

Source identification, spatial distribution and ozone formation potential of benzene, toluene, ethylbenzene, and xylene (BTEX) emissions in Zarand, an industrial city of southeastern Iran

Mohammad Malakootian^{1,2}, Sobhan Maleki^{1,2}, Saeed Rajabi^{3,4}, Fatemeh Hasanzadeh², Alireza Nasiri¹, Amir Mohammadi⁵, Maryam Faraji^{1,2,*}

¹ Environmental Health Engineering Research Center, Kerman University of Medical Sciences, Kerman, Iran

² Department of Environmental Health Engineering, Faculty of Public Health, Kerman University of Medical Sciences, Kerman, Iran

³ Department of Environmental Health Engineering, School of Health, Shiraz University of Medical Sciences, Shiraz, Iran

⁴ Student Research Committee, Shiraz University of Medical Sciences, Shiraz, Iran

⁵ Department of Public Health, School of Nursing and Midwifery, Maragheh University of Medical Sciences, Maragheh, Iran

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CORRESPONDING AUTHOR:

m.faraji@kmu.ac.ir

Tel: (+98 34) 31325103

Fax: (+98 34) 31325103

ABSTRACT

Introduction: Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) as the ozone precursors have been classified as the hazardous air pollutants because of their negative effects on humans. This article presents the results of the first assessment of source identification, spatial distribution and BTEX's Ozone-Forming Potential (OFP) in Zarand.

Materials and methods: The current study was conducted at 30 geographically separated locations, in Zarand, Kerman, southeastern Iran, during the summer and winter of 2020. BTEX samples were collected using passive samplers and then analyzed using Gas Chromatography-Mass Spectrometry (GC-MS). Spatial variations were surveyed using the Kriging method in GIS.

Results: Total BTEX levels ($79.26 \pm 26.87 \mu\text{g}/\text{m}^3$) during the summer were greater than their levels in the winter ($37.38 \pm 29.18 \mu\text{g}/\text{m}^3$). The ranking of BTEX level in all samples followed as: toluene > m,p-xylene > o-xylene > ethylbenzene > benzene. The overall OFP of $374.79 \pm 135.08 \mu\text{g}/\text{m}^3$ in the summer and $172.61 \pm 148.81 \mu\text{g}/\text{m}^3$ in the winter were more than $100 \mu\text{g}/\text{m}^3$ as recommended guideline defined by World Health Organization (WHO), with toluene having the highest potential.

Conclusion: According to the results of the present study, BTEX relative abundances in all samples were toluene > m,p-xylene > o-xylene > ethylbenzene > benzene. Despite of concerns among inhabitants and workers, benzene concentration was lower than other studied species. Control measures such as management of fuel use in motor vehicles and industries and development of green space must be adopted to attenuate the level of toluene in the atmosphere in the studied area.

Introduction

Air pollution has considered as one of the most important environmental challenges in the world

[1]. The primary sources of air pollution are industrial operations, automobile transportation, and residential activities. Criteria air pollutants (O_3 , SO_2 , NO_2 , CO , and Particulate Matter (PM))

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and Volatile Organic Compounds (VOCs) are considered as the main air pollutants [2, 3]. VOCs release in the environment primarily through vehicle exhausts, gasoline and diesel vapors, leakage from Liquefied Petroleum and Compressed Natural Gas (LPG and CNG) sources, and industrial activities mainly petrochemical operations [4]. VOCs contribute to the depletion of the stratospheric ozone layer, tropospheric ozone production, global warming, and other adverse consequences on the environment. According to the International Agency for Research on Cancer (IARC), the most significant VOCs are benzene, toluene, ethylbenzene, and xylene (often known as BTEX), which are considered to be carcinogenic compounds (class 1 for benzene, 2B for ethylbenzene and 3 for the rest) [2, 5].

Benzene, the most carcinogenic of the BTEXs, can cause long-term effects in the biological system of the human body, including leukemia, hematological diseases, and myelodysplastic syndrome. The national annual standard for benzene has been defined to be $5 \mu\text{g}/\text{m}^3$. Toluene, ethylbenzene, and xylene, on the other hand, can affect the liver, kidneys, respiratory and reproductive systems, as well as the central nervous system [2, 6].

VOCs have Ozone Formation Potential (OFP) because they cause photochemical reactions with sunlight, resulting in radicals such as hydroxyl radicals ($\bullet\text{OH}$), which set off further processes. In the presence of sunlight, hydroxyl radicals create peroxy radicals (RO), which combine with Nitric acid (NO) to produce Nitrogen dioxide (NO_2), which eventually leads to tropospheric ozone formation. Asthma, diminished lung capacity, cough, shortness of breath, and eye irritation may cause by exposure to the tropospheric ozone. High concentrations of ozone, on the other hand, can damage plant crops and diminish plant growth and yield [7].

Sampling and analyzing VOCs in the ambient air is critical for determining their health effects. Therefore, a reliable technique needed for precise measurement [8]. Passive sampling method

has been acknowledged as effective method for air quality monitoring [9]. It can replace to the active sampling method in the more cost-effective, simple, reliable, and environmentally friendly approach. Long-term exposure to the air pollutants can also be determined using passive sampling method [10-12].

The purpose of the present study was to determine the levels of BTEX species and the OFP originated from BTEX compounds in the ambient air of Zarand, and assess possible sources and spatial distribution for the first time to the best of our knowledge. This study was done due to the health concerns among citizens and industrial workers resulting from presence of several industries in this area.

