Received: 18 December 2021 | Revised: 16 January 2022 | Accepted: Revised: 25 January 2022
DOI: 10.22034/ecc.2022.320520.1281

Eurasian Chemical Communications SAMI

FULL PAPER

Distribution trend of BTEX compounds in ambient air of urban solid waste landfill sites and surrounded environment: A case study on Ahvaz, Southwest of Iran

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Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) are classified as hazardous air pollutants that have been identified at landfill sites and surrounding environments. Therefore, in the present study, BTEX concentrations were measured at new and old solid waste landfill sites of Ahvaz during cold and warm seasons. As one of the megacities in the southwest of Iran, Ahvaz produces more than 1,000 tons per day of solid waste. The produced solid waste is transported to the new Borumi landfill site, which is located at 31° 17'28 "N and 31° 18'31" N latitude and 48° 48'12 "N and 48° 50'15" longitude. Air samples were taken in both cold and warm seasons from 6 points including, one point in the new site, three points in the old site, a point between two sites, and one point in the city boundary (as background point). Air sampling was performed in the prevailing wind direction (the southeast wind), and the meteorological parameters, including temperature and relative humidity, were also measured during air sampling. The results showed that the emission rate of BTEX compounds in the old and new landfill sites of Ahvaz is considerable. So that, the highest concentrations in the old landfill site in the warm season for benzene, toluene, ethyl-benzene, and xylene were 173.82, 234.51, 246.18, and 20.84 ppm, respectively. However, these values in the cold season were 16.6, 50.04, 2, and 70.28 ppm, respectively. It shows that the concentration levels of BTEX were significantly higher in the warm season compared to the cold one.

KEYWORDS

Volatile organic compounds; BTEX; municipal solid waste; landfill sites; Ahvaz.

Introduction

Nowadays, due to industrialization, urbanization, and increased motor vehicles in the cities, air pollution has become a serious threat that affects many parts of the world and causes many health problems. Air pollution has attracted the attention of many scientists and officials associated with human health and the environment [1,2].

VOCs are carbonated compounds that are capable of evaporating quickly at environmental temperatures. The inhalation way of exposure has become a critical pathway for intake of these pollutants. Among VOCs, Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) compounds are primarily present at high concentrations in different ambient environments. Environmental importance of VOCs are well known in many different ways. For example, their potential role in the formation of photochemical oxidants [3], or contamination associated with the sense of smell [4], or their controller effects on the stratospheric ozone.

Due to the diversity in chemical species and VOC characteristics diversity in different parts of the environment, the exact processes ruling their participation in the environment are relatively unknown. However, the fundamental approach to managing the consequences of VOCs is a trend toward accurate assessment of the distribution of these compounds in strategic areas [5].

Although some previous studies characterized the behavior of VOCs, they were conducted in different environments. However, it needs to be resolved to calculate the significance and the unique role of different sources on the environment [6] because they are suspected to be carcinogenic [7]. BTEX compounds cause damages to immune, neurogenic and cellular systems. Cardiovascular and respiratory organs are also affected by other immunologic illnesses [8]. Benzene, toluene, ethylbenzene, and xylene are among the emissions of volatile organic compounds [9], which are toxic at deficient concentrations. In the urban area, 20 to 40% of non-methane hydrocarbons compounds (NMHCs) allocates to BTEX [10,11].

Benzene is a carcinogen group I, and exposure to it in high concentrations in the short term causes drowsiness, headache, dizziness, and unconsciousness [12]. Benzene causes a variety of cancers; also, it destroys the bone marrow. Many studies have illustrated that anemia, bone abnormalities, and leukemia can be attributed to benzene [11,13]. According to previous research, women who had breathed a few months in environments with high benzene concentration experienced irregular periods, and their ovary tubes got small [14]. Human exposure to benzene in the long term causes damage to the liver, kidney, lung, heart, nerves, and DNA breaks down and destroys chromosomes. Toluene is applicable in the industry as a solvent. It can cause fatigue, dizziness, nausea, hearing loss, reducing color clarity of vision, and even blindness in some cases at low levels to mid-level. Breathing high levels of Toluene can cause unconsciousness and even death. Long-term exposure to toluene is usually caused by neurological diseases and visual disturbances [15, 16]. Ethylbenzene is in group 2B in terms of carcinogen compounds. This compound has been used for making styrene in the petrochemical industries. It affects the respiratory system and causes eye irritation, respiratory irritation, nausea, and confusion in high concentrations. It causes disorders in the blood, liver, and kidney [16, 17]. Xylene affects the nervous system, and the symptoms are headache, dizziness, vomiting, and nausea [11,17].

