

Forecasting Ambient Air Pollutants in Tehran, Iran

Azizallah Dehghan, Narges Khanjani, Abbas Bahrapour, Gholamreza Goudarzi, Masud Yunesian, Philip K. Hopke, and Aboubakr Jafarnezhad

ABSTRACT

Breathing healthy air is one of the most basic rights of human societies. Air pollution is currently one of the main global environmental health and justice concerns, because it is imposing its burden more severely on low socioeconomic regions and countries. Understanding the time pattern of these pollutants can help in better management and control. The aim of this study was to forecast ambient air pollutants by time series models in Tehran, Iran. This study was an ecological study about six ambient air pollutants (ozone [O₃], carbon monoxide [CO], nitrogen dioxide [NO₂], sulfur dioxide [SO₂], particulate matter [PM]₁₀ and PM_{2.5}) measured in Tehran during 2005–2018. Monthly mean values were calculated for each pollutant, and Holt-Winters models were used to predict values for the next 3 years (2019–2021). O₃, CO, NO₂, and SO₂ had a decreasing trend from 2005 until 2018, but PM₁₀ had an increasing trend. All pollutants showed a seasonal pattern. Higher concentrations of O₃ and PM₁₀ occurred in the warm months; and for CO and SO₂ higher concentrations occurred in the cool months. The forecasting models showed that PM₁₀ will increase, whereas other pollutants will decrease in the future. It can be concluded that in the next years (2019–2021), PM₁₀ could be a huge environmental problem for Tehran. Other pollutants have had a decreasing trend, but they still need surveillance.

Keywords: air pollution, time series, particulate matter, carbon monoxide, Tehran

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INTRODUCTION

AIR POLLUTION IS A complicated environmental health problem that endangers human life, especially in developing countries. Nowadays, air pollution has attracted the attention of researchers more than ever before.¹

Air pollution reduces visibility; causes eye irritation, cardiovascular and respiratory diseases, spontaneous abortion, and premature delivery; and reduces life

¹S.S. Yamamoto, R. Phalkey, and A.A. Malik. "A Systematic Review of Air Pollution as a Risk Factor for Cardiovascular Disease in South Asia: Limited Evidence from India and Pakistan." *International Journal of Hygiene and Environmental Health* 217 (2014): 133–144.

expectancy.^{2,3,4,5,6} It also causes global warming, loss of stratospheric ozone, and acidic rain.^{7,8}

Air pollution in developing countries is mainly due to overpopulation, vehicle malfunction, and the widespread use of fossil fuels. Urbanization and development of cities, inappropriate patterns of industrial development, and the improper location of facilities are also other important factors leading to air pollution.⁹ Each air pollutant affects human health in a different way. Particulate matter (PM), sulfur dioxide (SO₂), nitrogen oxides (NO_x), ozone (O₃), and carbon monoxide (CO) are the most important ambient air pollutants.^{6,10}

According to the World Health Organization (WHO), in 2016, ~91% of the world population was living in places where the WHO air quality guideline levels were not met. It is estimated that in 2016, outdoor air pollution in urban and rural areas caused 4.2 million premature deaths around the world; and nearly 91% of these premature deaths occurred in low- and middle-income countries, and most of these deaths were due to ischemic heart disease and strokes (58%), or chronic obstructive pulmonary diseases and acute lower respiratory infections (18%), and 6% of deaths were due to lung cancer.¹¹

²Maryam Dastoorpoor, Esmaeil Idani, Gholamreza Goudarzi, and Narges Khanjani. "Acute Effects of Air Pollution on Spontaneous Abortion, Premature Delivery, and Stillbirth in Ahvaz, Iran: A Time-Series Study." *Environmental Science and Pollution Research* 25 (Feb 2018): 5447–5458.

³Azizallah Dehghan, Narges Khanjani, Abbas Bahrampour, Gholamreza Goudarzi, and Masoud Yunesian. "The Relation Between Air Pollution and Respiratory Deaths in Tehran, Iran—Using Generalized Additive Models." *BMC Pulmonary Medicine* 18 (2018): 49.

⁴Azizallah Dehghan, Narges Khanjani, Abbas Bahrampour, Gholamreza Goudarzi, and Masoud Yunesian. "Short-Term Effects of Ambient (Outdoor) Air Pollution on Cardiovascular Death in Tehran, Iran—A Time Series Study." *Toxin Reviews* 39 (2020): 167–179.

⁵Manizheh Dadbakhsh, Narges Khanjani, and Abbas Bahrampour. "Death from Respiratory Diseases and Air Pollutants in Shiraz, Iran (2006–2012)." *Journal of Environment Pollution and Human Health* 3 (2015): 4–11.

⁶Mostafa Vahedian, Narges Khanjani, Moghaddameh Mirzaee, and Ali Koolivand. "Ambient Air Pollution and Daily Hospital Admissions for Cardiovascular Diseases in Arak, Iran." *ARYA Atherosclerosis* 13 (2017): 117.

