17/25 AQMS) concentrations were decreased, SO_2 concentrations at half of the AQMSs (11/25) did not show a significant change. There were stations at which higher pollutant concentrations were measured in the study period in 2020 compared to that of 2019. Excess risks associated with $PM_{2.5}$ and PM_{10} were estimated to be variable, albeit with a small difference. In conclusion, the heterogeneous actions taken in response to the COVID-19 pandemic resulted in mixed effects on ambient air quality.

Keywords: Air quality, COVID-19, Excess Risk, Turkey

1. Introduction

COVID-19 pandemic has been identified as one of the worst global health crises that human race faced so far. Since the report of the first one, there had been 4,013,728 confirmed cases, 278,993 of which ended in loss of life (WHO, 2020). The most affected regions are Americas and Europe, and the most affected countries are listed as United States of America, Spain, Italy, Germany, United Kingdom, and France. After the first report in March 10, case number in Turkey has risen to 107,773 as of April 26, 2020. Turkey acted promptly and took action to prevent the spread of the infection. These actions included closing of educational institutions at all levels (March 16), enforcing curfew on citizens older than age of 65 (March 21), enforcing curfew on citizens younger than age of 20 (March 28), travel restriction to enter and leave 30 metropolitan cities and Zonguldak (due to being in a province with coal mining, thermal power plants, and iron-steel industry, and having a higher rate of respiratory diseases) (April 3), enforcing general curfew on weekends (April 11), and continuous stay-at-home calls to general population. Furthermore, mobility between all cities was gradually decreased to the point of security forces controlling entries and exits. In order to prevent congregation of people in indoor spaces, most of the public sector has started to provide services online, leaving minimum staff in office buildings. Private sector was strongly encouraged to follow the example of the public sector. As a result, a large proportion of the population stayed at home, minimizing use of public transportation services and sustaining only basic commercial activities. Similar to global news reports on nature's regenerative power, Turkish media reported increased air quality based on visibility (Figure SM-1).

In this study, we investigated the combined effect of the preventive measures taken in COVID-19 pandemic on air quality of 11 cities in Turkey, seven of which were metropolitan cities. Data for the years of 2019 and 2020 were acquired from governmental air quality monitoring network that conduct real-time measurements of $PM_{2.5}$, PM_{10}, SO_2, NO_2, NO, NO_x, O_3 and CO. Concentrations measured in March 1-April 21 period in 2019 and 2020, and PM-associated excess health risks were compared to elucidate the effect of decreased human mobility and activity due to COVID-19 on air quality. This is the first study that investigates air pollution behavior and estimates excess risk levels of $PM_{2.5}$ and PM_{10} during COVID-19 pandemic period in Turkey.

2. Methods

2.1. Study area and air quality parameters

Eleven cities, Ankara (A), Bursa (B), Corum (C), Istanbul (I), Izmir (IZ), Kars (K), Kocaeli (KO), Konya (KON), Kutahya (KU), Trabzon (T), and Zonguldak (Z) were selected for investigating impact of COVID-19 on air quality (Figure 1). Selected cities represent 42.8% of Turkey's population. Istanbul, Kocaeli, and Bursa are heavily industrialized zones with energy, steel, automotive, chemical and textile sectors. Metropolitan cities are A, B, I, IZ, KO, KON, and T. Although Zonguldak is a non-metropolitan city, it was included in the travel restriction along with the metropolitan cities, due to having a higher rate of respiratory diseases (Table 1). Measured concentrations of air quality parameters ($PM_{2.5}$, PM_{10}, SO_2, NO_2, NO_X, NO, O_3, and CO) were obtained from the Air Quality Monitoring Database of the Ministry of Environment and Urban Urbanization in Turkey (URL1). Number of Air Quality Monitoring Stations (AQMS) in the selected cities are presented in the descriptive statistic tables for each air quality parameter (Table SM 1-4). Since measured values for any given parameter at a given city can be quite scattered, overall median, minimum and maximum values were used in assessment instead of mean values.

Figure 1. Investigated cities in Turkey (Adopted from Google Maps)

Table 1. Investigated cities in this study

City	Population (n)	Provincial Surface Area (km^2)	Population Density (n/km^2)	Road Motor Vehicles (n)	Industry
Ankara	5639076	25632	220	2064501	Construction, Furniture, Metal, Defence, Printing
Bursa	3056120	10813	283	913154	Automotive, Textile, Cement, Energy, Chemical, Furniture
Corum	530864	12428	43	172622	Tile and brick, Roasted Chickpea
Istanbul	15519267	5343	2905	4222821	Textile, Tourism, Metal, Chemical Printing
Izmir	4367251	11891	367	1440392	Dye, Iron and steel, Petrochemical, Metal, Chemical, Food and beverage, Cement, Tourism
Kars	285410	10193	28	45111	Food, Wood
Kocaeli	1953035	3397	575	403209	Automotive, Pulp and paper, Iron and steel, Cement, Petrochemical, Energy, Aluminum, Waste, Chemical
Konya	2232374	40838	55	729076	Food and beverage, Tourism, Energy, Plastic, Base metal and casting, Automotive, Machinery
Kutahya	579257	11634	50	211463	Ceramic
Trabzon	808974	4628	175	200385	Cement, Printing, Metal and casting, Food
Zonguldak	596053	3342	178	156125	Energy, Cement, Mining
Turkey	82003882	780043	105	23361062	

2.2. Excess risk

Health risks due to change in ambient air $PM_{2.5}$, PM_{10}, SO_2, NO, O_3, and CO concentrations between March 1-April 21 in 2019 and 2020 were determined by estimating the excess risk (ER). The relative risk (RR) and ER were calculated using Eqs. 1 and 2, respectively.

$$RR=\exp[\beta(C_i-C_t)],\ C_i>C_t \qquad \text{Eq. 1}$$

$$ER\ (\%)=(RR-1)\times 100 \qquad \text{Eq. 2}$$

where, C_i and C_t are contaminant concentration and threshold concentration, respectively. Threshold concentrations for $PM_{2.5}$, PM_{10}, SO_2, NO_2, O_3, and CO were 25 µg/m^3 (24-h average), 50 µg/m^3 (24-h average), 20 µg/m^3 (24-h average), 200 µg/m^3 (1-h average), 100 µg/m^3 (8-h average), and 4000 µg/m^3 (1-h average), respectively (WHO, 2005; Sharma et al., 2020). If the concentration of a pollutant (C_i) is equal or below the threshold concentration (C_t), it has no excess risk. β values were 0.38 % for $PM_{2.5}$, 0.32 % for PM_{10}, 0.81 % for SO_2, 1.30 % for NO, 0.48 % O_3, and 3.7 % for CO (Shang et al., 2013).

2.3. Statistical

Shapiro-Wilk normality test was conducted with the significance level of 0.05, which was rejected for most of the air quality parameters at all stations. Therefore, nonparametric Mann-Whitney U-test (M-W test) was used to compare the concentrations. Significance level of M-W test was 0.05. Criterion of inclusion in this study for a pollutant measured at a station was <25 % missing values.

3. Results and discussion

3.1. Effect of COVID-19 on levels of air quality parameters

Values for air quality parameters ($PM_{2.5}$, PM_{10}, SO_2, NO_2, NO_X, NO, O_3, and CO) were downloaded for the period of March 1 to April 21 in 2019 and 2020 for 11 cities in Turkey. Box-plots for the studied periods at each station are presented in Figure SM 2-46.

3.1.1. $PM_{2.5}$

$PM_{2.5}$ emissions are mainly originate from traffic, combustion of fossil fuels and biomass for energy production, and industrial facilities (Sharma et al., 2016; Guo et al., 2019). Exposure to high levels of $PM_{2.5}$ may cause adverse human health effects, such as respiratory and cardiovascular diseases, premature death, and lung cancer (WHO, 2013). Furthermore, since particles comprising $PM_{2.5}$ may be suspended in ambient air for prolonged periods of time, it may serve as an important vector in spread of infection (Zhu et al., 2020). Therefore, $PM_{2.5}$ may be the most important air quality parameter to be investigated.

Overall median concentrations of $PM_{2.5}$ were in the range of 10.2-23.7 µg/m^3 (2019) and 17.3-30.4 µg/m^3 (2020) (Table SM1 and Figure SM2-5). The median values showed a slight increase in Ankara, Bursa, Istanbul, Kocaeli, Kutahya, Trabzon, and Zonguldak, while there was only a slight reduction in Istanbul. Furthermore, the M-W test results indicate that the differences in $PM_{2.5}$ concentrations were either not significant for all stations in Kocaeli and Bursa, and for 3/4 stations in Istanbul, or higher in 2020 for Ankara, Kutahya, Trabzon, and Zonguldak. There was only one station (in Istanbul) that had a significantly higher $PM_{2.5}$ median concentration in 2019 compared to 2020.

A significant reduction in $PM_{2.5}$ concentrations was observed in other countries during the COVID-19 pandemic period due to strict curfew policies. For instance, the average $PM_{2.5}$ concentration reduction in northern region of Malaysia was found to be 23.7 % through a ban of business operation except for essentials and suspension of activities in several industries as well as enforcing curfew on citizens (Abdullah et al., 2020). In India, $PM_{2.5}$ and PM_{10} concentrations in 22 cities in different regions of the country were analyzed and overall decreases of 43% and 31% were reported, respectively (Sharma et al., 2020). With the strict traffic restrictions and self-quarantine implementations, the reduction in $PM_{2.5}$ concentration was also reported to be 20-30% in majority of China during the COVID-19 pandemic period compared with the same period in years 2017, 2018, and 2019 (Zambrano-Monserrate, et al., 2020). In comparison, curfew policy partly excluding public service and production based working population (ages between 20 and 65) in Turkey allowed continuation of industrial and construction activities, which also necessitated transportation activities. Furthermore, curfew on ages >65 and <20 may have increased residential heating emissions. These could be the main reasons for not observing reductions in the median $PM_{2.5}$ concentrations.

3.1.2. PM_{10}

Diesel engines, industry, resuspension of soil particles, industrial activities and residential fossil fuel heating are the main sources of PM_{10} pollution (Lenshow et al., 2001). Overall median concentrations of PM_{10} ranges were 24.2-55.2 μg/m^3 (2019) and 27.6-76.5 μg/m^3 (2020) (Table SM1 and Figure SM6-11). Reduction in overall median PM_{10} concentrations were 13.1%, 15.0%, 2.82%, 11.0%, 2.77%, and 8.79% in Corum, Bursa, Istanbul, Kars, Kocaeli, and Konya respectively. On the other hand, the overall median PM_{10} concentrations increased in Ankara (31.8%), Izmır (38.8%), Kutahya (9.80%), and Trabzon (11.6%). M-W test indicated that, in general, PM_{10} concentration distributions were not significantly affected by the actions taken against COVID-19 in Turkey. The median PM_{10} concentrations at all stations in Bursa (n=3), Corum (n=2), Kars (n=1), Kocaeli (n=9), and Kutahya (n=1), 1/3 stations in Ankara, 10/11 stations in Istanbul and 2/3 stations in Trabzon were not significantly different. There were only five stations with significantly differing concentrations: one in Ankara and Istanbul with 2019>2020, and one in Ankara, Trabzon, and Zonguldak with 2019<2020.

Partial lockdown has decreased the PM_{10} concentrations in Milan-Italy by 32.7-40.5% (Collivignarelli, 2020). Additional reductions were observed during the total lockdown period. In Turkey, white collar employees were allowed to work home-office and the traffic density decreased due to curfew policies in the business center(s) of the cities, which may be the reason for the reductions observed at two stations in Istanbul and Ankara but the remaining stations (10/11 in Istanbul and 2/3 in Ankara) did not support this observation. Industrial production (for Istanbul, Kocaeli, Bursa, and Ankara,) and shipping traffic (for Istanbul, Kocaeli, and Bursa) were not interrupted during the study period, which probably played a role in the not significantly differing concentrations between 2019 and 2020. Higher PM_{10} concentrations in Izmir in 2020 might be due to the increase in industrial production and shipping traffic to meet the demand in food sector. The increasing in PM_{10} concentrations at Besirli station in Trabzon might be due to combustion of fossil fuels for residential heating. The median concentration in Zonguldak was tripled from 2019 to 2020. We do not have the data to reasonably explain this sharpest change in PM_{10} concentrations other than to speculate that an increased residential heating may had a role while emissions of the seven thermal power plants and the iron-steel plant also continued.

3.1.3. NO_X

Overall median concentrations of NO_2 for seven cities (29 stations) were in the range of 24.9-77.9 µg/m^3 (2019) and 23.2-59.1 µg/m^3 (2020) (Table SM2 and Figure SM12-17). Results showed a significant decrease in COVID-19 pandemic period compared with the same period in 2019. The highest reduction was 40.9 % in Trabzon, while the lowest reduction was 6.83 % in Kocaeli. Concentrations did not significantly change from 2019 to 2020 at 1/4 stations in Bursa, 2/11 stations in Istanbul, 4/6 stations in Kocaeli, and 1/4 stations in Trabzon. On the other hand, they were significantly higher in 2019 at 20 stations (in A, B, I, K, KO, T, and Z). We have found that station location is a determining factor: NO_2 concentrations at stations in heavily industrialized/commercial areas or at transportation connection hubs did not differ significantly, most probably due to emissions from traffic despite preventive measures. Dantas et al. (2020) studied effect of COVID-19 pandemic period on air quality of Rio de Janeiro, Brazil. They found that the median NO_2 concentration was 24.1–32.9 % lower when compared with the same period in 2019. They also reported that the least reduction was observed for NO_2 most probably due to diesel combustion and industrial activities. The NO_2 reductions were found to be 20-30 % in Wuhan, China, Europe, Italy, France, Spain, and USA following lockdown periods (NASA, 2020; ESA, 2020).

Overall median NO concentrations were in the range of 6.24-31.8 $\mu g/m^3$ (2019) and 8.57-20.9 $\mu g/m^3$ (2020) (Table SM2 and Figure SM18-23). Similar to NO_2, a significant decrease was observed in NO concentrations. There were 12 stations at which reduced concentrations were measured (2 in Ankara and Kocaeli, 4 in Istanbul, 1 in Kars, and 3 in Trabzon) during the COVID-19 period. For the remaining stations, the difference in NO concentrations were not significant at 7 stations (2/4 in Bursa, 4/9 in Istanbul, 1/4 in Trabzon) and higher in 2020 at 4 stations (1/4 in Bursa, 1/9 in Istanbul, and 2/4 in Kocaeli). Furthermore, the overall median NO_x concentrations were 36.4-89.6 $\mu g/m^3$ (2019) and 33.8-72.1 $\mu g/m^3$ (2020) (Table SM3 and Figure SM24-29). The concentrations were lower in 2020 at 17 stations, no significant difference at 6 stations, and higher in 2020 at 2 stations (2/8 in Kocaeli).

3.1.4. SO_2

The overall median concentrations of SO_2 were 4.52-34.1 μg/m^3 and 4.31-12.6 μg/m^3 in 2019 and 2020 for nine cities (Table SM3 and Figure SM30-36). Furthermore, changes in overall median SO_2 concentrations were as follows: 15.4-61.9% reduction (Trabzon, Zonguldak, Kars, Izmir, Bursa, and Corum) and 7.74-63.7 % increase (Istanbul, Kocaeli, and Ankara). The highest reduction was 61.9 % (from 11.3 μg/m^3 to 4.31 μg/m^3) in Trabzon while the highest increase was 63.7 % in Istanbul (from 4.90 μg/m^3 to 8.02 μg/m^3). M-W test results indicated that the concentrations did not significant change in Corum, Izmir, Ankara (1/2 stations), Bursa (4/5 stations), Istanbul (2/9 stations), and Kocaeli (2/4 stations), whereas, increased concentrations were observed in 2020 in 1/2, 6/9, 2/4, and 1/1 stations in Ankara, Istanbul, Kocaeli, and Zonguldak respectively.

SO_2 concentration increase was significant in Ankara, Istanbul, and Kocaeli, which have a large number of industrial facilities and high population density. These results point to continuation of industrial activities and dense population as probable causes for the increased SO_2 concentrations during COVID-19 pandemic period.

3.1.5. CO

CO concentrations could be analyzed in seven cities because the inclusion criterion was not met at many stations. The overall median concentration ranges were 463-926 μg/m^3 and 1.09-2282 μg/m^3 in 2019 and 2020, respectively (Table SM4 and Figure SM37-41). Reduction in overall median CO concentrations were 3.82 %, 15.4 %, and 28.4 %, in Kars, Trabzon, and Zonguldak, respectively. On the other hand, the overall median CO concentrations almost doubled in Ankara, Bursa, and Istanbul. According to the M-W tests, the median CO concentrations were higher in 2019 compared to 2020 at 1/2 stations in Kars, 3/4 stations in Kocaeli, and all stations in Trabzon and in Zonguldak. However, the median CO concentrations were lower in 2019 compared to 2020 for all stations in Bursa and Istanbul, while the difference in CO concentrations were not significant in Ankara.

Based on the results, CO emissions significantly decreased in Kars, Trabzon, and Zonguldak as these cities had fewer industrial activities except for Zonguldak. Ankara, Istanbul, and Bursa are considered as the metropolitan cities with high industrial capacity and registered motor vehicles. No reduction in CO concentrations were observed in these cities during the COVID-19 pandemic period. The reason of the increase and/or no significant change in CO concentrations in these cities might be the continuation of industrial activities and associated transportation. Similar results observed in southern India, such that a significant increase was observed in CO concentration, while a significant decrease was observed in other pollutants concentrations (NO, NO_2, and O_3) during the COVID-19 pandemic period (Sharma et al., 2020).

3.1.6. O_3

O_3 was the parameter with the least available data. Its concentrations are presented in Table SM4 and Figure SM42-46. In Bursa, reduction in overall median O_3 concentration was 3.08% (45.5 μg/m^3 in 2019 and 44.1 μg/m^3 in 2020). Changes in median O_3 concentrations were lower during COVI-19 period at 1/3 stations in Bursa, while the difference was not significant at the meaning two stations. Studies on atmospheric O_3 concentrations revealed that the decrease in NO_x concentrations may be attributed to the increase in O_3 concentrations (Geraldino et al., 2020; Dantas et al., 2019). Moreover, the decrease in PM concentrations, which increasing sunlight passing through atmosphere, may be attributed the production of O_3 with photochemical activities (Dang and Liao, 2019). During the COVID-19 pandemic period, the decrease in PM and NO_2 concentrations were attributed to increase in O_3 concentrations. For instance, the median O_3

concentration increased by 6.34%, while PM_{10} and NO_2 median concentrations decreased by 14.0 % and 37.5 %, respectively at Uludag station, Bursa. On the other hand, at Kestel station, again Bursa but close to its Organized Industrial Zone, the median O_3 concentration decreased by 18.8%, while the PM_{10} concentration increased by 6.47%. Wang et al. (2020) reported significant increases in O_3 concentrations probably due to lower fine particle loadings, which cause less scavenging by HO_2, and thus observation of O_3 concentrations for longer periods. A similar trend was reported by Mahato et al. (2020) for megacity Delhi, India. They found that O_3 concentrations increased significantly during the COVID-19 pandemic period possibly due to decrease in NO_x and NO concentrations, and increase in insolation and temperature.

3.2. Excess risk assessment of air quality parameters

Exposure to $PM_{2.5}$ mainly causes respiratory and cardiovascular system problems. Hence, it may aggravate the COVID-19 infection symptoms and may increase mortality rate. Wu et al. (2020) studied the relationship between air pollution and COVID-19 mortality in the United States and found that comorbidities related to $PM_{2.5}$ dramatically increased the risk in COVID-19 patients. Overall and city-based excess risks (ER) were compared for $PM_{2.5}$ and PM_{10} median concentrations (Fig. 2 and 3). Comparisons of $ER_{PM2.5}$ values revealed decreases for Bursa, Istanbul, and Kocaeli, and increases for Trabzon, Kutahya, and Zonguldak (Fig. 2). Since Bursa, Istanbul, and Kocaeli are densely populated metropolitan cities, decrease in traffic and industrial activities due to progressive prevention measures during the COVID-19 pandemic period resulted in decrease of ER values. For the capital city of Ankara, the median ER values were similar (Table 2). The most significant increase in median ER values was calculated for Zonguldak, where coal mining is the major source of livelihood. Furthermore, the overall ER values decreased from 2019 to 2020 (Fig. 2). Sharma et al. (2020) compared the effect of restricted emissions during COVID-19 on air quality in India with previous three years. They reported that there was a considerable health risks related to $PM_{2.5}$ and PM_{10} in all the regions during the lockdown period of COVID-19 pandemic. However, the mean ER values for $PM_{2.5}$ and PM_{10} decreased by almost 52% on average in India compared with previous years. Relationship between COVID-19 infection and short-term exposure to $PM_{2.5}$, PM_{10}, CO, NO_2 and O_3 were investigated in China (Zhu et al., 2020), showing that daily counts of confirmed cases increased by 2.24 %, 1.76 %, 6.94 %, and 4.76 % with a 10 μg/m^3 increase in $PM_{2.5}$, PM_{10}, NO_2, and O_3, respectively. The median ER value associated with PM_{10} decreased in Corum, Ankara, Bursa, Kocaeli, and Kutahya, while it increased in Istanbul, Izmir, Kars, Konya, Trabzon, and Zonguldak from 2019 to 2020. The most pronounced increase was calculated for Zonguldak.

It should be noted that although both increases and decreases in concentrations were observed for the studied cities, they were mostly small changes (for PM_{10} median ER changed between -2.01% and +3.21% except for Zonguldak; for $PM_{2.5}$ ER changed between -1.87% and +3.68%). Due to the enforced partial curfews and calls for staying at home, emissions from transportation and industrial activities might have been limited because a portion of the population kept working. On the other hand, emissions from residential heating were probably increased because the remaining portion of the population were forced to stay at home. In Turkey, 15 °C is generally the threshold temperature for residential heating. For our study period (March 1-April 21), the highest average temperature was measured as 18.9 °C in Izmir, while the lowest average temperature was 9.5 °C in Kars. Despite the extensive infrastructure of natural gas in cities of Istanbul, Ankara, Bursa and Kocaeli, there are parts of these cities that still use coal and fuel oil for residential heating. The probable effect of fossil fuel based residential heating was most readily observed in Zonguldak for $PM_{2.5}$ and PM_{10}. Overall median ER values for $PM_{2.5}$ and PM_{10} decreased slightly during the COVID-19 pandemic period in Turkey based on the 11-city data. Atmospheric SO_2,

NO_2, NO_X, NO, O_3, and CO concentrations were below the limits recommended by World Health Organization, therefore, the ER levels were not calculated for these pollutants.

