Original Article

# Assessment of BTEX Concentration around Fuel Station in Eastern Province Kingdom of Saudi Arabia

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## Abstract

**Aim:** The aim of this study is to determine the benzene, toluene, ethylbenzene, and xylene (BTEX) concentration levels in and around the fuel station and its harmful health effects in the city of Dammam and Al Khobar, Saudi Arabia. **Materials and Methods:** Forty fuel-dispensing facilities were randomly selected on the basis of three different areas: residential, traffic intersection, and petrol pump locations (refueling stations). Samples were collected using coconut shell charcoal cartridges, and the portable ambient analyzer was used for measuring BTEX concentration. **Results:** Results shows that the average concentration of BTEX levels around fuel stations was 10.30, 4.09, and 2.47 ppm, respectively. All mean concentration values of BTEX around residential, traffic intersection, and fuel stations are exceeding the limits of air quality standards values ($P < 0.01$). The mean concentration of BTEX around the residential area, side street, and direct street was as follows: benzene 8, 12.2, and 11.5 ppm; toluene 2.5, 5.95, and 3.37 ppm; and xylene 2, 2.13, and 2.7 ppm. Hazard quotient was >1, which showed that carcinogenic probability has increased those exposed to this toxic chemical. **Conclusion:** Values for BTEX were greater than those found in the neighboring residential area of the city and even 100 m away from the fuel station which can have a negative impact on the health of several residences. The environmental contamination associated with BTEX in petrol fuel stations impulses the necessity of preventive programs to reduce further air quality deterioration and reduce the harmful health effects.

**Keywords:** Air, benzene, gasoline, pollution, xylenes

## Introduction

Petrol vapor emissions constitute one of the main sources of air pollutants in service stations.[1] There is a wide range of volatile aromatic hydrocarbons (VAHs) present in the atmosphere of service stations as a result of emissions of vapors during dispensing, loading, unloading, and transportation of petrol.[2] The major VAHs are benzene, toluene, and xylene often referred to as the BTX compounds.[3] In Saudi Arabia, fuel-dispensing facilities are located around houses, schools, and hospitals, particularly in urban areas of country.[1] Majority of fuel stations were constructed under the old regulations and do not follow the international standard of environmental regulations.[1]

The common sources of emission include benzene, toluene, and xylenes compounds from the vehicles on the roads and fuel stations. Among benzene, toluene, ethylbenzene, and xylene (BTEX), xylene is the most dangerous to human health.[2-4] Fuel and gas products have a high concentration of BTEX which emitted in the form of vapor in the environment. These volatile organic compounds (VOCs) were common source form gasoline vapor emission and motor vehicle exhaust.[5]

BTEX also plays an important role in atmospheric chemistry. It has been recognized as an important photochemical precursor for tropospheric ozone and secondary organic aerosols.[6]

There are different studies, results were found that the concentration of benzene was 89.09%, xylene was 25.2%, and toluene was 23.9% in the fuel compared to the normal threshold level.[7] Benzene and ethylbenzene are well-known

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carcinogens to the human body.[8] Population which are living near the petrol pump stations were directly exposed to BTEX. These toxic products are VOCs which commonly called BTEX.[9] These toxic compounds were classified as group 1 and 2b carcinogens.[10] Some studies regarding the VOC emissions from gas stations were conducted in the European countries with the aim of evaluating control systems to prevent emissions[11,12] and to study their health effects on workers.[13]

There are various health disorders due to exposure to these toxic organic compounds,[14] such disorders as neurological, cancers, and teratogenic effects. The main route of entry is inhalation or ingestion. The most common health impacts are leukemia, which is estimated that out of 1 million people affected around the world, and four cases of leukemia diagnosed in their lifetime risk on exposure to 1 mg/m$^3$ of benzene concentration.[15] In occupational settings, health impacts of BTEX are well known in oil industry. The association of BTEX with cancer was proved in different study results.[16-18]

A Saudi Arabia national law stipulates that benzene level in the fuel not exceed than 1 ppm/L, except in industries and laboratories that produce or use it in chemical synthesis, fuels, chemical analysis, and the production of anhydrous ethanol. However, the maximum values for occupational environments are relatively high compared to the air considered safe for an urban environment, which is used to ensure the welfare and health of the population, especially children, the elderly, and sick. This article presents data on the impact of evaporative emissions arising from gas stations with a focus on gasoline, which is a mixture of a number of light hydrocarbons, including aromatics. Based on the data obtained at 40 fuel stations on the atmospheric concentrations of benzene, toluene, ethylbenzene, and xylenes (BTEX), the content of these compounds in the gasoline samples and the health impacts on the human being for the exposure of BTEX were determined using the hazard quotient (HQ).