Materials and methods

Study area

Present study was done in Zarand (latitude $30^\circ 81'$, longitude $56^\circ 57'$) (Fig. 1), an industrial area located in the southeastern Iran), including several industrial units such as thermal power station, coal washing, tar cooking and refining complex, wagon manufacturing, and iron ore production. The Zarand city is semi-desert and it has relatively hot summers and cold winters. Average temperature was 37.8°C and 13°C in the sampling period in summer and winter, respectively [13]. The average rainfall in Zarand is 140 mm and the maximum rainfall is in December with 34.1 mm.

Sampling and measurement methods

Thirty air samples were collected in the selected points in Zarand city through the passive sampling method in each season. The passive samplers were purchased from Zist-Sephr Beyhagh (www.ZSBcompany.ir). They included granular charcoal in an open-ended glass tube. The ends of the tube were fixed by two porous plugs of cellulose acetate that act as diffusion barriers during operation. The tube was placed in a glass vial of a PTFE coated screw cap to avoid contamination during transport and storage. The

samplers were installed at the height of 1.5 m from ground level. All samplers were installed on the same day, collected after 30 days periods during summer (from 6 August to 5 September) and winter (from 23 January to 22 February) of 2020, and transferred to the laboratory in cool condition as soon as possible.

BTEXs were extracted from charcoal by the carbon disulfide (CS_2) and analyzed by a gas chromatography-mass spectrometry detector (GC-MS, model CP-3800 gas chromatography and Saturn 2200 mass spectrometer, Varian Technologies Japan Inc., Japan). Details of the GC-MS analysis is reported in Table 1.

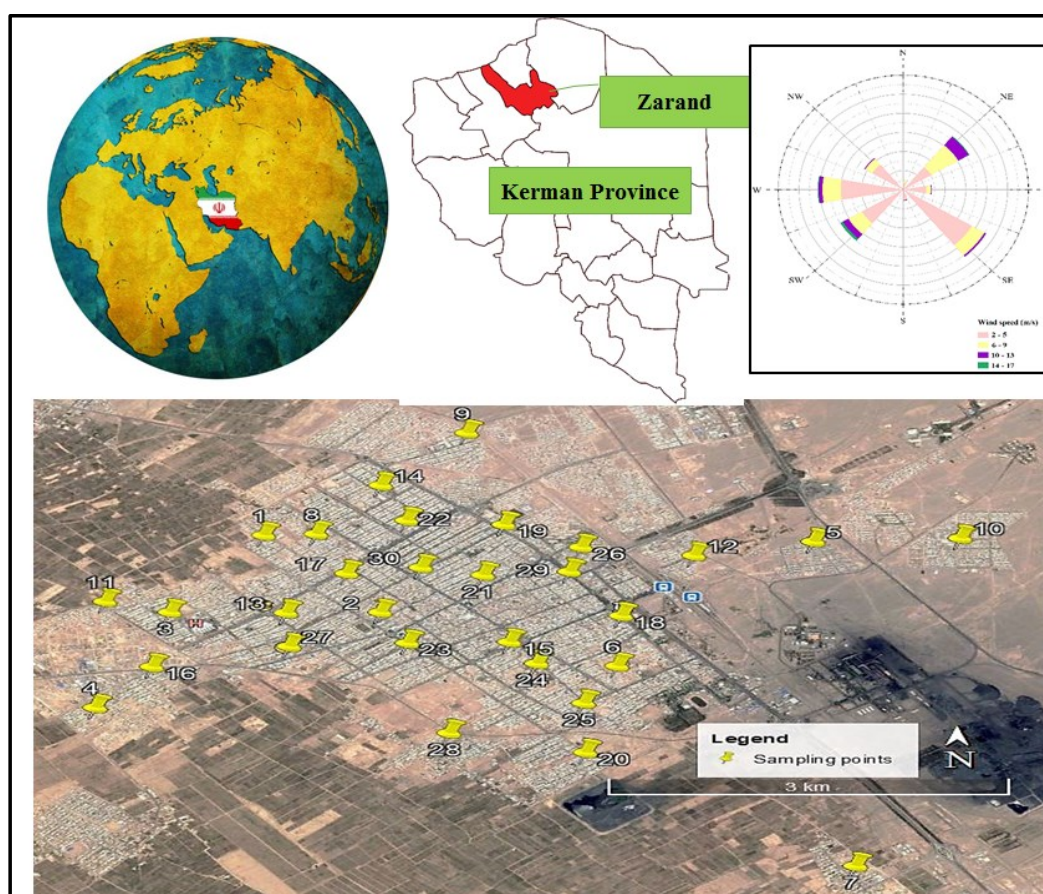


Fig. 1. Map of the study area and BTEX sampling points and wind rose plots showing the prevailing winds

Table 1. Details of the GC-MS analysis

Characteristics	Description
Column model	CP-Sil 8 CB column
Column characteristics	Varian capillary, 60 m×0.25 mm×1.5 μm
Carrier gas	Helium (purity 99.995%) with a flow rate of 1 mL/min
Injection port temperature	280°C
Oven temperature	55°C for 4 min and increased with a rate of 10°C/min to 180°C/min

Quality assurance and control (QA/QC)

The utilized BTEX standard was made from Sigma Aldrich (BTEX mix, 1×1 mL, 2000 µg/mL in methanol). Quality assurance and control methods were implemented at every stage of the analytical process. Calibrations were carried out by preparing five standard solutions of various concentrations. A blank sample was administered before and after each of the three samples. Linear calibrations were performed, and the BTEX were identified by matching their area and retention durations to standards. For all BTEX compounds including benzene, toluene, ethylbenzene, m,p-xylene, and o-xylene, the appropriate calibration curves had $R^2 > 0.95$, and a Limit of Detection (LOD) and Limit of Quantification (LOQ) of 0.01 and 0.03 µg/m³, respectively.

