AATCC Review

26 July 2024: Received
27 August 2024: Revised
04 October 2024: Accepted
05 November 2024: Available Online

https://aatcc.peerjournals.net/

Original Research Article Open Access

Evaluation of Temporal and Spatial Changes in Benzene-Toluene-Xylene Pollutants Levels in the atmosphere of Tehran, Iran

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ABSTRACT

This study evaluated spatial and temporal changes in Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) levels of ambient air in high-traffic highways of Tehran (Iran) individually during four seasons, 2021-2022. High traffic areas were selected in the study area. According to National Institute for Occupational Safety and Health method 1501, air samples were collected from 10 stations by personal air sampling pump and charcoal sorbent, extracted by carbon disulfide, and analyzed by gas chromatography-flame ionization detector. MATLAB software was used for spatial modeling of BTEX level changes and GIS software for zoning distribution of parameter level changes. The highest BTEX level was in the northwest regions, and the maximum pollution corresponded to autumn, especially the concentrations of benzene and toluene compounds, which were higher than the ambient air quality standards of Iran and the US Environmental Protection Agency. The highest amount of benzene was seen in the autumn season with an average value of 34.51 ppb and winter with an average value of 22.83 ppb, and the lowest amount of benzene was in the summer season with 22.84 ppb. The highest amount of toluene was 427.76 ppb in autumn and the lowest amount was 80.13 ppb in spring. The highest amount of xylene concentration with an average of 187.80 ppb was related to the summer season and the lowest amount was 0 ppb in autumn. The highest amount of ethylbenzene in summer was 95.67ppb. To conclude, there is a need to diminish and control the level of BTEX pollutants caused by transportation sources in Tehran.

Keywords: *Environmental measurement, Air Pollution, BTEX, Metropolitan city*

1. INTRODUCTION

Streets and highways are the main communication routes of cities, which are full of vehicles and cars due to the large population and poor transportation infrastructure. Heavy traffic and car congestion introduce combustion pollutants into urban environments. Air pollution caused by traffic congestion consists of various highly complicated compounds —–(Houot et al., 2015; Mostofie et al., 2014). Based on research results, Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) as one of these compounds are always present together with harmful effects on human health even in very low concentrations, which exist in higher amounts in urban and industrial environments (Muhibbu-din, 2020; Sekar et al., 2019). These substances are carcinogenic, mutagenic and harmful in the embryonic period (Rostami et al., 2012) and are classified as hazardous air pollutants (Abbasi et al., 2020; Fataei, 2020). One of the main sources of BTEX compounds are petroleum derivatives (Arabzadeh, 2018). In a study, the levels of volatile organic compounds (VOCs) were reported to be higher in unleaded gasoline than in leaded gasoline (Halek et al., 2004). The research results showed that the concentration of VOCs was very high near gas stations, and the level of hydrocarbons in these environments was especially high during refueling (Neghab et al., 2013).

Many studies have shown the connection between urban air pollution and these compounds as well as vehicles (Wallington et al.,2022; Khalek et al.2015). Toluene and benzene have been suggested as indicator pollutants for the contribution of traffic in the emission of volatile gases (Sadigh et al., 2021). An earlier study, investigated the emission of volatile gases in the urban area of Beijing and reported that benzene and toluene were the main sources of emission of these volatile gases around the area of vehicular traffic (Wang et al., 2012). Another study evaluated the role of BTEX pollution on the roadside and air in Algeria and found that the concentration of these pollutants on the roadside was two to three times higher than in urban areas, so that the average concentration of benzene and toluene on the roadside was 8.45 ppb and 10.35 ppb, respectively (Kerbachi et al., 2006). A group (Lan & Minh, 2013) measured the concentration of BTEX compounds at 17 road stations in urban areas of Vietnam and indicated that traffic, especially motorcycles, contributed the most to the emission of BTX pollutants. The daily concentration of benzene, toluene, ethylbenzene, para (p), meta (m)-xylene and ortho (o)-xylene were 17.53, 32.11, 4.87, 14.74, and 5.3 ppb, respectively. A research team (Masiol et al., 2014) conducted studies to control air pollutants including BTEX compounds from 2000 to 2013 in the eastern Po Valley, Italy, and determined that benzene/toluene ratio increased from 0.28 in 2000 to 0.5 in 2012 and was introduced as a traffic analysis index.

Ouabourane et al. (2015) in Morocco measured the concentration of BTEX (benzene, toluene and three xylene isomers) in the ambient air of large cities at four stations from

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DOI: https://doi.org/10.21276/AATCCReview.2024.12.04.198

February 2012 to November 2012, and observed no seasonal changes.