⁷A. Falahati, K. Soheili, M. Nazifi, and S. Abbaspour. "Evaluation and Modeling the Effect of Air Pollution on Health: Using Artificial Neural Network." *Iranian Journal of Epidemiology* 9 (2013): 39–49.

⁸S.I.V. Sousa, J.C.M. Pires, E.M. Martins, J.D.N. Fortes, M.C.M. Alvim-Ferraz, and F.G. Martins. "Short-Term Effects of Air Pollution on Respiratory Morbidity at Rio de Janeiro—Part II: Health Assessment." *Environment International* 43 (2012): 1–5.

⁹Richard W. Atkinson, Antonis Analitis, Evangelia Samoli, Gary W. Fuller, David C. Green, Ian S. Mudway, Hugh R. Anderson, and Frank J. Kelly. "Short-Term Exposure to Traffic-Related Air Pollution and Daily Mortality in London, UK." *Journal of Exposure Science & Environmental Epidemiology* 26 (2016): 125–132.

¹⁰Ehsan Gharehchahi, Amir Hossein Mahvi, Hassan Amini, Ramin Nabizadeh, Ali Asghar Akhlaghi, Mansour Shamsipour, and Masud Yunesian. "Health Impact Assessment of Air Pollution in Shiraz, Iran: A Two-Part Study." *Journal of Environmental Health Science and Engineering* 11 (2013): 11.

¹¹WHO (2018) Ambient (outdoor) air pollution. <[https://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health)> (Last accessed on June 23, 2020).

Clean air and breathing in healthy air are one of the most basic rights of humans. Air pollution is currently one of the main global environmental health and justice concerns, because it is imposing its burden more severely on low socioeconomic regions and countries. In Tehran, air pollutants, especially PM, have higher concentrations in less privileged areas. Also, although regions with a higher rank in terms of socioeconomic status have a greater share in the production of pollution, they suffer less from the adverse effects of air pollution, because of their better economic, social, and educational status; and regions with the lowest socioeconomic rank are more likely to suffer from air and noise pollution, and face the consequences of environmental injustice.¹² Environmental justice is defined by the U.S. Environmental Protection Agency as "fair treatment and meaningful involvement of all people regardless of race, skin color, origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies."^{13,14}

In recent decades, various statistical models have been used for studying air pollution. Common descriptive statistics have limitations in interpreting the changes of ambient air pollutants. Although there are different models for prediction, such as regression, and artificial neural network, the time series model has been more popular and has been used to forecast air pollutant values in many cities around the world.^{15,16,17,18} Time series data are continuous observations recorded over time in a specific location.¹⁹ The main objective of time series analysis is picturing and forecasting the temporal changes of variables over time. Univariate time series methods can do forecasting better than other univariate models.¹² Holt-Winters is one of the most popular forecasting techniques for time series.

Several studies have predicted air pollution in Tehran. However, they differ from this study in terms of the

¹²S. Ghorbani, E. Salehi, S. Faryadi, and H.R. Jafari. "The Assessment of Environmental Justice in Tehran Based on Spatial Distribution of Air and Noise Pollution." *Geography and Sustainability of Environment* 32 (2019): 19–31.

¹³Kristy Langerman. "An Environmental Justice Perspective on Air Quality Offsets." *Clean Air Journal* 29 (2019): 1–14.

¹⁴Jordan Fox Besek, Erin E. Robinson, and Avery L. Rosenbloom. "Critical Environmental Justice Studies Through the Veil." *Environmental Justice* 13 (2020): 1–5.

¹⁵Ujjwal Kumar and V.K. Jain. "ARIMA Forecasting of Ambient Air Pollutants (O₃, NO, NO₂ and CO)." *Stochastic Environmental Research and Risk Assessment* 24 (2010): 751–760.

¹⁶Jason C. Lau, W.T. Hung, David D. Yuen, and C.S. Cheung. "Long-Memory Characteristics of Urban Roadside Air Quality." *Transportation Research Part D: Transport and Environment* 14 (2009): 353–359.

¹⁷Muhammad H. Lee, Nur H.A. Rahman, Mohd T. Latif, Maria E. Nor, and Nur A.B. Kamisan. "Seasonal ARIMA for Forecasting Air Pollution Index: A Case Study." *American Journal of Applied Sciences* 9 (2012): 570.

¹⁸G. Saffarinia and S. Odat. "Time Series Analysis of Air Pollution in Al-Hashimeya Town Zarqa, Jordan." *Jordan Journal of Earth and Environmental Sciences* 1 (2008): 63–72.

¹⁹R.L.R. Salcedo, M.C.M. Alvim Ferraz, C.A. Alves, and F.G. Martins. "Time-Series Analysis of Air Pollution Data." *Atmospheric Environment* 33 (1999): 2361–2372.