Ozone formation potential

The ozone formation potential (OFP, µg/m³) is expressed as the amount of ozone generated per mass of emitted VOCs and is one of the most important factors for determining the effect of VOC species on the O₃ generation. Three variables influence the ability of each VOC species to generate O₃ including VOC concentration, •OH reactivity as an oxidizing agent, and maximum incremental reactivity (MIR) [14]. BTEX concentration and MIR coefficient can be used to calculate OFP. Carter established the MIR coefficient in 1994, and it was modified and used in 2009 to determine the amount of ozone formed per emitted VOCs (15). The modified MIR coefficients for benzene, toluene, ethylbenzene, m,p-xylene, and o-xylene are defined to be 0.69, 3.88, 2.93, 7.44, and 7.4, respectively. Eq. 1 was used to compute OFP [2, 16]:

(1)

$$\text{OFP} = \text{BTEX concentration } (\mu\text{g}/\text{m}^3) \times \text{MIR } (\text{g O}_3/\text{g VOCs})$$

Statistical analysis

The BTEX concentrations and OFP values in the samples were analyzed by descriptive statistics. The mean values in different seasons

and locations was compared through the ANOVA test. The sources of BTEXs were recognized by the correlation analysis and Principal Component Analysis (PCA) that were used to describe the pattern of correlations between species and recognize the main underlying factor, respectively. Statistical analysis was done by R software version 3.6.2 and a p-value less than 0.05 was considered as the significant level.

Spatial distribution analysis

The spatial trend of the OFP was demonstrated through ArcGIS 10.8.1. The ordinary Kriging method was employed to presume the distance or direction between sampling points to reflect a spatial correlation. This technique effortlessly defines the variance or precision of predictions among the interpolation techniques. Based on this technique, the nearby measured amounts are weighted to predict a value for an unmeasured place. Kriging interpolation is based on the weighting of independent data, so weights can be used for all data sets after the first estimation. Eq. 2 is used in the Kriging method:

$$\hat{Z}(s_0) = \sum_{i=1}^N \lambda_i Z(s_i) \quad (2)$$

Where $Z(s_i)$ is the measured value at the i th location, λ_i is an unknown weight for the measured value at the i th location, $Z(s_0)$ is the prediction location, and N is the number of measured values [17]. In addition, the root mean square error (RMSE) was evaluated in Eq. 3 and Eq.4 to validate the Kriging interpolation method [18].

$$\text{RMSE} = \sqrt{\frac{1}{n} \sum_{i=1}^n (q_i - \hat{q}_i)^2} \quad (3)$$

(4)

$$\% \text{ RMSE} = \left(\frac{\text{RMSE}}{\mu} \right) \times 100$$

Where n is the number of measured data, q_i denotes the measured data, \hat{q}_i represents the value forecasted by the Kriging method, and μ denotes the mean of each component [19]. The validity of the Kriging method in air pollutants

mapping was accepted if the RMSE index was below 50% (20). The % RMSE for the ordinary Kriging in the summer and winter was calculated to be 49 and 43%, respectively in the current study. These values are within the acceptable range and indicate confidence between predicted and measured values.

Results and discussion

BTEX concentration

The BTEX concentrations measured in the current study show in Table 2. Total BTEX levels were found to be $79.26 \pm 26.87 \mu\text{g}/\text{m}^3$ in the summer and $37.38 \pm 29.18 \mu\text{g}/\text{m}^3$ in the winter. During the two sampling periods (summer and winter), BTEX concentration was found to be $113 \pm 41.60 \mu\text{g}/\text{m}^3$. Mean levels of all BTEX compounds in summer were more than them in winter. According to ANOVA analysis, the mean difference in the two sampling seasons was not significant (see Table 2). There was not significant difference in the BTEX levels in different sampling sites. BTEXs are volatile compounds that can be more disseminated in the air during the warmer months through fuels and other materials containing these compounds. Furthermore, due to the higher wind speed in the summer, BTEX can be transported in a long range, resulting in a greater BTEX concentration in the summer compared to the winter [21, 22].

The ranking of BTEXs in all samples followed as: toluene > m, p-xylene > o-xylene > ethylbenzene > benzene. Toluene has been found as the most prevalent BTEX compound in other previous studies [19, 23, 24]. Combustion activities in vehicles and industries have a key role to release toluene into the atmosphere [5, 25]. Toluene's high concentration can be attributed to the fact that it may represent up to 15% of the volume of unleaded gasoline aromatic hydrocarbons. Toluene is also included in the conventional diesel used by heavy-duty vehicles [26]. The main cause of the elevated amounts of toluene, according to other studies, it seems to be

the usage of gasoline and diesel for transportation [27, 28].