In a study by Zdanevitch et al. (2001) on September 22, 1998, 35 French cities participated in a pilot experiment involving a drastic reduction of vehicular traffic in city centers. The BTEX samples were collected over three days to determine the impact of traffic restrictions on air quality. Sampling locations were selected near the busiest traffic routes. During three days, the reduction in traffic flow resulted in a reduction of BTEX concentration in the streets of city centers between 30 % and 80 %. The correlation between BTEX and CO obviously showed traffic as the main source of air pollution.

Considering the harmful effects of BTEX on human health, it is vital to monitor and control the concentration of these compounds to prevent the resulting complications. To this end, examining the changes and modeling how their levels change in urban air is an effective step in the prediction and prevention of their resultant complications. Accordingly, the present study aimed to investigate the spatial and temporal changes in BTEX levels of ambient air in high-traffic highways in the west and northwest of Tehran, Iran, at 10 stations during four seasons between 2021 and 2022.

2. METHODS

Tehran, the most populous city and capital of Iran and Tehran province with a population of over 9,039,000 people in 2022, is the second most populous metropolis in the Middle East. The city suffers from serious air quality problems due to pollution causes including geographic factors such as the enclosing effect of mountains, vehicles such as cars and motorcycles, fuel from houses and pollution from factories. Air currents have a great influence on the weather of this city. The prevailing wind blowing from the west means that the west of the city is always exposed to fresh air; even though this wind brings smoke and pollution to the industrial areas of the west, its strong wind can take the polluted air out of Tehran city.

The current research was conducted between 2021 and 2022 in order to analyse the temporal and spatial changes in BTEX concentration in the ambient air of Tehran. Samples were collected from 10 stations during the peak traffic times, from 6 to 8 a.m. and from 4 to 6 p.m. (Table 1). Sampling was done on 3 days in each season. Sampling results were obtained daily. Sampling points were selected according to traffic volume and proximity to high traffic places. Proximity to gas stations was also a factor in choosing some places. Each sampling in each station had 3 replications. Figure 1 show the location of sampling point on the map.

Table 1. Geographical coordinates of sampling points

Station No.	Sampling points	Longitude	Latitude
1	Hakim expressway, corner of Geisha St	35/740937	51/374848
2	Hakim highway, Chamran corner	35/742644	51/383216
3	Hakim Expressway after Azadegan Blvd	35/753859	51/278739
4	Hammat Expressway, corner of Ayatollah Kashani Blvd	35/753859	51/278739
5	Hammet Expressway, Bakeri highway corner	35/753337	51/292365
6	Sheikh Fazlollah Nouri Expressway, corner of Jinnah Expressway	35/713066	51/334722
7	Sheikh Fazlollah Nouri Expressway, between Jinnah Highway and Sattari Expressway	35/715253	51/320576
8	Shahid Fahmideh Expressway, after Bakeri Expressway, Shishe Mina corner	35/716246	51/287274
9	Hakim Highway, Resalat Tunnel	35/744048007	51/4055
10	Hakim Highway, Azadegan Blvd	35/741076	51.397081

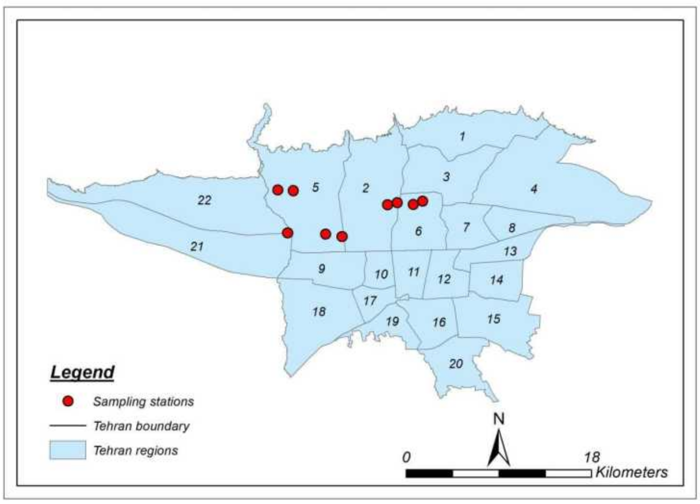

Fig. 1. Location of sampling point on the Tehran map.

