Does Industrial Reductions Matter More than Traffic Reductions in Improving Air Quality During COVID-19 Lockdown Period in Istanbul?

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Abstract - **Air pollution is a critical environmental challenge, especially in urban centers like İstanbul. The COVID-19 lockdown in 2020 provided an unexpected opportunity to analyze the impacts of reduced human activity on air quality. This study investigates whether reductions in industrial activity or traffic played a more significant role in improving İstanbul's air quality during the lockdown period. Utilizing air quality monitoring data and electricity consumption as a proxy for industrial activity, this study compares the effects of these factors to reductions in pollutants such as $PM_{2.5}$, PM_{10}, SO_2, and NO_2. Initial findings suggest that while traffic reductions significantly lowered NO_2 levels, industrial reductions were a critical factor in decreasing particulate matter levels. This analysis aims to offer actionable insights for future environmental policies.**

Index Terms - air pollution, COVID-19 lockdown, traffic emissions, industrial activity, Istanbul air quality

I. Introduction

Air pollution is an important environmental problem, especially in modern cities. In 2020, the COVID19 led to lockdowns all around the world, which resulted in an opportunity to explore how economic and social inactivity affected environmental factors, especially air quality. Istanbul, the biggest city in Türkiye, experienced a significant reduction in traffic and experienced a reduction in industrial activity during the lockdown period. These changes provided a once in a lifetime opportunity to analyze whether reduced traffic or decreased industrial activity played a larger part in improvement in air quality of Istanbul during this period. The Istanbul Metropolitan Municipality (IBB) reported that air quality in the city improved by 30% during the lockdown. They noted that the reduction in cars on the road was the main reason for this cleaner air [1]. Before the pandemic, pollution levels were much higher and with fewer people driving, the air quality improved. While it is assumed by the significant part of the population that fewer vehicles on the road were the primary reason for cleaner air, this project will analyze air quality data to see whether industrial emissions played a larger role in influencing pollution levels.

II. Hypotheses

H1: Industrial activity reductions significantly improve air quality.

H2: Traffic reductions significantly improve air quality.

H3: The effect on industrial activity reductions on air quality is greater than that of traffic reductions.

H4: Combined reductions in both traffic and industrial activity have the most significant effect on air quality.

III. Methodology

As emphasized before, this paper focuses on examining how reductions in industrial activity and traffic during the COVID-19 lockdown affected air quality in İstanbul. To achieve this, secondary data from reliable sources such as the Çevre ve Şehircilik Bakanlığı Sürekli İzleme Merkezi (Ministry of Environment and Urbanization Continuous Monitoring Center), AYEDAŞ, and BEDAŞ was collected and analyzed. The study focuses on quantitative data to assess changes in pollution levels across different periods supported by insights from these sources.

Air quality data, including key pollutants like $PM_{2.5}$, PM_{10}, SO_2, and NO_2 was sourced from the Sürekli İzleme Merkezi. The study uses SO_2, and NO_2 levels as proxies to measure the impact of traffic reductions, as these pollutants are closely linked to vehicular emissions. Industrial activity was assessed using electricity consumption data provided by AYEDAŞ (for districts on the Anatolian side, such as Kartal, Ümraniye, Üsküdar) and BEDAŞ (for districts on the European side, such as Arnavutköy, Silivri, Sultangazi). These datasets offer insights into industrial activity levels during distinct periods: pre-lockdown (2019), lockdown (2020), and post-lockdown (2021).

The key lockdown dates were derived from the timeline of restrictions implemented during Turkiye's COVID-19 response. The first lockdown in Turkey occurred in April, 2020 with following restrictions continuing throughout the year. The study categorizes dates into three phases: "Pre-COVID" (before April 12, 2020), "During COVID" (April 13, 2020, to December 31, 2020), and "Post-COVID" (from January 1, 2021, onward) [2].

Data cleaning was performed to handle missing values and outliers to ensure accurate analysis. RStudio was used as an integrated development environment (IDE) for statistical processing and creating graphs comparing air quality and electricity consumption across different time periods to demonstrate the data.

IV. Descriptive Analysis

This section provides a detailed analysis of the descriptive statistics for the data used in this study. The analysis covers air quality indicators and electricity consumption levels, focusing on six districts across İstanbul.