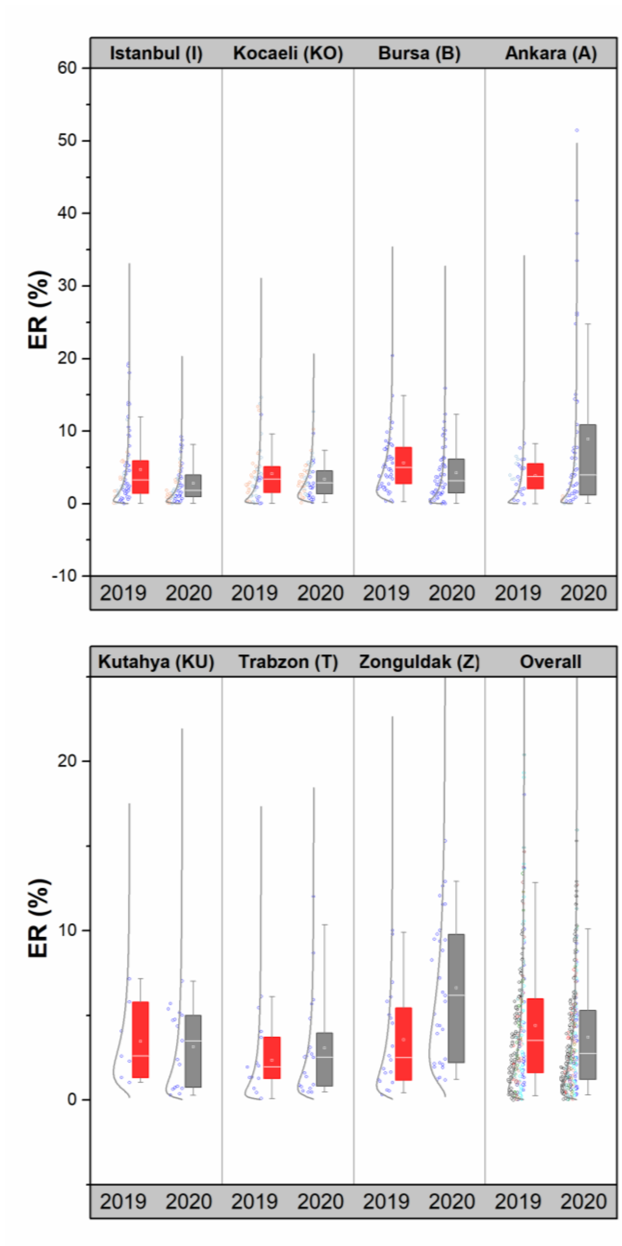

Figure 2. Excess risks related to $PM_{2.5}$ in 2019 and 2020.

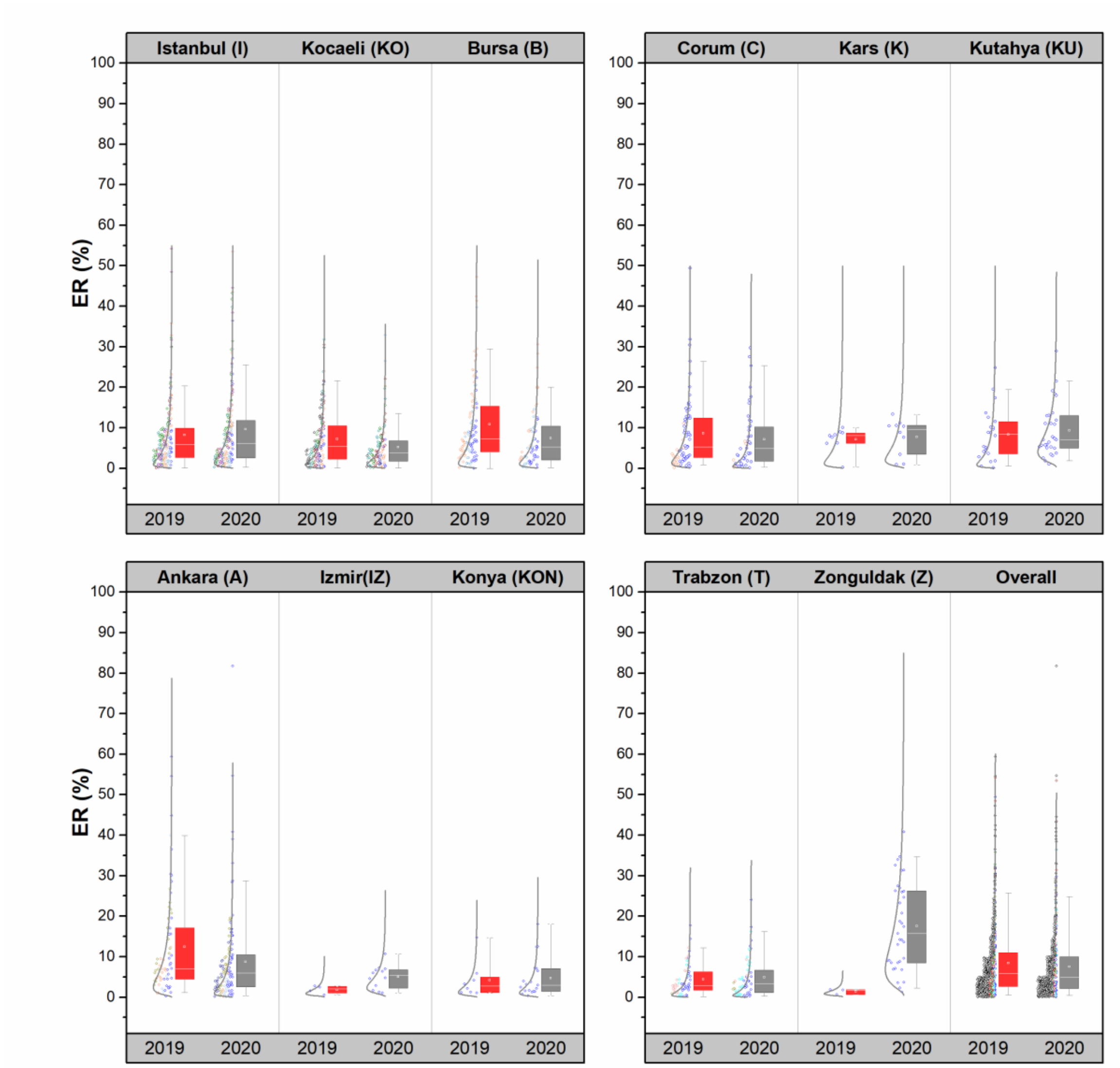

Figure 3. Excess risks of PM_{10} in 2019 and 2020.

Table 2. Descriptive statistics of excess risk levels (%) of $PM_{2.5}$ and PM_{10}

Parameter	City	Number of AQMS	Year	Median	Mean	Min	Max
$PM_{2.5}$	Ankara	4	2019	3.71	3.85	0.004	8.29
			2020	3.96	8.90	0.03	51.4
	Bursa	2	2019	5.02	5.65	0.27	20.4
			2020	3.15	4.26	0.01	15.9
	Istanbul	4	2019	3.28	4.72	0.03	19.3
			2020	1.85	2.80	0.01	9.25
	Kocaeli	4	2019	3.40	4.13	0.03	14.7
			2020	2.84	3.39	0.13	12.7
	Kutahya	1	2019	2.59	3.46	1.04	7.16
			2020	3.50	3.15	0.28	7.03
	Trabzon	1	2019	1.95	2.36	0.09	6.11
			2020	2.53	3.06	0.46	12.0
	Zonguldak	1	2019	2.49	3.56	0.31	10.0
			2020	6.17	6.62	1.18	15.3
PM_{10}	Corum	3	2019	5.31	8.60	0.08	49.4
			2020	4.83	7.12	0.06	29.8
	Ankara	7	2019	7.04	12.4	0.25	59.4
			2020	5.98	8.69	0.05	81.8
	Bursa	4	2019	7.33	10.8	0.002	47.2
			2020	5.32	7.40	0.11	30.6
	Istanbul	11	2019	5.89	8.19	0.03	54.1
			2020	6.18	9.76	0.13	53.5
	Izmir	1	2019	2.04	1.85	0.54	2.78
			2020	5.36	5.01	1.11	10.7
	Kars	1	2019	8.05	7.14	0.22	10.1
			2020	9.59	7.76	0.88	13.3
	Kocaeli	11	2019	5.37	7.25	0.04	31.8
			2020	3.87	5.27	0.03	32.9
	Konya	2	2019	2.72	4.20	1.08	14.7
			2020	3.01	4.77	0.33	18.0
	Kutahya	1	2019	8.40	8.38	0.06	24.8
			2020	7.03	9.30	1.01	28.9
	Trabzon	5	2019	2.91	4.38	0.04	17.7
			2020	3.27	4.92	0.04	24.0
	Zonguldak	1	2019	1.76	1.43	0.62	1.89
			2020	15.7	17.6	1.26	40.8

4. Conclusion

This study shows the effects of curfew policies on air quality parameters in Turkey. Selected AQMSs represents 42.8 % of the population in Turkey (Ankara, Bursa, Corum, Istanbul, Izmir, Kars, Kutahya, Kocaeli, Konya Trabzon, and Zonguldak). Statistical comparison shows that, in general, there were no significant difference in PM concentrations, and at half of the stations for SO_2 between March-April periods of 2019 and 2020, whereas, overall NO_x, NO_2, and NO concentrations were significantly decreased. While the highest NO_2 reduction was determined in a non-industrial city with 40.9 %, the lowest reduction was in a heavily industrialized one with 6.83 %. Similar trends were observed for NO and NO_x. While the CO emissions were increased in metropolitan cities, others were decrease since fewer industrial activities. Current available ozone data was only in Bursa, with an overall insignificant decrease. There were stations at which concentration increases were observed, such as tripling of PM in a non-metropolitan but with dense coal mining and thermal power plants city and a 63.7 % in SO_2 in Istanbul. Excess risk (ER) associated with PM is important for the spread of the virus because it may act as a transport media. ER could only be estimated for $PM_{2.5}$ and PM_{10} since concentrations of the other pollutants were below their threshold levels. Overall countrywide median ER values for $PM_{2.5}$ and PM_{10} decreased slightly during the investigated period. In conclusion, the heterogeneous actions taken in response to the COVID-19 pandemic resulted in mixed effects on ambient air quality.

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DECLARATIONS

The authors declare that there is no conflict of interest.

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SUPPLEMENTARY MATERIAL

Figure SM1. Uludağ mountain could be seen from Istanbul after the partial curfew period (URL SM1)

Table SM1. Descriptive statistics of atmospheric $PM_{2.5}$ and PM_{10} concentrations.

Parameter	City	Number of AQMS	Year	Median	Mean	Min	Max
$PM_{2.5}$ (µg/m^3)	Ankara	4	2019	10.2	14.7	0.82	46.0
			2020	17.3	22.1	3.43	134
	Bursa	2	2019	23.7	26.7	6.87	73.9
			2020	25.6	27.8	8.08	63.9
	Istanbul	4	2019	20.5	23.1	5.34	71.5
			2020	19.9	20.9	5.20	48.3
	Kocaeli	4	2019	16.6	19.6	2.56	61.0
			2020	17.9	20.3	4.42	56.5
	Kutahya	1	2019	10.9	12.7	1.73	43.2
			2020	19.2	20.1	1.99	42.88
	Trabzon	1	2019	20.0	20.5	6.68	40.6
			2020	24.8	26.0	9.46	54.9
	Zonguldak	1	2019	20.3	21.8	3.47	50.1
			2020	30.4	30.7	3.23	62.5
PM_{10} (µg/m^3)	Corum	3	2019	45.1	49.1	7.6	176
			2020	39.2	45.0	10.3	131
	Ankara	7	2019	33.0	43.1	4.82	196
			2020	43.5	47.8	2.95	237
	Bursa	4	2019	55.2	59.6	10.9	171
			2020	46.9	49.3	9.2	133
	Istanbul	11	2019	39.0	44.6	6.1	185
			2020	37.9	44.9	9.4	184
	Izmir	1	2019	30.7	33.7	11.7	58.6
			2020	42.6	44.5	17.4	81.8
	Kars	1	2019	31.0	34.9	7.6	80.0
			2020	27.6	34.3	7.72	89.2
	Kocaeli	11	2019	32.5	39.1	4.55	136
			2020	31.6	36.7	6.07	409
	Konya	2	2019	30.7	34.0	9.83	928
			2020	28.0	32.9	8.48	102
	Kutahya	1	2019	55.1	57.3	14.05	119
			2020	60.5	60.0	14.7	129
	Trabzon	5	2019	34.5	37.6	11.5	101
			2020	38.50	42.3	17.6	117
	Zonguldak	1	2019	24.2	26.1	4.63	55.9
			2020	76.5	77.2	8.11	157

Table SM2. Descriptive statistics of atmospheric NO and NO_2 concentrations.

Parameter	City	Number of AQMS	Year	Median	Mean	Min	Max
NO ($\mu g/m^3$)	Ankara	5	2019	14.7	25.3	0.19	155
			2020	12.6	24.6	1.90	164
	Bursa	4	2019	10.9	21.9	0.29	178
			2020	11.1	18.8	1.50	139
	Istanbul	11	2019	19.1	28.9	0.28	229
			2020	18.2	25.5	0.49	210
	Kars	1	2019	13.1	13.9	4.56	31.0
			2020	8.57	10.2	2.98	27.8
	Kocaeli	11	2019	6.24	15.8	0.24	170
			2020	11.9	35.3	0.40	376
	Kutahya	1	2019	6.84	10.6	2.46	35.5
			2020	9.75	13.2	2.18	38.5
	Trabzon	5	2019	18.5	22.3	1.42	115
			2020	10.6	19.8	1.02	158
	Zonguldak	1	2019	31.8	33.0	11.8	60.7
			2020	20.9	25.4	9.52	73.6
NO_2 ($\mu g/m^3$)	Corum	1	2019	77.9	85.9	40.1	167
			2020	59.1	57.9	34.3	90.3
	Ankara	5	2019	49.2	48.8	3.95	110
			2020	38.0	40.9	10.8	90.1
	Bursa	4	2019	37.8	44.0	1.20	132
			2020	31.5	33.3	4.87	98.7
	Istanbul	12	2019	32.9	40.0	0.84	164
			2020	27.7	28.0	0.27	120
	Kars	1	2019	29.0	29.9	15.7	55.9
			2020	25.2	27.4	12.9	53.5
	Kocaeli	11	2019	24.9	29.1	0.73	191
			2020	23.2	26.8	0.20	78.3
	Kutahya	1	2019	29.4	30.0	13.0	53.5
			2020	41.4	40.3	12.3	71.1
	Trabzon	5	2019	46.5	48.1	19.6	86.5
			2020	27.5	38.5	8.94	99.7
	Zonguldak	1	2019	41.3	44.6	24.4	65.1
			2020	32.9	33.4	18.1	63.3

Table SM3. Descriptive statistics of atmospheric NO_x and SO_2 concentrations.

Parameter	City	Number of AQMS	Year	Median	Mean	Min	Max
NO_x ($\mu g/m^3$)	Corum	1	2019	89.6	106	46.2	234
			2020	72.1	80.2	40.5	147
	Ankara	5	2019	63.3	74.1	4.62	254
			2020	51.7	65.6	13.9	254
	Bursa	5	2019	49.9	74.8	1.19	405
			2020	51.5	67.7	13.0	306
	Istanbul	12	2019	66.2	85.5	3.24	516
			2020	43.9	59.7	1.08	438
	Kars	1	2019	41.8	43.7	22.7	86.8
			2020	33.8	37.6	15.9	81.3
	Kocaeli	11	2019	36.8	55.3	0.83	337
			2020	39.4	76.1	1.09	683
	Kutahya	1	2019	36.4	40.6	16.5	81.5
			2020	53.8	53.5	14.4	103
	Trabzon	5	2019	66.3	70.3	22.7	195
			2020	48.3	58.3	10.7	257
	Zonguldak	1	2019	74.6	78.1	41.3	126
			2020	53.8	58.9	28.5	137
SO_2 ($\mu g/m^3$)	Corum	1	2019	10.1	12.9	2.25	38.3
			2020	7.52	10.6	5.88	24.6
	Ankara	6	2019	4.52	8.86	0.25	34.4
			2020	4.87	5.32	0.73	20.4
	Bursa	5	2019	9.41	11.4	0.81	59.3
			2020	7.08	9.95	0.79	83.2
	Istanbul	10	2019	4.90	6.48	0.66	43.2
			2020	8.02	13.02	0.23	71.5
	Izmir	1	2019	9.25	10.3	3.71	30.4
			2020	7.83	8.78	3.76	16.1
	Kars	1	2019	8.80	10.9	3.04	27.1
			2020	4.37	5.08	2.12	11.4
	Kocaeli	7	2019	5.19	7.88	0.43	49.7
			2020	7.44	11.4	0.69	75.0
	Konya	2	2019	13.9	14.6	5.47	39.8
			2020	7.36	8.89	3.02	26.1
	Kutahya	1	2019	34.1	30.4	11.9	62.5
			2020	12.6	13.1	4.28	31.5
	Trabzon	4	2019	11.3	16.2	2.56	66.3
			2020	4.31	5.46	1.87	16.2
	Zonguldak	1	2019	12.8	15.4	1.83	36.7
			2020	5.06	6.61	1.01	26.5

Table SM4. Descriptive statistics of atmospheric CO and O_3 concentrations.

Parameter	City	Number of AQMS	Year	Median	Mean	Min	Max
CO ($\mu g/m^3$)	Ankara	2	2019	463	773	128	3833
			2020	655	795	200	2569
	Bursa	1	2019	926	1104	442	3284
			2020	2282	2386	1437	3905
	Istanbul	6	2019	564	608	177	2208
			2020	1342	2266	219	10527
	Kars	2	2019	498	501	274	965
			2020	479	496	297	936
	Kocaeli	4	2019	612	794	409	2321
			2020	1.09	608	0.29	2721
	Kutahya	1	2019	822	861	552	1361
			2020	640	606	180	1002
	Trabzon	2	2019	752	768	379	1587
			2020	636	652	290	1130
	Zonguldak	1	2019	870	904	378	1576
			2020	623	667	151	1793
O_3 ($\mu g/m^3$)	Corum	1	2019	23.9	26.9	17.5	43.1
			2020	36.5	32.3	6.58	44.4
	Ankara	2	2019	57.5	57.6	43.5	79.4
			2020	22.5	29.8	4.88	83.6
	Bursa	4	2019	45.5	47.4	11.4	97.9
			2020	44.1	46.6	13.0	91.7

Table SM5. Hypothesis and p-values of Mann-Whitney tests of $PM_{2.5}$.

AQMS	Null hypothesis	Alternative Hypothesis	p-value
Bahcelievler-Ankara	2019=2020	2019>2020	1
Uludag-Bursa	2019=2020	2019≠2020	0.533
City Center-Bursa	2019=2020	2019≠2020	0.438
Umraniye-Istanbul	2019=2020	2019≠2020	0.289
Kagithane-Istanbul	2019=2020	2019>2020	0.004
Sultangazi-Istanbul	2019=2020	2019≠2020	0.656
Silivri-Istanbul	2019=2020	2019≠2020	0.637
City Center-Kocaeli	2019=2020	2019≠2020	0.067
Kandira-Kocaeli	2019=2020	2019≠2020	0.836
Golcuk-Kocaeli	2019=2020	2019≠2020	0.860
Korfez-Kocaeli	2019=2020	2019≠2020	0.901
Kentpark-Kutahya	2019=2020	2019>2020	0.999
Besirli-Trabzon	2019=2020	2019>2020	0.999
Trafik-Zonguldak	2019=2020	2019>2020	0.998

Table SM6. Hypothesis and p-values of Mann-Whitney tests of PM_{10}.

AQMS	Null hypothesis	Alternative Hypothesis	p-value
Kecioren-Ankara	2019=2020	2019≠2020	0.552
Kayas-Ankara	2019=2020	2019>2020	0.0004
Bahcelievler-Ankara	2019=2020	2019>2020	1
Inegol-Bursa	2019=2020	2019≠2020	0.582
Kestel-Bursa	2019=2020	2019≠2020	0.128
Beyazit-Bursa	2019=2020	2019≠2020	0.072
Bahabey-Corum	2019=2020	2019≠2020	0.498
Mimarsinan-Corum	2019=2020	2019≠2020	0.069
Kandilli-Istanbul	2019=2020	2019≠2020	0.616
Uskudar-Istanbul	2019=2020	2019≠2020	0.842
Sirinevler-Istanbul	2019=2020	2019≠2020	0.609
Mecidiyekoy-Istanbul	2019=2020	2019>2020	0.009
Umraniye-Istanbul	2019=2020	2019≠2020	0.542
Basaksehir-Istanbul	2019=2020	2019≠2020	0.516
Esenyurt-Istanbul	2019=2020	2019≠2020	0.512
Sultanbeyli-Istanbul	2019=2020	2019≠2020	0.630
Sultangazi-Istanbul	2019=2020	2019≠2020	0.227
Silivri-Istanbul	2019=2020	2019≠2020	0.749
Sile-Istanbul	2019=2020	2019≠2020	0.063
Gaziemir-Izmir	2019=2020	2019>2020	0.999
Istasyon-Kars	2019=2020	2019≠2020	0.739
Gebze-Kocaeli	2019=2020	2019≠2020	0.759
Dilovasi-2-Kocaeli	2019=2020	2019≠2020	0.308
Dilovasi-1-Kocaeli	2019=2020	2019≠2020	0.699
City Center-Kocaeli	2019=2020	2019≠2020	0.394
Yenikoy-Kocaeli	2019=2020	2019≠2020	0.296
Golcuk-Kocaeli	2019=2020	2019≠2020	0.062
Alikahya-Kocaeli	2019=2020	2019≠2020	0.896
Korfez-Kocaeli	2019=2020	2019≠2020	0.604
Izmit-Kocaeli	2019=2020	2019≠2020	0.495
Kentpark-Kutahya	2019=2020	2019≠2020	0.250
Fatih-Trabzon	2019=2020	2019≠2020	0.311
Akcaabat-Trabzon	2019=2020	2019≠2020	0.234
Besirli-Trabzon	2019=2020	2019>2020	0.999
Trafik-Zonguldak	2019=2020	2019>2020	1

Table SM7. Hypothesis and p-values of Mann-Whitney tests of NO.