BTEX concentration was measured according to National Institute for Occupational Safety and Health (NIOSH) method 1501 and sampling was done using SKC activated charcoal sorbent tubes. Vertically installed carbon tubes were used to collect air samples. The collection tubes contained 150 mg of charcoal from coconut wood, which were divided into two parts of 100 and 50 mg. These parts are made of glass wool and urethane foam, the larger one collects volatile gases and the smaller one is used when the larger part cannot collect all the gases. The present study used a personal air sampling pump (model 224-44EX, SKC) with a flow rate of 100 mL/min equipped with charcoal tubes. The flow pumps were calibrated at a flow rate of 270 mL/min, and the pressure drop was monitored across the charcoal tube using a manometer placed between the pumps and the charcoal tube. The allowable pressure drop was 2.5 cm Hg in a stream with a flow rate of 1 L/min. Temperature and atmospheric pressure were recorded during sampling. To measure the concentration of BTEX, charcoal was placed on the wall of a small sealed jar, followed by adding 1 mL of carbon disulfide (CS_2). The sample was ultra-sonicated with this mixture for 3 to 5 minutes. Then, 2 ml of the sample was injected into a gas chromatography-flame ionization detector (GC-FID). Similarly, smaller sections were processed to ensure the accuracy of the sample. First, an aliquot of CS_2 was added to 100 mg of charcoal in a beaker. The small sealed jar was kept overnight for complete absorption of CS_2 into the charcoal. Another tube containing 100 mg of charcoal (but free of CS_2) was similarly sealed and kept overnight. After that, they were compared with the standard solution; sample preparation and pollutant extraction were done by CS_2 solvent and the samples were analyzed by GC-FID (Agilent detector, model 6890N).

In the standard solution, different amounts of charcoal were added to one mL of CS2.

MATLAB software was used to design and present the spatial model of changes in BTEX levels at the studied stations, and Geographic Information System (GIS) was used for zoning the spatial changes of BTEX concentration at the studied stations in the west and northwest of Tehran during different seasons.

3. RESULTS

3.1 Seasonal changes in ambient air BTEX levels

Figure 2 shows the changes in the average concentration of BTEX during different seasons at 10 stations measured in the western and northwestern regions of Tehran. The concentration of toluene was the highest in all seasons, with the highest level (427.76 ppb) in autumn and the lowest level (80.13 ppb) in spring.

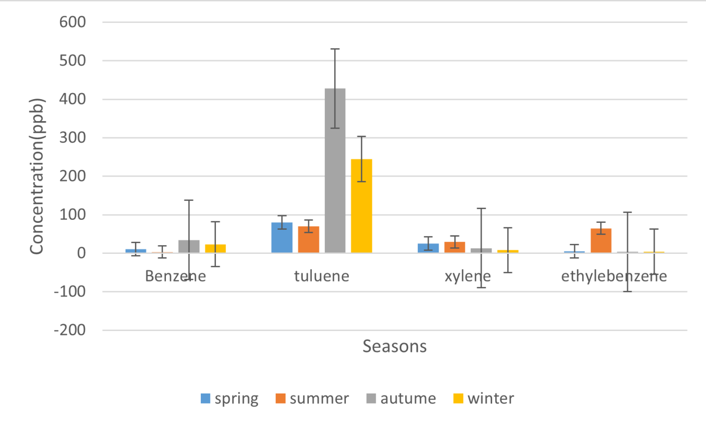

Fig. 2. Average concentration of BTEX during different seasons at 10 stations measured in the western and northwestern regions of Tehran, Iran, 2020-2021

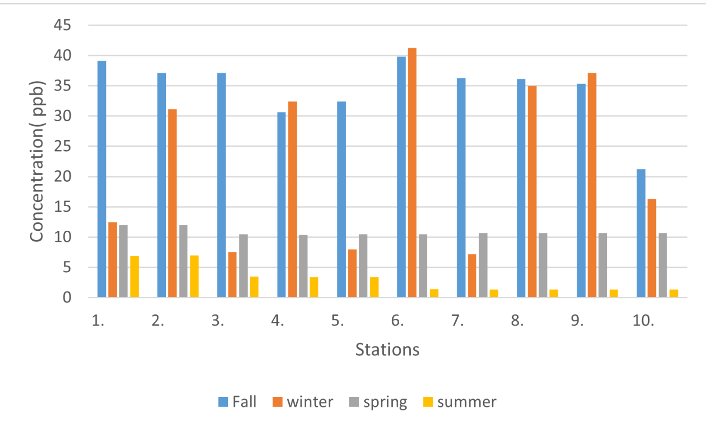

Fig. 3. Seasonal changes in benzene concentration during different seasons at 10 stations measured in the western and northwestern regions of Tehran, Iran, 2020-2021

Figure (4) shows seasonal changes in toluene concentration; as can be seen, the concentration of toluene was the highest in autumn and summer and the lowest was in winter.