Table 1 demonstrates the $PM_{2.5}$ levels across the six districts between the years 2019-2021. Kartal showed the highest median $PM_{2.5}$ levels which indicates a potential mix of industrial and traffic related particulate matter pollution. Arnavutköy, with the lowest median levels, reflected better air quality.

On one hand, *table 2* gives details about the changes in PM_{10} levels which shows variations in particulate matter pollution influenced by both industrial activity and traffic emissions. Sultangazi recorded the highest PM_{10} levels due to its dense urban population and industrial activity. Silivri and Üsküdar showed lower PM_{10} levels, which suits their less industrial profiles.

On the other hand, *table 3* presents descriptive statistics for SO_2 levels, which is used as a proxy for industrial emissions.

Moreover, *table 4* shows the changes in NO_2 levels indicating significant traffic related emissions. Kartal and Üsküdar demonstrated the highest median NO_2 levels, whereas, Arnavutköy and Silivri had reduced NO_2 levels with lower vehicular activity. *Table 5* shows the electricity consumption levels across districts during the same period, which is an indirect measure of industrial activity.

Furthermore, a comparison of SO_2 levels in *table 3* and electricity consumption in *table 5* indicates a noticeable correlation between industrial emissions and energy usage. Districts like Ümraniye, Sultangazi and Kartal with high recorded electricity consumption also showed increased SO_2 levels. This suggests that industrial activities were significant contributors to pollution in these areas. Conversely, Silivri displayed both low electricity consumption and low SO_2 levels, also validating this trend.

These findings suggest the strong correlation between industrial activity, proxied by electricity consumption and SO_2 emissions, while also highlighting the role of traffic emissions in influencing air quality during the study period. This analysis sets the basis for a deeper understanding of the contributions of industrial and traffic related pollution in Istanbul.

	n	**mean**	**sd**	**median**	**trimmed mean**	**mad**	**min**	**max**	**1st. Qua**	**3rd Qua**	**NAs and outliers**	**skewness**	**kurtosis**	**se**
Kartal	21128	19.76	13.25	17	18.33	12.75	0	64.20	9.40	27.40	5176	0.91	3.35	0.09
Üsküdar	18902	12.09	6.87	10.70	11.36	6.67	1.20	35.70	6.70	16	7402	0.89	3.30	0.05
Ümraniye	15609	18.46	10.55	16.40	17.46	9.79	0	53.10	10.60	24.40	10695	0.82	3.28	0.08
Silivri	19276	14.15	5.91	13.07	13.58	5.30	1.04	34.94	8.89	17.27	7028	0.89	3.67	0.04
Arnavutköy	20217	9.99	6.33	9	9.46	5.93	0	31	6	13.10	6087	0.82	3.57	0.04
Sultangazi	20681	14.19	8	12.46	13.39	7.10	0.01	38.89	8.35	18.47	5623	0.88	3.31	0.06

Table 1. $PM_{2.5}$ descriptive statistics for each selected district in Istanbul during 2019-2021.

	n	mean	sd	median	trimmed mean	mad	min	max	1st. Qua	3rd Qua	NAs and outliers	skewness	kurtosis	se
Kartal	21128	33.82	21.93	29.50	31.58	20.46	0	106.30	17.30	46.10	5176	0.89	3.4	0.15
Üsküdar	18902	22.73	10.96	21	21.81	10.23	0	57.40	14.70	28.90	7402	0.76	3.31	0.08
Ümraniye	15609	26.85	15.39	24.20	25.44	14.68	0	78	15.20	35.60	10695	0.81	3.32	0.12
Silivri	19276	23.26	11.04	21.59	22.33	10.60	0.82	61.34	15.17	29.64	7028	0.78	3.46	0.08
Arnavutköy	20217	27.81	17.26	25.20	26.41	15.12	0	86.20	16	37.20	6087	0.80	3.57	0.12
Sultangazi	20681	48.39	25.72	44.28	46.29	25.98	1.98	131.80	28.61	64.53	5623	0.70	3.03	0.18

Table 2. PM_{10} descriptive statistics for each selected district in Istanbul during 2019-2021.