Benzene had the lowest concentration among all compounds. It was below the detection limit in the samples collected in the winter. Similar findings were observed in a study that benzene concentrations were lower than other compounds. However, in most studies, the minimum concentration of BTEX was associated to the ethylbenzene (Table 3) [29, 30]. Changes in the meteorological data, atmospheric stability, and hence pollutant distribution might all be contributing factors in the release of BTEXs [31].

Ozone formation potential

The impact of VOCs on the production of tropospheric ozone has been investigated through the calculation of OFP to assess ozone generation. The OFP values in air samples in Zarand are seasonally compared in Fig. 2. Because of the undetectable levels of benzene in the winter, statistical analysis was impossible.

The ranking of OFP values in all sample as followed: toluene > m,p-xylene > o-xylene > ethylbenzene > benzene. So, toluene and m,p-xylene had a maximum contribution to the production of tropospheric ozone in the current study. Benzene had the minimum contribution in the summer OFP, which was consistent with the findings of research in Korea [32], India [33], Saudi Arabia [28], and central urban area of Iran [19]. In all BTEX species, the mean OFP values in summer were more than the values in winter but this difference was not significant. This finding matched with other studies [19, 34]. The overall OFP of $374.79 \pm 135.08 \mu\text{g}/\text{m}^3$ in the summer and $172.61 \pm 148.81 \mu\text{g}/\text{m}^3$ in the winter was more than $100 \mu\text{g}/\text{m}^3$ as recommended guideline defined by WHO [35].

OFP levels in the study areas are compared with those reported for other regions in Table 4. According to other studies, toluene and xylene produced the most ozone, which is consistent with the findings of the current study, which show that these two pollutants are produced in

Table 2. Statistical descriptive of the BTEXs in air samples ($\mu\text{g}/\text{m}^3$)

	Benzene	Toluene	Ethylbenzene	m,p-Xylene	o-Xylene	BTEX
Summer (n:30)						
Min	0.36	21.66	1.05	3.65	1.85	29.29
Mean	0.91	53.71	3.84	13.73	7.08	79.26
Standard deviation	0.18	16.25	1.66	6.29	3.25	26.87
Max	1.22	81.49	6.26	22.82	13.70	116.17
Winter (n:30)						
Min	ND ¹	0.03	0.32	0.89	1.49	0.03
Mean	ND	28.79	1.06	5.51	4.59	37.38
Standard deviation	ND	20.09	2.82	8.11	5.46	29.18
Max	ND	76.89	12.37	34.52	22.40	128.69
Overall						
Min	0.36	45.92	1.37	5.02	5.67	61.14
Mean	0.91	82.49	4.75	18.56	11.08	113.28
Standard deviation	0.18	26.86	3.28	9.89	5.48	41.60
Max	1.22	146.24	16.40	42.46	27.77	219.51
² p-Value for sampling sites	0.60	0.65	0.37	0.30	0.64	0.50
² p-Value for the seasons	- ³	0.66	0.78	0.87	0.18	0.92

¹ ND: Not Detectable

² p-value is significant at the 0.05 level.

³ Due to the undetectable concentration of benzene in the winter, statistical analysis was not possible.

more quantities in the most urban areas across the world [31].

High levels of OFP may cause the ozone-related unfavorable health consequences [39]. Short-term consequences of ozone exposure included respiratory system irritation, inflammatory processes, and bronchial hyperresponsiveness. Furthermore, ozone inhalation has long-term consequences such as asthmatic progression, and Chronic Obstructive Pulmonary Disease (COPD). According to the WHO reports, pulmonary disorders induced by a $20 \mu\text{g}/\text{m}^3$ ozone concentration in the ambient atmosphere are responsible for 0.23-6.6% of the related

mortality. [40]. In the presence of elevated VOCs concentrations, substantial O_3 generation occurs. It should be mentioned that O_3 production is a non-linear process as compared to the VOCs and NO_x . The VOC/NO_x proportion should be considered to calculate the proportion of each component in the O_3 production. For example, at lower VOC/NO_x proportions, O_3 formation is more susceptible to VOC levels, whereas, at larger proportions, O_3 formation is more susceptible to NO_x levels [41, 42].

In urban regions, ozone precursors including BTEX, particularly xylenes and toluene, have the main contribution to the OFP [43]. BTEX

Table 3. Comparison of studies on the BTEX

Location		Benzene $\mu\text{g}/\text{m}^3$ (PoT ¹)	Toluene $\mu\text{g}/\text{m}^3$ (PoT)	Ethylbenzene $\mu\text{g}/\text{m}^3$ (PoT)	Xylene $\mu\text{g}/\text{m}^3$ (PoT)	Ref.
Zarand, Iran	Summer	0.91 (1.15%)	53.71 (67.76%)	3.84 (4.84%)	20.81 (26.25%)	Current study
	Winter	ND ²	28.79 (72.07%)	1.06 (2.65%)	10.10 (25.28%)	
Ahvaz, Iran (Petrochemical sites)	Summer	1.75 (12.91%)	4.05 (29.87%)	4.58 (33.78%)	3.18 (23.45%)	[29]
	Winter	0.81 (10.18%)	1.19 (14.95%)	4.32 (54.27%)	1.64 (20.60%)	
Qom, Iran		15.2 (27%)	22.5 (40%)	5.7 (10%)	12.4 (22%)	[31]
Bangkok, Thailand		18.59 (17%)	77.41 (72%)	4.33 (4%)	7.3 (7%)	[36]
Yazd, Iran		21 (18%)	38 (33%)	14 (12%)	41 (36%)	[19]
Tabriz, Iran		8.16 (22%)	14.61 (39%)	ND	14.64 (39%)	[2]
Tehran, Iran	Spring	4.8 (13%)	14.6 (40%)	3.2 (9%)	13.7 (38%)	[37]
	Winter	7.2 (14%)	21.3 (40%)	5.3 (10%)	19.3 (36%)	
Shiraz, Iran	Morning	26.15 (29%)	12.97 (15%)	7.5 (8%)	42.72 (48%)	[38]
	Evening	34.44 (38%)	11.2 (12%)	6.58 (7%)	38.06 (42%)	