Since landfills are designed and built as the ultimate solution for the disposal of industrial and domestic wastes, they are often considered a significant source of a wide range of pollutants [18], including VOCs and BTEX compounds [2]. Lightening or reducing landfill gas emissions (LFG) emissions were often investigated as a critical component of landfill gas emission due to a significant impact on local or regional air quality [19, 20].

More than 2.2×10^9 tons of waste in 2300 landfills is annually buried in the United States. It is estimated that about 10% of the total greenhouse gases produced by VOC come from landfill gases (EPA 2002). As one of the major cities in the southwest of Iran, Ahvaz produced more than 1,000 tons per day of household and commercial waste buried at the Borumi landfill site until five years ago, and since then, it has been buried at the new landfill site. This high volume of waste produces high volumes of VOCs and BTEX. As BTEX is suspected of carcinogenicity properties, WHO has limited exposure to BTEX in the ambient environment [21]. Owing to the growing concern on increasing the population and further generating solid waste globally, monitoring BTEX concentration in one of the emission sources of VOCs, such as landfill sites, is of utmost importance. Therefore, the present study investigates the BTEX concentration in the old and new Borumi landfill site in Ahvaz city, southwest of Iran. In this study, six sampling points are selected for air sampling. The A, B, and C are located in the old landfill; D is located in the new landfill. E is located between the old and new landfills, and F is located in the closest metropolitan area to the landfills. The sampling pump was put at the height of 1.5 to 2 m above ground level to stimulate breathing.

Materials and methods

Site description

This cross-sectional study was done in Ahvaz city. Daily, 1000 tons of solid waste is produced in Ahvaz city, the center of Khuzestan province, as one of Iran's seven largest most significant cities. The produced solid waste was buried in the old landfill named Borumi until July 2012. The landfill is located about one mile from the village Borumi and on the sidelines of Ahvaz city, in 31° 17'28 "N latitude and 31° 18'31" N and 48 ° 48'12 "N and 48 ° 50'15" longitude. It has an area of approximately 300 ha and has been a landfill for the past 20 years. Ahvaz city residues have been transferred to the city's new landfill since July 2012, which has an area of 120 ha and is located 8 kilometers away from the old landfill. The two landfill sites and related sampling points are illustrated in Figure 1.

FIGURE 1 The new and old landfill locations and related sampling points

Sampling method

In the present study, six sampling points are selected for air sampling. In Figure 1, the selected points are marked whit A, B, C, D, E, and F points. The A, B, and C are located in the old landfill; D is located in the new landfill. E is located between the old and new landfills, and F is located in the closest metropolitan area to the landfills; E was located downstream in the direction of the prevailing south and southeast wind. The geographic information systems (GIS) of the sampling points are illustrated in Table 1. The F point was selected as a background point to compare a point far away from the source of pollution with the rest. Air sampling was carried out in two periods, the warm season (between July to September) and a cold season (between January to March) in the alternation of 15 days. Air sampling was done two times a day, from 8 to 11 am and 3 to 6 pm.

Air Sampling was conducted using SKC sampling pumps, according to the standard of TO-17 EPA, 1501 NIOSH (National Institute for Occupational Safety and Health), and OSHA (Occupational Safety and Health Administration). Pumps were calibrated by defender 510-H Bios International Corp; the activated carbon adsorbent (code 226-01) was put into pumps in the sampling site. The pump was put at the height of 1.5 to 2 m above ground level to stimulate the breathing area. The air sampling flow rate was 200 mL/min for 1 h. After sampling, the absorbent sides were closed with a plastic cap, and the samples were taken to the laboratory in a cool box at 4°C. The extraction operations were done by CS2 as a solvent in the laboratory, and concentrations were determined using GC-MS/MS [22].