	n	mean	sd	median	trimmed mean	mad	min	max	1st. Qua	3rd Qua	NAs and outliers	skewness	kurtosis	se
Kartal	21128	1.95	1	1.70	1.86	0.74	0	5	1.30	2.50	5176	0.72	3.64	0.01
Üsküdar	18902	2.23	0.97	2.20	2.18	1.04	0	5.30	1.50	2.90	7402	0.34	2.83	0.01
Ümraniye	15609	2.46	1.14	2.20	2.35	1.04	0	5.90	1.60	3.10	10695	0.79	3.34	0.01
Silivri	19276	1.79	1.04	1.54	1.65	0.85	0.02	5.39	1.04	2.24	7028	1.23	4.26	0.01
Arnavutköy	20217	3.61	1.71	3.40	3.48	1.63	0	9	2.30	4.60	6087	0.71	3.39	0.01
Sultangazi	20681	4.46	2.52	3.76	4.13	2.09	0.24	12.37	2.60	5.75	5623	1.09	3.66	0.02

Table 3. SO_2 descriptive statistics for each selected district in Istanbul during 2019-2021.

	n	mean	sd	median	trimmed mean	mad	min	max	1st. Qua	3rd Qua	NAs and outliers	skewness	kurtosis	se
Kartal	21128	39.9	25.97	34.10	37.27	26.09	0	125.1	18.80	56.40	5176	0.81	2.97	0.12
Üsküdar	18902	38.38	17.87	35.70	37	18.38	2	97.50	24.20	49.90	7402	0.69	3.14	0.13
Ümraniye	15609	31.09	21.56	25	28.23	17.64	0	100.40	15	41.6	10695	1.11	3.7	0.17
Silivri	19276	15.76	11.07	12.11	14.11	8.40	0.87	51.08	7.59	21.06	7028	1.22	3.80	0.08
Arnavutköy	20217	15.55	10.91	12.50	14.07	8.60	0	52.1	7.70	20.60	6087	1.16	3.92	0.08
Sultangazi	20681	33.03	19.08	28.91	31.27	17.42	0	91.44	18.90	44.24	5623	0.78	3.01	0.13

Table 4. NO_2 descriptive statistics for each selected district in Istanbul during 2019-2021.

	n	mean	sd	median	trimmed mean	mad	min	max	1st. Qua	3rd Qua	NAs and outliers	skewness	kurtosis	se
Kartal	36	0.81	0.17	0.80	0.81	0.20	0.53	1.23	0.68	0.95	4	0.33	2.5	0.03
Üsküdar	36	1.30	0.23	1.33	1.32	0.25	0.86	1.81	1.14	1.50	4	-0.17	2.3	0.04
Ümraniye	36	1.43	0.24	1.45	1.44	0.21	0.99	1.88	1.28	1.56	4	0	2.5	0.04
Silivri	36	1.11	0.23	1.12	1.11	0.32	0.75	1.64	0.92	1.32	2	0.29	2.12	0.04
Arnavutköy	36	1.02	0.21	1.01	1.01	0.22	0.49	1.47	0.87	1.16	2	-0.03	2.77	0.03
Sultangazi	36	0.73	0.14	0.71	0.72	0.17	0.52	1.01	0.63	0.84	2	0.21	2.14	0.02

Table 5. Total electricity consumption (GWh) descriptive statistics for each selected district in Istanbul during 2019-2021.

V. Results and Discussion

The COVID-19 pandemic provided an unprecedented opportunity to analyze the impact of reduced human activity on air pollution in Istanbul. Lockdown measures implemented to reduce the spread of the virus led to significant decreases in both traffic and industrial activity, with significant effects on air quality. The Istanbul Metropolitan Municipality (IBB) reported a 30% improvement in air quality during this period, largely attributing it to reduced traffic volumes [1]. However, this study expands on their findings by incorporating industrial emissions data to assess the relative contributions of traffic and industrial activity to air pollution levels. By analyzing reductions in key pollutants such as NO_2, SO_2, PM_{10}, and $PM_{2.5}$ across different districts, the study evaluates hypotheses regarding the influence of these two sources on air quality.