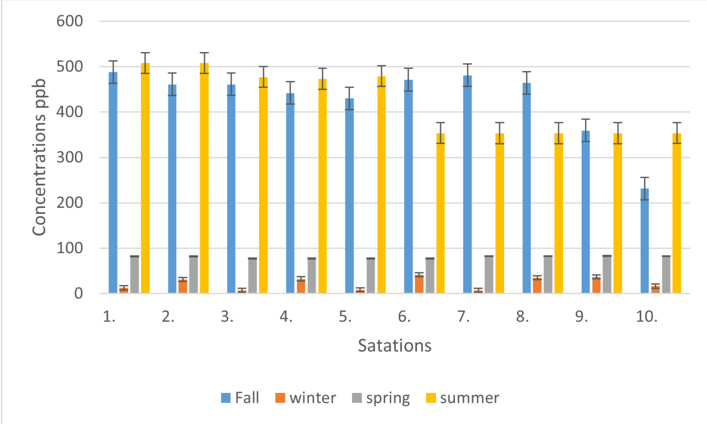

Fig. 4. Seasonal changes in toluene concentration during different seasons at 10 stations measured in the western and northwestern regions of Tehran, Iran, 2020-2021

Based on the results presented in Figure 5, the highest concentration of ethylbenzene was found at all stations in summer, with the highest amount at Station 1 (95.67).

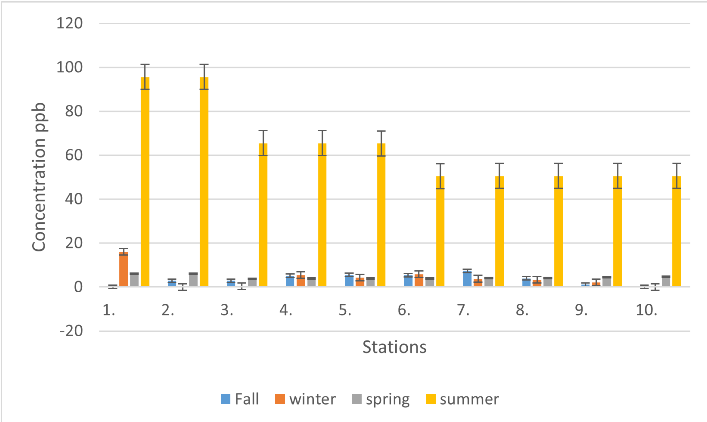

Fig. 5. Seasonal changes in ethylbenzene concentration during different seasons at 10 stations measured in the western and northwestern regions of Tehran, Iran, 2020-2021

Seasonal changes in xylene concentration (Figure 6) revealed that the highest concentration with an average of 187.80 ppb was related to summer, with the highest value at Stations 6 (328.18 ppb), 7 (328.11 ppb) and 8 (328.01 ppb), respectively. The lowest concentration of xylene was in autumn, so that, except for Stations 4 and 6 with values of 5.49 and 30.04 ppb, respectively, its value was zero in the rest of the stations.

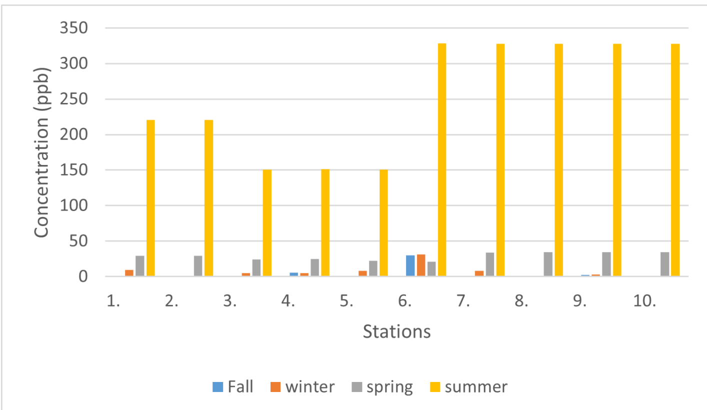

Fig. 6. Seasonal changes in xylene concentration during different seasons at 10 stations measured in the western and northwestern regions of Tehran, Iran, 2020-2021

3.2 Spatial changes in the ambient air BTEX levels

In this study, GIS software was used to indicate the distribution of BTEX concentration changes at studied stations. The values of parameters were grouped at five levels of pollution, including very high, high, medium, low and very low, as follows:

Spring: The analysis of the data measured in this season showed that although the concentrations of benzene and ethylbenzene were the lowest, the highest level was in the northwest stations compared to the western stations. The concentrations of toluene and xylene measured at all stations had high values, so that the pollution level was very high in the northwest and high in the west of Tehran (Figure 7). During this season, Stations 1 and 2 consistently had the highest BTEX concentrations.