TABLE 1 Geographic locations of sampling points in the new and old solid waste landfill site

Sampling Points	Latitude	Longitude
Point A	31º 17' 54"	48º 49' 25"
Point B	31º 17' 60"	48º 49' 14"
Point C	31º 18' 4"	48º 48' 41"
Point D	31º 18' 8"	48º 51' 11"
Point E	31º 17' 11"	48º 54' 59"
Point F	31º 18' 34"	48º 45' 29"

Statistical analysis

SPSS software was used to analyze the results of the air samples. In this study, according to the Shapiro-Wilk test, benzene, toluene, ethylbenzene, and xylene had no normal distribution ($p < 0.001$). Therefore, nonparametric tests such as the Kruskal-Wallis test, U Mann-Whitney Spearman's correlation coefficient were used.

Results and discussion

BTX concentration in warm and cold seasons

The BTEX concentration in warm and cold seasons was indicated in Table 2. Among the pollutants, only the median concentration of benzene in the cold season is statistically significant compared to the warm season. However, as demonstrated in Table 2, the results of other pollutants in both warm and cold seasons do not show significant differences.

TABLE 2 The concentration ranges of BTEX in the warm and cold seasons

Pollutants	Season	NO. of sampling	Mean	Median	IQR	p-value
Benzene	Warm	24	16.88	3.1	9.67	0.005
	Cold	18	27.67	**37.9**	52.21	0.005
Toluene	Warm	24	29.23	2.60	3.74	0.005
	Cold	18	11.19	0.00	0.00	0.005
Ethylbenzene	Warm	24	23.17	2.02	1.28	0.005
	Cold	18	19.28	0.00	44.6	0.005
Xylene	Warm	23	27.74	2.01	3.02	0.005
	Cold	18	12.39	0.00	0.00	0.005

Concentrations of BTEX in sampling points

Box Plot figures were used to show the BTEX concentrations in different sampling points. As illustrated in Figure 2 to 5, there is no significant difference between the median of data in each sampling point in all figures, which shows that the distribution of pollutants from one point to another is the same.

Relation between concentrations of BTEX and the seasons

One of the critical factors influencing BTEX production is the change in the seasons and, consequently, the change in ambient temperature. The Mann-Whitney U test was used to assess the relationship between BTEX concentration and the seasons. As illustrated in Table 3, there is a significant difference between benzene, toluene, and xylene concentration levels in the cold season compared to warm seasons statistically. They were higher during warm seasons compared to cold ones. In the case of ethylbenzene, there is no significant difference. The results also show that unusually high concentrations are seen repetitively in 2–3 samples regardless of the season.

The relationship between BTEX concentration and season was studied previously [22-24]. Those experiences indicated the generally enhanced BTEX concentration levels during warm seasons relative to cold ones.

TABLE 3 Relation between BTEX concentrations and seasons

Pollutants	Benzene	Toluene	Ethylbenzene	Xylene
Mann-Whitney U	105	30.50	176	52
Wilcoxon W	405	201.50	347	223
Z	-2.82	-4.85	-1.05	-4.27
P-value	0.005	0.000	0.292	0.000

The relationship between different concentrations of BTEX and time variations throughout the day

The relationship between different BTEX concentrations and time variations throughout the day was tested using the Kruskal Wallis test. As illustrated in Table 4, there is no significant difference between various BTEX concentrations and the time variations throughout the day (morning and evening). These results indicated that changes in meteorological parameters such as temperature and relative humidity throughout the day do not affect BTEX production. However, due to the limited data set obtained during this study, explaining such a trend should be done with caution.

TABLE 4 relation between BTEX concentrations and time variations

Pollutants	Benzene	Toluene	Ethylbenzene	Xylene
Chi-Square	0.224	0.035	2.122	1.303
Df	1	1	1	1
P-value	0.636	0.852	0.145	0.254

Relationship of BTEX compounds concentrations and meteorological parameters

The Spearman test was utilized to determine the relationship between different BTEX concentrations with each other and with weather conditions. As illustrated in Table 5, there is a significant relationship between the toluene concentration with ethyl-benzene and xylene and between toluene concentration and temperature, which shows that wherever the temperature is higher, the amount of toluene is also higher. Overall, the results show a significant correlation between the increase in temperature and relative humidity and the increase in toluene, ethyl-benzene, and xylene. However, this assumption is not valid for benzene. This result emphasizes e possibility of a crucial role of the temperature and relative humidity on benzene production.