Electricity consumption, a proxy for industrial activity, showed notable declines during the lockdown period, especially in industrially dense districts such as Sultangazi and Arnavutköy. As seen in *figure 1*, these declines were accompanied by reductions in SO_2 levels, a pollutant primarily linked to industrial emissions. The correlation between electricity consumption and SO_2 levels supports the hypothesis (H1) that reductions in industrial activity improve air quality. For example, in Sultangazi, where industrial operations are significant, SO_2 levels dropped by approximately by a great margin during the lockdown. This finding aligns with prior research by Tuygun et al. [3], which highlighted the substantial contribution of industrial emissions to particulate matter and SO_2 levels in Istanbul. However, the relatively smaller reduction in SO_2 levels compared to other pollutants indicates that industrial emissions, though reduced, remained a persistent source of pollution during this period.

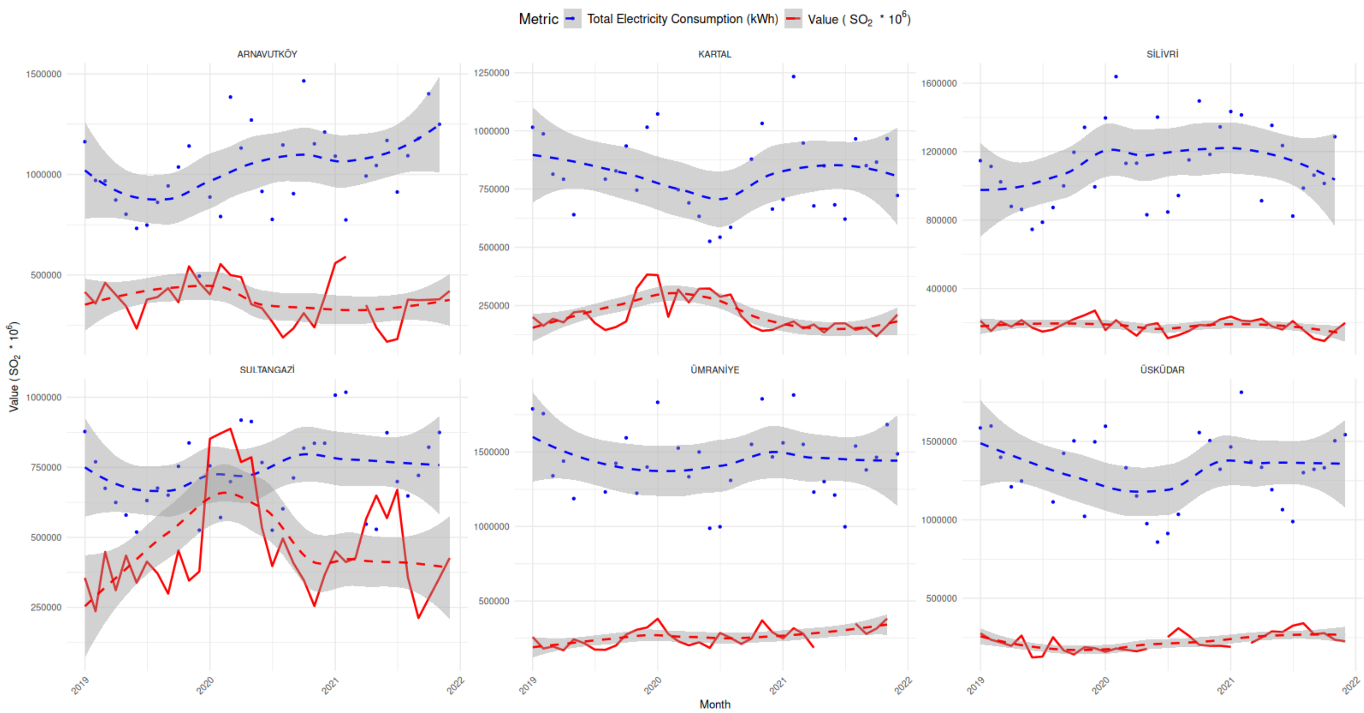


Figure 1. Changes in Electricity Use and SO_2 Levels Over Time in Istanbul Districts

