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Investigating the Impact of Virtual Education on Air Pollution Indicators in Tehran during the COVID-19 Outbreak

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ABSTRACT

This research aims to investigate the effect of virtual education during the COVID-19 outbreak on air pollution indicators in Tehran. The study uses quantitative methods, including One-Way ANOVA, to analyze the air pollution indicators before and during the COVID-19 pandemic. Data on air pollution indicators in Tehran from 2018, 2019, and 2020 were collected from Tehran Air Control Company and compared using statistical tests. The year 2019 represents virtual education, while 2018 and 2020 represent face-to-face education. The examined indicators include particulate matters with a diameter less or equal than 2.5µ ($PM_{2.5}$), SO_2, NOX (i.e., NO_2 and NO), O_3, and CO. The results of variance analysis show significant differences in the $PM_{2.5}$and NOX indices between virtual and face-to-face training days. Follow-up tests by Toki and Scheffé indicate that in 2019, when education was fully virtual, the levels of these pollutants were lower compared to 2018 and 2020. However, there were no significant differences in the SO_2, O_3, and CO indices during the days of virtual education compared to the years before and after. This suggests that virtual education during the COVID-19 outbreak contributed to pollution reduction by reducing traffic to educational organizations and its indirect effects.

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INTRODUCTION

Air pollution is a pressing issue in Tehran, with transportation and traffic being major contributors (Klasner et al., 1998). Today, air pollution problems have become an environmental challenge (Noori et al., 2013) that is affected by many factors. The increase in vehicle numbers is influenced by factors such as population growth, socio-economic conditions, and cultural developments. The rise in vehicle usage and distance traveled has led to severe air pollution problems, particularly in metropolises like Tehran. The pollution negatively impacts public health, increases costs, and calls for effective measures to reduce pollution levels. However, existing plans and studies often lack spatial and temporal forecasts for risk management and also air pollution modeling is always along with uncertainties which results in improper decision making and affects the health of the people exposed to the pollution (Moazami et al., 2016). This research focuses on virtual education as a potential solution to mitigate pollution during the COVID-19 outbreak.

Metropolises exhibit a new pattern of accommodation systems, city sizes, structures, and spatial organizations, influenced by the interplay between transportation, urban development patterns, and factors such as increasing income levels that promote societal motorization. Consequently, in many metropolises, over eighty percent of trips are made by motor vehicles.

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This surge in motor vehicle usage, coupled with longer travel distances, has resulted in air pollution (Davidson, 2004; Dennis, 2007; Te-Qi & Feng-Jun, 2009).

Tehran city is located between 35 degrees and 35 minutes to 35 degrees and 48 minutes north latitude and 51 degrees and 17 minutes to 51 degrees and 33 minutes east longitude. It resides in the southern foothills of the Alborz mountain range, covering an area of approximately 800 square kilometers. Tehran is comprised of 22 municipal districts, and according to the 2015 census, its population is 8,693,766. The city is bounded by the central desert to the south, the southern slopes of the central Alborz to the north, the Jajroud valleys to the east, and the Karaj valleys to the west. The 22 districts of Tehran municipality are situated within this area (Noori et al., 2022).

The environment, whether through mitigating cities' negative impact on it or enhancing cities' potential for sustainable development, is a significant concern for city managers and residents alike (Sarour and Mousavi, 2013). Air pollution, in particular, is a crucial problem in large cities, and researchers are striving to employ modern methods and technologies to understand and effectively manage this destructive phenomenon. Various pollutants are effective on pollution, for example In Carbon monoxide (CO) is one of the main air pollutant parameters in the atmosphere of Tehran, Iran (Noori et al., 2017).

Urban air pollution is a complex amalgamation of various toxic pollutants that significantly affect urban residents and tourists (Kolemanin et al., 2001). Therefore, predicting air pollution concentrations in urban areas is essential for safeguarding people's health. The rapid and global spread of COVID-19 prompted the World Health Organization (WHO) to designate it as a public health emergency of international concern. The COVID-19 pandemic is one of the most significant infectious diseases and threats to global public health in the last century (Yu and Le, 2020; Barber et al., 2021). This threat precipitated a global health emergency, resulting in unprecedented government decisions such as city-wide quarantines and travel restrictions in some regions or entire countries.

The COVID-19 pandemic has demonstrated that altering human behavior can minimize disease transmission and yield new insights and information. Unprecedented measures like quarantines and movement restrictions within cities were implemented to reduce air pollution and curb the spread of infectious diseases. These measures reduced vehicular emissions and led to a new baseline of air pollution during specific seasons. Traffic reductions and imposed bans provided valuable insights into how minimizing air pollution can allow the development of strategies to mitigate public health risks. However, quarantine cannot serve as a permanent or long-term solution for reducing air pollution levels in any geographical area. Instead, alternative policies and measures such as teleworking, virtual online classes, virtual conferences, and digital banking should be reinforced (Khaiwal Ravindraa et al., 2022).