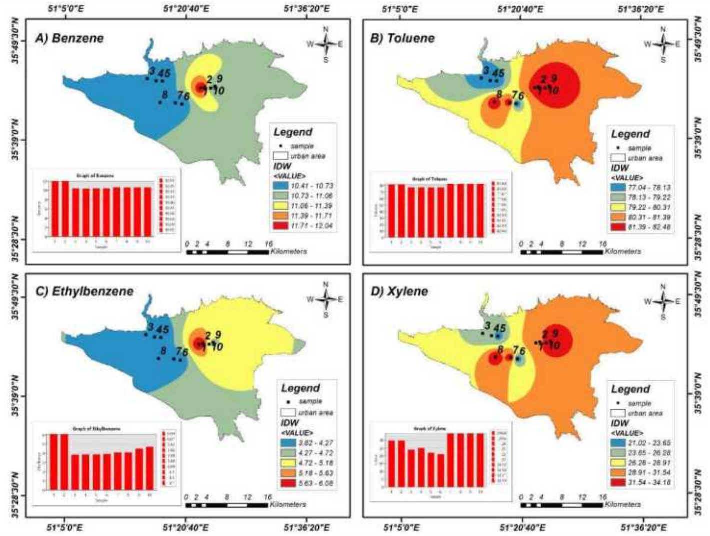

Fig. 7. Zoning of BTEX concentration changes at the western and northwestern sampling stations of Tehran, Iran, in spring, 2020-2021

Summer: The BTEX concentrations measured in this season indicated that the highest amount in medium to high levels was related to xylene in the central and eastern parts of the study area (Figure 8). Stations 1 and 2 located at the northwest of the study area had the highest concentration of benzene, toluene and ethylbenzene.

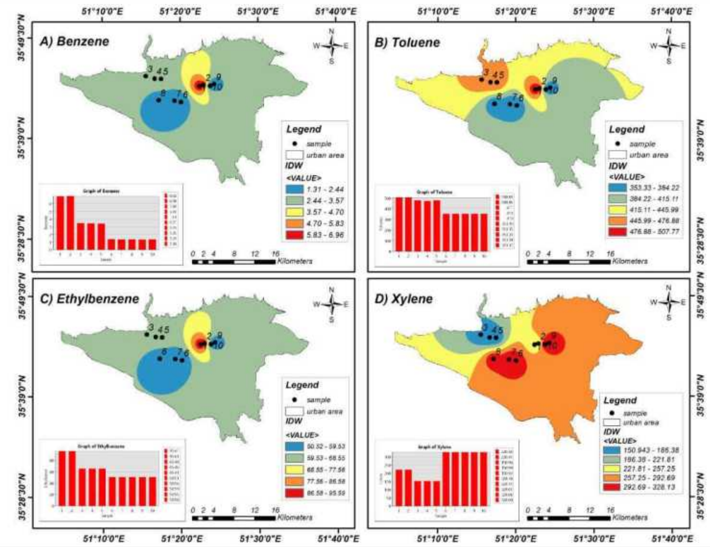

Fig. 8. Zoning of BTEX concentration changes at the western and northwestern sampling stations of Tehran, Iran, in summer, 2020-2021

Autumn: The concentrations of benzene, toluene, ethylbenzene, p-xylene and xylene were measured in this season, the results of which indicated the high level of toluene in the western half of the study area (Figure 9). Most of the study area showed high levels of benzene pollution, while most of the studied area was at a low level in terms of p-xylene pollution.