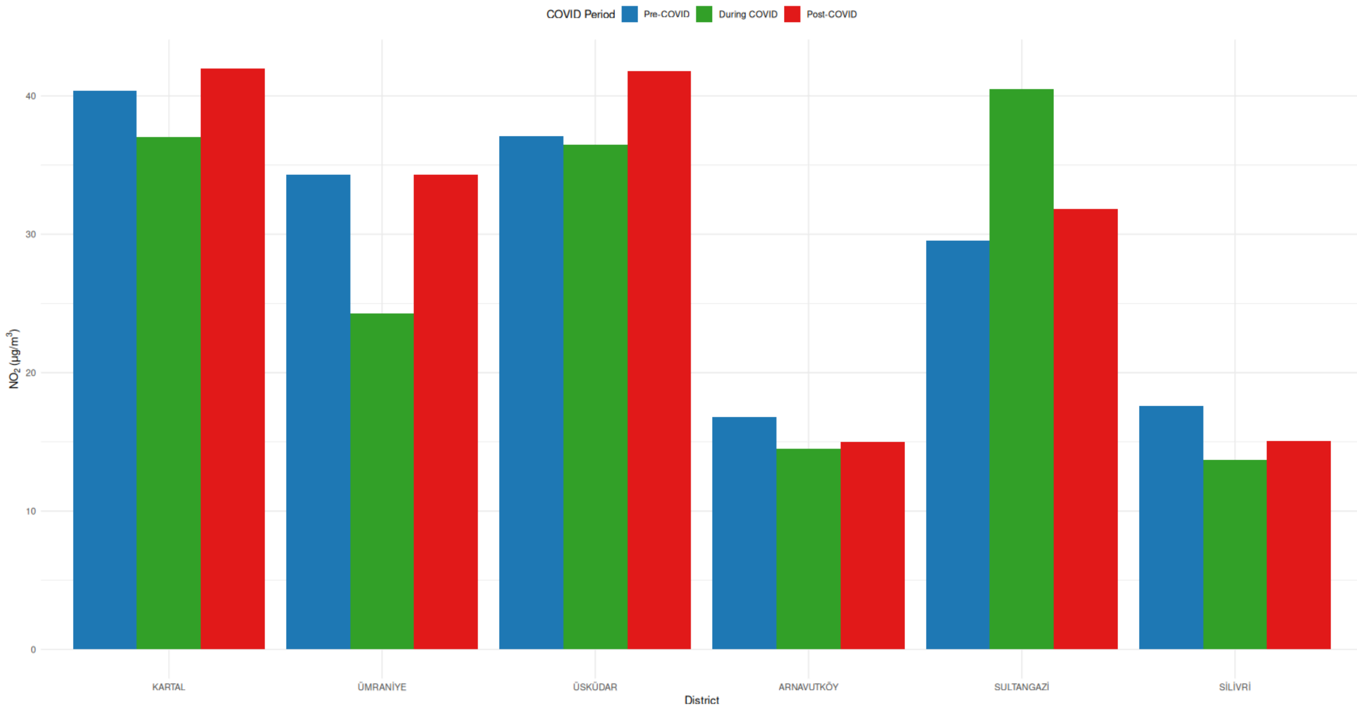


Figure 2. NO₂ Levels During Different COVID-19 Periods in Istanbul Districts

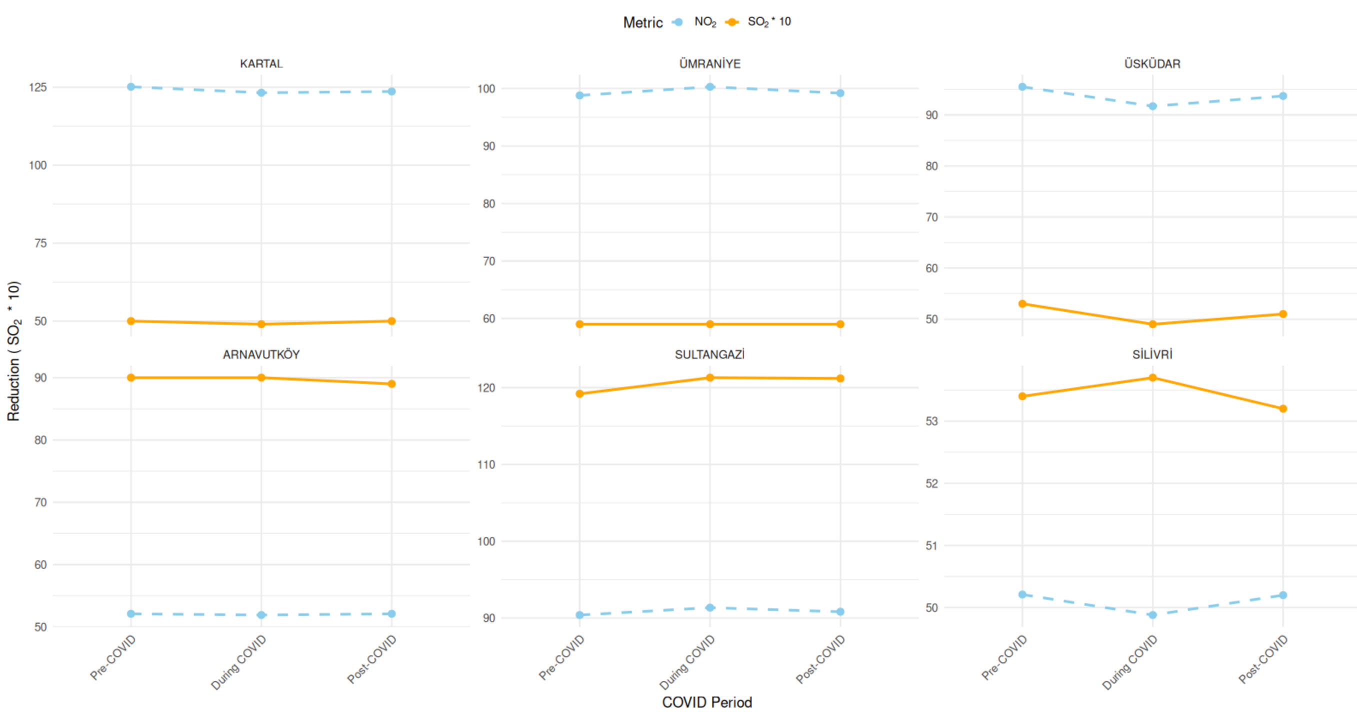


Figure 3. Changes in SO₂ and NO₂ Levels During COVID-19 Periods in Istanbul Districts

The comparison of SO_2 and NO_2 reductions across districts highlights the differential impact of traffic and industrial reductions on air quality. In industrial districts like Arnavutköy and Sultangazi, SO_2 reductions were more clear, as shown in *figure 3*, while NO_2 levels were fairly stable. This stability indicates that reduced traffic had minimal impact on air quality in such districts, which highlights the dominance of industrial emissions. Conversely, *figure 2* highlights that traffic-dominated districts like Ümraniye and Kartal experienced significant NO_2 reductions. This reflects the critical role of traffic in shaping air quality.

These observations support hypothesis (H3), which suggests that industrial activity reductions have a greater impact on air quality than traffic reductions in certain contexts. For instance, the stable NO_2 levels in Arnavutköy during the lockdown suggests a dominance of industrial emissions, while the sharp decline in NO_2 levels in Kartal highlights the significant role of traffic reductions. This duality aligns with findings by Şahin [4], who observed that urban air pollution patterns are influenced by a combination of local traffic and industrial factors.

The combined effects of traffic and industrial reductions are particularly apparent in the analysis of particulate matter (PM_{10} and $PM_{2.5}$) levels, as shown in *figure 4*. Districts like Sultangazi and Ümraniye, which experienced parallel reductions in both traffic and industrial activity, exhibited the most significant improvements in air quality. For instance, PM_{10} levels in Sultangazi dropped by over 129 μg/m³, highlighting the compounded benefits of addressing both sources of pollution. These findings support hypothesis (H4), which suggests that combined reductions in traffic and industrial activity create the most significant improvements in air quality. This is further supported by studies by Akan [5] and Sönmez et al. [6], which demonstrated the mutually changing effects of reducing both traffic and industrial emissions on urban air quality.