¹ PoT: Percentage of Total

² ND: Not Detectable

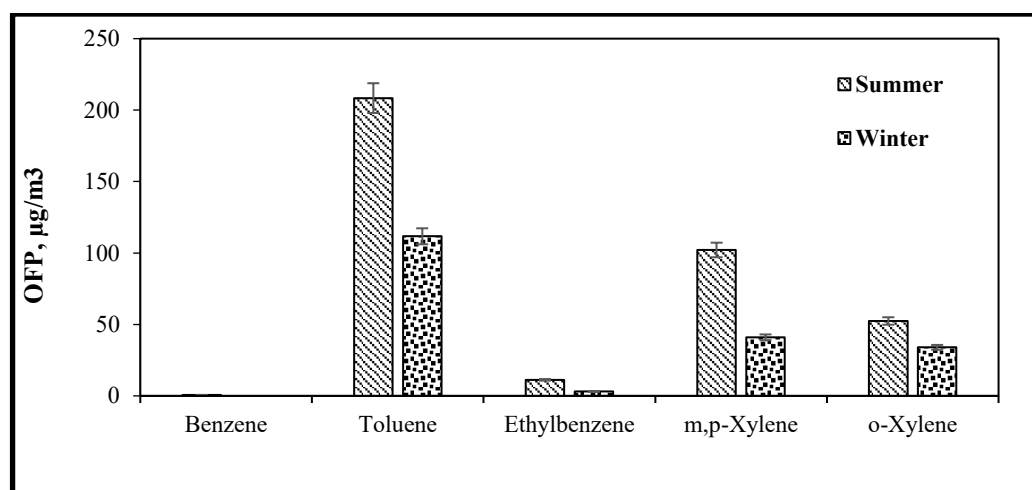


Fig. 2. Seasonal comparison of OFP values in air samples in Zarand; Note: Due to the undetectable concentration of benzene in winter, the OFP value could not be calculated.

concentrations are often dominating in urban regions, and hence have a considerable impact on ozone formation [44]. Aromatic groups can provide approximately 14% of total OFP, according to Tan et al.'s study [45].

Spatial distribution of OFP

The spatial distribution of OFP values in two studied seasons for different species of BTEX is illustrated in Fig. 3. A different spatial variations were observed in the various parts of the city for individual species of BTEXs and studied seasons. The maps generally showed that the maximum levels of total OFP were detected at the S3, S4, S5, S7, S8, S16 and S17 in the summer and S4, S10 and S11 in the winter. Investigation of the location of mentioned stations showed that they located in the nearby gas stations (S4 and S5), industrial facilities (S8) or both of them (S7), or areas with the intermediate or high traffic density (S3, S10, S11 and S17). High level of OFP in the S5 located in the area with low traffic density could be associated to the prevailing winds in the studied area that were primarily being from southeast to northwest (see Fig. 1).

Source identification

The sources of BTEXs were identified through correlation analysis and PCA. The correlation matrix between BTEX species in both seasons is shown in Fig. 4a and 4b. All species, except benzene and xylenes in summer ($r=0.43$ for o-xylene and $r=0.5$ for m,p-xylene) and toluene and ethylbenzene and toluene and o-xylenes in winter ($r=0.40$), had a strong positive correlation ($r>0.6$). So, it could be concluded that these species may be originated from vehicle fuel emissions and gas stations [19]. Moreover, the intermediate positive correlation of other mentioned species suggested another source besides motor vehicle emissions, such as industrial activities [46].

The results of PCA for different compounds of BTEX are shown in Table 5. During the analysis, the variables with similar characteristics

were clustered together [49]. Two principal components (PC1 and PC2) were extracted. In the summer, two principal components were allocated for 96% of the total variation within the variables. The first principal component (PC1) as factor 1, with 83% of the total variance, comprised the toluene, ethylbenzene, m.p-xylene, and o-xylene. Benzene is classified in the second principal component (PC2) as factor 2 amounting to 13% of the total variance. In the winter, two principal components were allocated for 97% of the total variation within the variables. The first principal component (PC1) as factor 1, with 78% of the total variance, comprised the toluene, ethylbenzene, m.p-xylene, and o-xylene. The concentration of benzene in the winter could not be calculated because of its undetectable concentration. According to the results obtained by PCA, the first factors explained more total variation. Therefore, they influenced the BTEX levels in a great manner indicating vehicles as the major potential sources of BTEX emissions in the studied area for all compounds except benzene in the summer [49]. Benzene in summer could have another source other than vehicles. It must be noticed that benzene was undetectable in winter during this study. The Tar cooking and refining complex located in Zarand is considered the first unit of benzene production with a purity of over 97% in Iran. Benzene is a volatile compound with a vapor pressure of 94.8 mmHg at 25 °C and can release into the atmosphere from this complex at high temperatures in summer. Of course, benzene had the minimum concentration among all compounds in summer and as mentioned before, it was below the detection limit in the samples associated to the winter. Consequently, with existence of important complex of benzene production, its level in the studied area, despite of concerns among citizens and industrial workers, was lower than other studied compounds. Health risk assessment of benzene and other measured constituents has been investigating by researchers of the current study and will be published as soon as possible.