TABLE 1. MONTHLY DESCRIPTIVE STATISTICS OF AIR POLLUTANTS IN TEHRAN FROM 2005 TO 2018

Pollutants	Mean	Standard deviation	Minimum	25th percentile	Median	75th percentile	Maximum
O ₃ (ppb)	22.57	8.86	7	16.67	22.6	28	46.01
CO (ppm)	3.14	0.76	1.90	2.62	2.99	3.65	5.81
NO ₂ (ppb)	52.57	13.27	23	44.52	49.97	59.58	98.31
SO ₂ (ppb)	30.84	9.89	9	24.80	29.71	36.94	68.76
PM ₁₀ (µg/m ³)	73.19	13.57	34	63.78	71.97	80.90	117.03

CO, carbon monoxide; NO₂, nitrogen dioxide; O₃, ozone; PM, particulate matter; SO₂, sulfur dioxide.

period under study and the models used for prediction. Some have only made predictions for parts of Tehran.^{20,21} This is the first time series study conducted about air pollution in greater Tehran.

Tehran, the capital of Iran, has a population of more than 12 million people. It is one of the world's most polluted cities with respect to air pollution and lies in a geographical setting between mountains at an altitude of 3300 to 5000 feet. Like many mountain-valley locations, the topography has exacerbated Tehran's air pollution problems.²² The aim of this study was to determine the long-term variability of air pollutant concentrations in Tehran and predict the likely concentrations of ambient air pollutants for the next several years.

MATERIALS AND METHODS

Study plan

This study was based on the hourly air pollution data (CO, O₃, NO₂, SO₂, and PM₁₀) measured in Tehran, Iran. Data from March 2005 to February 2018 were acquired from the Tehran Province Environmental Protection Agency and the Tehran Air Quality Control Unit. There are currently 21 air quality monitoring stations supervised by the Municipality Air Quality Control Units and 16 stations supervised by the Tehran Province Environmental Protection Agency. However, most stations have been established in recent years and have only limited data. Thus, seven stations that had recorded air pollutant concentrations for at least 10 years and had the least missing data were selected.

²⁰M. Asghari and H. Nematzadeh. "Predicting Air Pollution in Tehran: Genetic Algorithm and Back Propagation Neural Network." *Journal of AI and Data Mining* 4 (2016): 49–54.

²¹Saba Fotouhi, M. Hassan Shirali-Shahreza, and Adel Mohammadpour. "Concentration Prediction of Air Pollutants in Tehran." In: *Proceedings of the International Conference on Smart Cities and Internet of Things*, (Mashhad Ferdowsi University, 2018), 1–7.

²²Ahmad Reza Hosseinpour, Mohammad Hossein Forouzanfar, Masoud Yunesian, Fariba Asghari, Koroush Holakouie Naieni, and Dariush Farhood. "Air Pollution and Hospitalization Due to Angina Pectoris in Tehran, Iran: A Time-Series Study." *Environmental Research* 99 (2005): 126–131.

Measurement, quality assurance, and quality control

In all stations, beta absorption (β attenuation) was used to measure PM₁₀. Ground level ozone (GLO) was detected by UV absorption instruments. Nitrogen oxides (NO and NO_x) and SO₂ were measured by using chemiluminescence and UV fluorescence, respectively. CO was measured by using infrared absorption. As part of the QA/QC program, calibrations for the instruments were performed at the time of installations. Daily inspections (regular and unprecedented), weekly zero check, span check, and semiannual interval calibrations were conducted by experts.

The reported measurement units differed from station to station and even within one station for different years. Therefore, the measurements at all stations were converted to a uniform set of units. The measurement units for O₃, SO₂, and nitrogen dioxide (NO₂) were converted to ppb. The unit for CO was ppm. The units for PM₁₀ and PM_{2.5} were µg/m³.

Statistical analysis

A spatiotemporal tool was used to detect outliers, and a range was defined for each observation. This range included 2-hour intervals before and after each observation in the same station and adjacent stations. Then, the mean and standard deviation was calculated for each spatiotemporal range and the values that were not within the mean \pm 2 standard deviation (SD), and were outliers, were deleted and considered missing data. More than 75% of the data of air pollutants was recorded every month and at all stations; for this reason, the monthly average of recorded data was calculated regardless of the hours when the data were not recorded.

In this study, we used trend analysis by Minitab 17 software to detect the trend, seasonality, and pattern of air pollutants. The Mean Absolute Percentage Error index was used to select the model. Also, the trend of pollutants was tested with the Mann-Kendall test by using the "Kendal" package in R software.

Because of the non-normal distribution of air pollution data, the Holt Winters model was used to predict data for the next 36 next months (March 2018–February 2021).

TABLE 2. SPEARMAN CORRELATION COEFFICIENTS BETWEEN AIR POLLUTANTS

	O_3	CO	NO_2	SO_2	PM_{10}
O_3	1				
CO	0.043	1			
NO_2	0.083	0.533**	1		
SO_2	0.272*	0.606**	0.455**	1	
PM_{10}	0.024	0.034	0.119	0.006	1

* $p < 0.01$.** $p < 0.001$.

The Holt Winters model is a prediction model that has been used since 1960 to predict the linear and seasonal trends of time series. This model uses the modified form of the exponential smoothing formula and applies three exponential smoothing steps:

1. The mean is smoothed to give a local average value for the series.
2. The trend is smoothed, and then each seasonal sub-series is smoothed separately to give a seasonal estimate for each season.