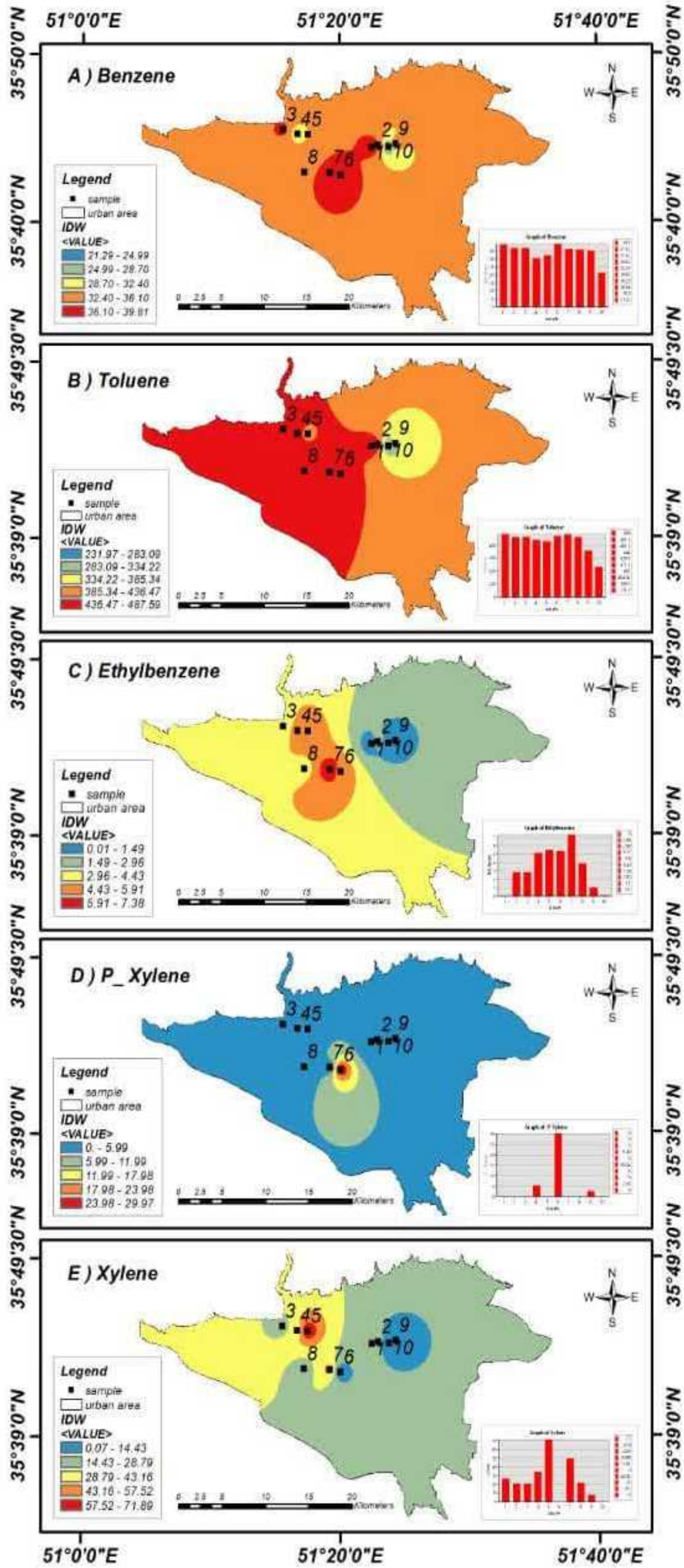

Fig. 9. Zoning of BTEX concentration changes at the western and northwestern sampling stations of Tehran, Iran, in autumn, 2020-2021

Winter: The concentrations of benzene, toluene, ethylbenzene, p-xylene, o-xylene and m-xylene measured in this season showed pollution at very low to low levels in a wide range of sampling stations. Only Stations 6 and 8 had the highest toluene level (Figure 10).

