Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 54(10) (2023) 775-778
DOI: 10.22060/ceej.2022.19727.7245

Analytical study of the effect of nitrogen oxides, volatile organic compounds, and ambient temperature on ozone in Tehran

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ABSTRACT: The aim of this study is to evaluate the effect of nitrogen oxides (NOx), volatile organic compounds (VOCs), and ambient temperature on ozone (O3) concentration in the city of Tehran. In this regard, the hourly concentration for ozone and nitrogen oxides for the first half of 1396-98 were used. Moreover, the 2-weeks averaged data for BTEX monitored by passive sampling method and 30-minutes averaged temperature data monitored at Mehrabad airport were used. First, daily variations of ozone and nitrogen oxides with their corresponding indexes were analyzed. Then, the role of nitrogen oxide (NO) and nitrogen dioxide (NO2) on ozone concentration were investigated by statistical analysis. The results show a meaningful relationship between ozone and both nitrogen oxide and nitrogen dioxide with the coefficient of determinations of 0.83 and 0.8, respectively. Although an apparent increasing trend in ozone concentrations has been observed in recent years, however, no similar trends are detected for nitrogen oxide and nitrogen dioxide. The limited available data for BTEX, shows a 17.3% increase from 1394 to 1398. The daytime temperature analysis for the 30 days with the highest ozone concentrations showed an increasing trend from 1396 to 1398. Therefore, it can be concluded that the increasing trends of BTEX concentrations and ambient temperature were probably responsible for the increasing trend of ozone concentration in the study period.

Review History:

Received: May, 08, 2020
Revised: Apr. 24, 2022
Accepted: May, 16, 2022
Available Online: Jun. 08, 2022

Keywords:

Air pollution
Ozone
Nitrogen oxides
Volatile Organic Compounds
Temperature
Tehran

1- Introduction

The city of Tehran, with a population of more than 8.5 million people per night and more than 11 million people per day [1], faces a number of environmental challenges, including air pollution. Tehran has had an air pollution problem for more than forty years, which has been intensified by the uncontrolled growth of automobiles and an increase in fossil fuel consumption. The increase in the emission of pollutants as well as increases in the temperature and sunlight radiation in Tehran, has resulted in an increase in O_3 concentration. Consequently, O_3 has become one of the city's major pollutants, especially during the warm months of the year. Ozone is one of the criteria pollutants that has many adverse effects on human health, especially the respiratory system. A number of studies have been conducted in Tehran to investigate the O_3 trend and its relationship with NO_x, the most important of which were undertaken by Shariapour [2], Motesadi Zarandi, et al. [3], and Rafipour et al. [4]. These studies examined O_3 and NO_x trends and found a good correlation between the two. The role of NO_x in the production of O_3 has also been researched, and reducing nitrogen oxide emissions has been suggested as the most efficient way to reduce O_3. While O_3 concentration and its statistical relationship with NO_x and temperature have been evaluated in previous studies, the role of VOCs as an influential factor in O_3 concentration has not been discussed. For the first time, the effect of VOCs on the O_3 concentration has been examined in this study. On the other hand, due to the significant increase in the O_3 concentrations in recent years and the increase in the number of unhealthy days (based on O_3 concentration) from 7 days in 1396 to 25 days in 1398, the role of NO_x, VOCs, and ambient temperature is examined. As a result, this study aims to analyze the effect of NO, NO_2, VOCs, and ambient temperature on O_3 in Tehran from 1396 to 1398.

2- Methodology

The study area covers the 22 urban regions of Tehran designated by the Tehran Municipality. This study analyzes hourly data of O_3 and NO_x acquired from the 21 air quality monitoring stations operated by Air Quality Control Company (a subsidiary of Tehran Municipality) in the period from 1396 to 1398. Additionally, relevant data is extracted from the annual air quality reports for the years 96 [5] and 97 [6] published by the Air Quality Control Company. Furthermore, VOCs data was measured by passive method with a mean of two weeks. Also, the ambient temperature with a time interval of 30 minutes measured at Mehrabad meteorological station has been used.

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MATLAB and SPSS were used to analyze the trends and statistics. The calculations of daily and annual trends and correlations between NO and O_3 concentration data were conducted using MATLAB. In addition, statistical analysis was performed using SPSS.

3- Results and Discussion

The concentration of O_3 in the atmosphere depends on several factors, the most important of which are: environmental conditions (such as temperature, sunlight, and humidity), the concentration of precursors (NO_x, VOCs, carbon monoxide, etc.), and chemical reactions [7-9]. Chemical reactions are very complex. However, these processes can be simplified quite well. In general, the reactions between O_3, NO, and NO_2 can be expressed as follows: [7-9]

$$NO + O_3 \rightarrow NO_2 + O_2 \quad (1)$$

$$NO_2 + h\nu(+O_2) \rightarrow NO + O_3 \quad (2)$$

Thus, O_3 is produced directly from NO_2 in the presence of sunlight, then the products of Reaction (2) participate in Reaction (1) as reactants, consuming the O_3 produced and re-producing NO_2. Therefore, these two reactions are a closed (null) cycle with no pure chemical output and form an equilibrium between the species involved in the reaction. The equilibrium and the concentration of each species also depend on other factors such as environmental variables and the concentration of VOCs.

Figure 1 shows the cumulative average of NO, NO_2, and O_3 in the first half of 1396-98. As shown in the graph, the concentration of NO_x decreases during the day and with increasing sunlight. In addition, photochemical reactions increase the O_3 concentration.