In recent years, various information and communication technologies, including television, mobile phones, the internet, satellite systems, and computer technologies, have undergone daily transformations. These changes have influenced domains such as education, health, environment, culture, art, and entertainment (Hoffman et al., 2004). Consequently, the majority of the population struggles to keep up with the rapid advancements in technology. Change is an inevitable part of everyone's life. The COVID-19 pandemic and reduced traffic have imposed restrictions on various in-person gatherings, including education.

This shift has resulted in a rapid increase in virtual and remote training courses and seminars. While these options have their limitations, they offer the advantage of increased accessibility worldwide. Virtual training takes into consideration the constraints of face-to-face sessions and enables the avoidance of direct physical contact. In light of this, air pollution emerges as one of the most significant issues, particularly in large cities. Researchers are actively exploring new methods and technologies, including virtual training, to mitigate the movement of professors, students, employees, and the spread of pollution. They seek to understand and implement effective strategies to combat this detrimental phenomenon. Although many researches in Iran have studied Tehran's air pollution (Ahmadi Moghadam and Mahmoudi, 2012; Bahadori and Hosseini, 2021; Bastan Fard, 2017; Alisultani et al., 2018; Bayat et al., 2020; Dashti et al., 2019), less research has been done on the role of educational system on the pollution of Tehran city. So this research aims to investigate the impact of virtual education in addressing this issue.

MATERIALS AND METHODS

Tehran is the capital and the largest city of Iran which is located between 35° 34′–35° 50′N and 51° 02′–51° 36′E with the area about 570 km^2 (Noori et al., 2010). The present research utilized a quantitative method to compare the level of pollution before and after the onset of the COVID-19 pandemic. In the quantitative approach, real data and a relative data scale were employed, supported by statistical tests. Quantitative research should be regarded as a systematic and scientific method of investigation that involves the collection of data and information pertaining to the phenomena under study. In this research, after categorizing and preparing the data for analysis, statistical, mathematical, and computational techniques were employed to model the behavior of the phenomena. Data analysis and statistical tests were conducted using SPSS software version 21.

The research examined five indicators of air pollution: particulate matter with a diameter equal to or less than 2.5 µm ($PM_{2.5}$), SO_2, NO_X, O_3, and CO. Data pertaining to the pollution levels in Tehran's air for the years 2018, 2019, and 2020, representing the periods before, during, and after the COVID-19 pandemic, were obtained from the Tehran Air Pollution Control Company and encompassed measurements from all monitoring stations in the city over the course of 12 months.

The data pertaining to the pollution levels in the air of Tehran during the years 2018, 2019, and 2020, representing the periods before, during, and after the COVID-19 pandemic, were obtained from the Tehran Air Pollution Control Company's website and collected from all monitoring stations across the city throughout each month of the year. These indicators were assessed on a monthly basis in the districts of Tehran for the available data in 2018, 2019, and 2020.

The distribution of universities investigated in Tehran, as well as the distribution of air pollution measurement stations in the city, is depicted. With the onset of the COVID-19 pandemic in 2019 and the subsequent virtualization of most major universities in Tehran,

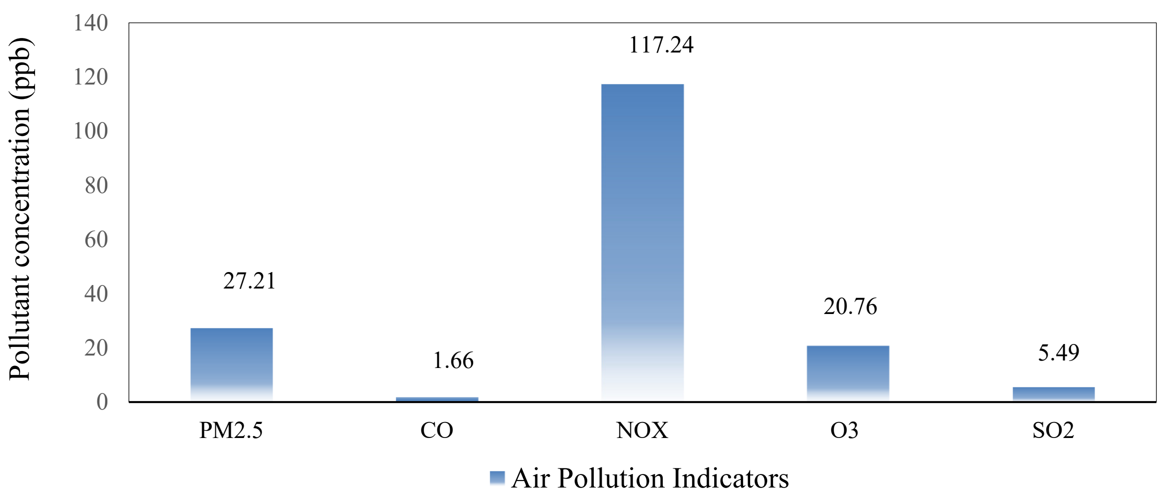

Fig. 1. Concentration of air pollution indicators in 2018.