AQMS	Null hypothesis	Alternative Hypothesis	p-value
Demetevler-Ankara	2019=2020	2019>2020	0.021
Bahcelievler-Ankara	2019=2020	2019>2020	0.010
Inegol-Bursa	2019=2020	2019≠2020	0.919
Kestel-Bursa	2019=2020	2019>2020	<0.001
Uludag-Bursa	2019=2020	2019>2020	1
Beyazıt-Bursa	2019=2020	2019≠2020	0.144
Kandilli-Istanbul	2019=2020	2019≠2020	0.102
Uskudar-Istanbul	2019=2020	2019>2020	0.998
Sirinevler-Istanbul	2019=2020	2019≠2020	0.103
Mecidiyekoy-Istanbul	2019=2020	2019>2020	<0.001
Umraniye-Istanbul	2019=2020	2019>2020	0.001
Basaksehir-Istanbul	2019=2020	2019≠2020	0.745
Esenyurt-Istanbul	2019=2020	2019>2020	0.014
Sultangazi-Istanbul	2019=2020	2019≠2020	0.166
Silivri-Istanbul	2019=2020	2019>2020	0.953
Trafik-Kars	2019=2020	2019>2020	0.001
Gebze-Kocaeli	2019=2020	2019>2020	<0.001
Dilovasi 1-Kocaeli	2019=2020	2019>2020	0.999
Dilovasi 2-Kocaeli	2019=2020	2019>2020	1
City Center-Kocaeli	2019=2020	2019>2020	<0.001
Fatih-Trabzon	2019=2020	2019>2020	0.024
Akcaabat-Trabzon	2019=2020	2019>2020	<0.001
Besirli-Trabzon	2019=2020	2019>2020	<0.001
City Square-Trabzon	2019=2020	2019≠2020	0.267

Table SM8. Hypothesis and p-values of Mann-Whitney tests of NO_2 at significance value of 0.05.

AQMS	Null hypothesis	Alternative Hypothesis	p-value
Demetevler-Ankara	2019=2020	2019>2020	0.014
Bahcelievler-Ankara	2019=2020	2019>2020	0.041
Inegol-Bursa	2019=2020	2019≠2020	0.820
Kestel-Bursa	2019=2020	2019>2020	<0.001
Uludag-Bursa	2019=2020	2019>2020	<0.001
Beyazıt-Bursa	2019=2020	2019>2020	<0.001
Kandilli-Istanbul	2019=2020	2019>2020	<0.001
Uskudar-Istanbul	2019=2020	2019≠2020	0.131
Sirinevler-Istanbul	2019=2020	2019>2020	<0.001
Mecidiyekoy-Istanbul	2019=2020	2019>2020	<0.001
Umraniye-Istanbul	2019=2020	2019>2020	<0.001
Basaksehir-Istanbul	2019=2020	2019>2020	<0.001
Esenyurt-Istanbul	2019=2020	2019>2020	<0.001
Sultanbeyli-Istanbul	2019=2020	2019≠2020	0.398
Kagithane-Istanbul	2019=2020	2019>2020	<0.001
Sultangazi-Istanbul	2019=2020	2019>2020	<0.001
Silivri-Istanbul	2019=2020	2019>2020	0.010
Trafik-Kars	2019=2020	2019>2020	0.013
Dilovasi 1-Kocaeli	2019=2020	2019>2020	0.998
Dilovasi 2-Kocaeli	2019=2020	2019≠2020	0.799
Dilovasi 3-Kocaeli	2019=2020	2019≠2020	0.968
City Center-Kocaeli	2019=2020	2019>2020	<0.001
Korfez-Kocaeli	2019=2020	2019≠2020	0.103
Izmit-Kocaeli	2019=2020	2019≠2020	0.195
Fatih-Trabzon	2019=2020	2019≠2020	0.211
Akcaabat-Trabzon	2019=2020	2019>2020	<0.001
Besirli-Trabzon	2019=2020	2019>2020	<0.001
City Square-Trabzon	2019=2020	2019>2020	<0.001
Trafik-Zonguldak	2019=2020	2019>2020	<0.001

Table SM9. Hypothesis and p-values of Mann-Whitney tests of NO_x.

AQMS	Null hypothesis	Alternative Hypothesis	p-value
Demetevler-Ankara	2019=2020	2019>2020	0.033
Bahcelievler-Ankara	2019=2020	2019>2020	0.015
Inegol-Bursa	2019=2020	2019≠2020	0.936
Kestel-Bursa	2019=2020	2019>2020	<0.001
Beyazıt-Bursa	2019=2020	2019>2020	0.003
Kandilli-Istanbul	2019=2020	2019>2020	0.003
Uskudar-Istanbul	2019=2020	2019≠2020	0.900
Sirinevler-Istanbul	2019=2020	2019>2020	0.004
Mecidiyekoy-Istanbul	2019=2020	2019>2020	<0.001
Umraniye-Istanbul	2019=2020	2019>2020	<0.001
Basaksehir-Istanbul	2019=2020	2019>2020	0.004
Esenyurt-Istanbul	2019=2020	2019>2020	<0.001
Sultanbeyli-Istanbul	2019=2020	2019≠2020	0.131
Kagithane-Istanbul	2019=2020	2019>2020	<0.001
Sultangazi-Istanbul	2019=2020	2019>2020	<0.001
Silivri-Istanbul	2019=2020	2019≠2020	0.431
Trafik-Kars	2019=2020	2019>2020	0.001
Gebze-Kocaeli	2019=2020	2019>2020	<0.001
Dilovasi 1-Kocaeli	2019=2020	2019>2020	<0.001
Dilovasi 2-Kocaeli	2019=2020	2019≠2020	0.109
City Center-Kocaeli	2019=2020	2019>2020	0.002
Kandira-Kocaeli	2019=2020	2019≠2020	0.225
Yenikoy-Kocaeli	2019=2020	2019>2020	<0.001
Korfez-Kocaeli	2019=2020	2019>2020	1
Izmit-Kocaeli	2019=2020	2019>2020	1

Table SM10. Hypothesis and p-values of Mann-Whitney tests of SO_2.

AQMS	Null hypothesis	Alternative Hypothesis	p-value
Demetevler-Ankara	2019=2020	2019≠2020	0.169
Bahcelievler-Ankara	2019=2020	2019>2020	1
Inegol-Bursa	2019=2020	2019≠2020	0.490
Kestel-Bursa	2019=2020	2019≠2020	0.715
Uludag-Bursa	2019=2020	2019≠2020	0.704
Beyazıt-Bursa	2019=2020	2019>2020	<0.001
Kultur-Bursa	2019=2020	2019≠2020	0.868
Corum	2019=2020	2019≠2020	0.354
Kandilli-Istanbul	2019=2020	2019≠2020	0.944
Sirinevler-Istanbul	2019=2020	2019>2020	1
Umraniye-Istanbul	2019=2020	2019>2020	0.999
Basaksehir-Istanbul	2019=2020	2019>2020	1
Esenyurt-Istanbul	2019=2020	2019>2020	<0.001
Sultanbeyli-Istanbul	2019=2020	2019>2020	1
Sultangazi-Istanbul	2019=2020	2019>2020	1
Sile-Istanbul	2019=2020	2019>2020	0.002
Silivri-Istanbul	2019=2020	2019≠2020	0.642
Gaziemir-Izmir	2019=2020	2019≠2020	0.368
Trafik-Station	2019=2020	2019>2020	<0.001
City Center-Kocaeli	2019=2020	2019≠2020	0.198
Yenikoy-Kocaeli	2019=2020	2019>2020	0.999
Golcuk-Kocaeli	2019=2020	2019>2020	0.995
Korfez-Kocaeli	2019=2020	2019≠2020	0.414
Akcaabat-Trabzon	2019=2020	2019>2020	<0.001
Trafik-Zonguldak	2019=2020	2019>2020	<0.001

Table SM11. Hypothesis and p-values of Mann-Whitney tests of CO.

AQMS	Null hypothesis	Alternative Hypothesis	p-value
Bahcelievler-Ankara	2019=2020	2019≠2020	0.171
Beyazıt-Bursa	2019=2020	2019>2020	1
Kandilli-Istanbul	2019=2020	2019>2020	1
Uskudar-Istanbul	2019=2020	2019>2020	1
Sirinevler-Istanbul	2019=2020	2019>2020	1
Umraniye-Istanbul	2019=2020	2019>2020	1
Basaksehir-Istanbul	2019=2020	2019>2020	1
Trafik-Kars	2019=2020	2019>2020	<0.001
Station-Kars	2019=2020	2019≠2020	0.142
Dilovasi 1-Kocaeli	2019=2020	2019>2020	<0.001
Dilovasi 2-Kocaeli	2019=2020	2019>2020	<0.001
Dilovasi 3-Kocaeli	2019=2020	2019>2020	0.999
Izmit-Kocaeli	2019=2020	2019>2020	0.999
Akcaabat-Trabzon	2019=2020	2019>2020	<0.001
Besirli-Trabzon	2019=2020	2019>2020	<0.001
Trafik-Zonguldak	2019=2020	2019>2020	<0.001

Table SM12. Hypothesis and p-values of Mann-Whitney tests of O_3.

AQMS	Null hypothesis	Alternative Hypothesis	p-value
Kestel-Bursa	2019=2020	2019>2020	<0.001
Uludag-Bursa	2019=2020	2019≠2020	0.248
City Center-Bursa	2019=2020	2019≠2020	0.061