## Materials and Methods

### Study settings and study design

This is the cross-sectional study and 40 petroleum fuel stations were randomly selected, 20 samples each from the city of Dammam and Khobar. Each station has residential, traffic intersection, and station area for measuring the concentration of BTEX. Fuel station was selected through simple random sampling, and this specific gas station was chosen because it is located in a residential area, near two big hospitals and two schools.

### Risk assessment

Benzene intake though inhalation was calculated following the United States Environmental Protection Agency's (USEPA)[19] conditions for occupational exposure. Exposure duration (ED) and exposure frequency (EF) values were derived from the interviewed data, and the inhalation uptake of 50% of all intakes (exposure concentration [EC]). Exposure was done by the calculation of inhalation intake (EC) at concentration of inhaled air benzene as the following formula: EC = EC or intake (μg/m$^3$) EC = (CA × ET × EF × ED)/AT.

CA = benzene concentration (μg/m$^3$),

ET = exposure time, h/day = 8 h/day or longer exposure time depending on individual data of workers,

EF = exposure frequency (5 days/week × 50 weeks/year) = 250 days/year guided by the USEPA. ED = ED (25 years) AT = averaging time = average time in hours/ exposure period (25 years for general working period is equivalent to 219,150 h, and 70 years for lifetime cancer-risk characterization (70 years × 365 days/year × 24 h/day = 613,200 h) guided by the USEPA.[19]

Cancer-risk characterization in comparison to the inhalation unit risk (IUR) was considered as the following: Cancer risk = IUR × EC.

Where IUR = $2.2 \times 10^{-6}$–$7.8 \times 10^{-6}$ per 1 μg/m$^3$,

The risk value >IUR or $2.2 \times 10^{-6}$–$7.8 \times 10^{-6}$means an unacceptable risk concerning cancer.

The risk value <$2.2 \times 10^{-6}$means an acceptable risk of cancer.

Noncancer risk assessment is considered as the HQs calculation of noncancer risk from chronic exposure to inhaled benzene was done by following the USEPA.[19]

HQ (unitless) = EC/reference concentration (RfC).

EC (μg/m$^3$) = exposure concentration in air.

RfC of benzene is 0.03 mg/m$^3$ from the USEPA-Integrated Risk Information System.

### Sampling and measurements

The exposure to BTEX in ambient air was monitored during the work shifts of 8 h. Ambient air samples were collected at 1.5 m above ground about 2–3 m from the fuel pump by active sampling with a flow rate of 100 ml/min using SKC battery-operated air sampling pump model PCXR4. Activated charcoal cartridges were used to collect samples. At each station, two to three samples were collected at several time intervals (total of 40 samples). Air samples were collected during day and night times (24 h) at fixed sites in a congested and noncongested street. The stratified random sampling was used for the selection of fuel stations. BTEX concentration levels were measured using a standard calibrated instrument. MIRAN SapphIRe Portable Ambient Analyzer was used for measuring BTEX.[18] LOD ranges from 0.05 to 0.07 μg/L, and relative standard deviation (SD) ranges from 0.5% to 11.6% at concentrations 5 and 0.1 μg/L, respectively [Figure 2].

Data analysis was done using the Statistical Package for the Social Sciences (SPSS) software (IBM, USA). This software was used for the data analysis. Results were presented in the form of frequency tables. Descriptive statics, independent comparison *t*-test, correlation, and graphical presentation were used for data presentation. A HQ was calculated, which is the indicator of health hazard to the community. A value of HQ (HQ) ≥1 indicates the risk of carcinogenic probability and value <1 indicates a safe level.[19]

## Results

The mean concentration of BTEX was found city of Dammam and Khobar as following for benzene 10.3 (SD: 2.5) (benzene threshold limit value [TLV] 0.5 ppm), toluene 4.09 (SD: 2.1) (toluene TLV 20 ppm), and xylene 2.47 (SD: 1.7) (xylene TLV 100 ppm), respectively. Both toluene and xylene were within the normal TLV, but benzene found excessive allowed TLV in both cities, significant differences were found between the levels of toluene and xylene among fuel petrol stations in Dammam in comparison with Khobar fuel stations [Table 1 and Figure 1].