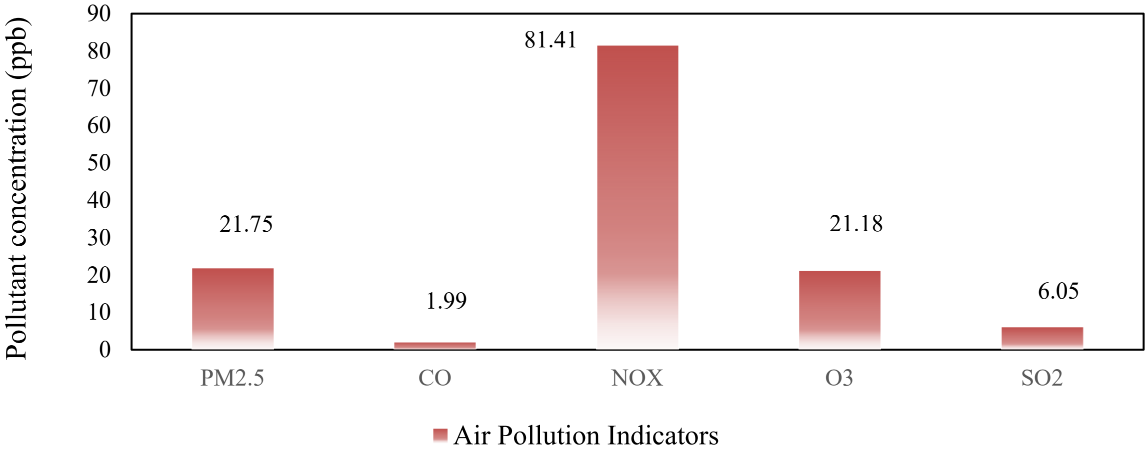

Fig. 2. Air pollution indicators in 2019.

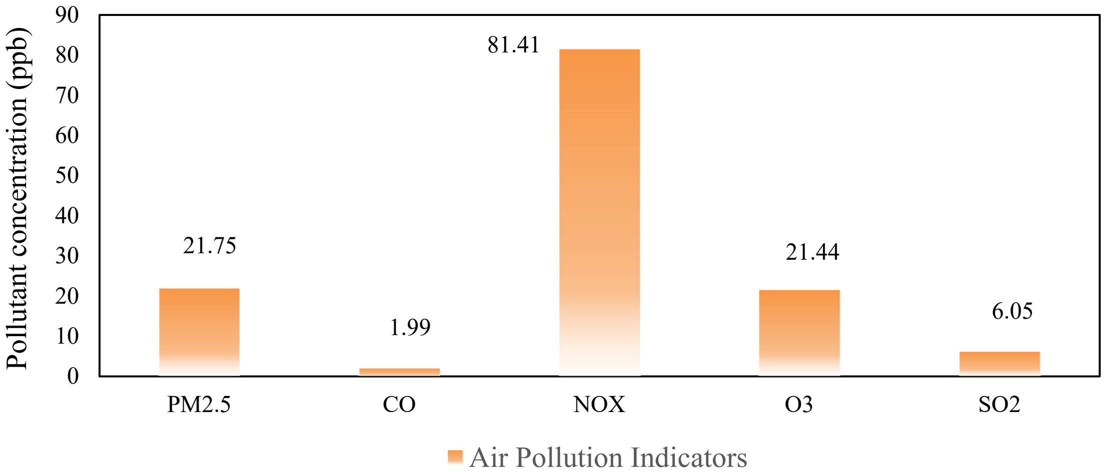

Fig. 3. Air pollution indicators in 2020.

including the University of Tehran, Shahid Beheshti University, Allameh Tabataba'i University, Kharazmi University, Amirkabir University of Technology, Sharif University of Technology, and Islamic Azad University Science and Research Branch, the duration of the pandemic in 2019 was taken into account. The pollution levels during this year were compared with the preceding and subsequent years, during which pollution effects were absent or reduced.