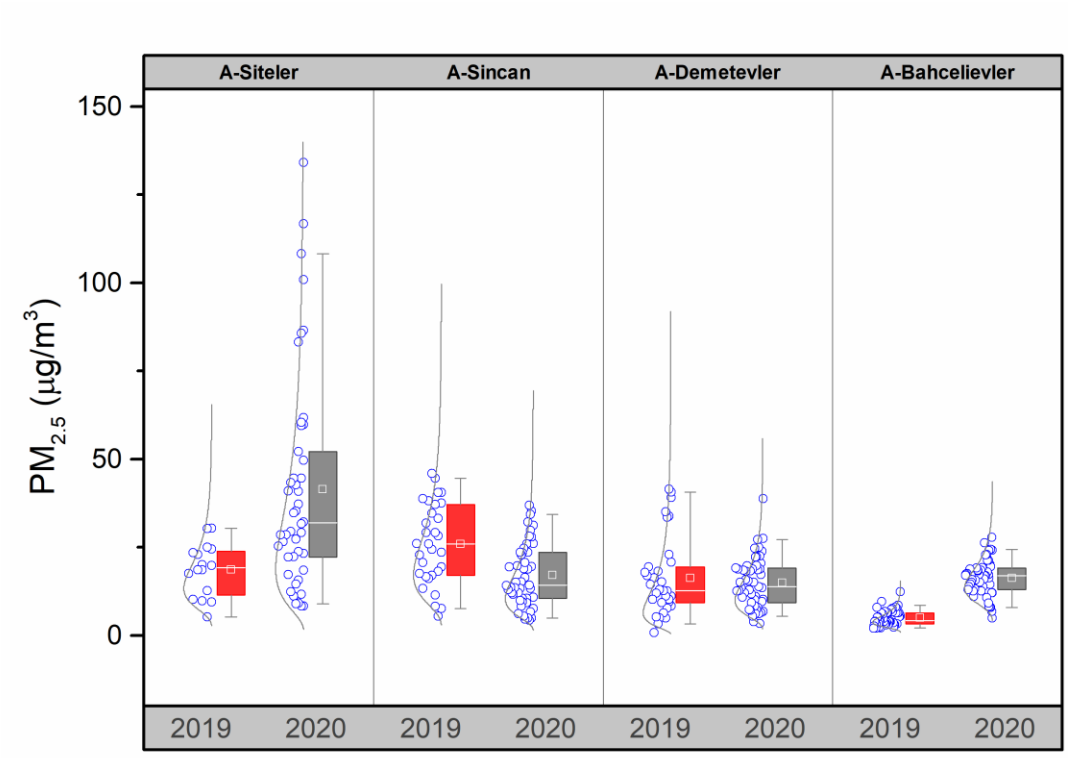

Figure SM2. $PM_{2.5}$ concentrations in Ankara

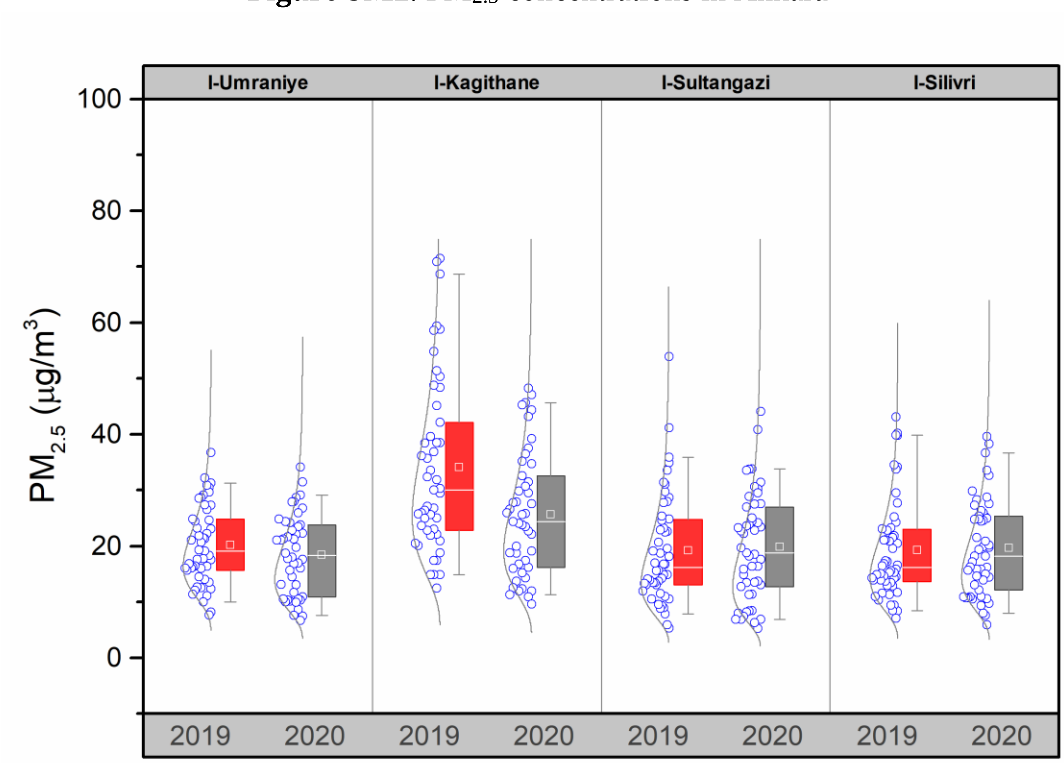

Figure SM3. $PM_{2.5}$ concentrations in Istanbul

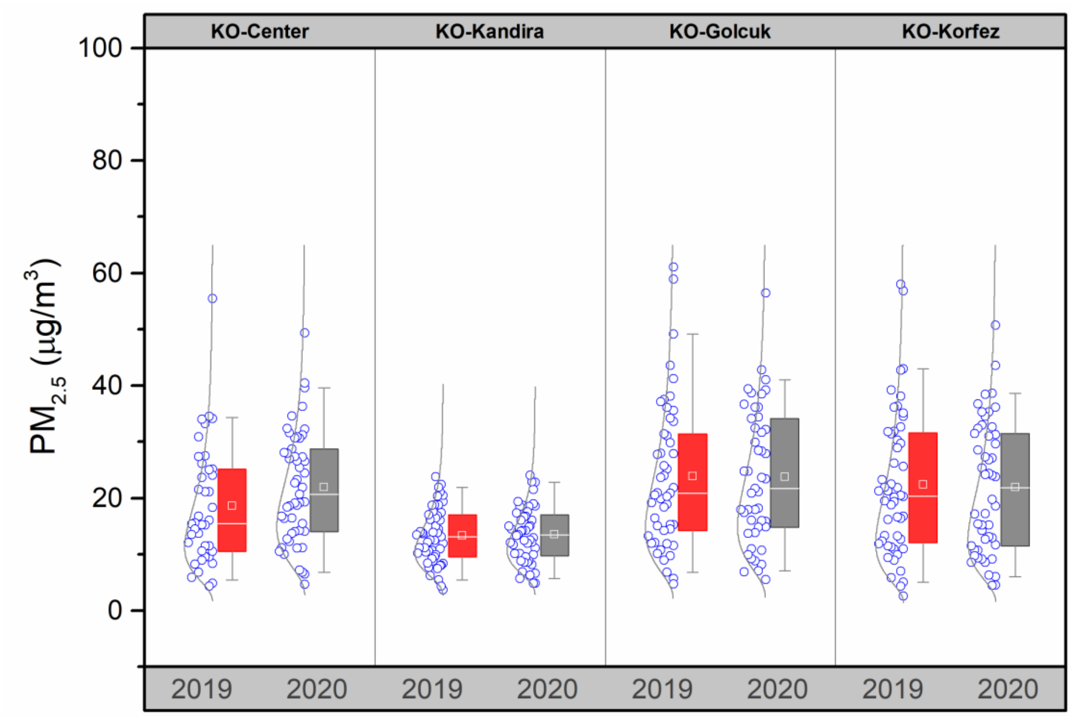

Figure SM4. $PM_{2.5}$ concentrations in Kocaeli

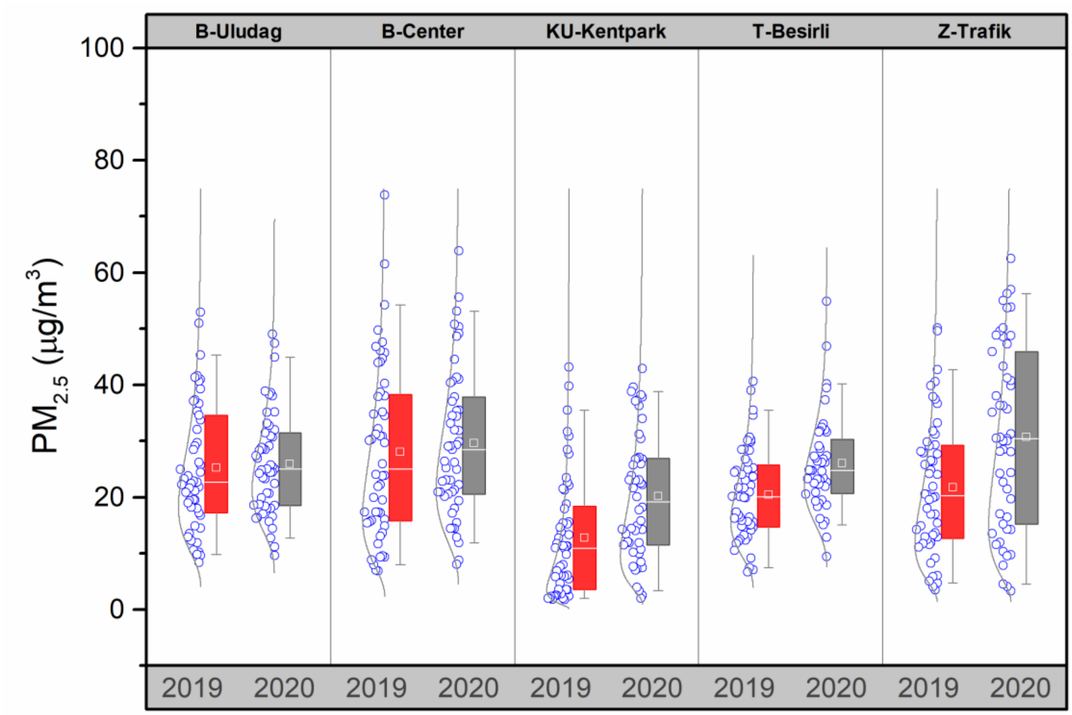

Figure SM5. $PM_{2.5}$ concentrations in Bursa, Kutahya, and Zonguldak

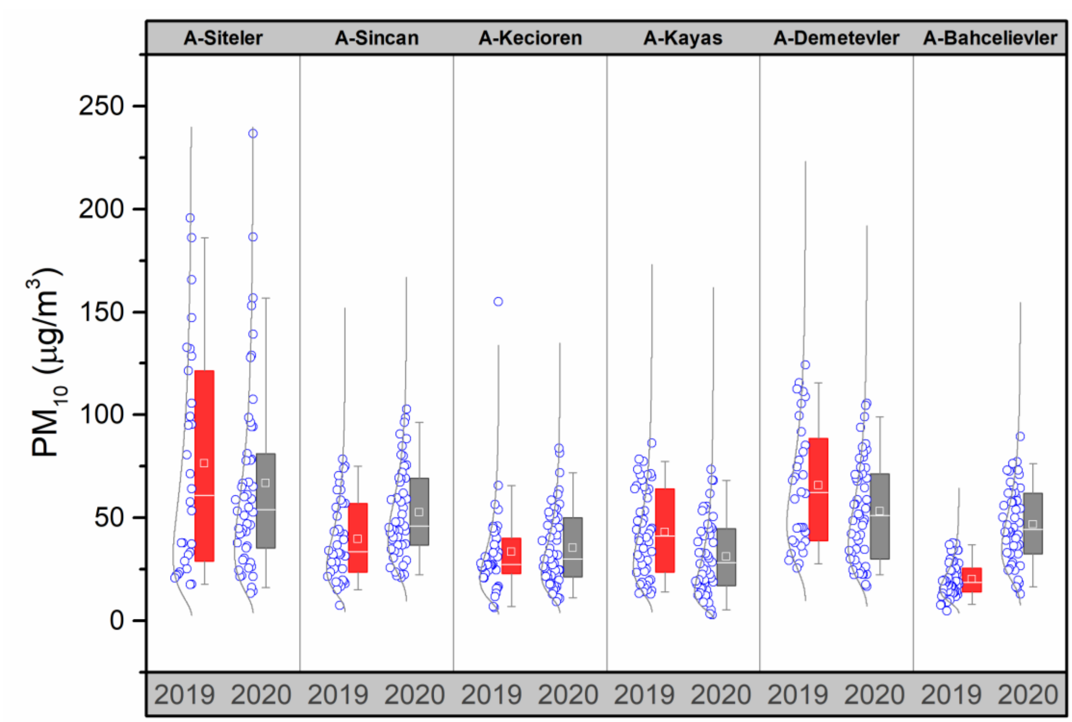

Figure SM6. PM_{10} concentrations in Ankara

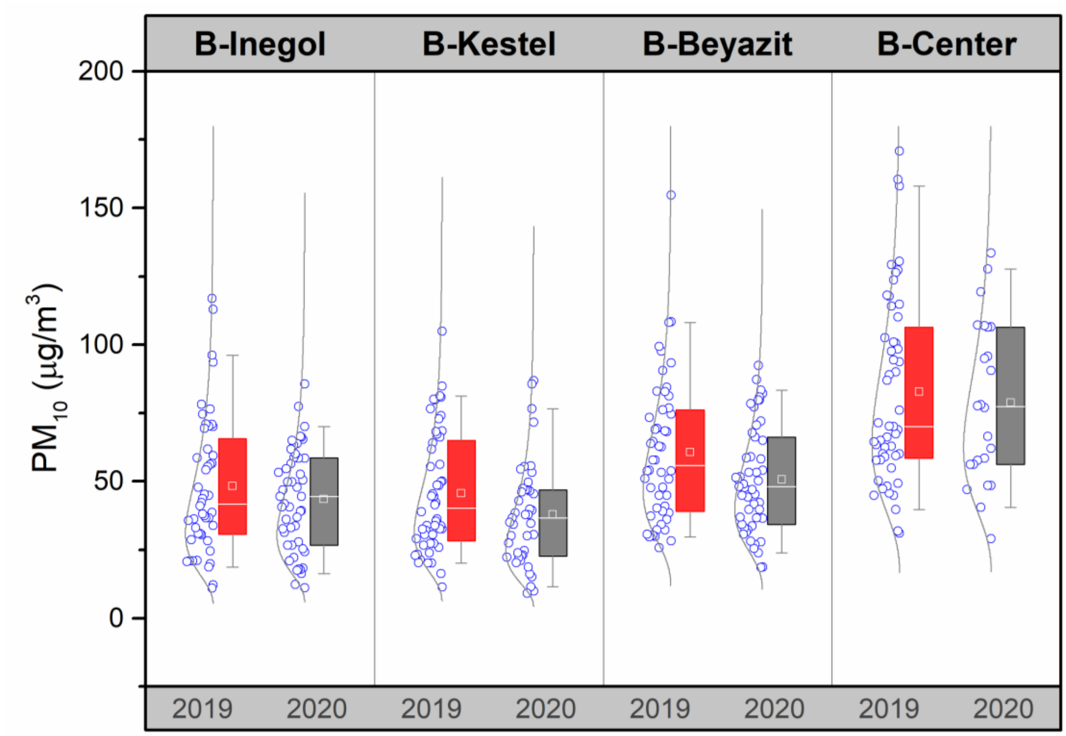

Figure SM7. PM_{10} concentrations in Bursa

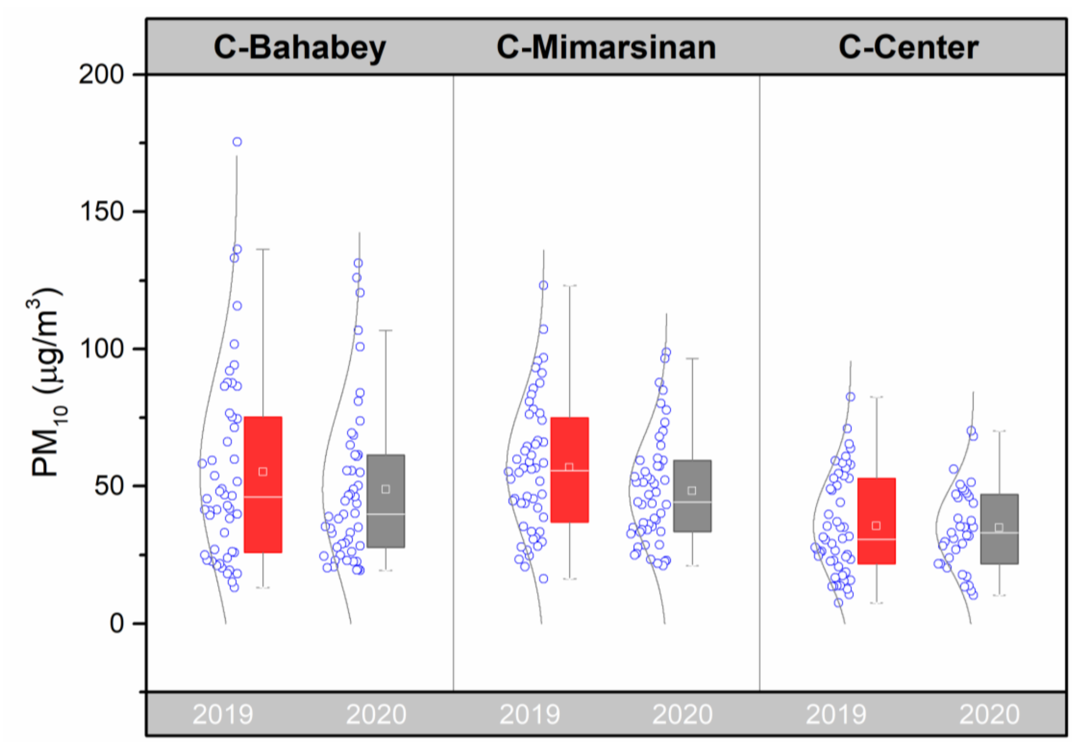

Figure SM8. PM_{10} concentrations in Corum

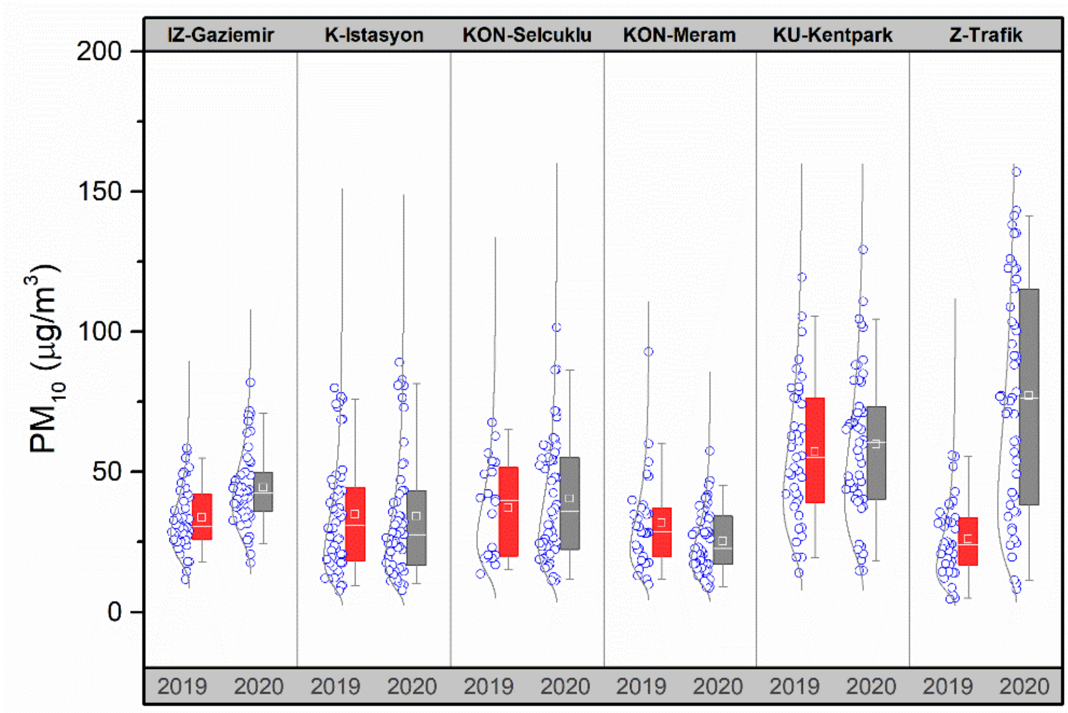

Figure SM9. PM_{10} concentrations in Izmır, Kars, Konya, Kutahya, and Zonguldak

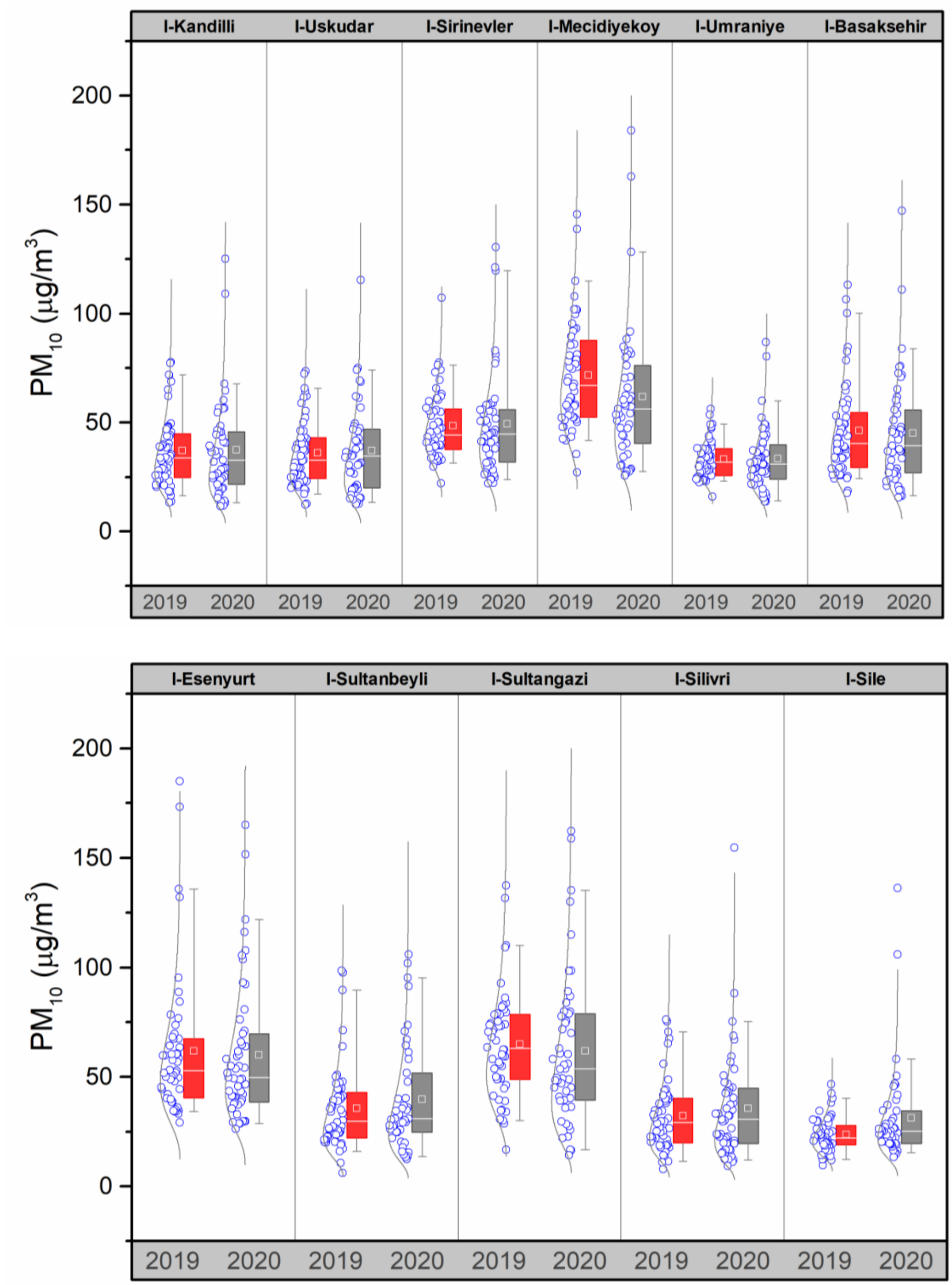

Figure SM10. PM_{10} concentrations in Istanbul