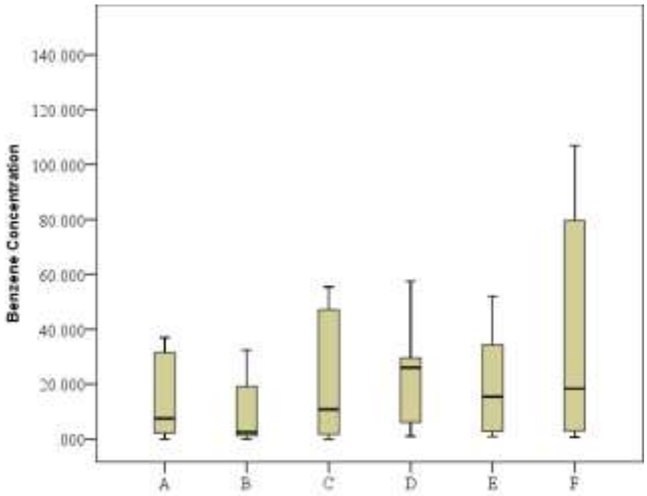

FIGURE 2 Benzene concentration in the different points during study

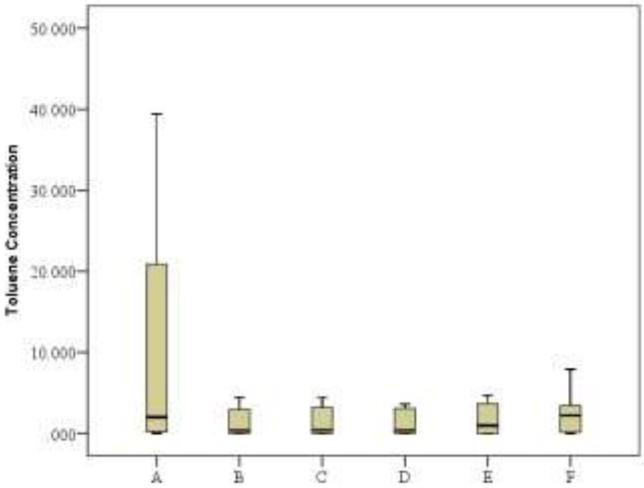

FIGURE 3 Toluene concentration in the different points during study

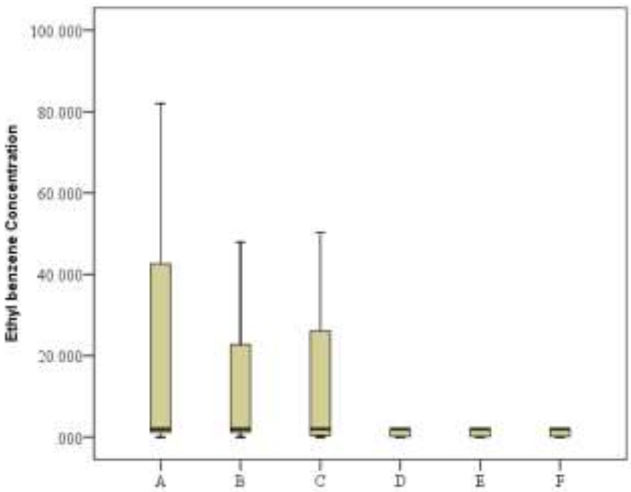

FIGURE 4 Ethyl benzene concentration in the different points during study

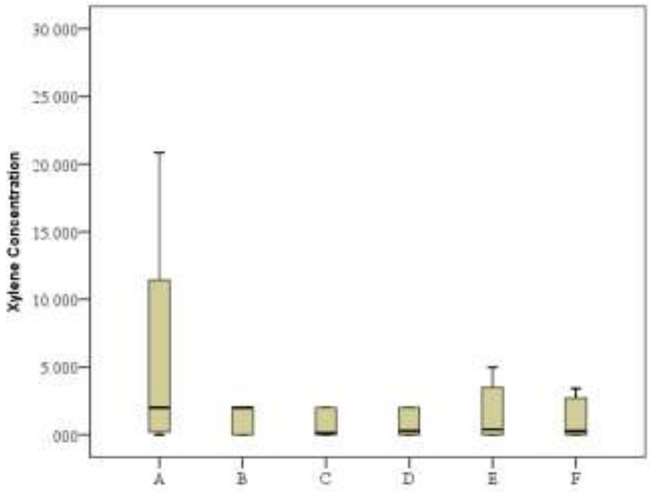

FIGURE 5 Xylene concentration in the different points during study

It can be noted that high ambient temperature and moisture content can stimulate the growth of microorganisms. Consequently, the microorganisms degrade the organic matter present in the disposed waste and thus lead to the release of a higher quantity of BTEX [25]. Several researchers have seen similar observations [6,25,26].

TABLE 5 The correlation between BTEX and meteorological parameters during the study period (sample size: N=42)

		Benzene	Toluene	Ethyl benzene	Xylene	Temp	RH
Benzene	Correlation Coefficient	1.000	-0.124	0.095	-0.015	-0.274	-0.127
	P-value		0.436	0.550	0.927	0.079	0.425
Toluene	Correlation Coefficient		1.000	**0.332***	**0.678****	**0.777****	**0.186****
	P-value			0.032	0.000	0.000	0.238
Ethylbenzene	Correlation Coefficient			1.000	0.269	**0.079****	**0.281****
	P-value				0.089	0.621	0.071
Xylene	Correlation Coefficient				1.000	**0.721****	**0.107****
	P-value					0.000	0.506
Temp	Correlation Coefficient					1.000	0.003
	P-value						0.985
RH	Correlation Coefficient						1.000
	P-value						

*. Correlation is significant at the P-value < 0.05
**. Correlation is significant at the P-value < 0.01

Conclusion

In this study, the concentration of BTEX in two new and old landfill sites of Ahvaz city was sampled in two cold and warm seasons. A point was selected between two sites and one point in the urban area to determine the distribution of pollutants. The present study results indicate that the