Mean levels of BTEX [Table 2] concentration from petrol stations located at the residential area (8.0 ppm [SD: 3.1]), side streets (12.2 ppm [SD: 1.9]), and direct street (11.5 ppm [SD: 1.3]) in Dammam and Khobar. Benzene concentrations in all sites were found to be exceeding the TLV (0.5 ppm), while the mean concentration of toluene and xylene were within the TLV (20 ppm and 100 ppm, respectively) in all selected sites.

The mean difference of BTEX [Table 3] concentration among different sites and *P* value shows that difference was statistically significant.

**Table 1: The concentration of benzene, toluene, and xylene in the fuel station**

| Concentration | TLV (ppm) | Dammam city | | Al Khobar city | | *P* |
|---|---|---|---|---|---|---|
| | | Mean (SD) | Range (minimum-maximum) | Mean (SD) | Range (minimum-maximum) | |
| Benzene (ppm) | 0.5 | 10.30 | 0.25-21.63 | 11.07 | 0.83-25.05 | 0.791 |
| Toluene (ppm) | 20 | 04.09 | 0.48-19.20 | 01.74 | 0.26-04.6 | 0.001* |
| Xylene (ppm) | 100 | 02.47 | 0.61-06.88 | 03.97 | 0.50-11.83 | 0.006* |