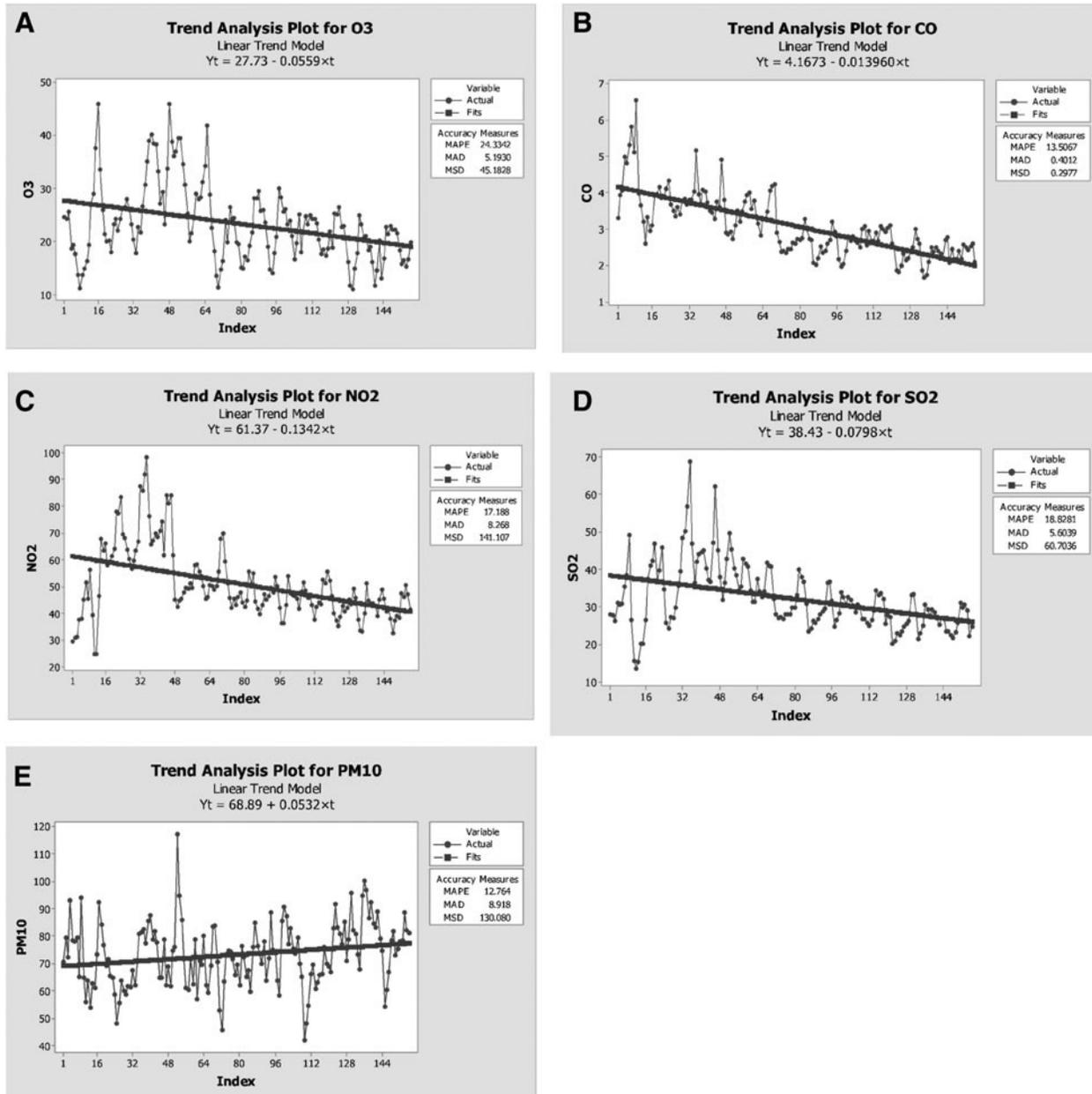


FIG. 1. The trend of air pollutants in Tehran from March 2005 until February 2018.

TABLE 3. ANNUAL AVERAGE OF AIR POLLUTANTS IN TEHRAN FROM 2005 TO 2018 AND THE AVERAGE FORECAST OF AIR POLLUTANTS FOR 2019 TO 2021