Table 4. Comparison of OFP levels in Zarand with those reported for other regions ($\mu\text{g}/\text{m}^3$)

Location	Stat.	OFP Benzene	OFP Toluene	OFP Ethylbenzene	OFP Xylene	Total OFP	Ref.
Zarand, Iran, Summer	Mean	0.63	208.39	11.25	154.54	374.81	Current study
	Std. ¹	0.12	63.03	4.88	70.80		
	Min	0.25	84.04	3.08	40.84		
	Max	0.84	316.18	18.34	271.16		
Zarand, Iran, Winter	Mean	-	111.67	3.12	74.93	189.72	
	Std.	-	77.95	8.27	100.73		
	Min	-	0.12	0.94	17.64		
	Max	-	298.33	36.24	422.58		
Qom, Iran	Mean	10.94	89.95	17.3	96.58	214.79	[31]
	Std.	14.18	127.3	28.65	120.48		
	Min	0	0	0	0		
	Max	55.5	683.33	182.4	585		
Tabriz, Iran, Summer	Mean	5.03	42.21	-	111.51	-	[2]
Tabriz, Iran, Winter	Mean	6.22	80	-	109.99	-	
Bangkok, Thailand, Roadside area	Mean	2.43	292.99	10.37	76.02	-	[36]
	Mean	18.36	654.96	12.49	52.27	-	
Bangkok, Thailand, Resident area	Mean	19.37	166.75	16.63	40.78	-	
Bangkok, Thailand, University area	Mean	19.37	166.75	16.63	40.78	-	
Benin, Southern Nigeria	Mean	1.3	1.63	8	26.72	-	[47]
Delhi, India	Mean	37	452	47	776	-	[33]
Brazil, Rainy season	Mean	-	-	-	-	22.55	[48]
Brazil, Dry season	Mean	-	-	-	-	32.11	
Jeddah, Saudi Arabia	Mean	0.55	14.24	5.74	76.66	-	[28]
Delhi, India, Road traffic	Mean	46.99	239.41	38.77	229.70	-	[6]
Bandar Abbas, Iran, Period I: Urban region	Mean	0.71	20.38	8.09	36.63	65.81	[23]
	Mean	0.07	4.01	5.14	15.14	24.36	
	Mean	0.07	0.60	3.86	6.91	11.44	
Bandar Abbas, Iran, Period I: Rural region	Mean	1.42	53.42	6.78	60.79	122.40	
	Mean	0.64	21.65	3.49	20.85	46.63	
	Mean	0.07	8.36	1.04	4.42	13.89	
Bandar Abbas, Iran, Period II: Industrial region	Mean	0.07	8.36	1.04	4.42	13.89	
	Mean	0.07	8.36	1.04	4.42	13.89	
	Mean	0.07	8.36	1.04	4.42	13.89	
Bandar Abbas, Iran, Period II: Rural region	Mean	0.07	8.36	1.04	4.42	13.89	
	Mean	0.07	8.36	1.04	4.42	13.89	
	Mean	0.07	8.36	1.04	4.42	13.89	