To analyze the data, one-way analysis of variance (ANOVA) was employed, enabling the comparison of more than two samples simultaneously. This analysis examined the pollution levels before, during, and after the COVID-19 period by assessing the variance between and within the groups of pollution indicators.

RESULTS AND DISCUSSION

The investigation of pollution indicators in the years 2018, 2019, and 2020 focused on selected districts in Tehran where high traffic volume and the presence of educational centers are common. The analysis was conducted using One-Way ANOVA and post hoc tests, specifically Toki and Scheffe tests. Each pollution indicator was individually examined and analyzed.

Regarding particulate matters with a diameter equal to or less than 2.5 µm ($PM_{2.5}$), the

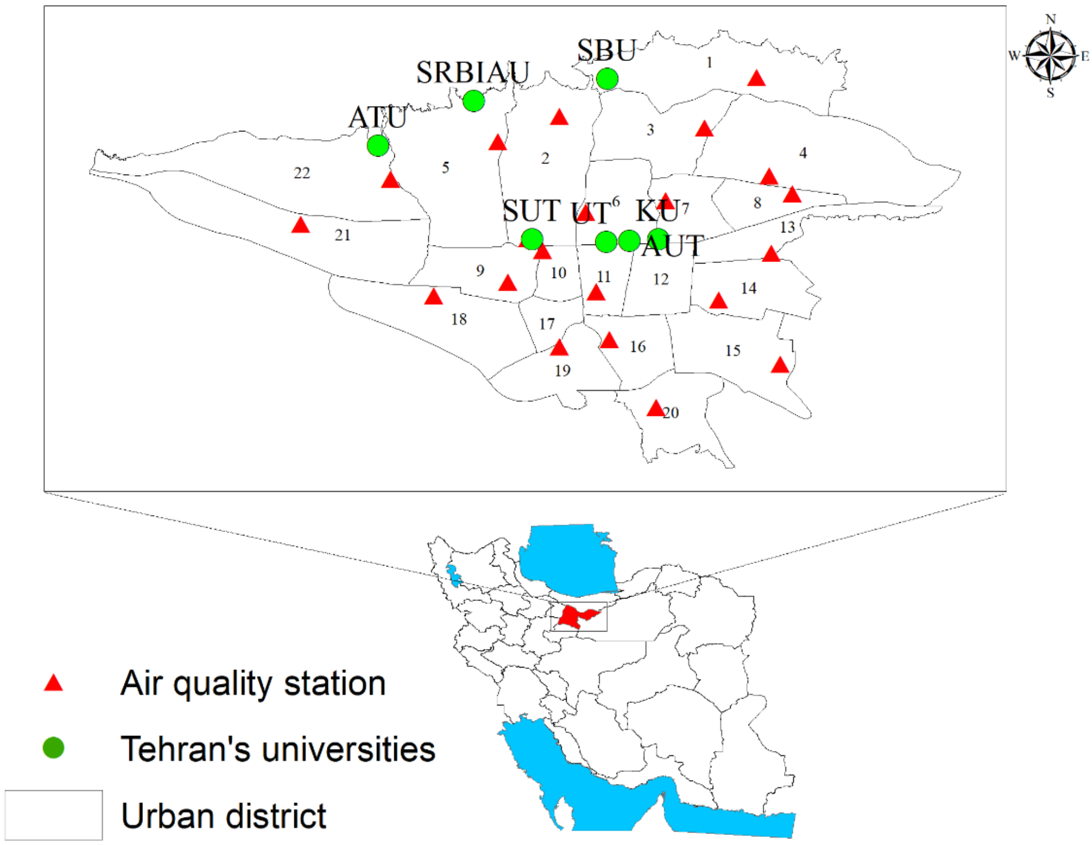

Fig. 4. Air pollution monitoring stations in Tehran, used in this study. ATU: Allameh Tabataba'i University; SR-BIAU: Science and Research Branch, Islamic Azad University; SBU: Shahid Beheshti University; SUT: Sharif University of Technology; UT: University of Tehran; KU: Kharazmi University; AUT: Amirkabir University of Technology

Table 1. Results of one–way ANOVA for particulate matter pollution with a diameter equal to or less than 2.5 µm ($PM_{2.5}$)

ANOVA					
$PM_{2.5}$					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	423.933	2	211.967	3.989	.028
Within Groups	1753.490	33	53.136		
Total	2177.424	35			

analysis of variance results at a significance level of 0.028 indicated significant changes in this index throughout the three-year period.

Upon conducting Tukey and Scheffé post hoc tests at a significance level of 0.05, it was observed that in the selected areas during 2019, when the peak of the COVID-19 pandemic occurred, there was a significant decrease in the average level of particulate matter pollution with a diameter equal to or less than 2.5 µm ($PM_{2.5}$). This finding confirms that the pollution of $PM_{2.5}$ decreased during the COVID-19 era in Tehran, as supported by the statistical data.