The VOCs in August 1398 compared to August 1394 increased by 17.3%. The leading cause of significant changes in the average concentration of VOCs in the study period is toluene and xylene. However, the Mann-Whitney U test showed that the concentrations of all five BTEX pollutants measured in 1394 and 1398 were significantly different from each other ($p > 0.05$).

Considering the concentration of NO_x and VOCs in Tehran, it can be concluded that the equilibrium state of these species for ozone production is in the NOx-saturated state. Therefore, O_3 concentration is expected to increase with decreasing concentration of NO_x and increasing concentration of VOCs. Also, increasing the concentration of NO_x and reducing the concentration of VOCs reduce O_3 concentration. With the analysis performed during the study period, the concentration of NO_x did not show significant changes, while

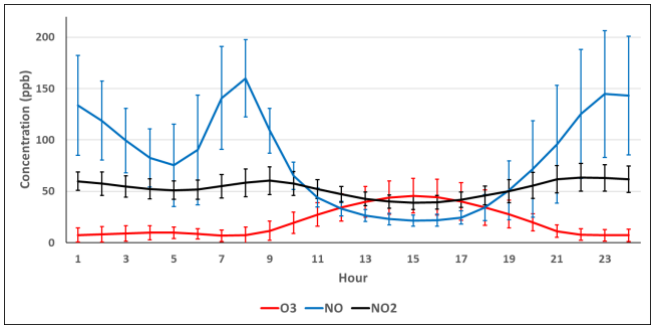

Fig. 1. cumulative average of NO, NO2, and O3

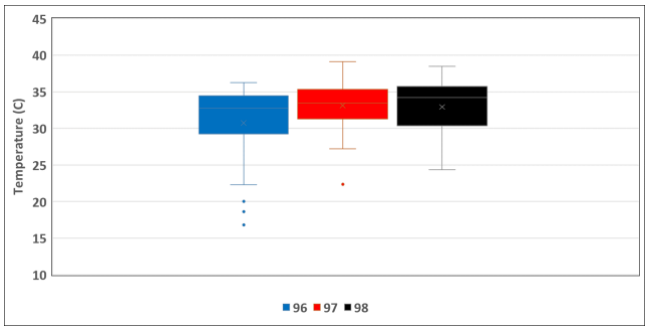

Fig. 2. Daytime temperature for 30 days with the highest average ozone concentration

the concentration of VOCs increased, which could be the reason for the increase in O_3 concentration in this period.

Figure 2 shows the daytime temperature for 30 days with the highest average ozone concentration. According to the figure, the average temperature from 1396 to 1398 had an upward trend. Furthermore, given the average increase from 1396 to 1398, it can be concluded that 15 days with the highest daily ozone concentration experienced higher temperatures in 1398 than in 1397 and 1397 compared to 1396. Therefore, the increase in temperature can be considered one of the factors that increased the ozone concentration from 96 to 98.

4- Conclusions

This study aimed to analyze the effect of NOx, VOCs, and temperature on O_3 in Tehran during the first half of 1396-98. Based on the studies performed, the results are as follows:

- NO and NO_2 have two peaks in the morning and evening, consistent with the traffic pattern.

- Contrary to the increasing trend observed for O_3, no specific changes are observed for NO_x. Therefore, it can be concluded that the changes in O_3 during this period were not due to an increase or decrease in NO_x.

- The average VOCs in the study period increased by 17.3%. Therefore, assuming a gradual increase in the period 94 to 98, this can also be considered as one of the reasons for the increase in O_3 concentration.

- With no noticeable changes in the concentration of NO_x and an increase in the average temperature and VOCs concentrations during the study period, temperature and VOCs can be considered the leading cause of the O_3 increase.

References

[1] Taheri, A., P. Aliasghari, and V. Hosseini, Black carbon and PM2.5 monitoring campaign on the roadside and residential urban background sites in the city of Tehran. Atmospheric Environment, 218 (2019) 116928.

[2] Shareipour Z., Evaluation of the temperature effect on Ozone and NOx concentration. 6th National Air and Noise Quality Management, (2017) (In persian).

[3] Motesadi S, M.A., Bagheri A, Sheykhmohammadi A, Production of tropospheric ozone and its precursors in Tehran city during 2001 to 2011. 16th National Conference on Environmental Health, (2017) (In persian).

[4] Rafipour M, A.A., Alimohammadi A, Sadeghi A, Investigation of Effective Meteorological Parameters on Ozone Concentration Using Principal Component Analysis. 2nd National Air and Noise Quality Management, (2013) (In persian).

[5] Tehran Annual Air and Noise Quality Report, 1396, Air Quality Control Company, Subsidiary of Tehran Municipality, adapted from air.tehran.ir, access date 1, November, (2019) (in Persian).

[6] Tehran Annual Air and Noise Quality Report, 1397, Air Quality Control Company, Subsidiary of Tehran Municipality, adapted from air.tehran.ir, access date 1, November, (2019) (in Persian).

[7] Leighton, P., Photochemistry of air pollution, Elsevier (2012).

[8] Jenkin, M.E. and K.C. Clemitshaw, Ozone and other secondary photochemical pollutants: chemical processes governing their formation in the planetary boundary layer. Atmospheric Environment, 34(16) (2000) 2499-2527.

[9] Wallington, T.J., J.H. Seinfeld, and J.R. Barker, 100 Years of progress in gas-phase atmospheric chemistry research. Meteorological Monographs, 59 (2019) 10.1-10.52.

HOW TO CITE THIS ARTICLE

A. Taheri, B. Khorsandi, M. R. Alavi Moghaddam, Analytical study of the effect of nitrogen oxides, volatile organic compounds, and ambient temperature on ozone in Tehran , Amirkabir J. Civil Eng., 54(10) (2023) 775-778.

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