Time	PM ₁₀	SO ₂	NO ₂	CO	O ₃
Actual value					
March 2005 to February 2006	77.38	32.36	40.37	4.77	18.23
March 2006 to February 2007	69.10	29.59	57.53	3.55	27.15
March 2007 to February 2008	60.93	37.11	71.35	3.72	23.74
March 2008 to February 2009	78.37	45.91	75.11	3.92	34.50
March 2009 to February 2010	75.41	40.04	50.17	3.33	31.33
March 2010 to February 2011	70.49	36.77	53.56	3.49	24.03
March 2011 to February 2012	66.67	29.78	47.23	2.60	20.03
March 2012 to February 2013	72.85	29.55	46.93	2.52	22.38
March 2013 to February 2014	76.82	30.69	44.68	2.52	23.23
March 2014 to February 2015	62.16	29.42	46.82	2.86	21.55
March 2015 to February 2016	79.19	24.95	42.71	2.36	21.91
March 2016 to February 2017	85.84	27.29	41.62	2.23	21.28
March 2017 to February 2018	83.98	26.16	42.11	2.40	20.76
March 2018 to February 2019	81.47	23.36	44.16	2.33	19.38
Predicted value					
March 2019 to February 2020	84.86	23.08	41.76	2.01	18.23
March 2020 to February 2021	96.76	20.34	41.64	1.64	19.55
March 2021 to February 2022	108.67	18.14	41.52	1.26	18.19

3. The exponential smoothing formula is applied to the series with a trend and constant seasonal component by using the Holt Winters additive or multiplicative methods.²³

Minitab17 was used to calculate the descriptive indicators (mean, median, SD, minimum, maximum, and percentile) and draw the graphs of time series.

RESULTS

Table 1 presents the monthly descriptive statistics of air pollutants from March 2005 to February 2018 in Tehran, Iran. The annual averages of PM₁₀ and NO₂ are higher than the air quality standard values. Spearman correlation coefficients between the air pollutants are shown in Table 2. Some pollutants such as NO₂, SO₂, and CO were correlated. O₃ was correlated with SO₂.

Figure 1A–E shows the pollutant time trends. Figure 1A depicts the seasonal pattern for O₃. The maximum and minimum concentrations were observed in the warm (July, August, and September) and cool (November, December, and January) months, respectively. Decreasing trends can be seen in the O₃ plot ($p < 0.001$).

Ambient CO has significantly decreased during these years in Tehran ($p < 0.001$). Also, a seasonal pattern was observed with maximum and minimum levels in the cold (November, December, and January) and warm (July, August, and September) months, respectively (Fig. 1B).

NO₂ showed a seasonal and significant decreasing time trend ($p < 0.001$) (Fig. 1C). High concentrations of NO₂ were seen in October and November.

A significant seasonal pattern was seen for SO₂ (Fig. 1D), in which SO₂ concentrations were higher in the cold months (November and December). SO₂ showed a significant decreasing trend ($p < 0.001$).

PM₁₀ showed an increasing trend ($p = 0.011$) and seasonal variation during the time interval under study. The highest PM₁₀ concentrations occurred in June and July (Fig. 1).

The annual average of air pollutants in Tehran from 2005 to 2018, and the average forecast of air pollutants for 2019 to 2021 are shown in Table 3.

Forecasts for all pollutants can be seen in Figure 2A–E for 2019–2021. These forecasts indicate that if the sources of pollution continue emitting at their current rates and do not increase, except for PM₁₀, none of the pollutants under study will increase by 2021. And the trend of all pollutants will be decreasing. But the increasing trend of PM₁₀ is alarming.

Figure 3 shows Q-Q Plot charts for determining the fitness of prediction models. As can be seen, the forecasting models have a good fit for all pollutants under study.

DISCUSSION

Times series studies have been conducted to forecast air pollution levels in many world cities.^{16,24,25,26}

²⁴Inderjeet Kaushik and Rinki Melwani. "Time Series Analysis of Ambient Air Quality at ITO Intersection in Delhi (India)." *Journal of Environmental Research And Development* 2 (2007).

²⁵Mansouri Fatemeh, Narges Khanjani N, Laleh Ranadeh Kalankesh, and Reza Pourmousa. "Forecasting Air Pollutant Situation Using the Time Series Models in Kerman." *Scientific Journal of School of Public Health and Institute of Public Health Research* 11 (2013): 75–86.

²⁶R. Modares and A. Khosravi Dehkordi. "Daily Air Pollution Time Series Analysis of Isfahan City." *International Journal of Environmental Science & Technology* 2 (2005): 259–267.

²³Peter R. Winters. "Forecasting Sales by Exponentially Weighted Moving Averages." *Management Science* 6 (1960): 324–342.