The decrease in $PM_{2.5}$ pollution during the COVID-19 era in Tehran can be attributed to the changes brought about by the pandemic. This finding is supported by the analysis of statistical data, which confirms the significant reduction in $PM_{2.5}$ levels.

Table 2. Results of Tukey and Scheffe tests for particulate matter pollution with a diameter equal to or less than 2.5 µm ($PM_{2.5}$)

Multiple Comparisons							
Dependent Variable: $PM_{2.5}$							
	(I) YEAR	(J) YEAR	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	98.00	99.00	5.36568	2.97591	.184	-1.9366	12.6679
		400.00	-2.92062	2.97591	.594	-10.2229	4.3816
	99.00	98.00	-5.36568	2.97591	.184	-12.6679	1.9366
		400.00	-8.28630*	2.97591	.023	-15.5886	-.9840
	400.00	98.00	2.92062	2.97591	.594	-4.3816	10.2229
		99.00	8.28630*	2.97591	.023	.9840	15.5886
Scheffe	98.00	99.00	5.36568	2.97591	.212	-2.2621	12.9934
		400.00	-2.92062	2.97591	.622	-10.5484	4.7071
	99.00	98.00	-5.36568	2.97591	.212	-12.9934	2.2621
		400.00	-8.28630*	2.97591	.031	-15.9140	-.6585
	400.00	98.00	2.92062	2.97591	.622	-4.7071	10.5484
		99.00	8.28630*	2.97591	.031	.6585	15.9140

*. The mean difference is significant at the 0.05 level.

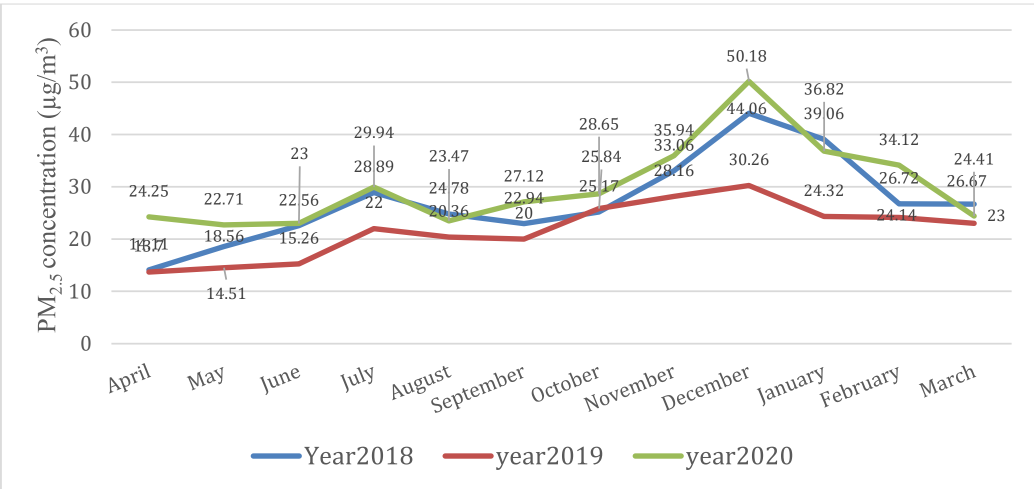

Fig. 5. Monthly concentration of air pollution ($PM_{2.5}$).

Table 3. Results of One –Way ANOVA for sulfur dioxide (SO_2)

ANOVA					
SO_2					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.055	2	3.528	.971	.389
Within Groups	119.892	33	3.633		
Total	126.947	35			

The examination of the concentration index of air pollution $PM_{2.5}$ reveals that in 2019, there was a decrease in overall air pollution compared to 2018 and 2020. The data presented in the table also indicate that during the cold months of the year, when temperature inversion occurs,