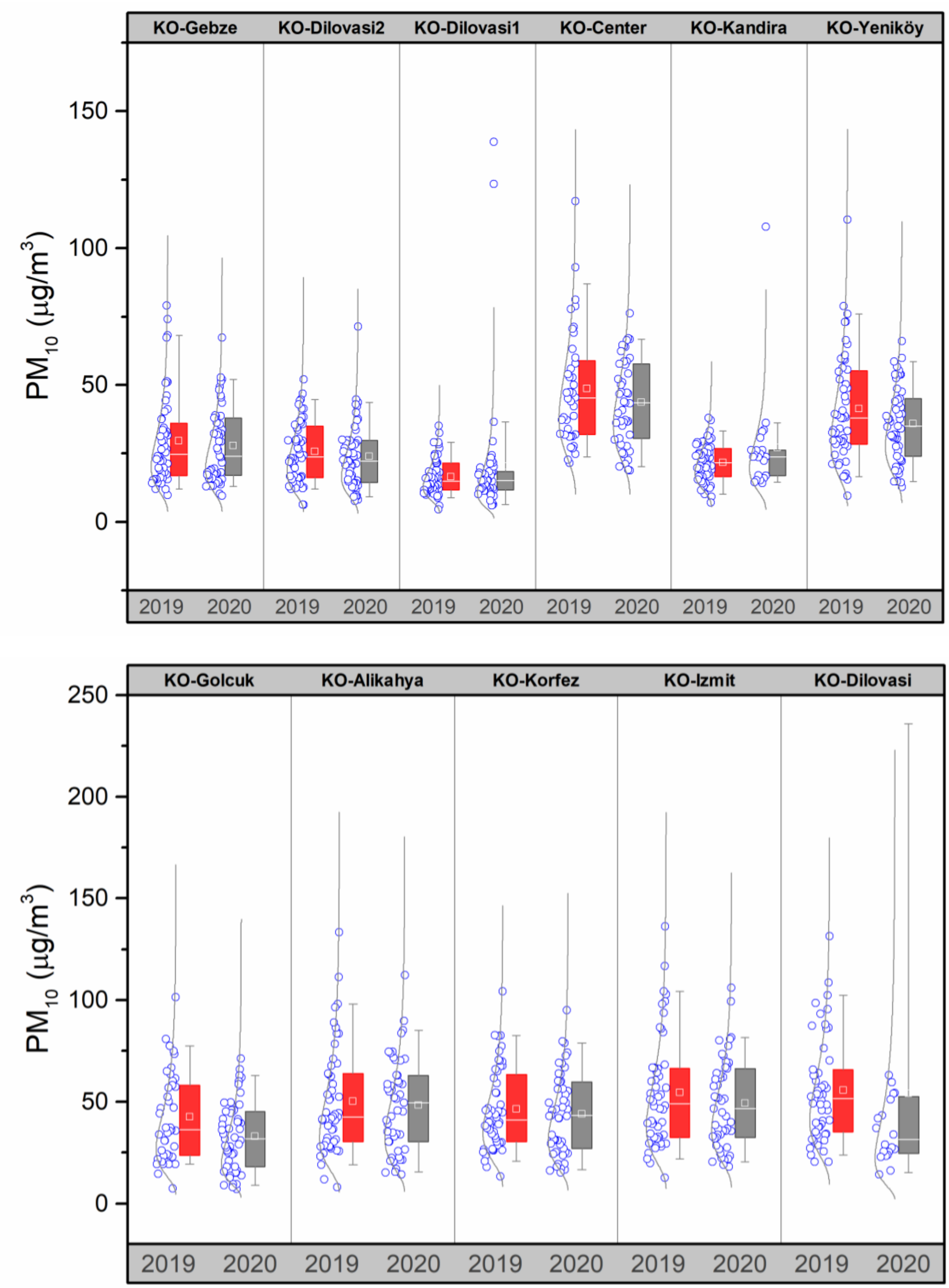

Figure SM11. PM_{10} concentrations in Kocaeli

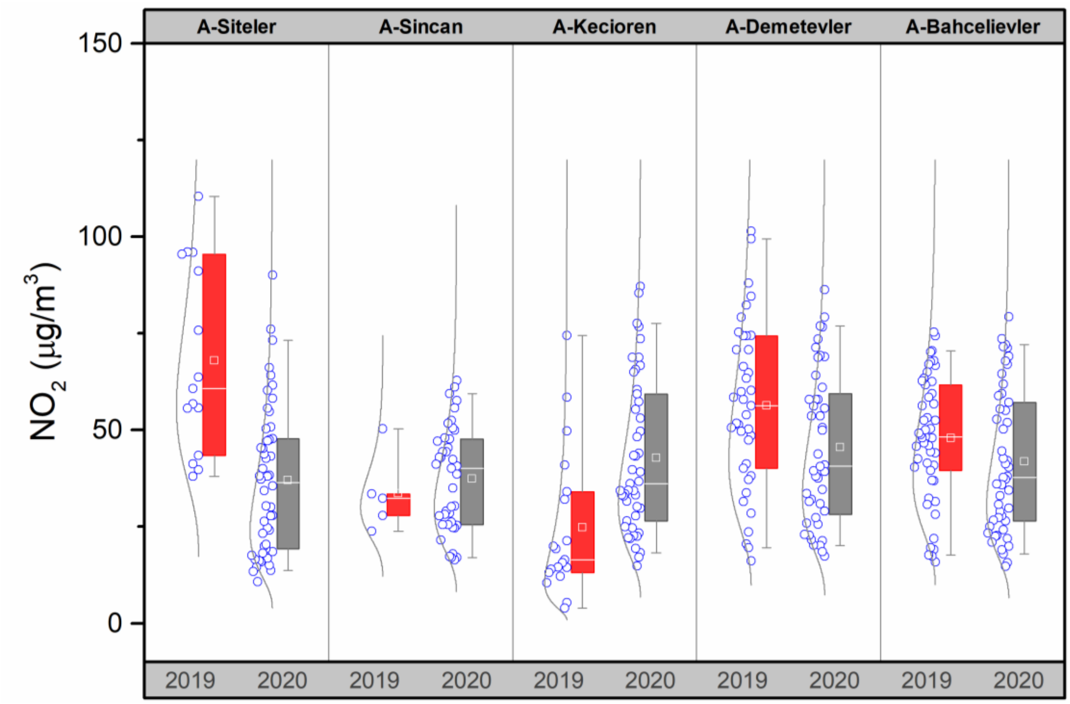

Figure SM12. NO_2 concentrations in Ankara

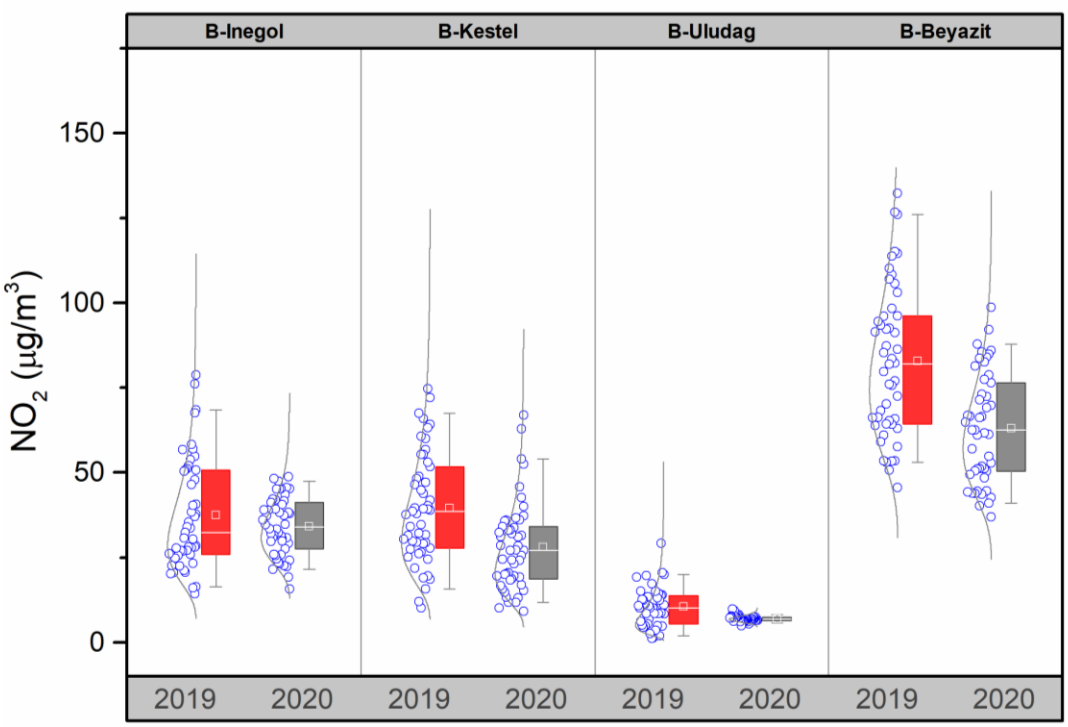

Figure SM13. NO_2 concentrations in Bursa

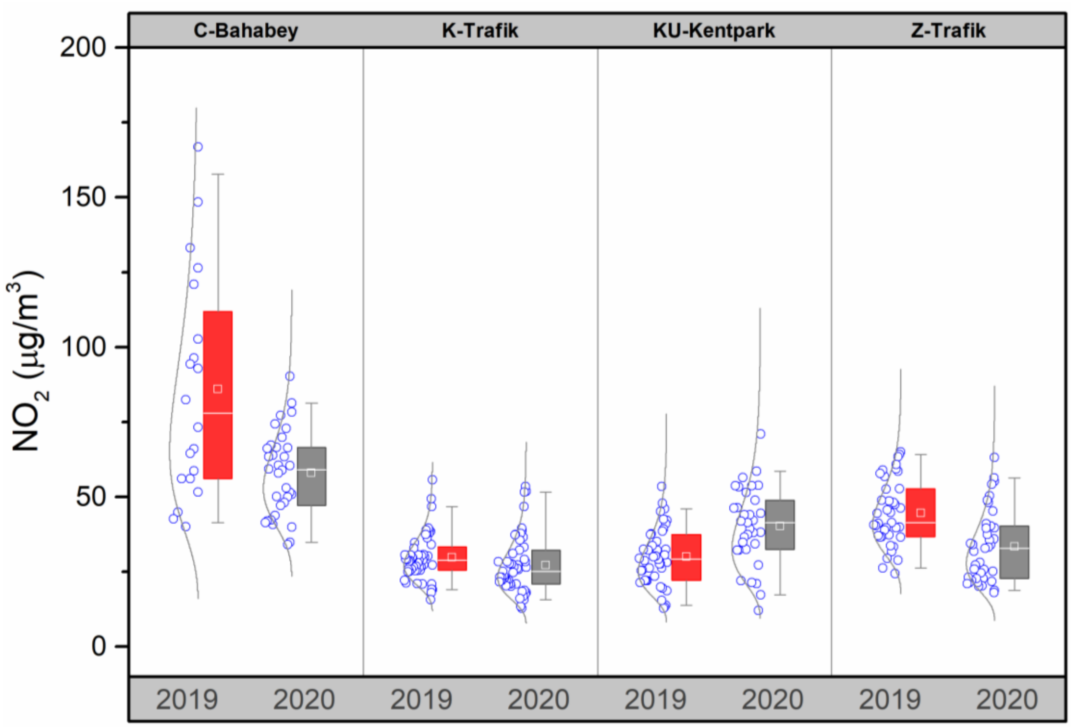

Figure SM14. NO_2 concentrations in Corum, Kars, Kutahya, and Zonguldak

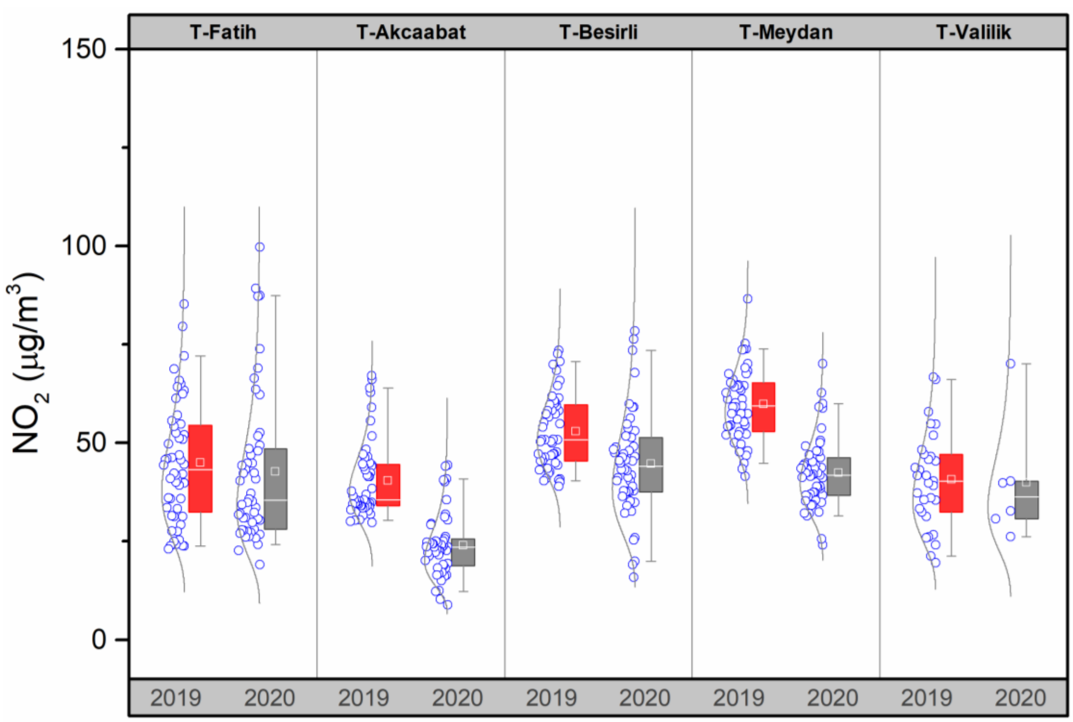

Figure SM15. NO_2 concentrations in Trabzon

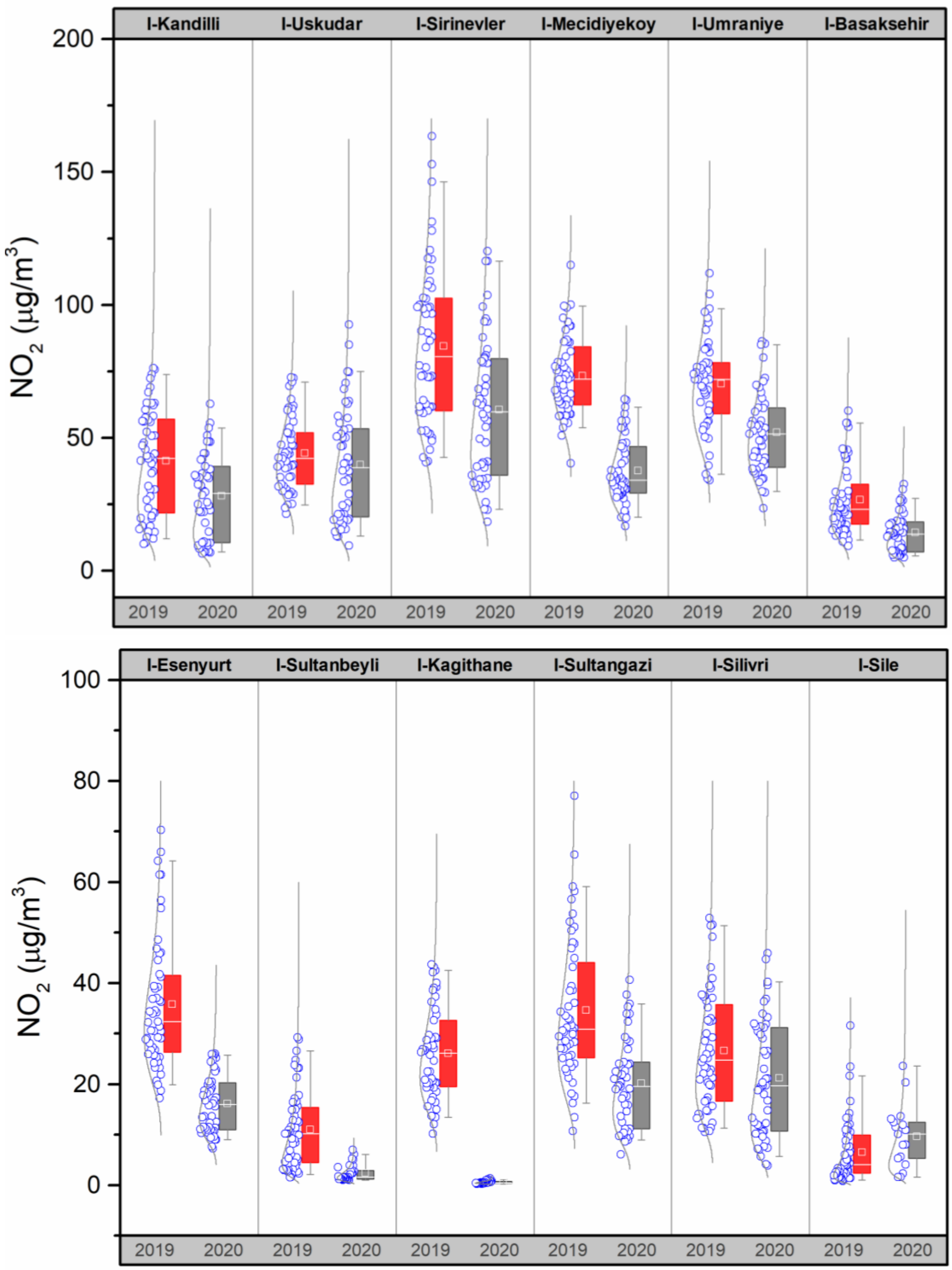

Figure SM16. NO_2 concentrations in Istanbul

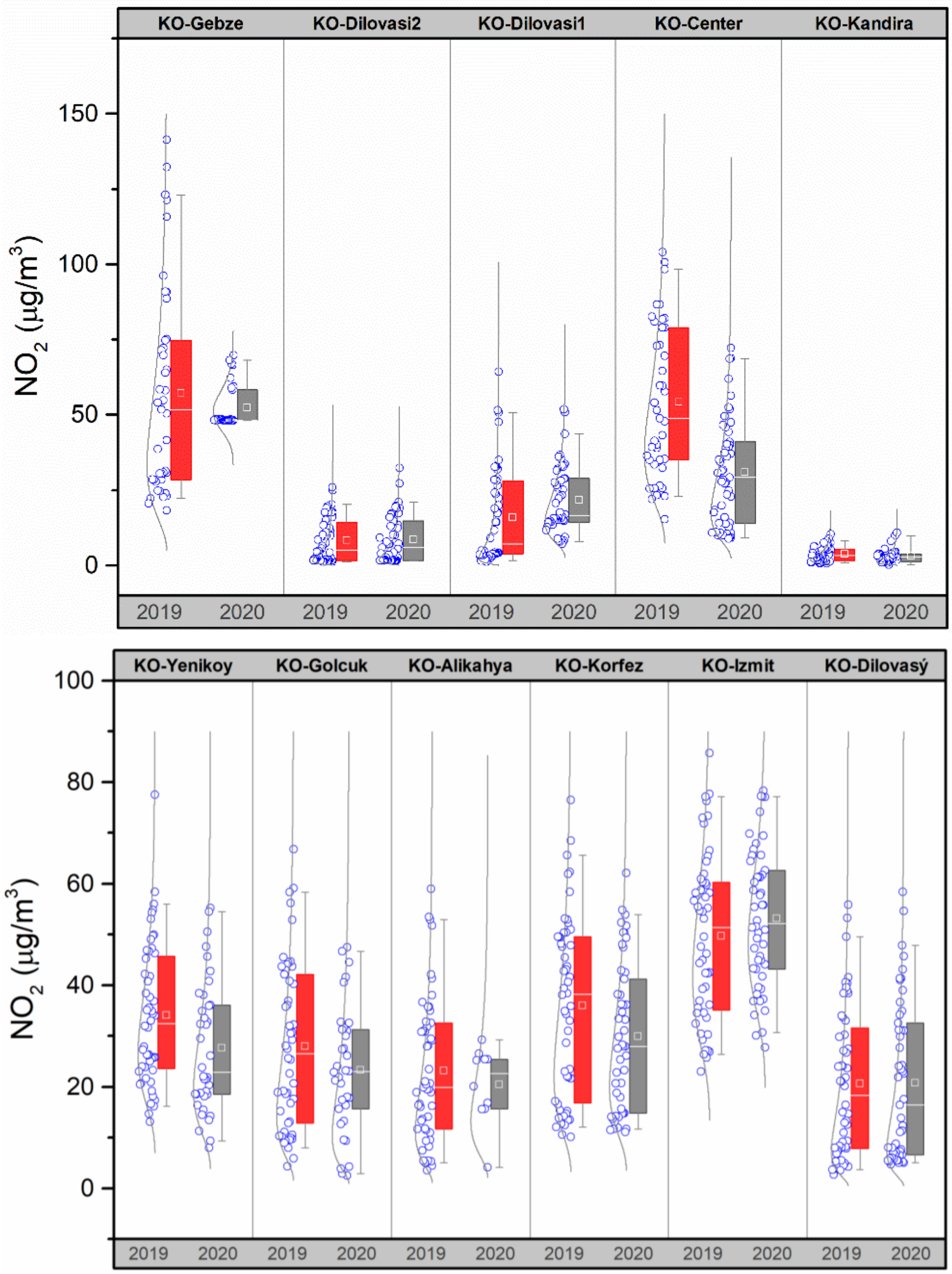

Figure SM17. NO_2 concentrations in Kocaeli

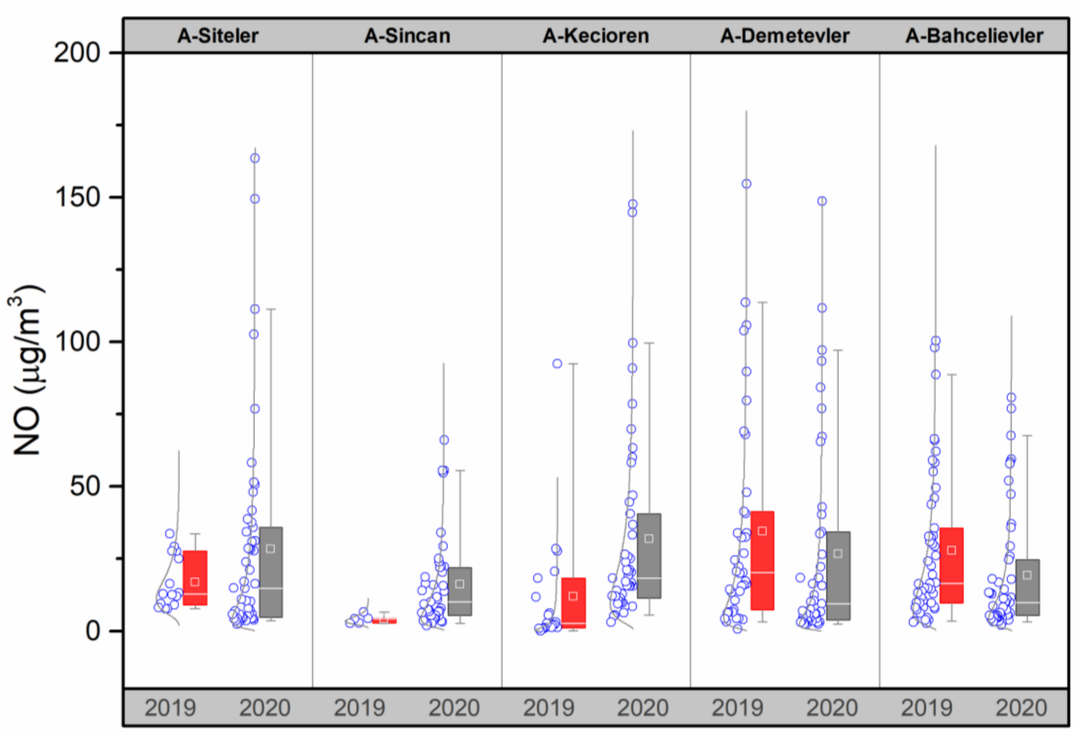

Figure SM18. NO concentrations in Ankara

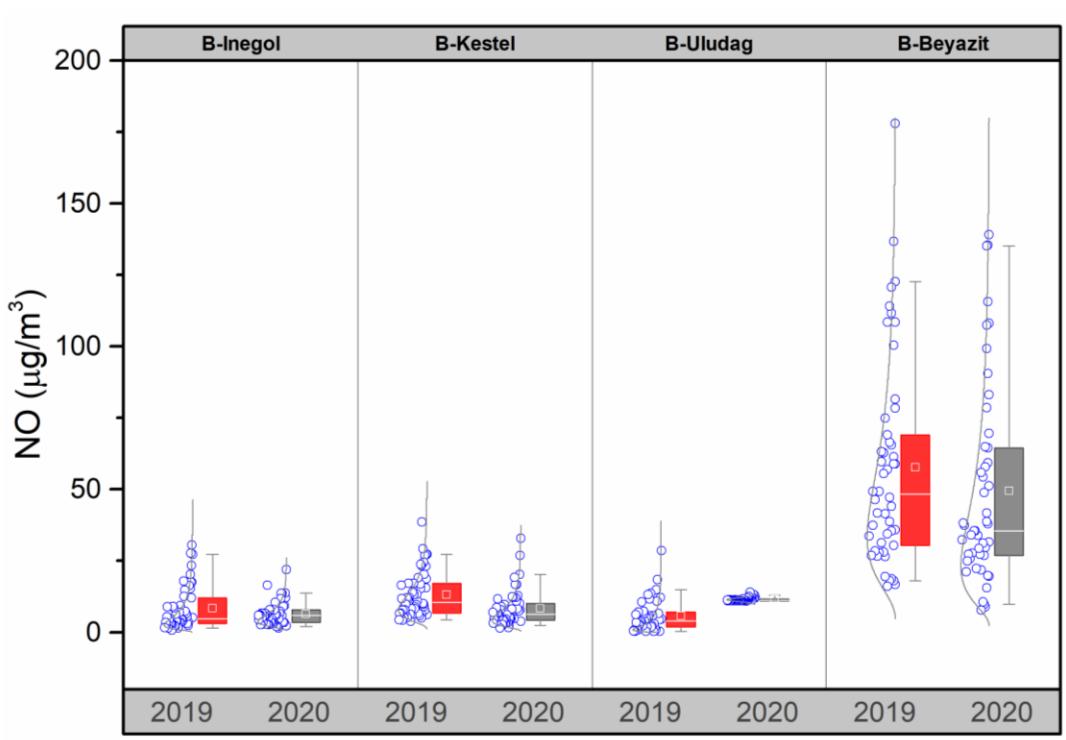

Figure SM19. NO concentrations in Bursa

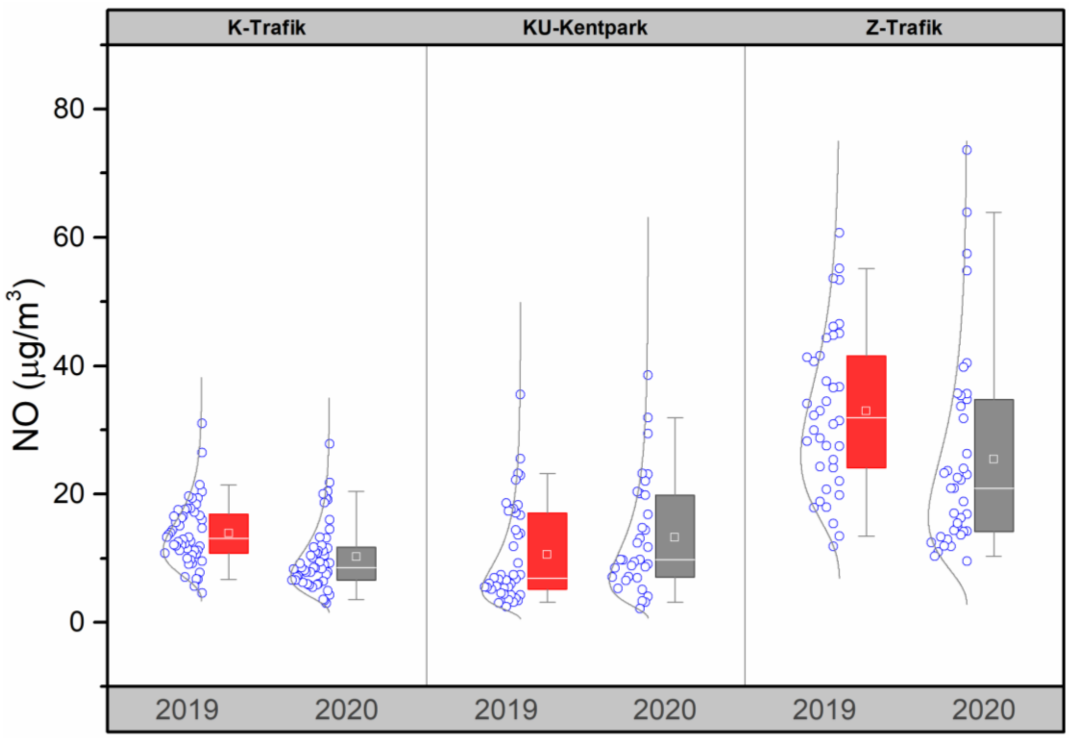