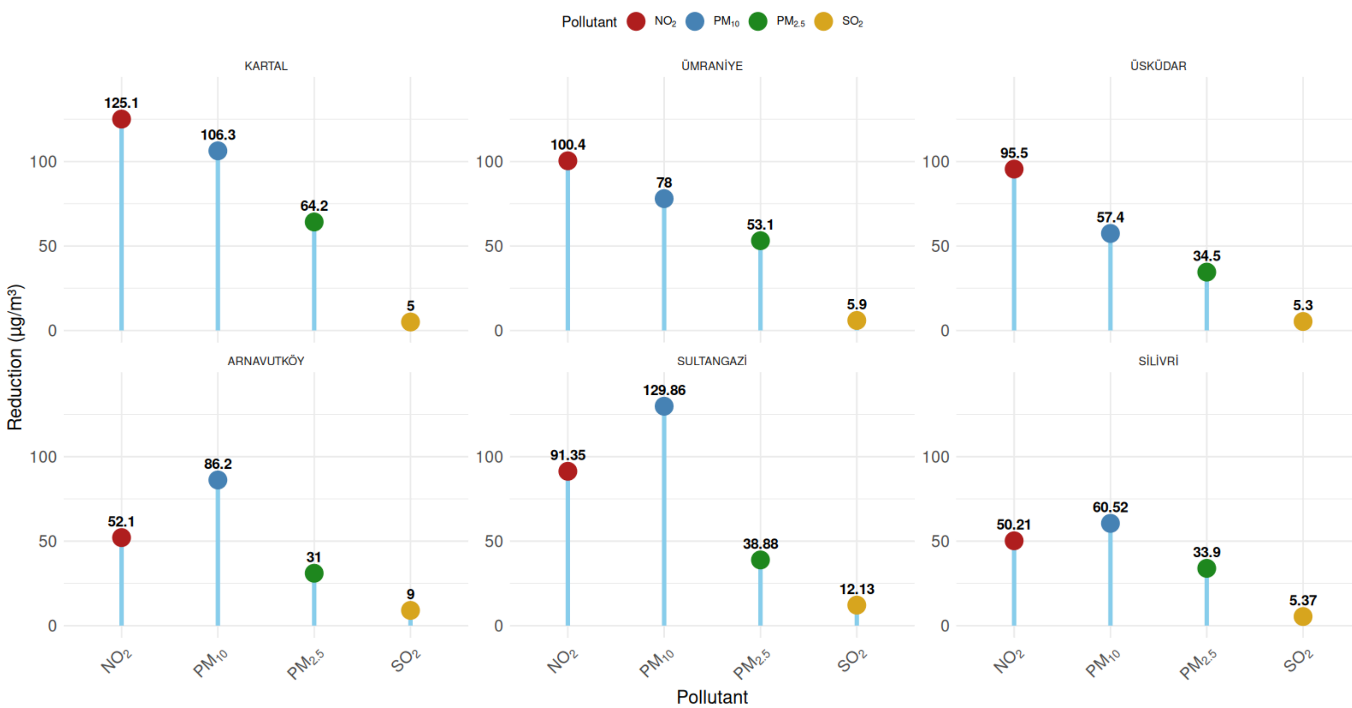


Figure 4. Reductions in Key Pollutants in Istanbul Districts During COVID-19

The analysis of pollutant levels provides valuable insights into the air quality during the COVID-19 lockdown. As illustrated in *figure 3*, pollutant levels began to rise in the post-lockdown period, particularly in districts with high industrial activity. This trend suggests that the improvements observed during the lockdown were temporary and reliant on sustained reductions in human activity. For instance, SO_2 levels in Silivri returned to pre-lockdown levels within months of the restrictions being lifted, highlighting the persistence of industrial emissions. This observation aligns with the findings of Şahin et al. [7], who emphasized the need for long term policies to address ongoing industrial pollution.