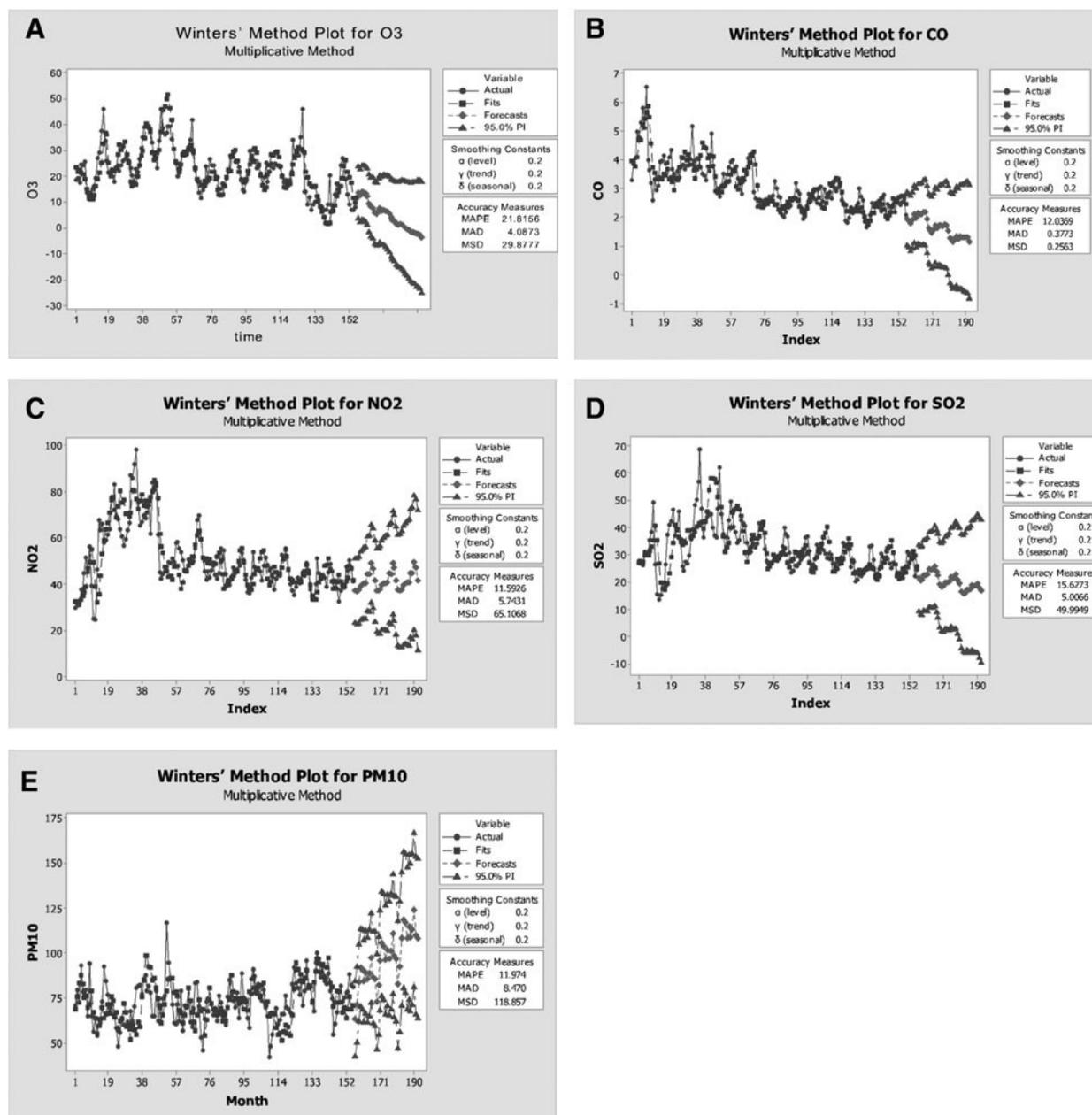


FIG. 2. The prediction of air pollutants in Tehran from 2019 until 2020.

A decreasing O₃ trend was observed in Tehran during 2005–2018. The highest average monthly concentrations for O₃ were in 2007 (34.50 ppb) and the lowest in 2017 (19.38 ppb), and they are predicted to decrease from 2019 to 2021 (Table 3). Nitrogen oxides, volatile organic compounds, heat, and sunlight are four main components that produce GLO.²⁷

Higher solar radiation and increased temperatures increase O₃ concentrations during the warm months.²⁸ This seasonal pattern for O₃ was observed in other studies^{12,15,29} as well. However, higher O₃ concentrations were reported during the cold months in Ahvaz in 2012.²⁵

²⁷Gholamreza Goudarzi, Sahar Geravandi, Hossein Forouzandeh, Ali Akbar Babaei, Nadali Alavi, Mehdi Vosoughi Niri, Mohammad Javad Khodayar, Shokrollah Salmanzadeh, and Mohammad Javad Mohammadi. "Cardiovascular and Respiratory Mortality Attributed to Ground-Level Ozone in Ahvaz, Iran." *Environmental Monitoring and Assessment* 187 (2015): 487.

²⁸C. Duenas, M.C. Fernández, S. Canete, J. Carretero, and E. Liger. "Stochastic Model to Forecast Ground-Level Ozone Concentration at Urban and Rural Areas." *Chemosphere* 61 (2005): 1379–1389.

²⁹Fengying Zhang, Wuyi Wang, Jinmei Lv, Thomas Krafft, and Jin Xu. "Time-series Studies on Air Pollution and Daily Outpatient Visits for Allergic Rhinitis in Beijing, China." *Science of the Total Environment* 409 (2011): 2486–2492.