production of BTEX compounds exists in the old and new landfill sites of Ahvaz, and it is significant on some days. Also, the results showed that the production rate of these compounds is higher in warm seasons compared to cold ones, but these changes are not significant within a day. The results also showed a significant relationship between meteorological parameters and the production of BTEX compounds. The production rate of these compounds increases by increasing the temperature and relative humidity. Of course, there is an exception to benzene. However, the need for further study in this regard is still felt, and it is necessary to study at a broader level with a more significant number of samples.

Acknowledgments

This work was financially supported by the Environmental Technologies Research Center of Ahvaz Jundishapur University of Medical Sciences (grant number: ETRC-9501).

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References

[1] K.S. Law, A. Roiger, J.L. Thomas, L. Marelle, J-C. Raut, S. Dalsøren, J. Fuglestvedt, P. Tuccella, B. Weinzierl, H. Schlager, *Ambio*, **2017**, *46*, 453-463. [crossref], [Google Scholar], [Publisher]

[2] P. Iovino, R. Polverino, S. Salvestrini, S. Capasso, *Environ. Monit. Assess.*, **2009**, *150*, 437. [crossref], [Google Scholar], [Publisher]

[3] C.A. Cardelino, W.L. Chameides, *Atmos. Environ.*, **2000**, *34*, 2325-2332. [crossref], [Google Scholar], [Publisher]

[4] E. Davoli, M.L. Gangai, L. Morselli, D. Tonelli, *Chemosphere*, **2003**, *51*, 357-368. [crossref], [Google Scholar], [Publisher]

[5] R. Behroozmand, H. Oya, K.V. Nourski, H. Kawasaki, C.R. Larson, J.F. Brugge, M.A. Howard III, J.D.W. Greenlee, *J. Neurosci. Res.*, **2016**, *36*, 2302-2315. [crossref], [Google Scholar], [Publisher]

[6] K.H. Kim, M.-Y. Kim, *Atmos. Environ.*, **2002**, *36*, 2433-2446. [crossref], [Google Scholar], [Publisher]