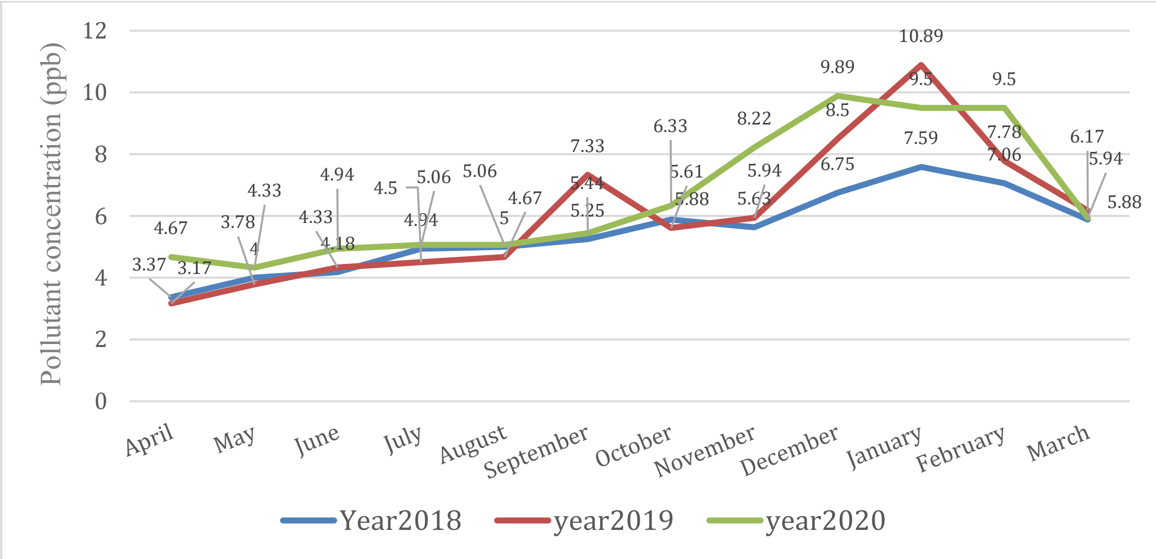

Fig. 6. Monthly concentration of air pollution (SO_2).

Table 4. Results of One –Way ANOVA for nitrogen oxides (NO_X)

ANOVA					
NO_X					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10933.144	2	5466.572	4.345	.021
Within Groups	41515.302	33	1258.039		
Total	52448.446	35			

there was a similar increase in air pollution levels across the three years.

Regarding the pollution index of SO_2, the analysis of variance results indicates that there were no significant changes in this index throughout the three-year period under study.

The monthly analysis of the SO_2 air pollution index demonstrates that this index exhibited similar trends over the course of three years. Diagram 5 clearly illustrates a significant increase in this index during certain months of the year compared to others. This can be attributed to temperature inversion in Tehran and the accumulation of pollutants.

Regarding the NO_X index, which comprises NO_2 and NO gases and is a significant pollutant stemming from fossil fuels, it is worth noting that these nitrogen oxides emitted by vehicles not only contribute to pollution but also give rise to the brownish appearance of the city on cold days. However, the analysis of variance results indicate that the NO_X pollution index did not undergo significant changes during the three-year period under examination.

The Toki and Scheffé post hoc tests reveal that during the peak of the COVID-19 pandemic in Iran, when education transitioned to a fully virtual and virtual format, there was a decrease in the amount of NO_X pollutants compared to the previous year and the subsequent year. This reduction can be attributed to various factors, including the decreased number of trips to and from educational centers due to virtualization. As a result of education shifting online, educational professionals no longer needed to commute within the city, which has had an impact on reducing pollution levels, among other factors.

The monthly analysis of the NO_X air pollution index reveals a decrease in this index during 2019, which coincided with the peak of the COVID-19 epidemic in Iran and the virtual closure of universities and large educational centers. The trend of this index demonstrates that, like

Table 5. Results of Tukey and Scheffé exam for nitrogen oxides (NO_X)

Multiple Comparisons

Dependent Variable: NO_X

	(I) YEAR	(J) YEAR	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	98.00	99.00	35.82866*	14.48010	.048	.2975	71.3599
		400.00	-2.18226	14.48010	.988	-37.7134	33.3489
	99.00	98.00	-35.82866*	14.48010	.048	-71.3599	-.2975
		400.00	-38.01093*	14.48010	.034	-73.5421	-2.4797
	400.00	98.00	2.18226	14.48010	.988	-33.3489	37.7134
		99.00	38.01093*	14.48010	.034	2.4797	73.5421
Scheffe	98.00	99.00	35.82866	14.48010	.060	-1.2863	72.9436
		400.00	-2.18226	14.48010	.989	-39.2972	34.9327
	99.00	98.00	-35.82866	14.48010	.060	-72.9436	1.2863
		400.00	-38.01093*	14.48010	.044	-75.1259	-.8960
	400.00	98.00	2.18226	14.48010	.989	-34.9327	39.2972
		99.00	38.01093*	14.48010	.044	.8960	75.1259

*. The mean difference is significant at the 0.05 level.