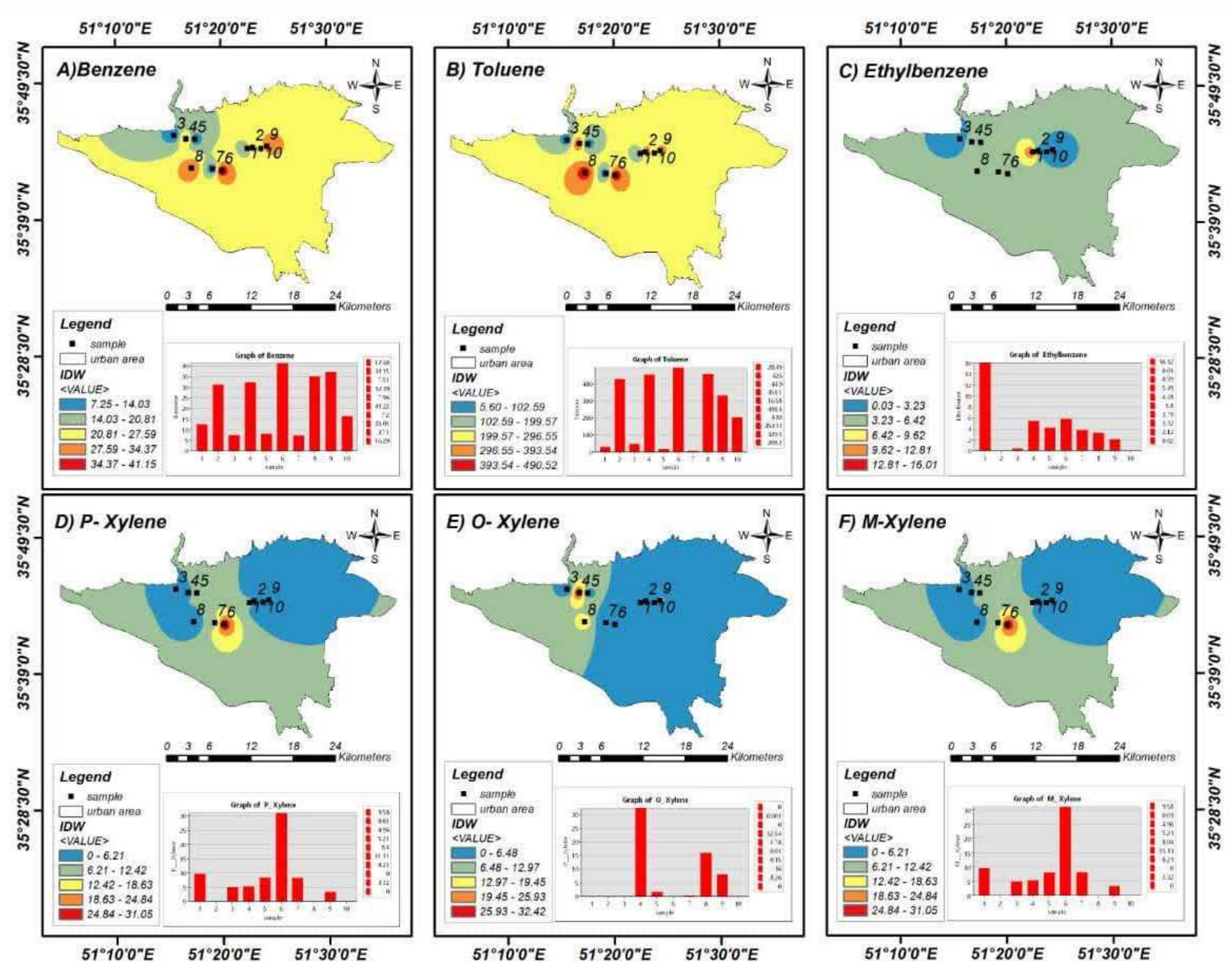

Fig. 10. Zoning of BTEX concentration changes at the western and northwestern sampling stations of Tehran, Iran, in Winter, 2020-2021

Based on the benzene concentrations measured in different stations and seasons in the western and northwestern regions of Tehran and applying topographical conditions in the modeling through the MATLAB program (Figure 11), it was found that there was a significant difference in the concentration of benzene in the central and northwestern regions of Tehran, with the highest values in the northwestern region and the lowest values in the western region.

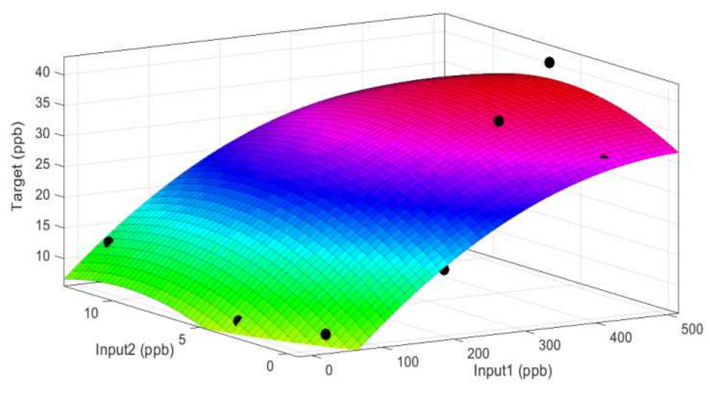

Fig. 11. Benzene concentration based on linear model in 10 points

5. DISCUSSION

The measurement of benzene concentrations at noon indicated that Station 4 had the lowest value in highway sampling, while Station 6 showed the highest value as in morning sampling. The lowest value corresponded to Station 10. In general, the concentration of benzene at noon showed a lower value than in the morning; this difference could be due to the wind blowing at noon because the wind speed has an inverse relationship with the concentration of benzene (Khani et al., 2018). The half-life of benzene in the air is two days, and increasing temperature and sunlight cause faster decomposition of benzene (Hoque et al., 2008; Muhibbu-din & Isaac, 2021), so this issue can also be a reason for its decrease in noon time. On the other hand, the high traffic load can be the most important factor, so that the amount of traffic in the morning is more than in the afternoon; the concentration of o-xylene also showed the highest level in morning sampling at Station 5. Moreover, the results indicated that the concentration of ethylbenzene was higher in night sampling; the cooler air in these areas can be considered to be involved, so that the decrease in temperature seems to have an effect on BTX values (Salmani et al., 2017). It seems that the cooling of the air can lead to a decrease in the level of o-xylene. T Temperature affects the concentration of this pollutant. In addition, the concentration of toluene in noon and night sampling indicated that the level of toluene decreases with the