*$P<0.01$. TLV: Threshold limit value, SD: Standard deviation

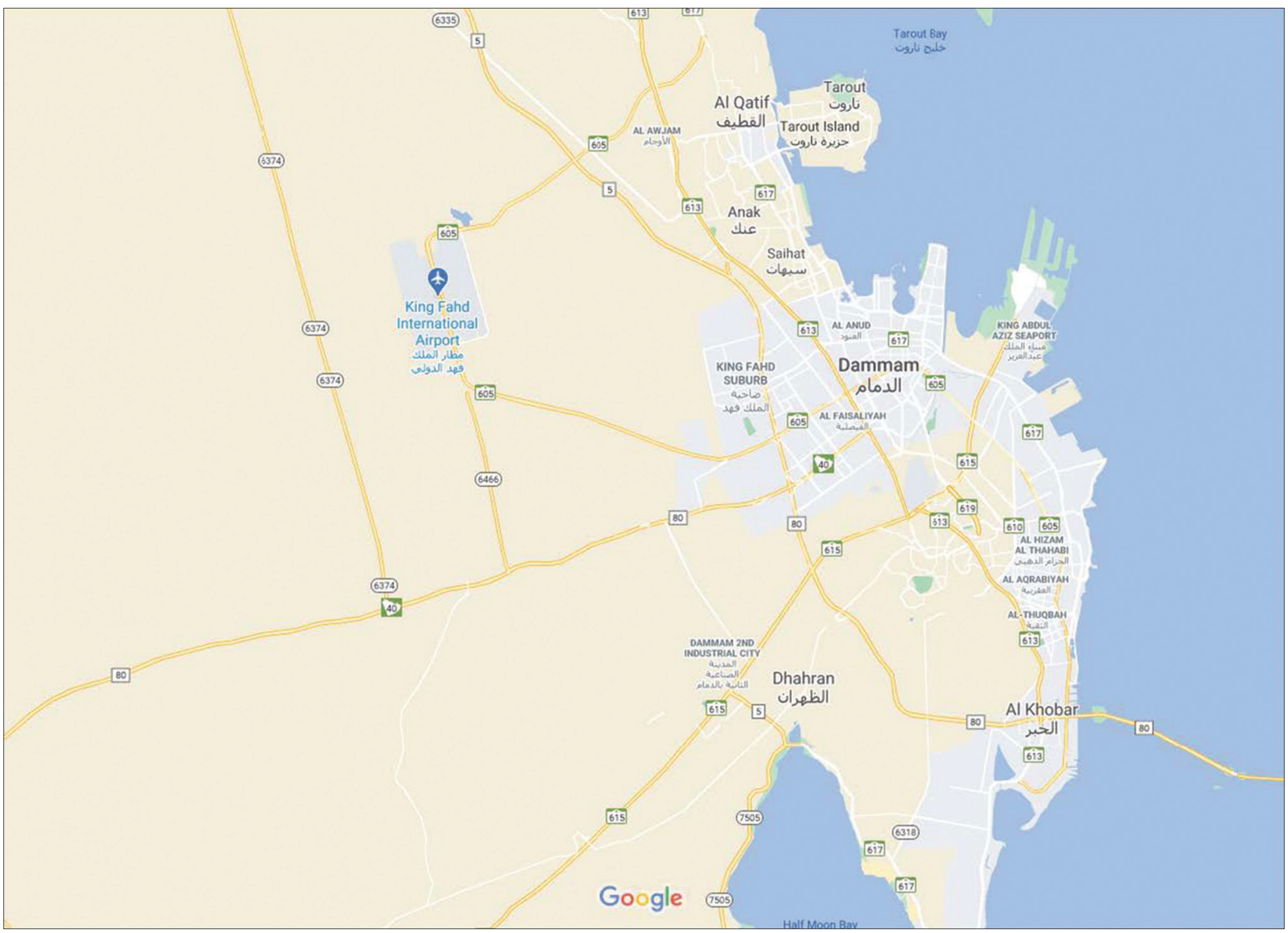


**Figure 1:** GIS Map for data collection sites

**Table 2: The concentration of benzene, toluene, and xylene in different sites adjacent to fuel stations in the city of Dammam and Khobar**

| Sites near to fuel station | Benzene TLV 0.5 ppm | | | Toluene TLV 20 ppm | | | Xylene TLV 100 ppm | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean ppm | Maximum ppm | Minimum ppm | Mean ppm | Maximum ppm | Minimum ppm | Mean ppm | Maximum ppm | Minimum ppm |
| Residential (*n*=8) | 8.0 | 10.40 | 5.60 | 2.5 | 3.61 | 1.40 | 2.0 | 2.80 | 1.20 |
| Site street (*n*=10) | 12.2 | 18.99 | 11.91 | 5.95 | 13.64 | 2.22 | 2.13 | 4.35 | 0.20 |
| Direct street (*n*=6) | 11.5 | 13.80 | 9.20 | 3.37 | 4.77 | 1.46 | 2.70 | 2.83 | 2.10 |

TLV: Threshold limit value

**Table 3: Concentration of benzene, toluene, and xylene in different areas of the fuel stations at Khobar city**

| Areas | *t*-test | Mean difference | *P* |
|---|---|---|---|
| Residential, side street and direct street | 8.13 | 10.56 | 0.05 |

**Table 4: The hazard quotient for benzene, toluene, and xylene**

| Areas | Benzene | Toluene | Xylenes |
|---|---|---|---|
| Residential | 1.76 | 10.48 | 11.75 |
| Side street | 2.34 | 12.77 | 11.89 |
| Direct street | 3.45 | 13.87 | 12.23 |

An HQ >1 is considered an adverse carcinogenic effect of concern.
HQ: Hazard quotient

**Table 5: Comparison between means levels of meteorological factor in fuel stations located in side street and direct street**

| Characteristics | Mean difference | *P* |
|---|---|---|
| Temperature (°C) | 23.27 | 0.14 |
| Humidity (%) | 42.81 | 0.037 |
| Wind speed (m/s) | 4.137 | 0.003** |

***P*<0.01

From the HQ [Table 4] for BTEX among different sites, HQ values shows that there is a risk of carcinogenic effect to the nearby community who living near to the fuel station.

The mean difference of meteorological factors such as [Table 5] temperature, humidity, and wind speed around the fuel stations, only wind speed was statistically significant ($P < 0.05$).

## Discussion

The results of the present study show that the concentrations of BTEX concentration levels in both cities were high at fuel station and around the fuel stations. All the mean values of measured BTEX in fuel petroleum stations in both Dammam and Khobar exceed the limits of air quality criteria. Hazards quotient value indicated that there is a risk of probability of cancers to the nearby living population.