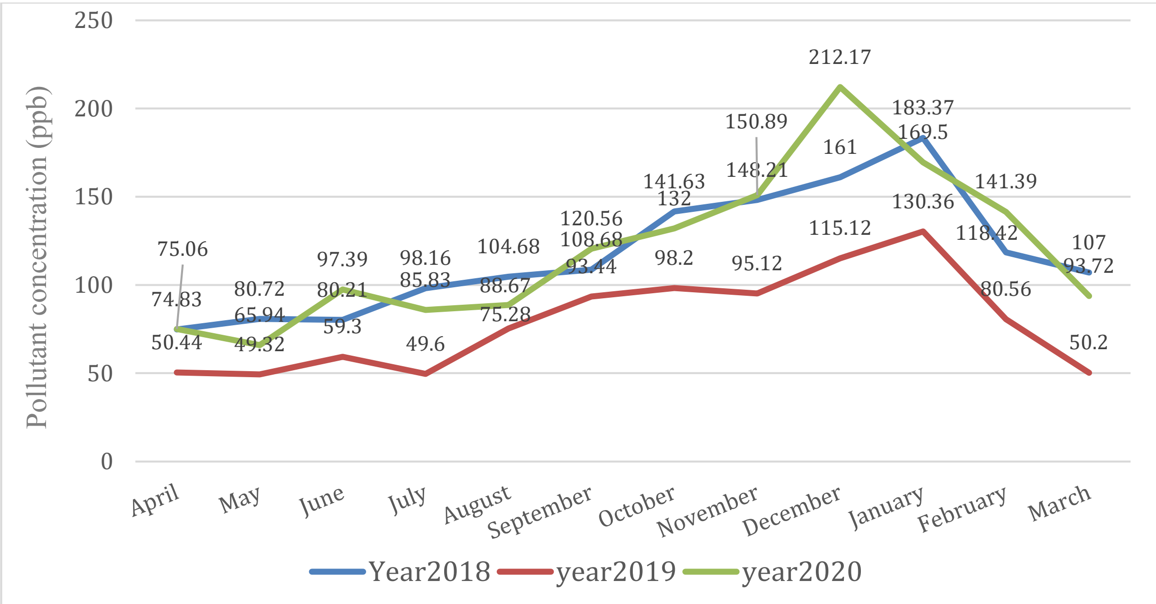

Fig. 7. Monthly concentration of air pollution (NO_X).

Table 6. Results of One –Way ANOVA for ozone (O_3)

ANOVA

O_3

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.779	2	1.389	.015	.985
Within Groups	3109.537	33	94.228		
Total	3112.316	35			

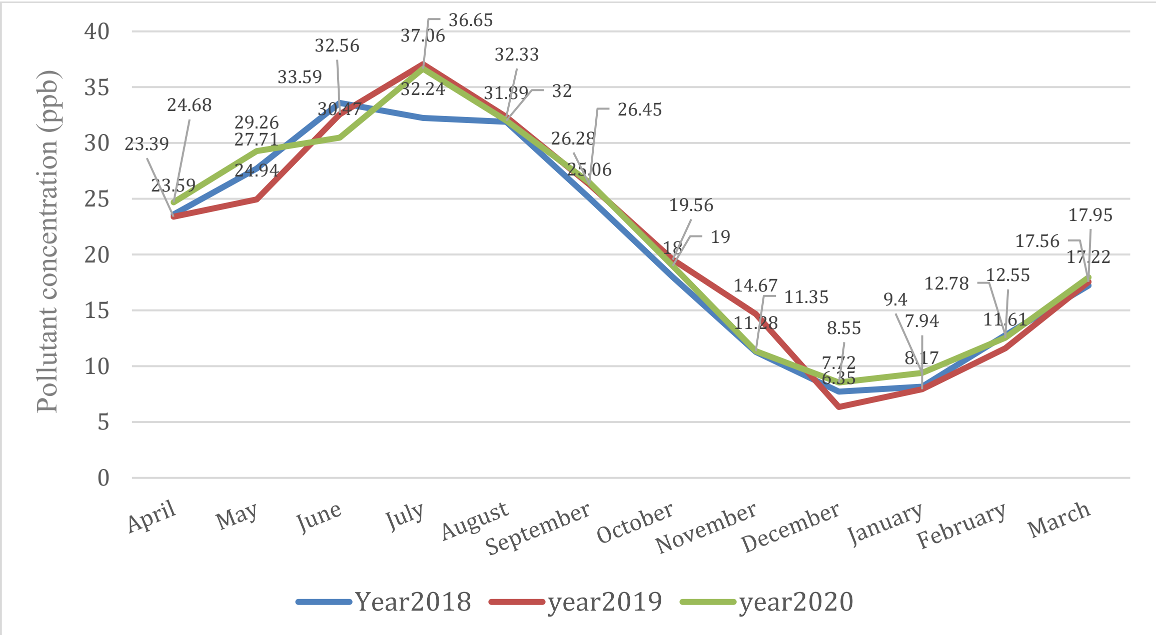

Fig. 8. Monthly concentration of air pollution (O_3).