decrease in the amount of traffic; this conclusion was also reached in the city of Yazd, Iran (Mohammadi et al., 2016). The low amounts of xylene indicate its presence in photochemical reactions that react with free OH radicals to produce ozone(Hamid et al.,2019).
Seasonal changes in BTEX concentration showed that the highest benzene concentration was seen in autumn (34.51 ppb) and the lowest benzene concentration was in winter (22.83 ppb). A study reached similar results and stated that the inversion could be a reason for the high level of benzene in winter (Pakfard et al., 2017). In determining the VOC concentration in an industrial city in the south of France (Roukos et al., 2009), the results showed that the concentration of these compounds was higher in winter than in summer, in line with the present results. The concentration of toluene was the highest in summer and autumn, respectively, and the lowest in spring. Based on the results, the highest concentration of ethylbenzene was measured in summer at all study stations. Seasonal changes in xylene levels revealed that the highest and lowest concentrations were in autumn and spring, respectively. The study, which was carried out at Naples, showed that the values were reduced during summer and this is due to a rise of sun radiation And that in the hot months, photo degradation is more (Iovino et al.,2009). The rate of degradation of BTX in the air varies (Ho et al., 2004).
Toluene and benzene compounds are known as traffic indicator pollutants due to their high concentrations during traffic congestion (Borhani et al., 2017). The results of the present study demonstrated the highest concentration of benzene at Station 6 (39.82 ppb). It can be claimed that the presence of the passenger terminal, the proximity to industrial centers and the high traffic are among the reasons for this. The lowest level of this parameter was related to Station 10 (21.22 ppb) where the area is residential and has less traffic volume. The results obtained are consistent with other researches (Khani et al., 2018) regarding the compliance of air benzene concentration with the concentration of urban and industrial pollutants. A study reported the traffic of motorcycles and cars in Tehran as a cause of hydrocarbon emissions (Hassani & Hosseini, 2016). Additionally, earlier research results showed that industrial activities and transportation vehicles were the most important sources of high concentrations of VOCs, nitrogen dioxide and sulfur dioxide(Civan et al., 2015).
According to the results, the concentration of ethylbenzene had the highest average (26.14 ppb) at Station 2, with the highest level in summer (95.61 ppb). It can be argued that the presence of the hospital and Milad Tower, as well as the proximity to Goftogu Park, sports and university centers, has increased the traffic volume, transportation load and ethylbenzene concentration. The main source of ethylbenzene is vehicle fuel (Miri et al.,2016). The highest concentration of xylene was measured at Station 6. In the reasoning of this finding, the existence of the bus repair shop of the municipal bus company, gas station, technical and development deputy of Tehran fire department, training center of fire department, food laboratory and shopping malls caused an increase in the amount of traffic and as a result, an increase in the concentration of xylene. As the volume of traffic decreased, the concentration of toluene decreased, so that a study in the city of Yazd, Iran, also reached this conclusion (Mohammadi et al., 2016). In the study of changes in the concentration of benzene and toluene in Yazd, the findings showed that the spatial changes of these pollutants were significantly different from one area to another (Mokhtari et al., 2016). This finding has also been reported in different cities, including Ahvaz, Iran (Fazlzadeh Davil et al., 2011), Tehran, Iran (Fazlzadeh Davil et al., 2011), Delhi, India (Hoque et al., 2008), and the villages of northern Spain (Gonzalez, 2006); the main reason for this conclusion is attributed to the variable volume of traffic. IDW method shown the same result in Shiraz city (abbasi et al., 2020).

6. CONCLUSION

Various anthropogenic and natural factors, including topographic conditions and inversion, topography and climatic factors, population explosion and traffic congestion, and industrial overdevelopment, have put Tehran in the group of the most polluted cities in the world. The results of the present study showed spatial and temporal changes in the concentration of BTEX pollutants in the western and north-western regions of Tehran, Iran, at 10 sampling stations. The highest mean level of BTEX pollution was found in the northwest of Tehran, and the highest amount of pollution was related to autumn. Among the BTEX pollutants, the toluene had the highest concentration over the rest of the parameters at all stations. The main source of BTEX pollutants in Tehran can be attributed to the high volume of traffic, as confirmed by high values in busy and traffic nodes. At the winter benzene shown the highest concentration (41.22 ppb). Higher amount of xylene was seen at summer (between 150-3210 ppb). Highest amount of toluene also seen at summer (508.06 ppm). Ethyl benzene concentration at summer was higher than other seasons (65.41ppb).
Consequently, there is a need to reduce and control the level of BTEX pollutants in transportation sources in Tehran. Since these compounds have a high potential for emission, it is recommended to continuously monitor these pollutants along with control measures, check public health to determine the consequences of exposure to these pollutants, especially in regions and seasons where the amount of pollutants exceeds the standards.

Statements and Declarations

Conflicts of Interest

The authors have declared no conflicts of interest.

Funding

There are no funding.

Data Availability Statement

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contribution

Arsalan Keramat & Shahrzad khoramnejadian: conceived and designed the analysis; Collected the data; Contributed data or analysis tools; Performed the analysis and wrote the papaert. farid Gholamerza Fahimi and Samira Ghiasi contributed in Wrote the paper and analysis data.

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