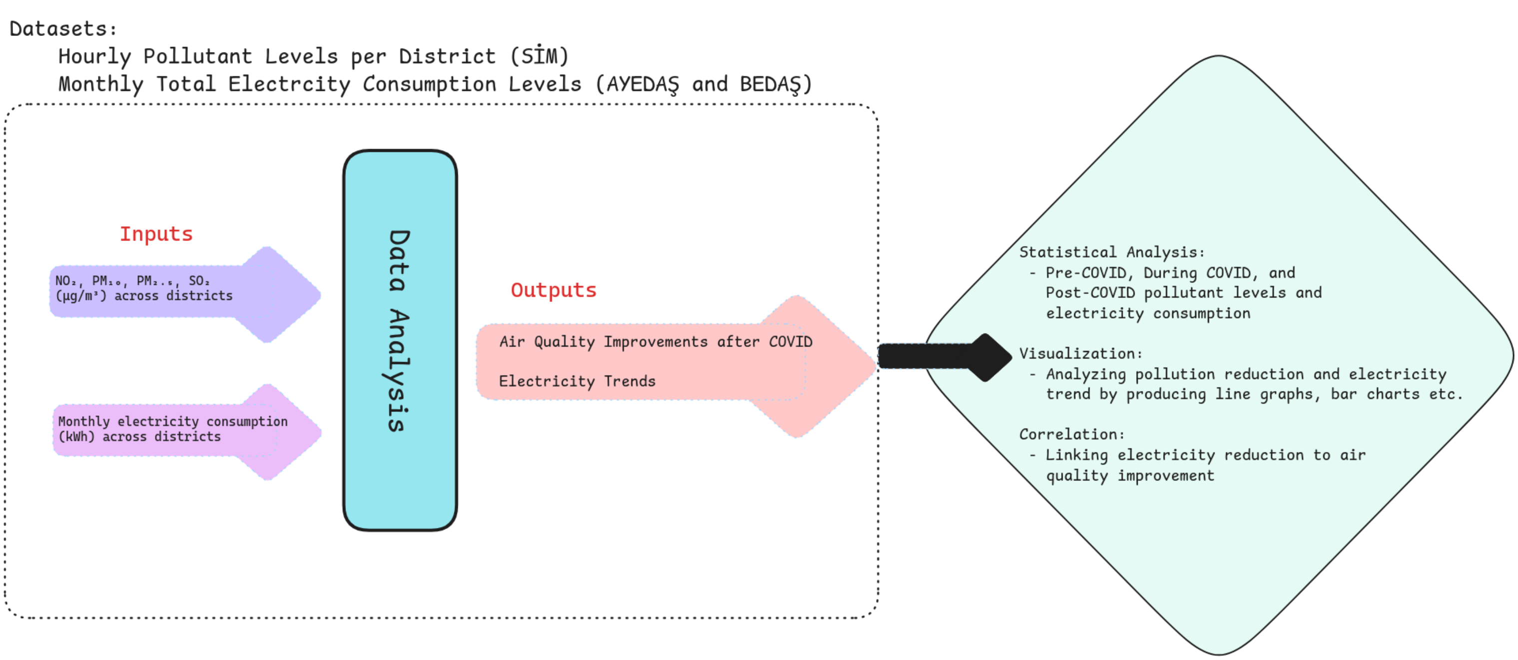
Furthermore, the data reveal notable district-specific differences in the contributions of traffic and industrial activity to air pollution. In Üsküdar, for example, traffic reductions led to a significant decline in NO_2 levels, showing the significant impact of vehicular emissions on air quality in this district.. In contrast, in Silivri, a district with lower traffic density, industrial emissions played a more dominant role, as indicated by the relatively stable NO_2 levels and the significant reduction in SO_2 levels. These findings highlight the importance of adopting a localized approach to air quality management, and calls for the need for tailored policies to address the specific sources of pollution in each district.

The findings also have implications for future air quality policies in Istanbul. The significant reductions in pollutant levels observed during the lockdown demonstrate the effectiveness of targeted actions to improve air quality. However, the post-lockdown rebound in pollution levels shows the need for sustained efforts to address both traffic and industrial emissions. Policies such as promoting green transportation, transitioning to cleaner industrial technologies and implementing a more strict emission standard could help maintain the air quality improvements achieved during the lockdown. Additionally, the district-specific variations in pollution sources suggest that a one-size-fits-all approach may not be effective. Instead, a combination of city or district wide measures could offer the best results.

VI. Conclusion

In conclusion, the study provides strong evidence supporting the hypotheses that reducing both traffic and industrial activity leads to significant improvements in air quality. While industrial activity reductions had a particularly notable impact in some districts, the combined effects of addressing both sources were most evident during the lockdown period. These findings highlight the need for integrated strategies to achieve long-term air quality improvements in Istanbul. The lessons learned from the COVID-19 lockdown offer a unique opportunity to rethink urban planning and environmental policies. This could ensure a healthier and more sustainable future for the city.

VII. Graphical Abstract



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