Table 7. Results of One –Way ANOVA for carbon monoxide (CO)

ANOVA					
TOTAL					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.599	2	.300	.796	.460
Within Groups	12.426	33	.377		
Total	13.025	35			

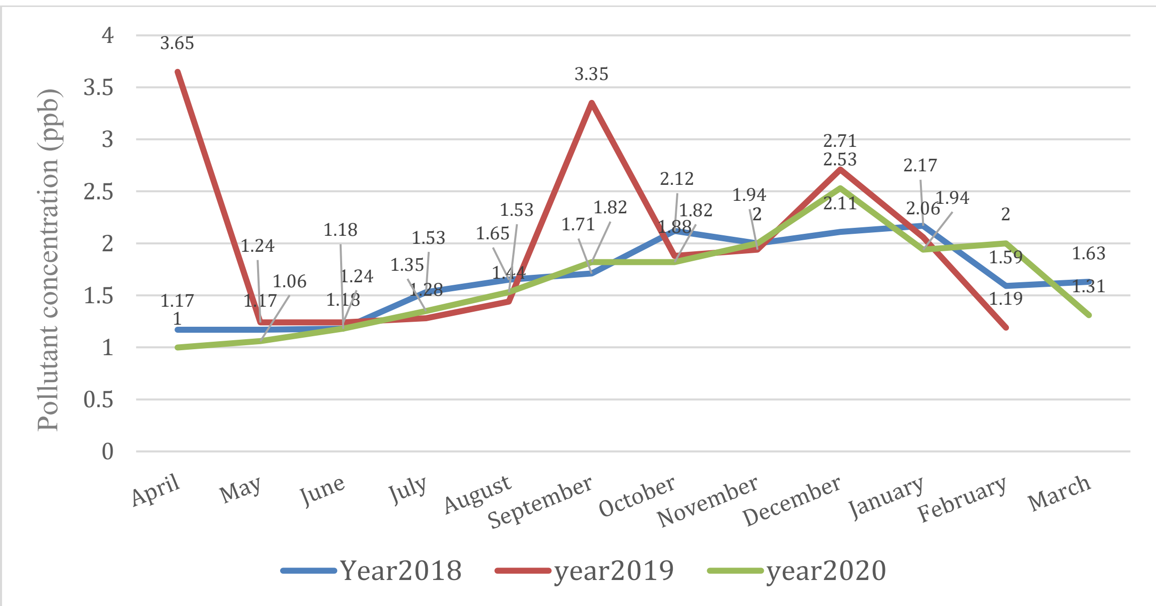

Fig. 9. Monthly concentration of air pollution (CO).

other indices, it tends to be higher during the cold months of the year.

Regarding the O_3 index, the analysis of variance results indicates that there were no significant changes in this index throughout the three-year period under study.

The monthly analysis of the O_3 air pollution index reveals a consistent trend across the three years of 2018, 2019, and 2020. However, during the hot months of the year, this index has exhibited a significant increase each year. In other words, the level of pollution has consistently risen during the hot months.

Regarding the CO index, the analysis of variance results indicates that there were no significant changes in this index throughout the three-year period under study.

The monthly analysis of the CO air pollution index reveals a consistent trend across the three years of 2018, 2019, and 2020. Although there are occasional spikes in the index during 2019, the overall trend of the index remains similar to the years 2018 and 2020. The statistical data and trends depicted in Figure 9 do not indicate significant changes. In other words, the level of contamination indicated by this index has remained relatively consistent over the three consecutive years.

CONCLUSIONS

Air pollution is a significant issue, particularly in large cities, and researchers are actively seeking new methods and technologies to identify and control this detrimental phenomenon. Urban air pollution encompasses a complex mixture of various toxic pollutants that greatly impact urban residents. In this study, the levels of these pollutants were extracted from air pollution monitoring stations for the three years prior to, during, and after the COVID-19 pandemic. The results were then compared to assess the impact of the pandemic-induced reduction in traffic and the shift towards virtual education on air pollution. The findings of this research revealed a decrease in the concentration of suspended particles smaller or equal than 2.5 µm and NO and NO_2 gases during the quarantine period and the virtualization of education. This reduction in traffic had a positive effect on air pollution, leading to a decrease in secondary pollutants. The primary objective of this study was to investigate the impact of virtual education during the COVID-19 pandemic on air pollution indicators, with the year 2019 representing the period of widespread virtual education. The results revealed that this mode of education can indeed influence the levels of air pollutants in Tehran. The reduction in traffic resulting from quarantine measures and the absence of university attendance led to a decrease in air pollutant levels.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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