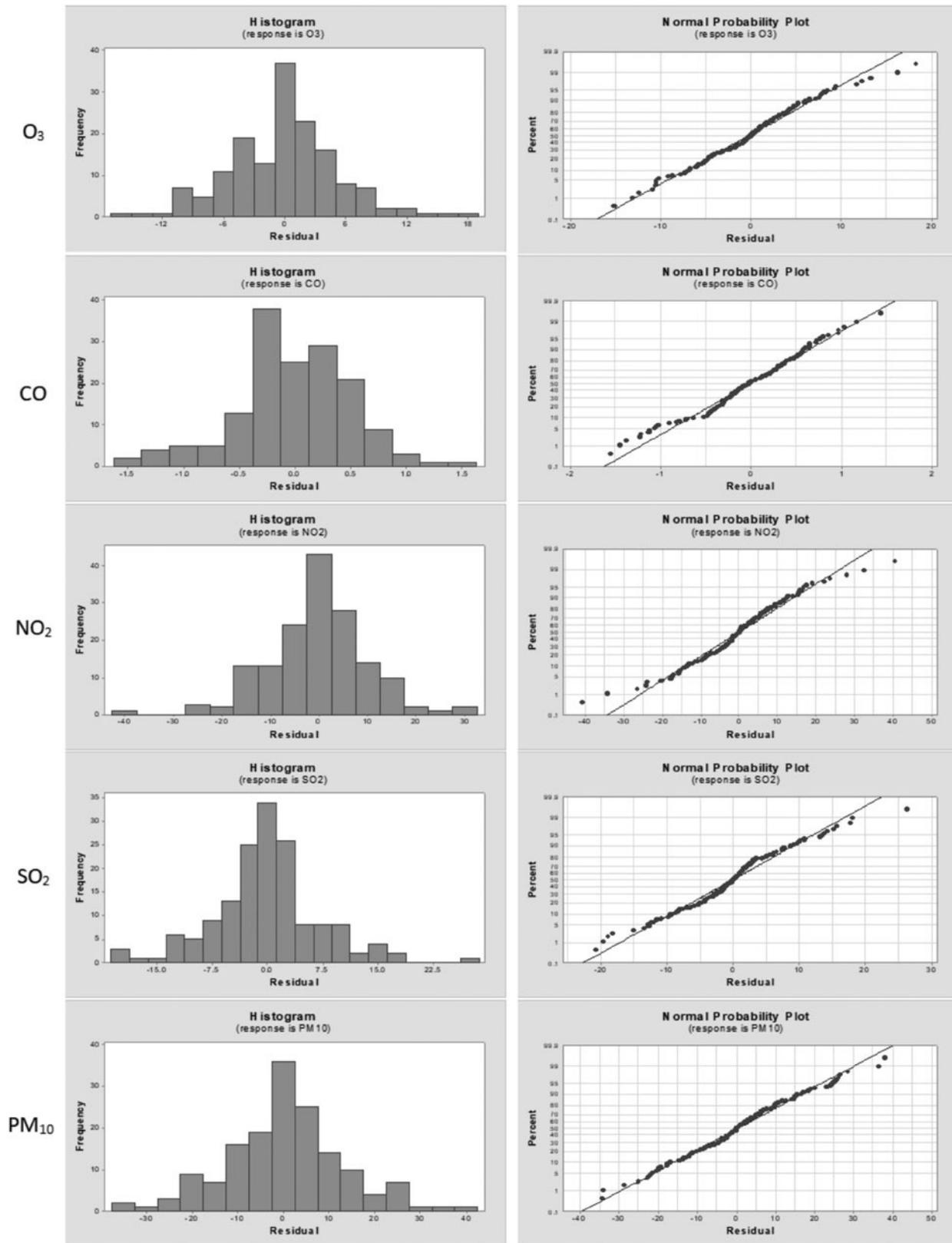


FIG. 3. The histogram and normal probability plots of the air pollutants.

CO had a decreasing and seasonal pattern in this study. The highest average monthly concentrations for CO were in 2005 (4.77 ppm) and the lowest in 2017 (2.33 ppm). CO is predicted to decrease from 2019 to 2021, and it will probably reach 1.26 ppm in 2021 (Table 3). Mansouri et al.²² also observed a decreasing and seasonal pattern for CO in Kerman, in southeastern Iran. However, Modarres et al. reported that in 2005, in Esfahan, in central Iran, CO was increasing.²³ Since June 2007, the quota system for fuel distribution has led to smarter fuel use, and reduced consumption of gasoline and diesel fuel in Iran. Also, the replacement of old vehicles with new ones and the increasing use of cleaner fuels such as compressed natural gas instead of gasoline have contributed to the decrease in CO concentration since 2007. CO concentrations are higher in the cold months of the year due to heating in houses and buildings and burning fossil fuels.