In the current study, due to long exposure interval, the average levels of benzene (10.30 ± 1.88 ppm) were extremely higher in gasoline stations' environment as compared to the recommended exposure limits (0.5 ppm over 8 h exposure),[20] and in the USA, as the Occupational Safety and Health Administration permissible exposure level of benzene was 1 ppm. In addition, the National Institute of Occupational Safety and Health (NIOSH) recommended exposure level as 0.1 ppm). Furthermore, the American Conference of Governmental Industrial Hygienists TLV® for benzene was 0.5 ppm.[21]

The mean levels of benzene, ethylbenzene, toluene, and xylene in this study were higher than TLVs (100 ppm for each). These results could reveal the poor safety procedures applied in the studied stations, especially with the increasing number of transporting vehicles. Significant higher mean levels of BTEXs were also reported in fuel filling stations from Thailand (11.28 ± 5.03, 56.13 ± 73.96, 7.17 ± 9.20, and 10.59 ± 6.32 μg/m$^3$, respectively),[22] Brazil (mean values 144.5, 157.0, 35.8 and 46.7 μg/m$^3$, respectively)[23] and northern India (benzene, toluene, and xylene were 7.94 ± 1.45, 4.29 ± 0.69, 5.10 ± 1.08 ppm, respectively).[24]

Hazard ration in this which is found >1, indicated that increased risk of cancer in human body due to exposure to BTEX compund which is toxic to human health, this result is consistent with previous study result.[25] These results agreed with a study from North India[26] and in Brazil[27] although benzene levels were lower than the American Conference of Governmental Industrial Hygienist.

Although BTEX concentration between the residential area and the side street and/or direct streets was different as reported, the highest levels were found in the side street and/or direct street where the petroleum station was located, and higher traffic was increased. The relationships between the overall concentrations of BTEX and traffic volume were found to be cofactors for the elevated values for BTEX in fuel petrol stations in both Dammam and Khobar. Similar studies results have indicated that the levels of BTEX and air pollution gases may be also affected by the atmospheric condition, the traffic density, and different activities in gas stations.[28,29] In the case of gasoline, BTEX are the chemicals of greatest concern because of their toxicity and carcinogenic activity.

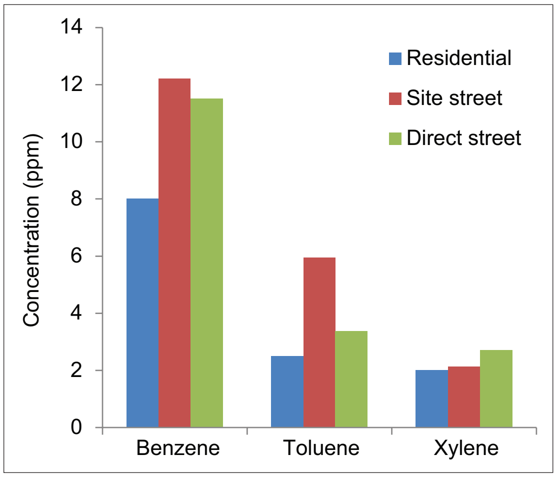


**Figure 2:** Concentration of benzene, toluene, and xylene in all selected fuel petrol stations at Dammam and Khobar city

The allowed levels of these compounds in the atmosphere for BTEX are 0.5, 50, 100, and 100 ppm, respectively. Furthermore, the NIOSH-issued guidelines for BTEX are 0.1, 100, 100, and 100 ppm, respectively.[22] The only significant differences in BTEX concentration levels between side street and residential area were found in the levels of benzene and toluene. These findings are in accordance with recent studies which revealed that apart from the increasing vehicular traffic, another major cause of worry is unacceptably high concentrations of air quality gases and BTEX in and around the refueling stations.[23,24]

The presence of BTEX in the fuel/gas products is a high risk for human health, specifically benzene compounds.[25] The results of this study have concluded that benzene concentration present in the fuel/gas products was higher than the standard level.

## Conclusion

The results of this study showed that BTEX concentrations in the ambient air of fuel stations were higher than the average values in fuel station areas and near to fuel satiation areas, and HQ values were also >1 which showed that probability of cancer among resident were high. Therefore, effective intervention will be needed to prevent harmful health effects.

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### Conflicts of interest

There are no conflicts of interest.

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