¹ Std.: Standard Deviation

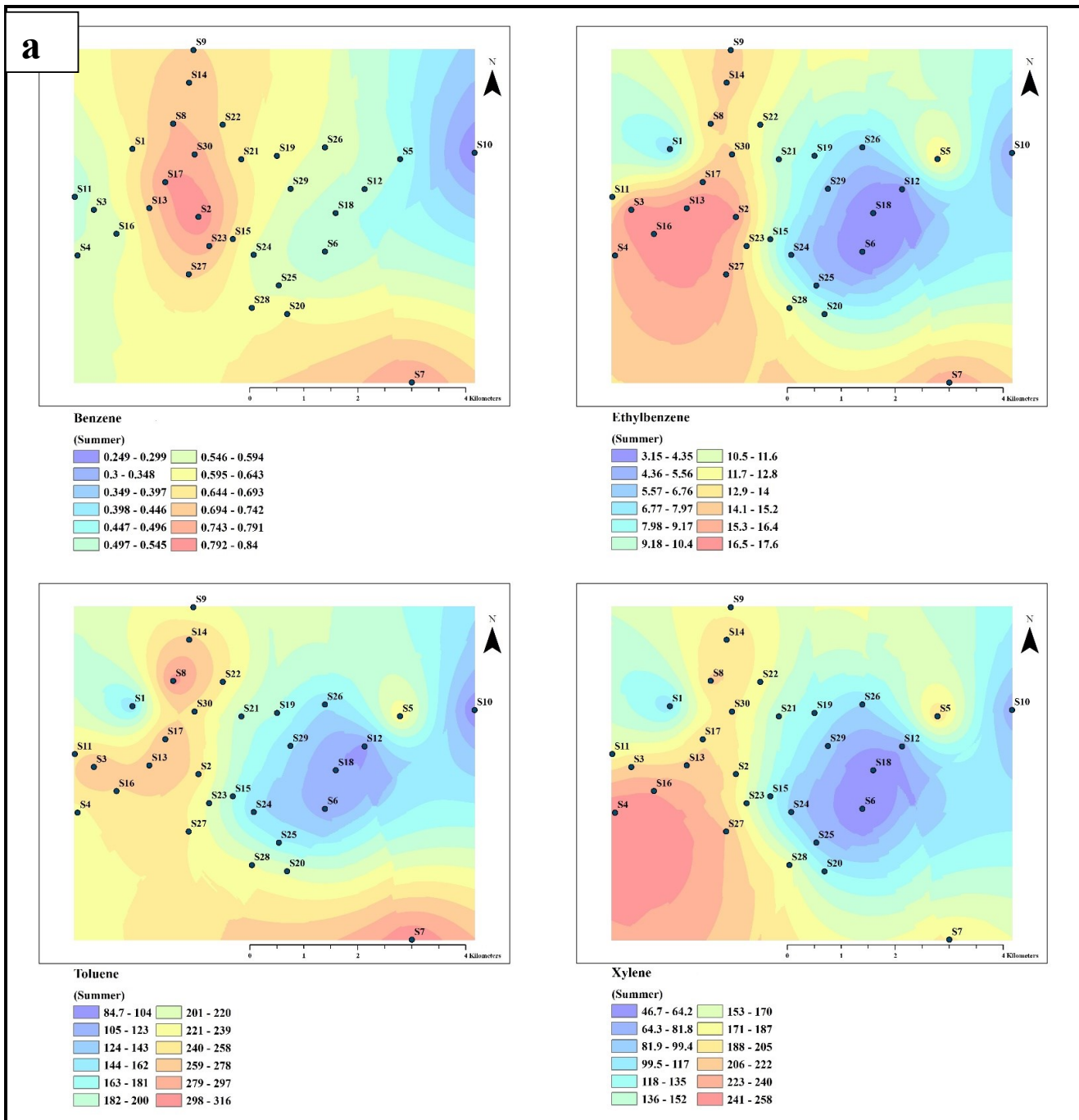


Fig. 3. Spatial distribution of OFP values in the summer (a) and winter (b) for different species of BTEX