In this study, NO₂ also showed a decreasing trend, but NO₂ concentration is generally high in Tehran's air. The highest average monthly concentration for NO₂ was in 2007 (71.35 ppb) and the lowest in 2016 (41.62 ppb). NO₂ is predicted to decrease from 2019 to 2021. Fossil fuels are the main sources of NO₂.⁸ The decreasing trend of nitrogen oxides in Tehran can be related to recent smarter fuel consumption strategies and quota for gasoline and diesel distribution. However, Mansouri et al. reported an almost stable trend of NO₂ in Kerman, Iran.²²

In this study, SO₂ had a decreasing trend and a seasonal pattern. The highest average monthly concentration for SO₂ was in 2008 (45.91 ppb) and the lowest in 2018 (23.36 ppb). For the years 2019 to 2021, a decreasing trend is predicted; and it is likely to reach 18.14 ppb in 2021. In Kaushik et al.'s study in Delhi, SO₂ also had a seasonal pattern, and high concentrations were seen in cool months.²¹ However, Mansouri et al.'s study reported a stable trend for SO₂ in Kerman, Iran.²²

In recent years, the west part of Iran, from Ahvaz to Tabriz has suffered from the Middle East Dust storms.^{30,31} Tehran has also faced the consequences of these storms in the recent decade. Fine dust is one of the important air pollutants in cities and villages of Iran and is currently considered a serious health problem. Particles suspended in air are a matter of concern in environmental health, as they can enter the respiratory system and cause breathing and cardiovascular problems. Evidence suggests that the adverse health effects of suspended particles with diameters smaller than 10 (PM₁₀) micrometers are more than other pollutants. In this study, PM₁₀ had a seasonal pattern and

an increasing trend. The highest average monthly concentration for PM₁₀ was in 2016 (85.84 µg/m³) and the lowest in 2007 (60.93 µg/m³). An increasing trend is predicted for PM₁₀, and it will probably reach 108.67 µg/m³ in 2021. The study conducted in Kerman, Iran also showed that fine particles had an increasing trend over the years.²² Apparently, PM₁₀ reaches its maximum concentration in Tehran in September and October. However, PM₁₀ in some other cities, such as Kerman in the south east of Iran, has two peaks, one in May and one in October.²² Liu et al. also showed that PM₁₀ has a seasonal pattern in Taiwan, and maximum values are seen in spring.³²

The destruction of forests, building new dams and other destructive factors, as well as problems caused by the Iraq civil wars, vegetation loss, and degradation are a number of reasons for the increase in ambient PM in Iran.

Increasing vegetation around cities and villages, shrinking deserts, and cooperating with neighboring countries, especially Iraq, can help decrease ambient PM in Iran. Also, more restrictions on private vehicles, greater use of public transport, cleaner fuels, replacement of old cars, and routine vehicle inspections are necessary to decrease air pollution in Tehran.

Considering that several studies have shown a link between PM₁₀ and cardiovascular and respiratory diseases,^{3,4,33,34} the increasing trend of PM₁₀ can increase hospital referrals and deaths from cardiovascular and respiratory diseases, especially in the low socioeconomic groups, in the future years, in Tehran; and this is alarming for the health system.

CONCLUSIONS

PM₁₀ will probably increase in the next 3 years (2019–2021) in Tehran, Iran. Other air pollutants will probably not increase, but they should be under surveillance. Efforts should continue to manage ambient air pollution in Tehran, especially PM₁₀. Displacing industries from the west to the east of Tehran, using low sulfur fuels, supporting public transportation, minimizing the activity of industries particularly in cold seasons, and upgrading the level of auto manufactures to at least four or five Euro standards are recommended to reduce air pollution in Tehran.

AUTHORS' CONTRIBUTIONS

Dr. Dehghan is from Fasa University of Medical Sciences; Dr. Khanjani, Dr. Bahrapour, are from Kerman

³⁰Heidar Maleki, Armin Sorooshian, Gholamreza Goudarzi, Amirhossein Nikfal, and Mohammad Mehdi Baneshi. "Temporal Profile of PM10 and Associated Health Effects in One of the Most Polluted Cities of the World (Ahvaz, Iran) Between 2009 and 2014." *Aeolian Research* 22 (2016): 135–140.

³¹Mohammad Bagherian Marzouni, Toubia Alizadeh, Majid Rezaei Banafsheh, Ali Mohammad Khorshiddoust, Mohammad Ghanbari Ghozikali, Shayan Akbaripoor, Rahman Sharifi, and Gholamreza Goudarzi. "A Comparison of Health Impacts Assessment for PM10 During Two Successive Years in the Ambient Air of Kermanshah, Iran." *Atmospheric Pollution Research* 7 (2016): 768–774.

³²Pao-Wen Grace Liu. "Simulation of the Daily Average PM10 Concentrations at Ta-Liao with Box-Jenkins Time Series Models and Multivariate Analysis." *Atmospheric Environment* 43 (2009): 2104–2113.

³³Zhengmin Qian, Qingci He, Hung-Mo Lin, Lingli Kong, Duanping Liao, Jijun Dan, Christy M. Bentley, and Beiwei Wang. "Association of Daily Cause-Specific Mortality with Ambient Particle Air Pollution in Wuhan, China." *Environmental Research* 105 (2007): 380–389.

³⁴Jiandong Wang, Bin Zhao, Shuxiao Wang, Fumo Yang, Jia Xing, Lidia Morawska, Aijun Ding, et al. "Particulate Matter Pollution over China and the Effects of Control Policies." *Science of the Total Environment* 584 (2017): 426–447.

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