Figure SM20. NO concentrations in Kars, Kutahya, and Zonguldak

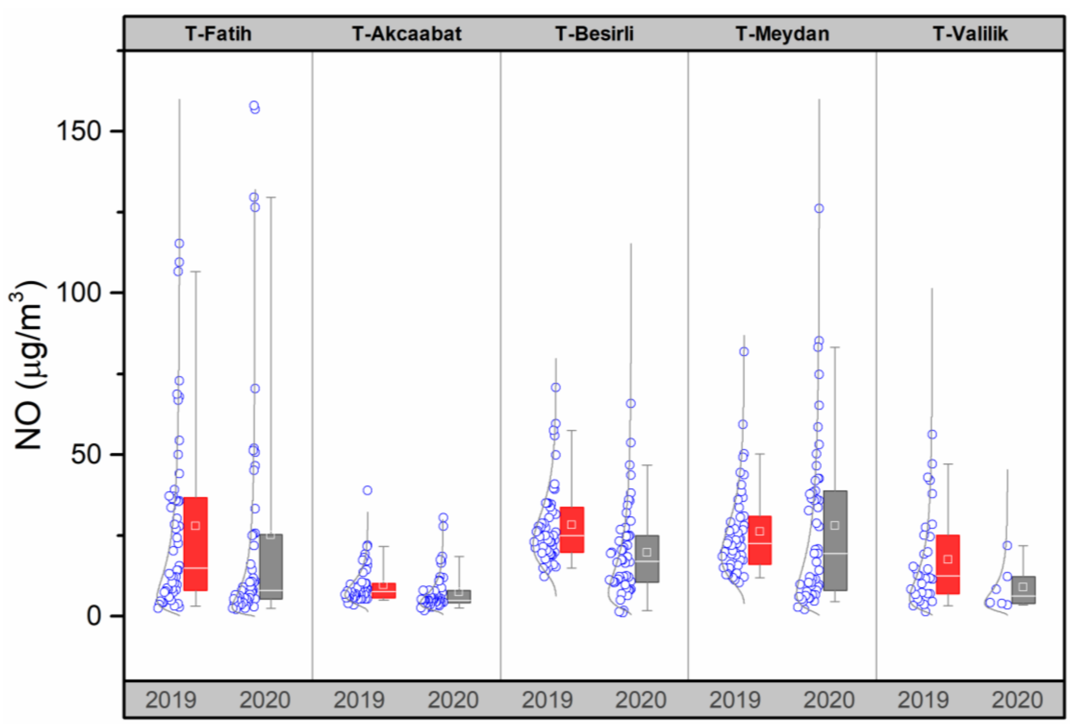

Figure SM21. NO concentrations in Trabzon

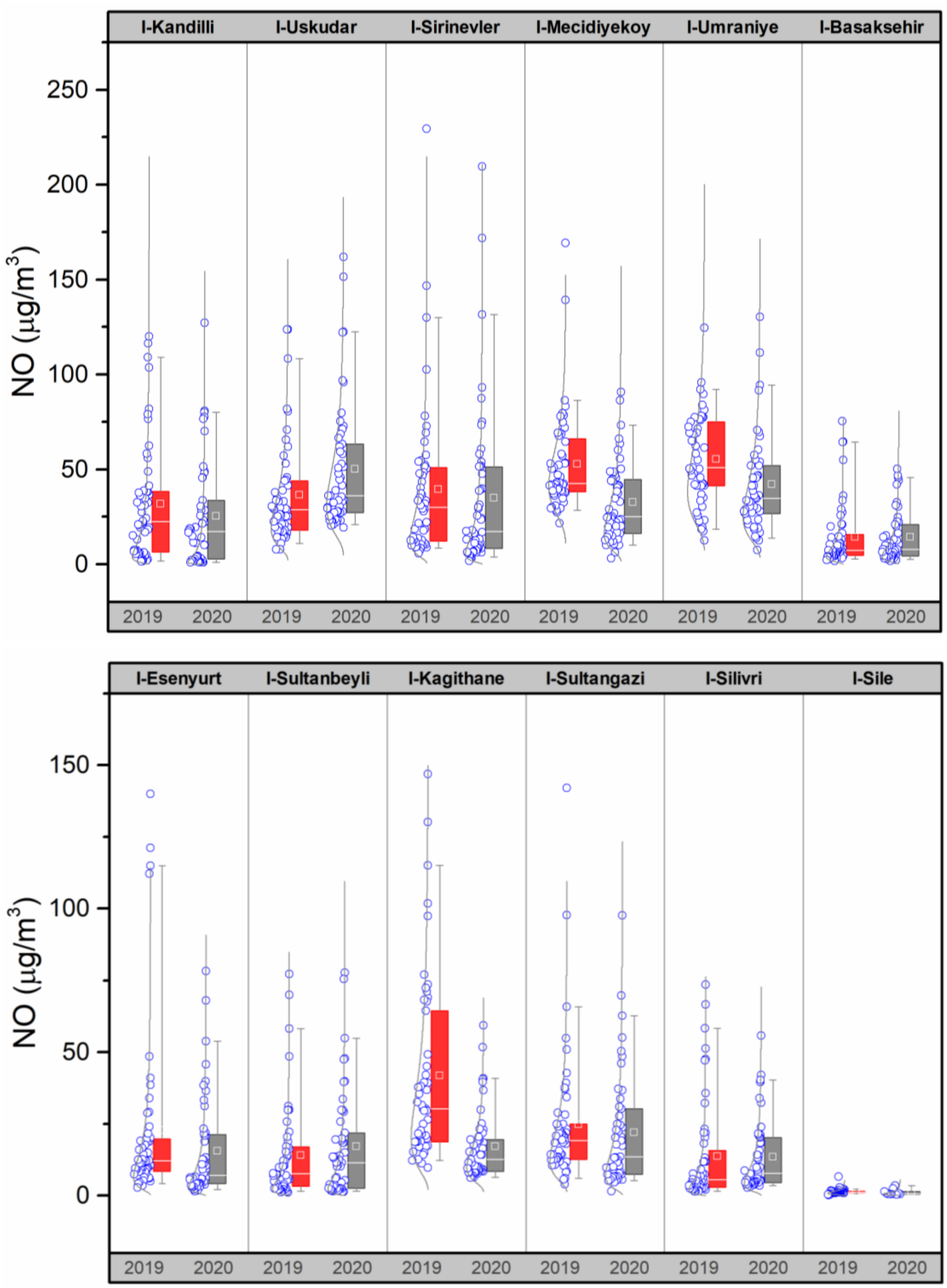

Figure SM22. NO concentrations in Istanbul

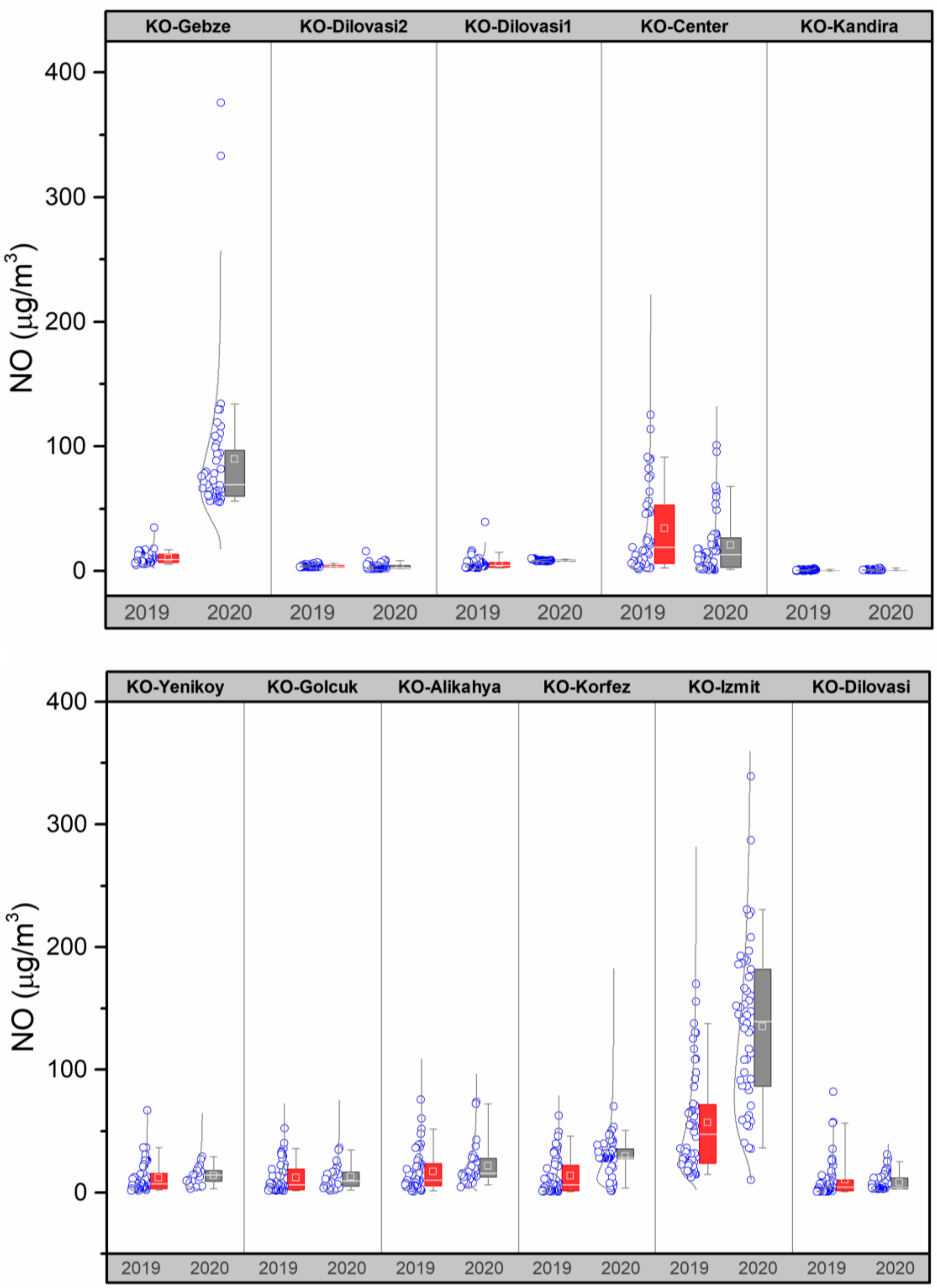

Figure SM23. NO concentrations in Kocaeli

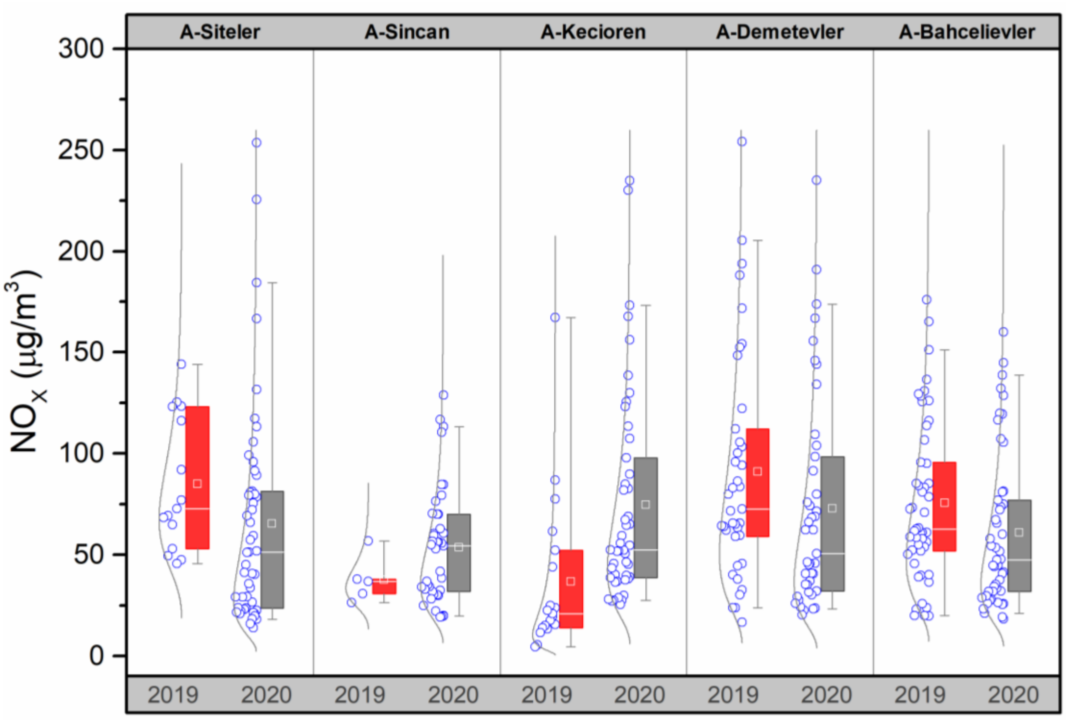

Figure SM24. NO_x concentrations in Ankara

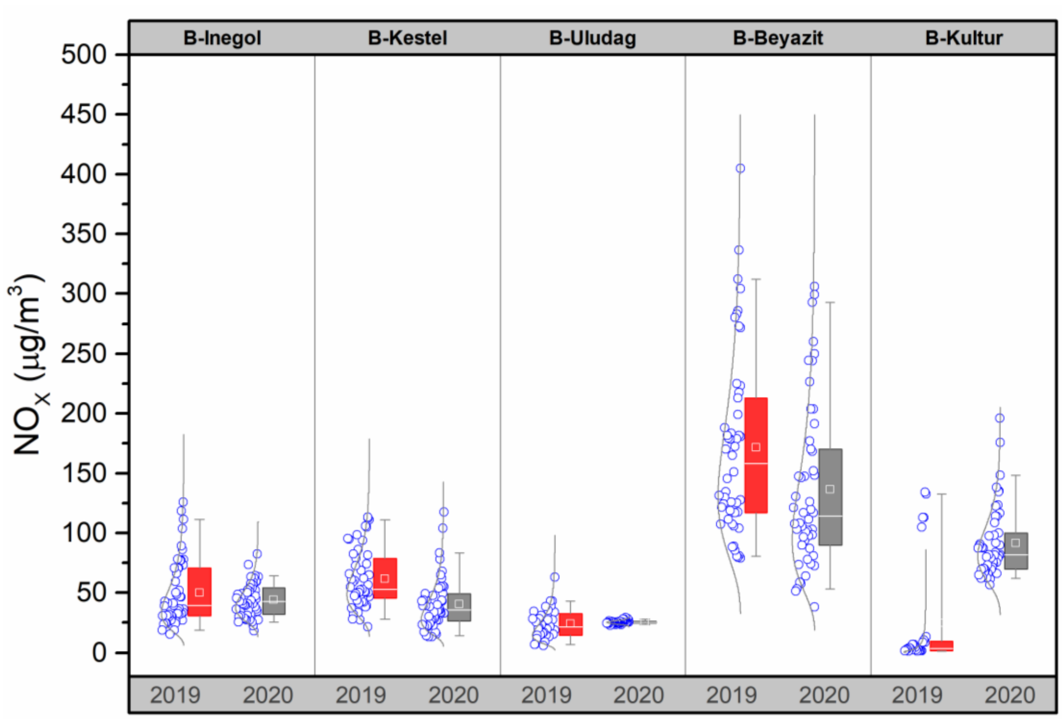

Figure SM25. NO_x concentrations in Bursa

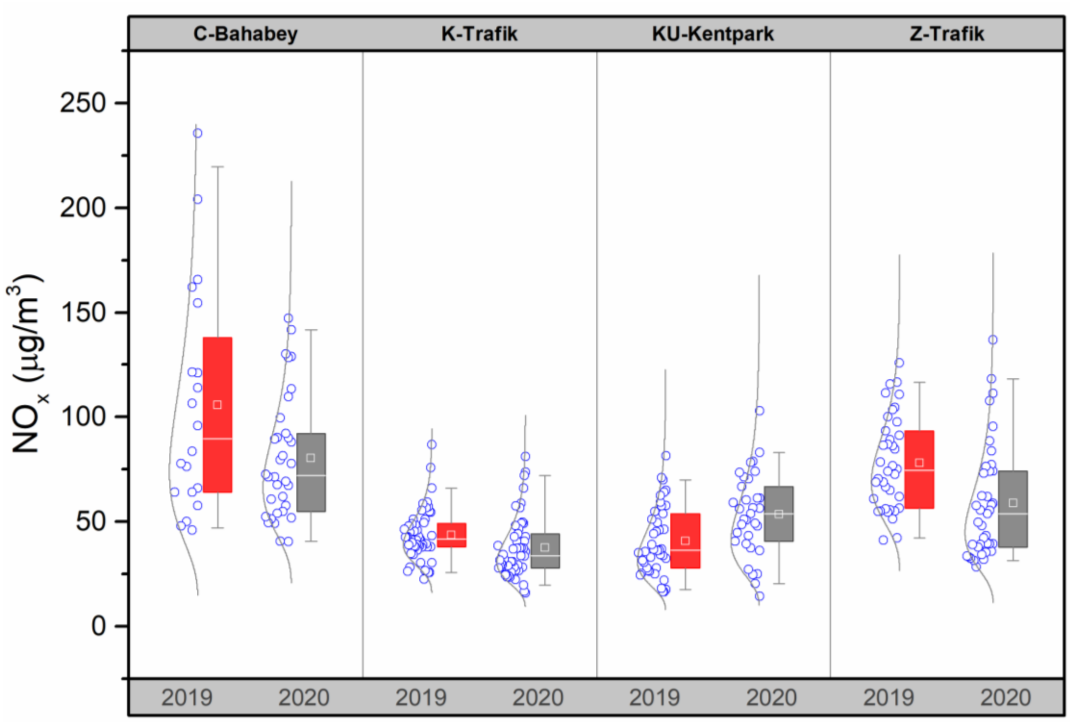

Figure SM26. NO$_x$ concentrations in Corum, Kars, Kutahya, and Zonguldak

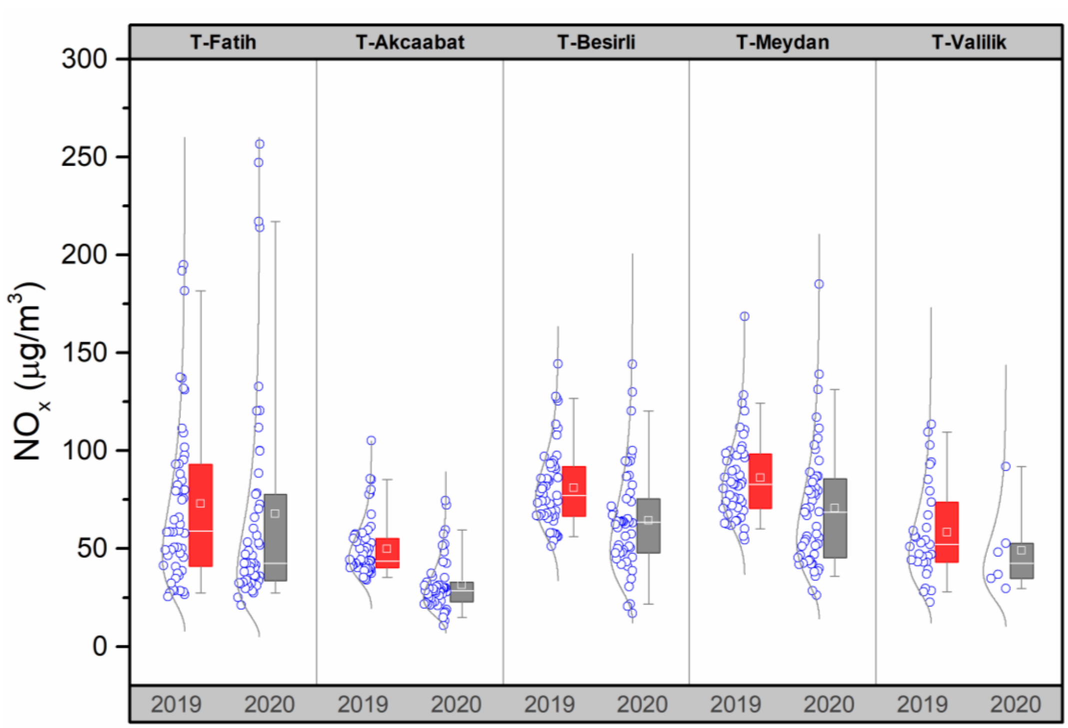

Figure SM27. NO$_x$ concentrations in Trabzon

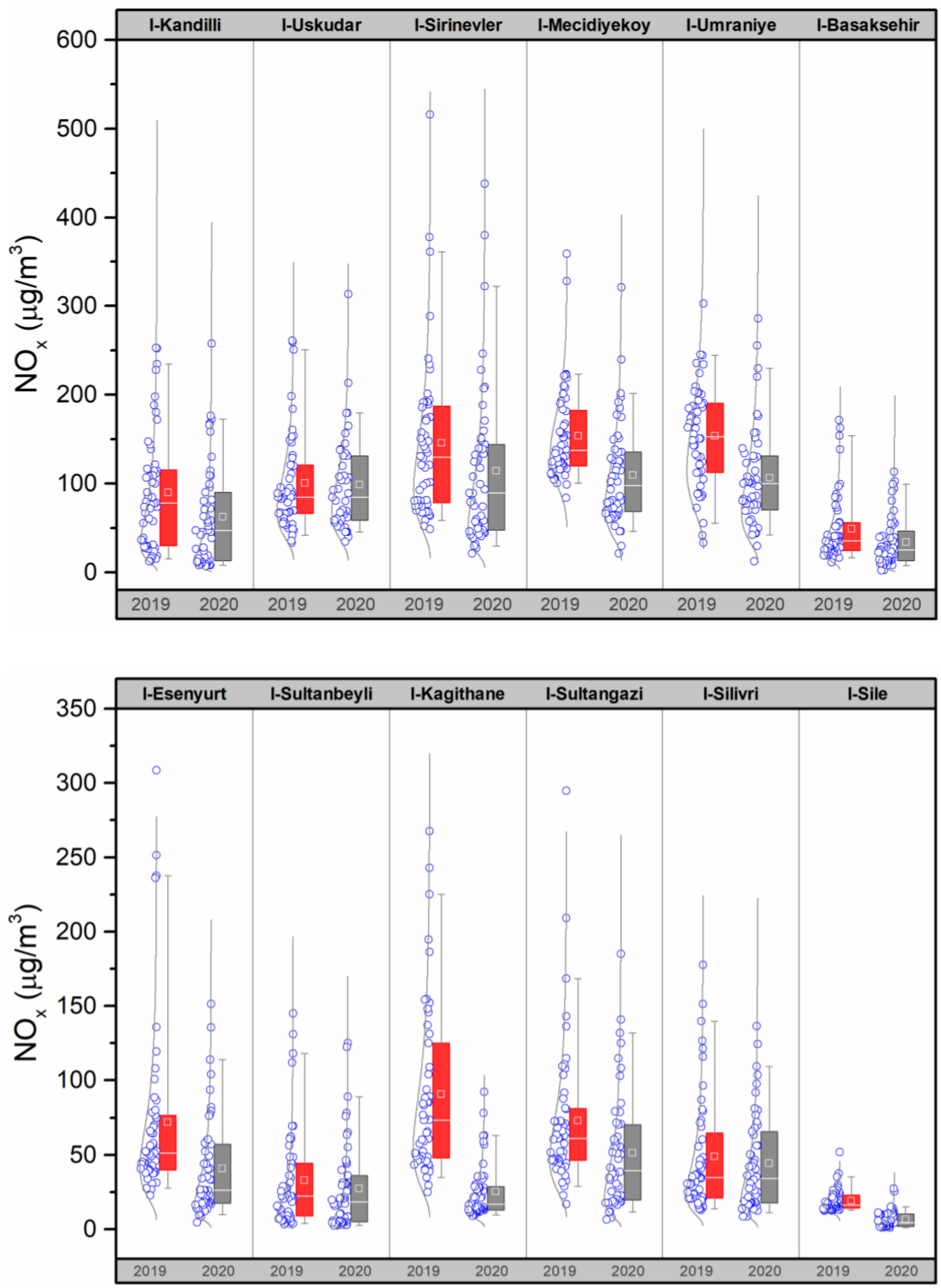

Figure SM28. NO_x concentrations in Istanbul

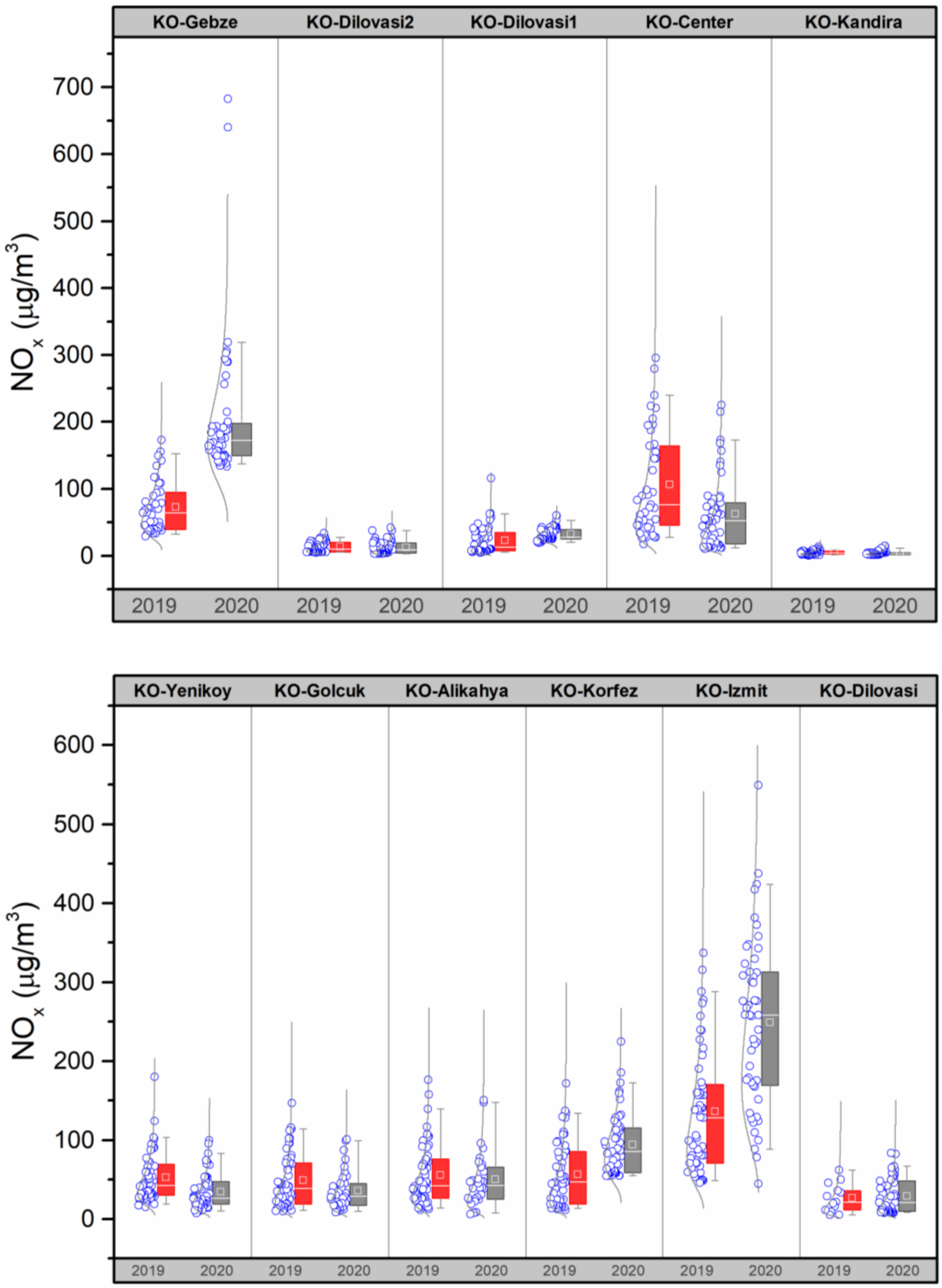

Figure SM29. NO_x concentrations in Kocaeli