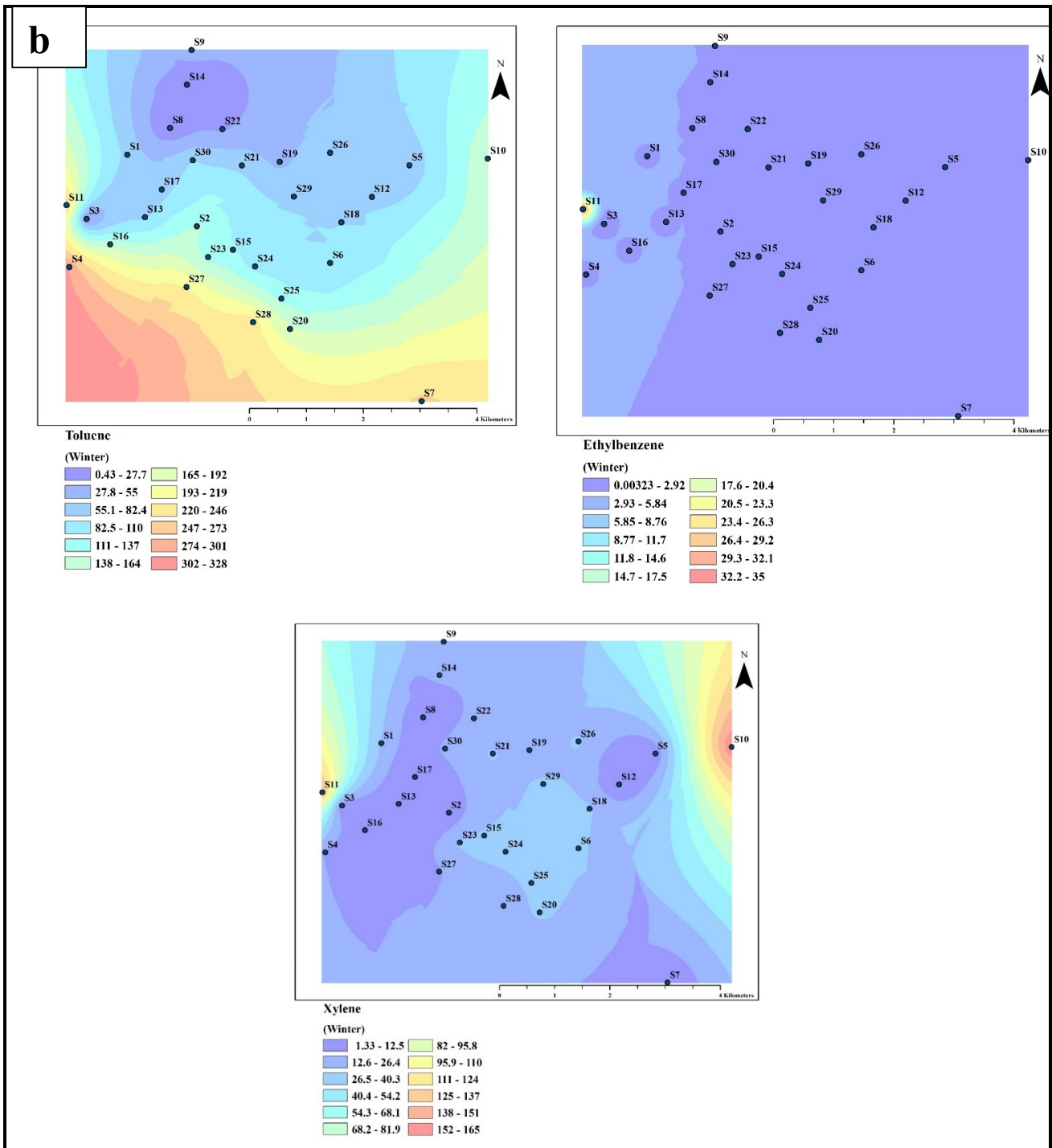


Fig. 3. Spatial distribution of OFP values in the summer (a) and winter (b) for different species of BTEX

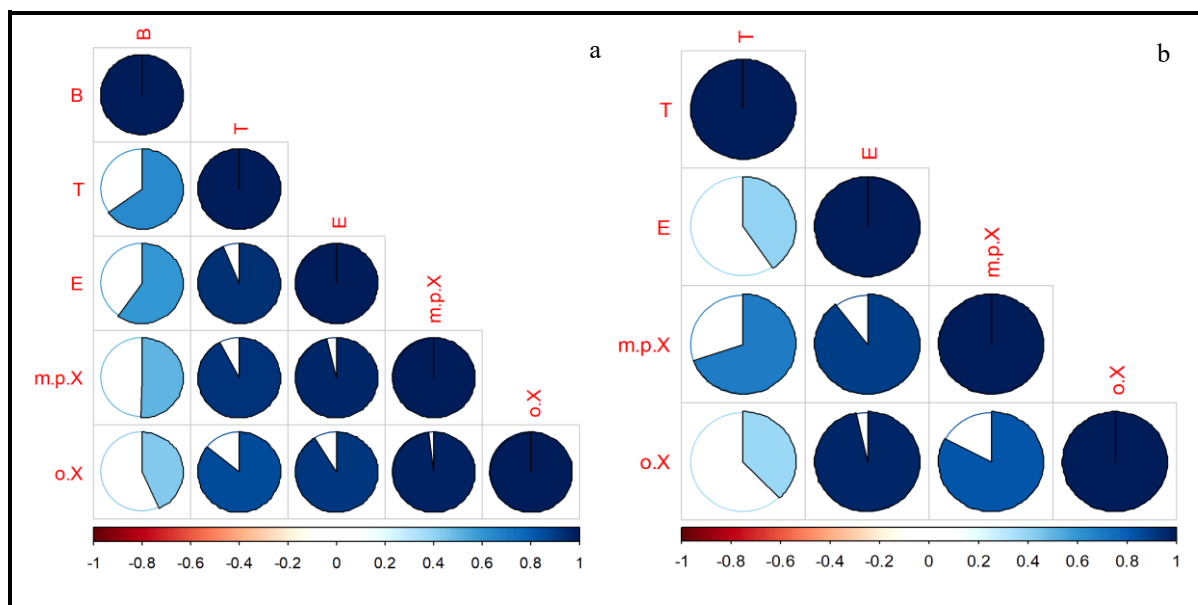


Fig. 4. Correlation coefficients (r) of BTEX compounds in summer (a) and winter (b); B: Benzene, T: Toluene, E: Ethylbenzene, o-X: o-Xylene, m,p-X: m,p-Xylene

Table 5. Principal Component Analysis of BTEXs as well as regression factor scores

Variables	Factor 1	Factor 2
Summer		
Benzene	0.67	0.74
Toluene	0.97	0.04
Ethylbenzene	0.98	-0.06
m,p-Xylene	0.97	-0.21
o-Xylene	0.94	-0.28
Initial eigenvalues	4.16	0.67
% of variance	83	13
Cumulative % of variance	83	96
Winter		
Toluene	0.85	0.81
Ethylbenzene	0.96	-0.21
m,p-Xylene	0.97	-0.02
o-Xylene	0.95	-0.28
Initial eigenvalues	3.12	0.77
% of variance	78	19
Cumulative % of variance	78	97

Conclusion

This study was done to determine the levels of BTEX species, and the OFP originated from BTEX compounds in the ambient air of Zarand during the summer and winter seasons, and assess their possible sources and spatial distribution. The finding of study presented that the concentrations of BTEX were higher in the summer indicating that seasonal fluctuations had a key impact on the emission of aromatic compounds into the ambient air. BTEX relative abundances in all samples were toluene>m,p-xylene>o-xylene>ethylbenzene>benzene. Therefore, despite of concerns among inhabitants and workers, benzene concentration was lower than other studied species. The overall OFP in both seasons was found to be more than 100 $\mu\text{g}/\text{m}^3$ as recommended guideline defined by WHO.

More researches on the BTEX sources, control measures, development of green space, improvement of the fuel quality in motor vehicles and factories can be suggested to control BTEX and decrease of OFP levels in this area.

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Competing interests

The authors declare that they have no conflict of interest.

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Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors

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