[7] S.C. Lee, M.Y. Chiu, K.F. Ho, S.C. Zou, X. Wang *Chemosphere*, **2002**, *48*, 375-382. [crossref], [Google Scholar], [Publisher]

[8] M.A. Parra, D. Elustondo, R. Bermejo, J.M. Santamaría,*Sci. Total Environ.*, **2008**, *404*, 18-25. [crossref], [Google Scholar], [Publisher]

[9] L. Miller, Xiaohong, Xu, A. Wheeler, T. Zhang, M. Hamadani, U. Ejaz, *Atmos. Environ.*, **2018**, *181*, 126-134. [crossref], [Google Scholar], [Publisher]

[10] K.H. Kim, Z.-H. Shon, M.-Y. Kim, Y. Sunwoo, E.-C. Jeon, J.-H. Honge, *J. Hazard. Mater.*, **2008**, *150*, 754-764. [crossref], [Google Scholar], [Publisher]

[11] F. Golkhorshidi, A. Sorooshian, A.J. Jafari, A. Norouzian Baghani, M. Kermani, R. Rezaei Kalantary, Q. Ashournejad, M. Delikhoon, *Atmos. Pollut. Res.*, **2019**, *10*, 921-930. [crossref], [Google Scholar], [Publisher]

[12] J. Huff, *Int. J. Occup. Med. Environ. Health*, **2007**, *13*, 213-221. [crossref], [Google Scholar], [Publisher]

[13] M.T. Smith, *Annu. Rev. Public Health*, **2010**, *31*, 133-148. [crossref], [Google Scholar], [Publisher]

[14] P.J. Lupo, E. Symanski, D.K. Waller, W. Chan, P.H. Langlois, M.A. Canfield, L.E. Mitchell, *Environ. Health Perspect.*, **2011**, *119*, 397-402. [crossref], [Google Scholar], [Publisher]

[15] J. Ran, H. Qiu, S. Sun, L. Tian, *Environ. Int.*, **2018**, *117*, 91-98. [crossref], [Google Scholar], [Publisher]

[16] S. Wilbur, D. Wohlers, S. Paikoff, L.S. Keith, O. Faroon, *Toxicol. Ind. Health*, **2008**, *24*, 263-398. [crossref], [Google Scholar], [Publisher]

[17] M. Conte, V. Cagnazzo, A. Donateo, D. Cesari, F.M. Grasso, D. Contini, *Open Atmospheric Sci. J.*, **2018**, *12*, 1-13. [crossref], [Google Scholar], [Publisher]

[18] M. Huber-Humer, *Waste Management*, **2004**, *24*, 425-427. [crossref], [Google Scholar], [Publisher]

[19] J.G. Pickin, S.T.S. Yuen, H. Hennings, *Atmos. Environ.*, **2002**, *36*, 741-752. [crossref], [Google Scholar], [Publisher]

[20] Y. Hajizadeh, M. Mokhtari, M. Faraji, A. Mohammadi, S. Nemati, R. Ghanbari, A. Abdolahnejad, R. FouladiFard, A. Nikoonahad, N. Jafari, M. Miri, *Atmos. Pollut. Res.*, **2018**, *9*, 220-229. [crossref], [Google Scholar], [Publisher]

[21] C. Liu, Z. Xu, Y. Du, H. Guo, *Atmos. Environ.*, **2000**, *34*, 4459-4466. [crossref], [Google Scholar], [Publisher]

[22] K. Na, Y.P. Kim, *Atmos. Environ.*, **2001**, *35*, 2603-2614. [crossref], [Google Scholar], [Publisher]

[23] A. Majdinasab, Q. Yuan, *Ecol. Eng.*, **2017**, *104*, 116-130. [crossref], [Google Scholar], [Publisher]

How to cite this article: Neda Kaydi, Parviz Mahmoudi, Neamatollah Jaafarzadeh*, Seyyed Abbas Mirzaee*, Mohammad Reza Samaei, Mostafa Hardani. Distribution trend of BTEX compounds in ambient air of urban solid waste landfill sites and surrounded environment: A case study on Ahvaz, Southwest of Iran. *Eurasian Chemical Communications*, 2022, 4(3), 232-240. **Link:** http://www.echemcom.com/article_144209.html