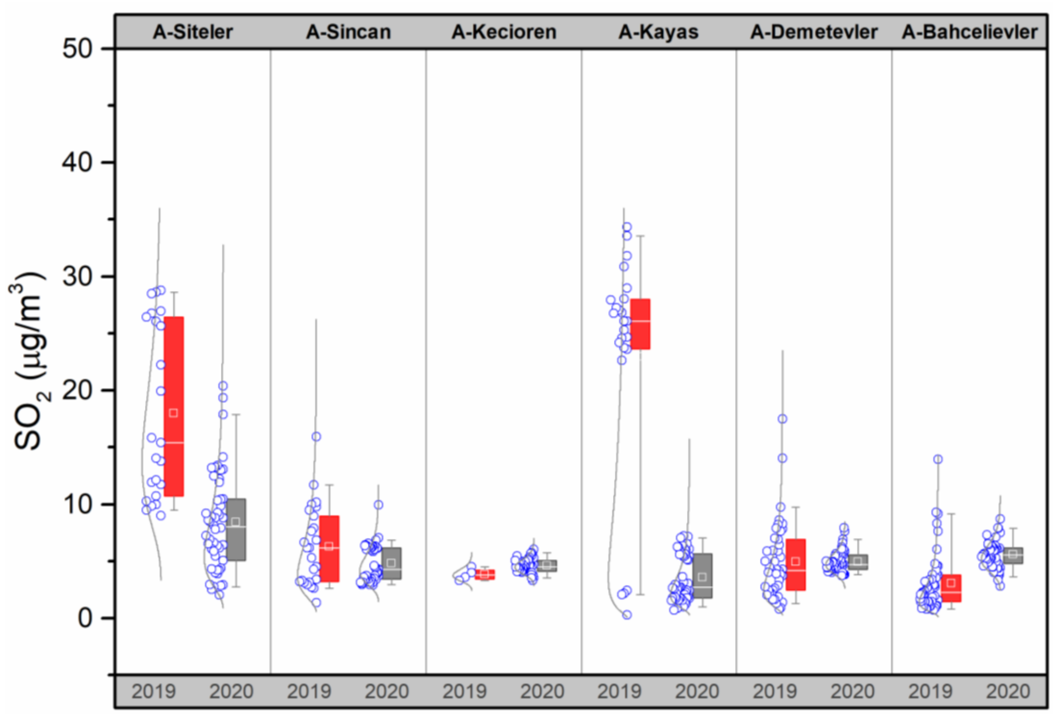

Figure SM30. SO_2 concentrations in Ankara

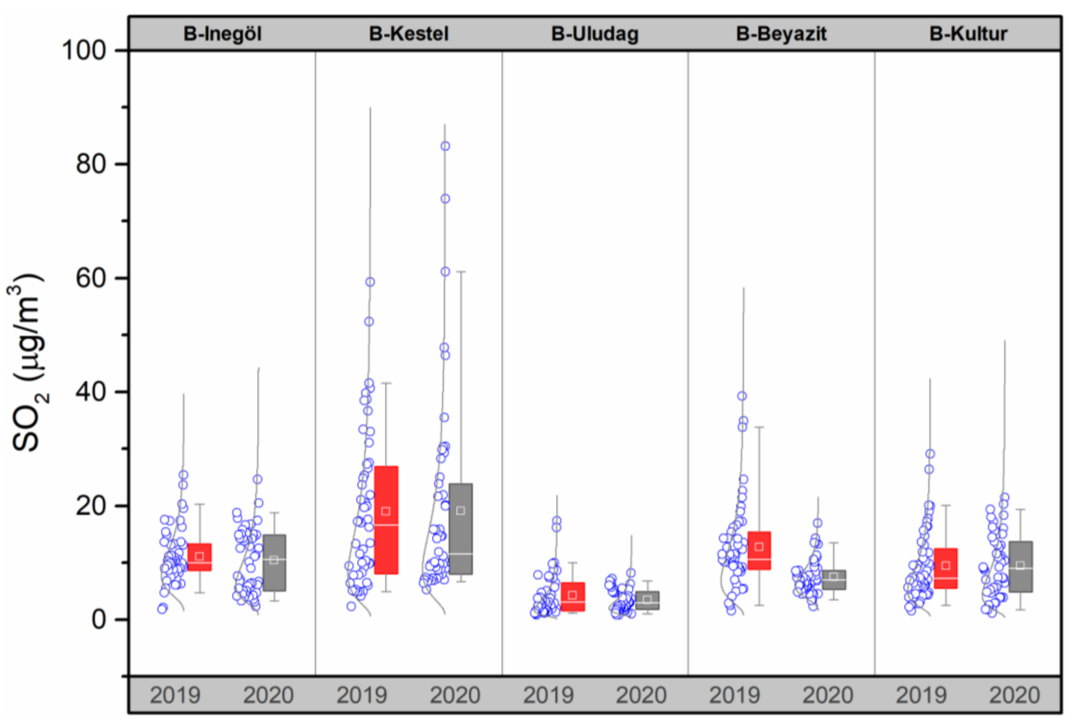

Figure SM31. SO_2 concentrations in Bursa

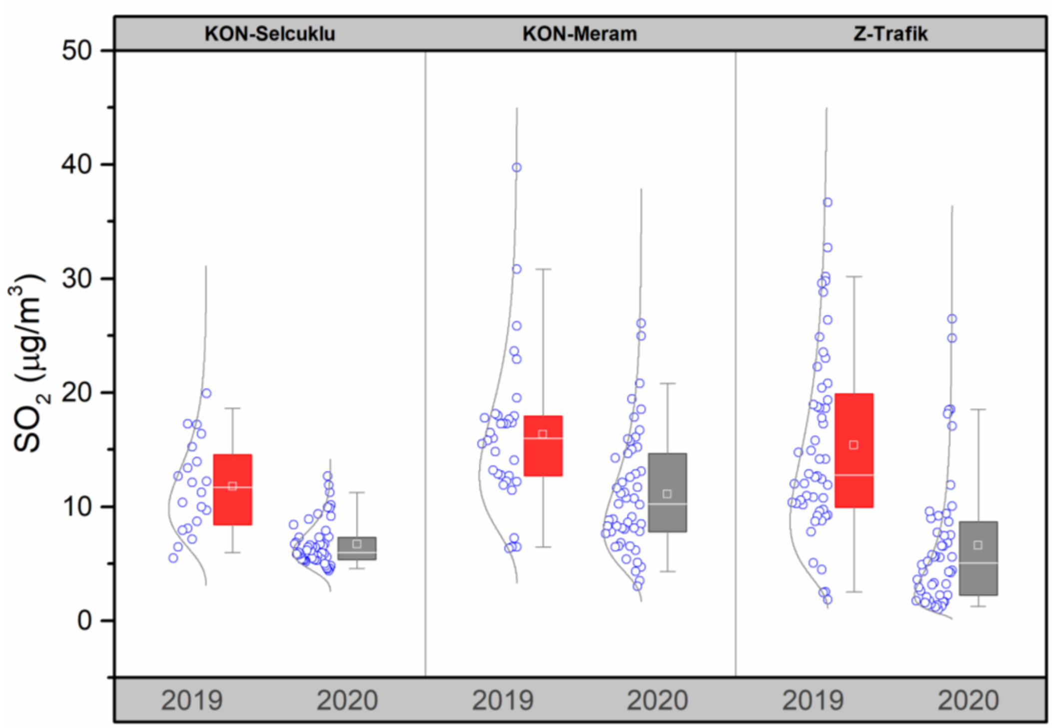

Figure SM32. SO_2 concentrations in Konya and Zonguldak

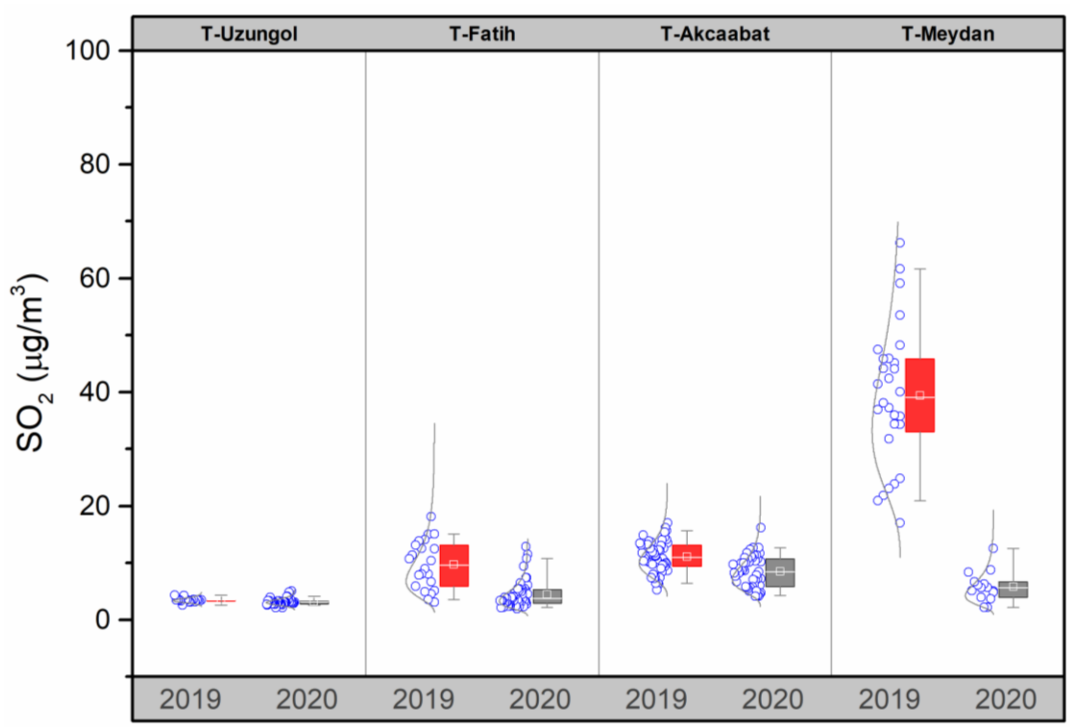

Figure SM33. SO_2 concentrations in Trabzon

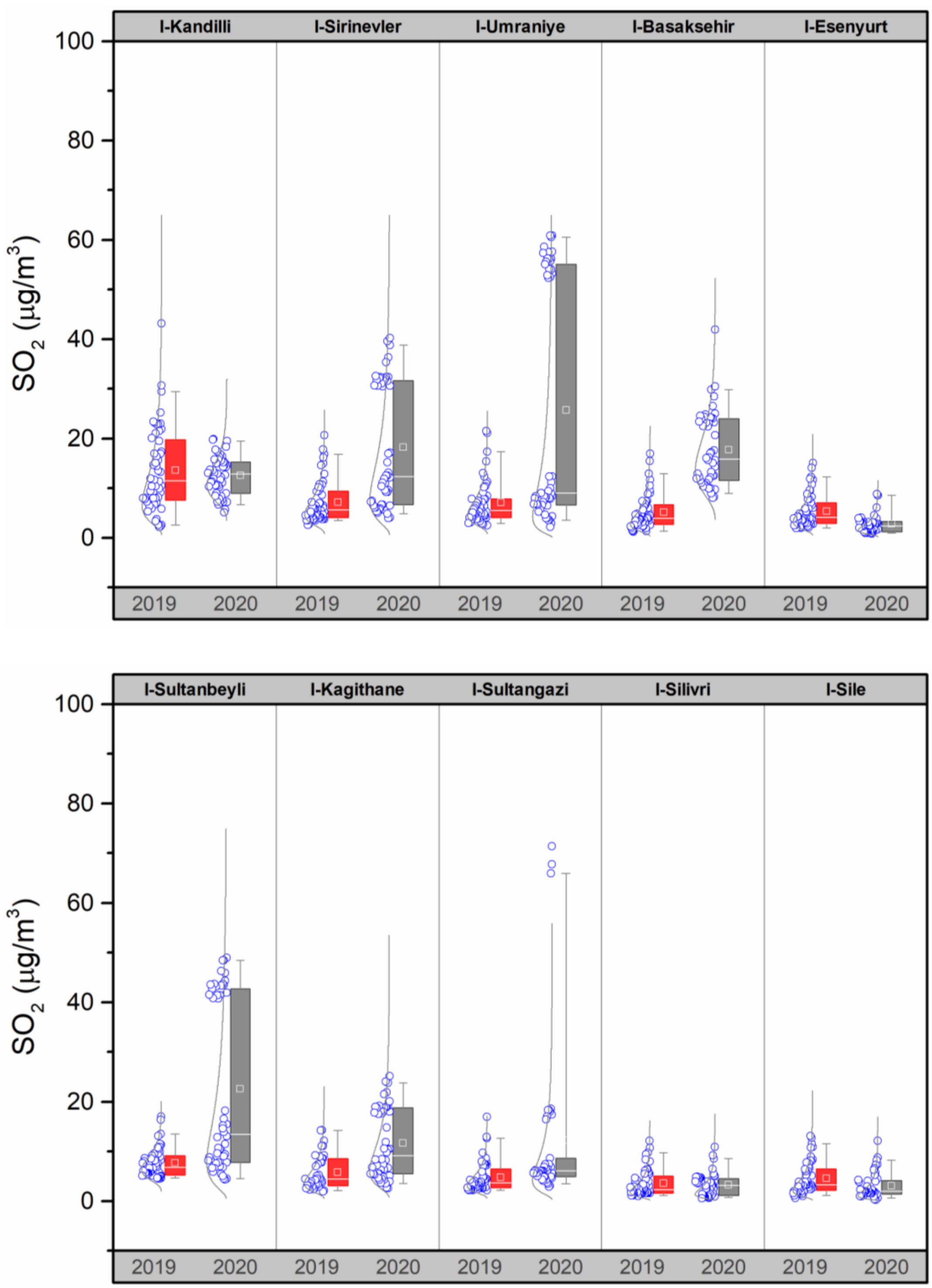

Figure SM34. SO_2 concentrations in Istanbul

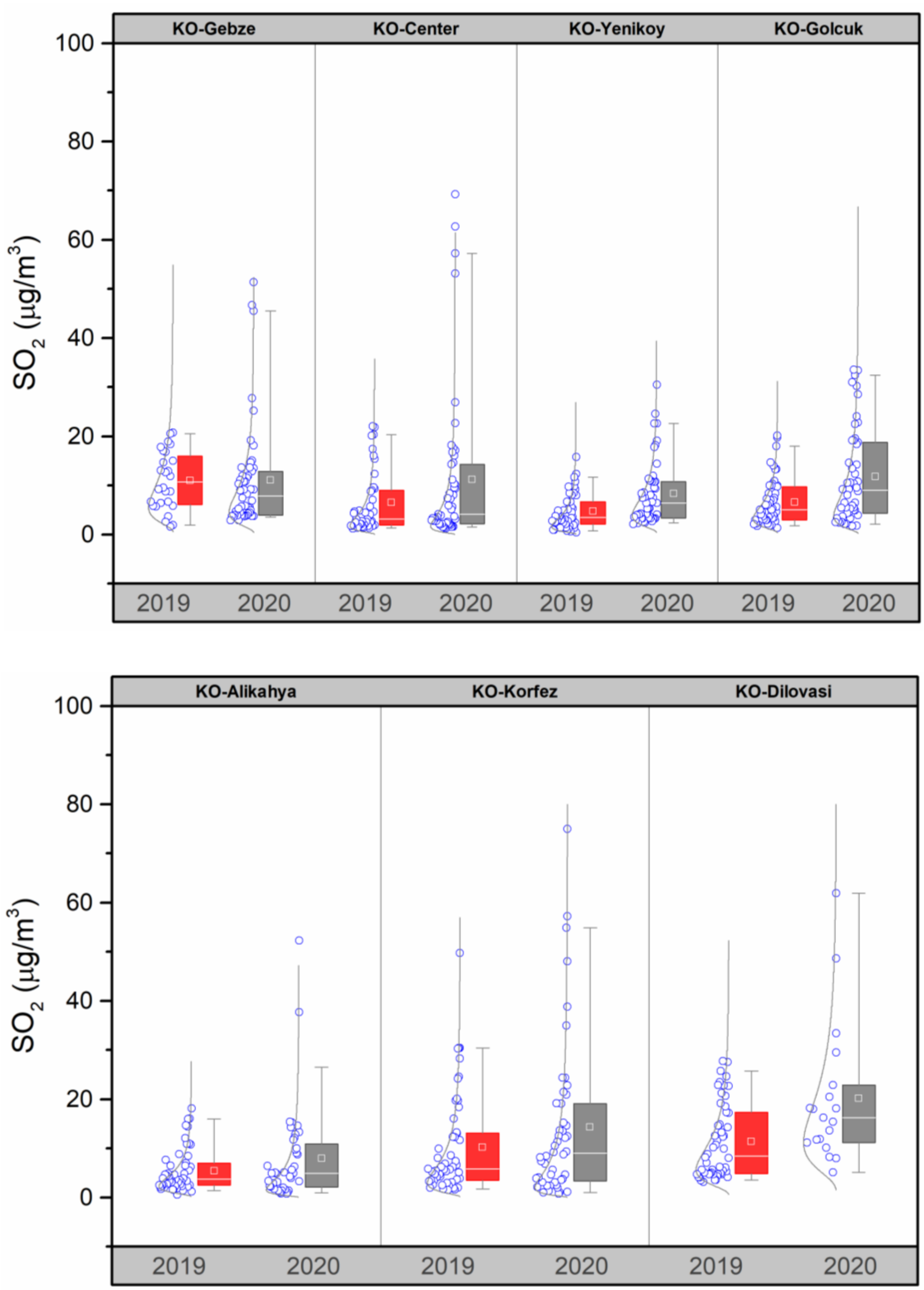

Figure SM35. SO_2 concentrations in Kocaeli

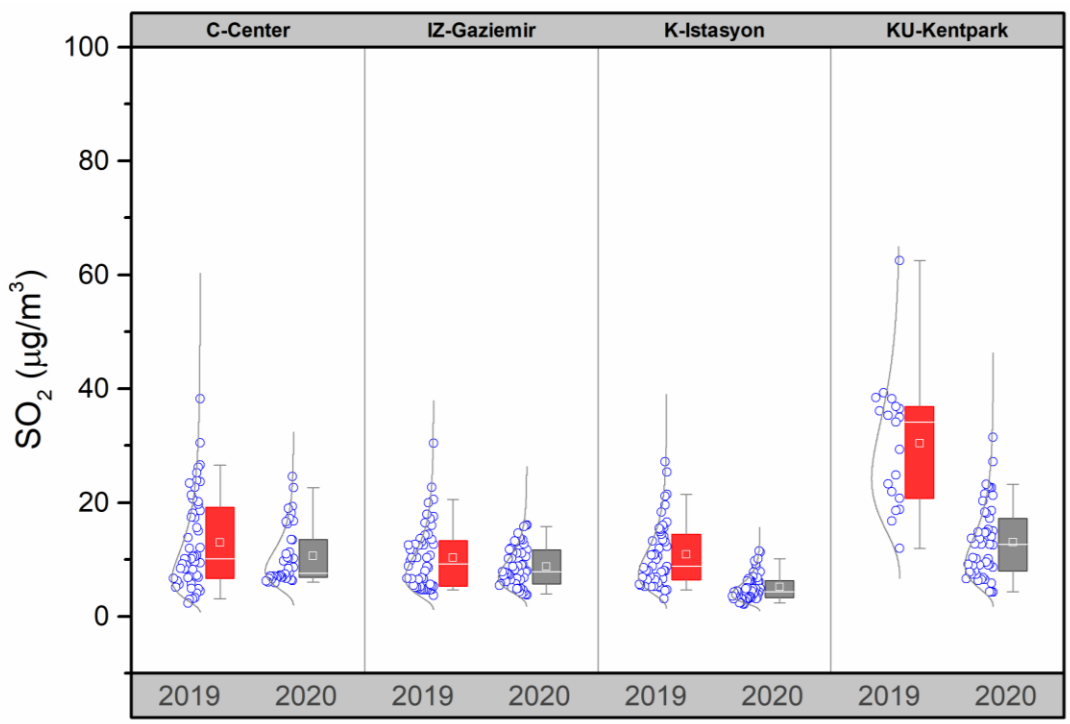

Figure SM36. SO_2 concentrations in Corum, Izmir, Kars, and Kutahya

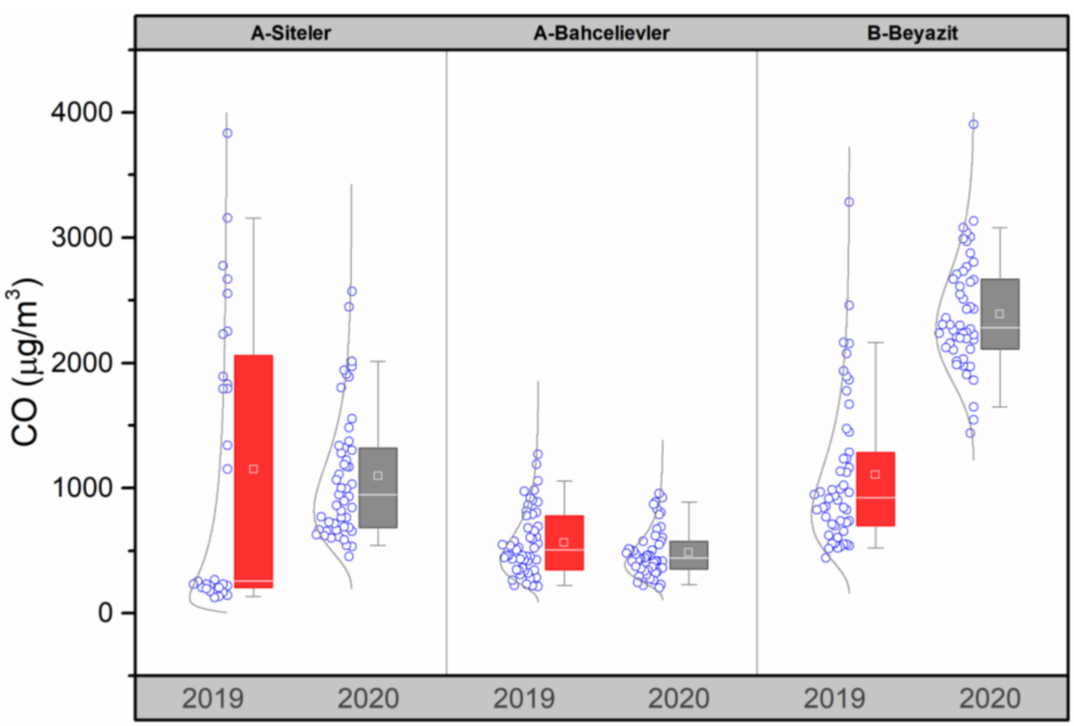

Figure SM37. CO concentrations in Ankara and Bursa

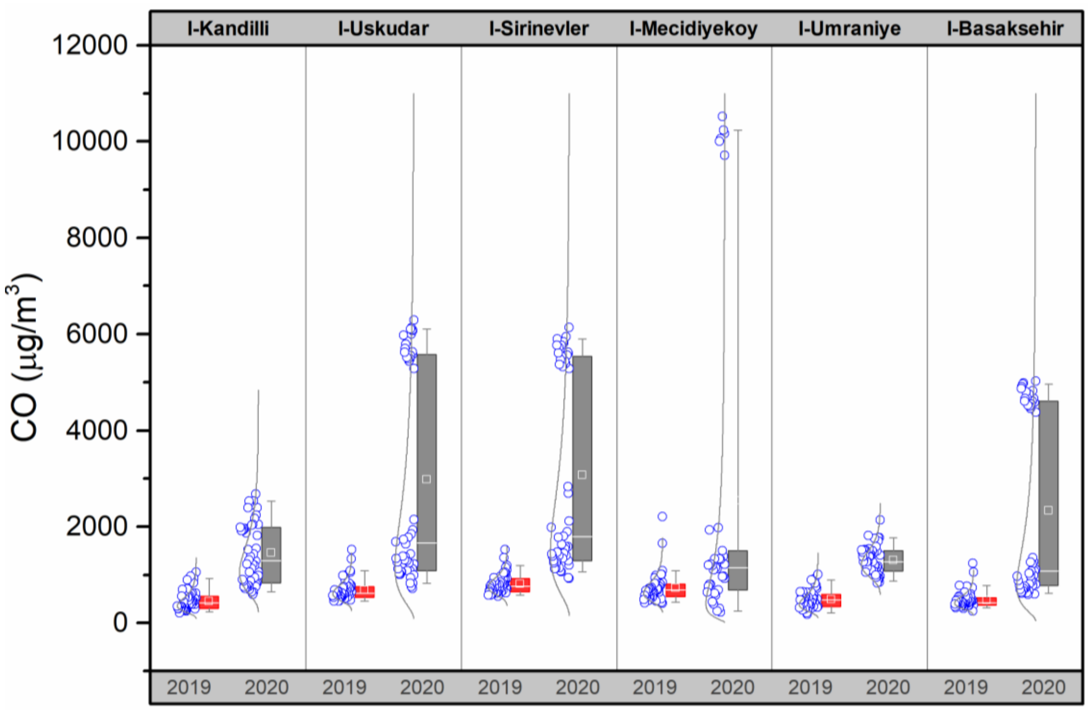

Figure SM38. CO concentrations in Istanbul

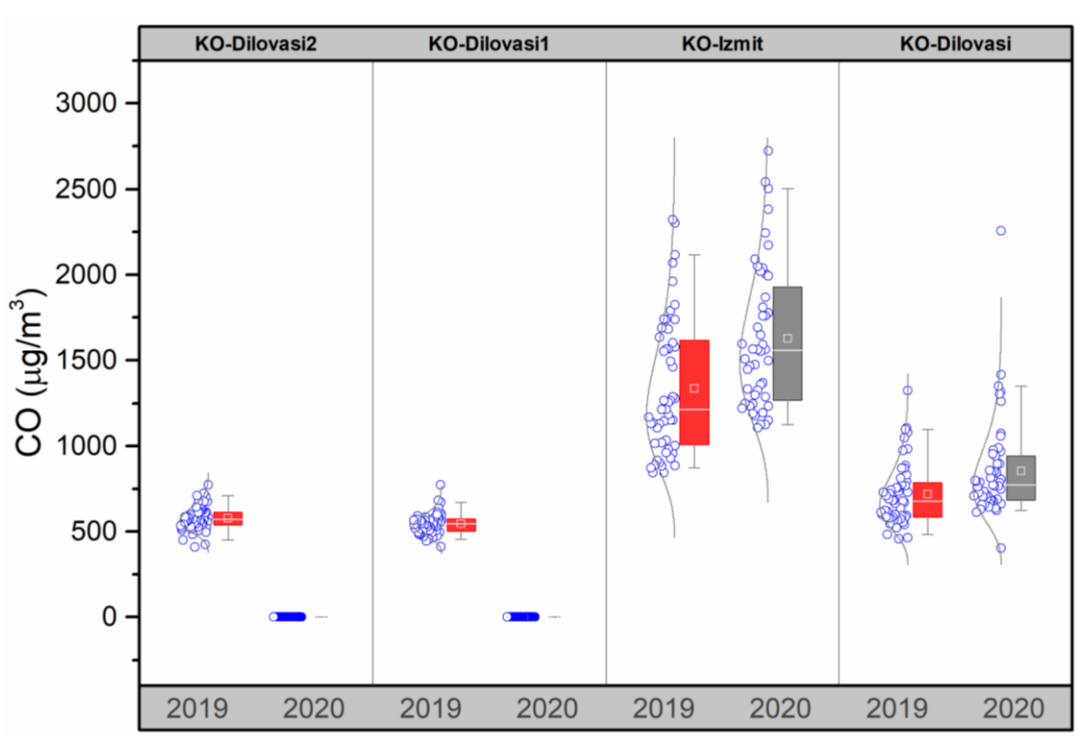

Figure SM39. CO concentrations in Kocaeli

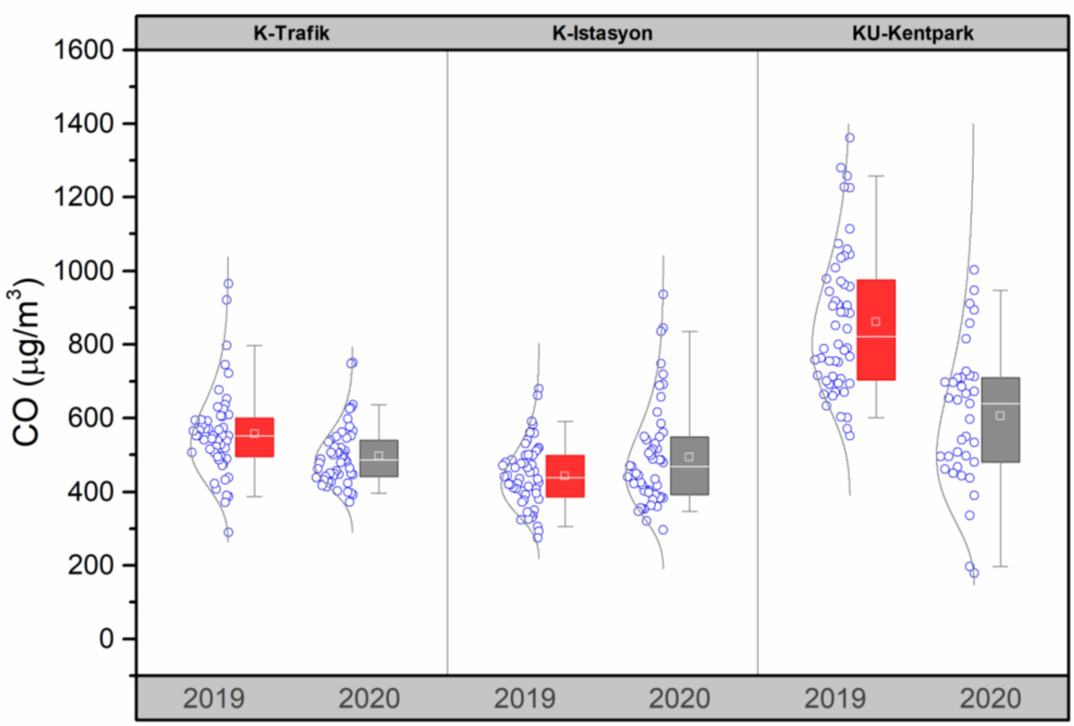

Figure SM40. CO concentrations in Kars and Kutahya

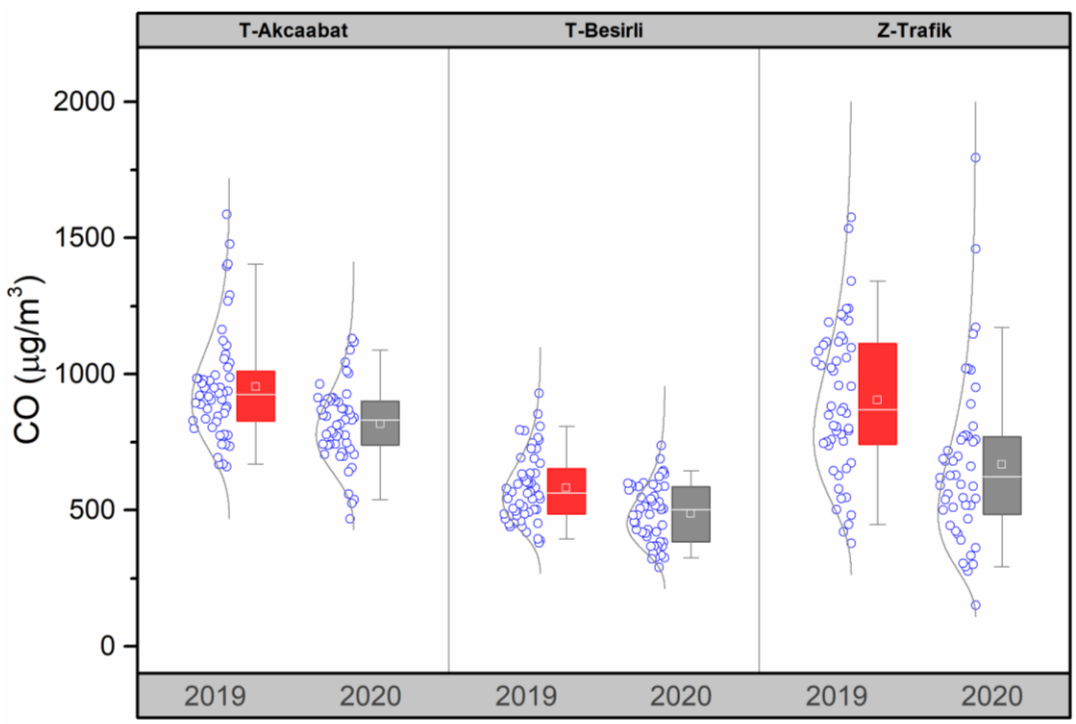

Figure SM41. CO concentrations in Trabzon and Zonguldak

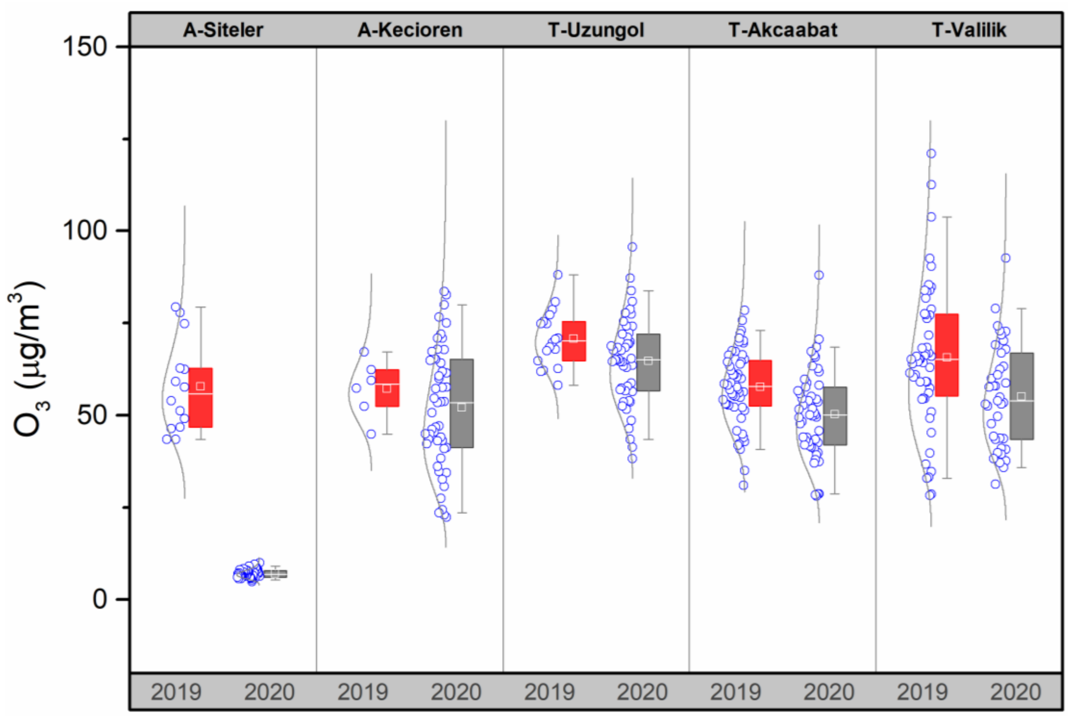

Figure SM42. O_3 concentrations in Ankara and Trabzon

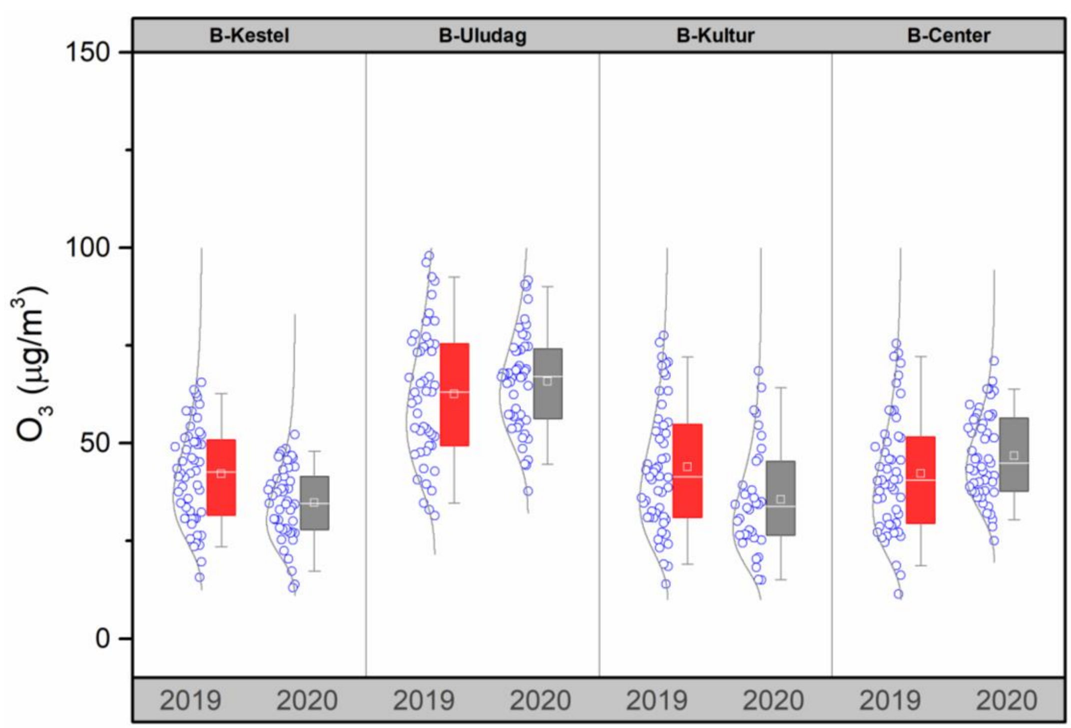

Figure SM43. O_3 concentrations in Bursa

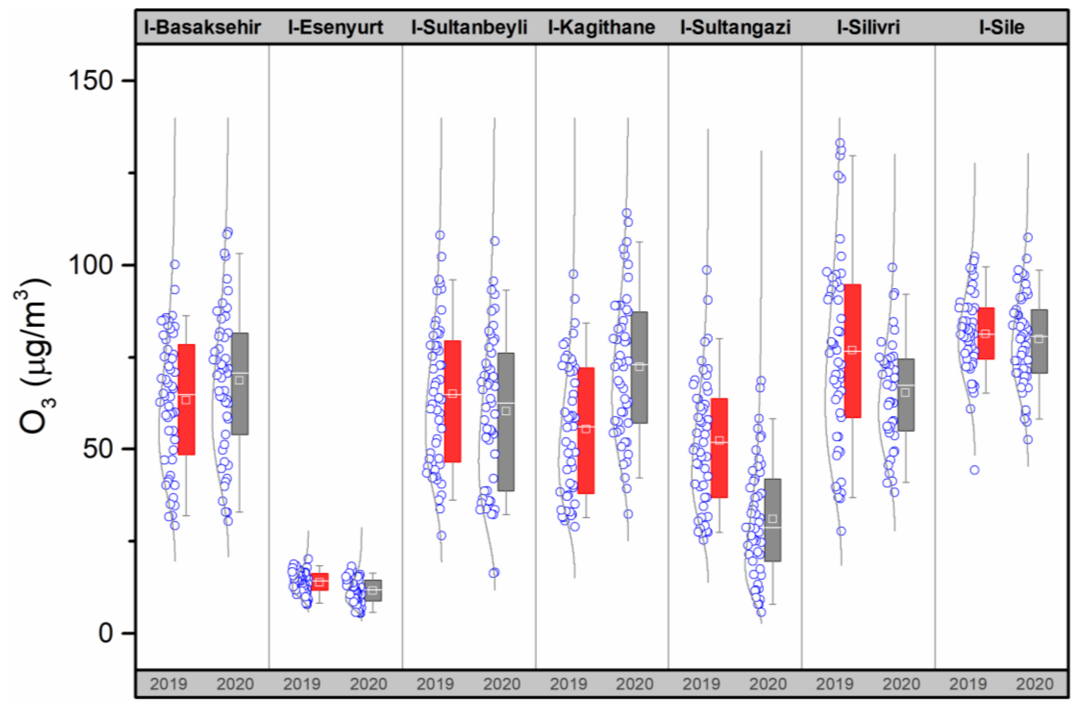

Figure SM44. O_3 concentrations in Istanbul

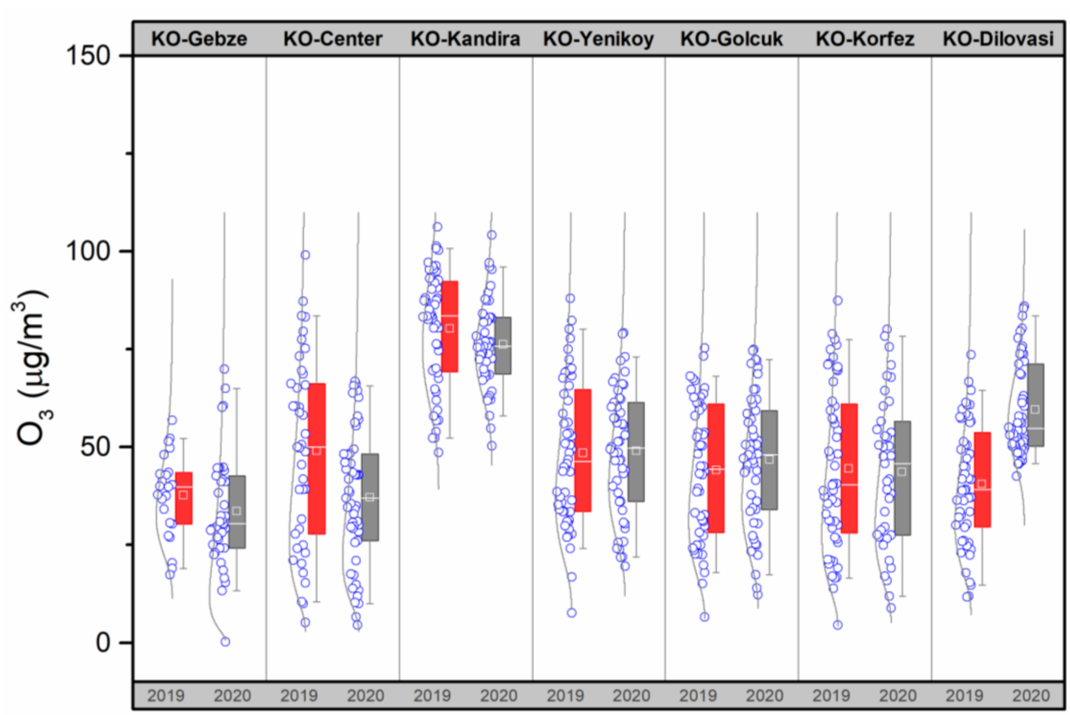

Figure SM45. O_3 concentrations in Kocaeli

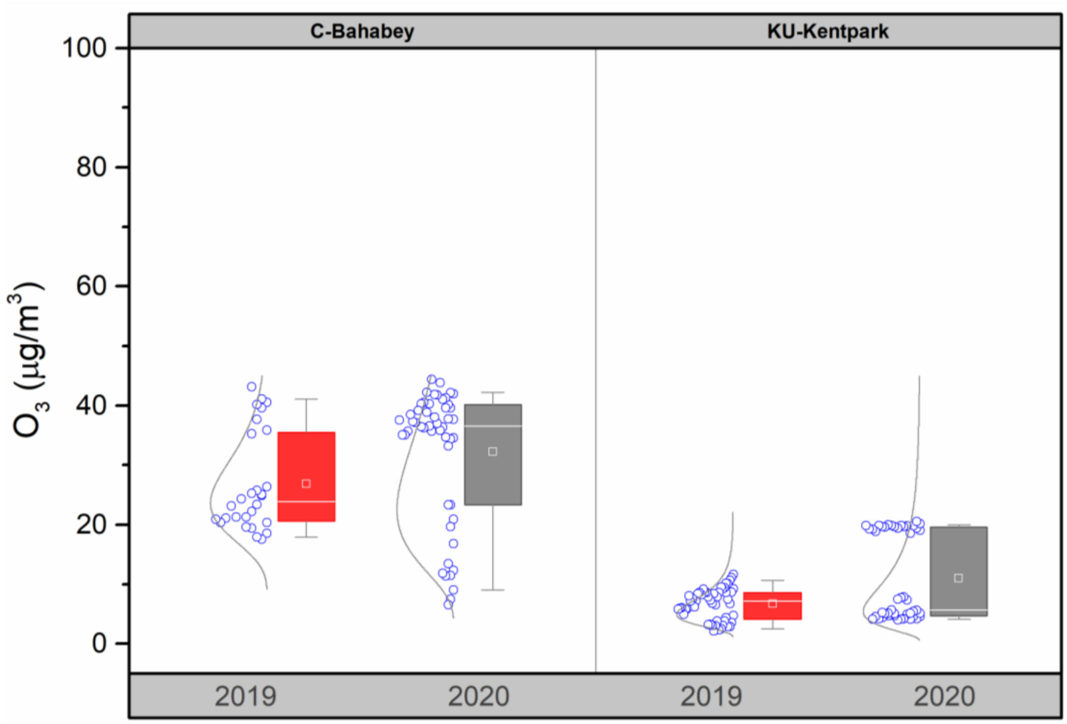

Figure SM46. O_3 concentrations in Corum and Kutahya

SM References

URL SM1. Newspaper headline, https://www.takvim.com.tr/yasam/2020/04/18/istanbul-evlere-kapandi-uludagin-zirvesi-gorundu (retrieved date: 25.04.2020)