

## Spatial and temporal variation of BTEX in Villahermosa, Tabasco, during the dry and rainy seasons of 2024

### Variación espacial y temporal de BTEX en Villahermosa, Tabasco, en épocas seca y lluviosa de 2024

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#### Abstract

BTEX are common volatile organic compounds in urban air that, at high concentrations, can affect the health of the exposed population. In Mexico there are no regulatory limits or continuous monitoring for these compounds. In this study, BTEX concentrations were evaluated by passive sampling at five sites in Tabasco and their health risk during the dry and rainy seasons of 2024. Eighty samples were collected and analyzed by gas chromatography with a flame ionization detector (FID). The relative abundance was  $B < X < E < T$  in the dry season and  $B < X < T < E$  in the rainy season. The BTEX ratios suggest recent emissions from vehicle traffic. The results show that all sites exceed the US EPA reference risk level ( $1 \times 10^{-6}$ ), except for the Airport site in the dry season and the football school in the rainy season, with children being the most vulnerable.

#### Resumen

Los BTEX son compuestos orgánicos volátiles comunes en el aire urbano que, en altas concentraciones, pueden afectar la salud de la población expuesta. En México no existen límites normativos ni monitoreo continuo para estos compuestos. En este estudio se evaluaron las concentraciones de BTEX mediante muestreo pasivo en cinco sitios de Tabasco y su riesgo a la salud durante las temporadas seca y lluviosa de 2024. Se recolectaron 80 muestras analizadas por cromatografía de gases con detector FID. La abundancia relativa fue  $B < X < E < T$  en secas y  $B < X < T < E$  en lluvias. Las razones BTEX sugieren emisiones recientes por tráfico vehicular. Los resultados muestran que todos los sitios superan el nivel de riesgo de referencia de la US EPA ( $1 \times 10^{-6}$ ), excepto los sitios Aeropuerto en secas y la escuela de fútbol en lluvias, siendo los niños los más vulnerables.

Spatial and temporal variation of BTEX in Villahermosa, Tabasco, during the dry and rainy seasons of 2024		
Objectives	Methodology	Contribution
Determine BTEX concentrations.	Sampling by passive method using Radiello®.	Report on the spatio-temporal distribution of BTEX in Tabasco.
Analyze by gas chromatography.	Obtain chromatograms by GC-FID.	Establishing relationships between meteorology and BTEX
Estimate the carcinogenic risk and non-carcinogenic risk of BTEX.	Statistical Analysis	Scientific basis for future research on air quality.

BTEX, Passive Sampling, Gas Chromatography

Variación espacial y temporal de BTEX en Villahermosa, Tabasco, en épocas seca y lluviosa de 2024		
Objetivos	Metodología	Contribución
Determinar la concentración de BTEX.	Muestreo de BTEX por método pasivo utilizando Radiello®.	Informar sobre la distribución espacio-temporal de BTEX en Tabasco.
Analizar por cromatografía de gases.	Obtener cromatogramas por GC-FID.	Establecer relaciones entre la meteorología y BTEX
Estimar el riesgo carcinogénico y el riesgo no carcinogénico de BTEX.	Análisis estadístico.	Base científica para futuras investigaciones sobre calidad del aire.

BTEX, muestreo pasivo, Cromatografía de gases

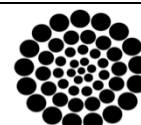
Area: Strengthening the scientific community

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## Introduction

Air, a vital resource for life, has been rapidly degraded by toxic pollutants due to social, economic, and industrial development. According to the (PAHO, 2014), 99% of the population is exposed to air pollution, which causes at least 4.2 million deaths worldwide each year. Air pollution generates high economic costs for health, the environment and productivity (Briz-Redón *et al.*, 2021). In Mexico, in 2023, atmospheric emissions represented an expenditure of 809,443.1 million pesos, equivalent to 2.5% of GDP (INEGI, 2024).

Among the known atmospheric pollutants are volatile organic compounds (VOCs), which are gases emitted by various sources that act as precursors to tropospheric ozone, some of which are toxic. The VOC group includes benzene, toluene, ethylbenzene, and xylenes (BTEX), which are the most common in urban air, and their health effects depend on the level and duration of exposure (David & Niculescu, 2021; Khoshakhlagh *et al.*, 2024).

In Mexico, as BTEX are not considered criteria pollutants, there are no regulations governing their maximum concentrations in ambient air. Therefore, their study and monitoring is important in order to establish regulatory frameworks in the future. In this regard, several studies on BTEX have been conducted in Mexico.

In León, Guanajuato, Mexico, BTEX concentrations in ambient air were evaluated in an urban and industrial area during two climatic seasons. The average BTEX concentrations in the rainy and cold dry seasons were  $3.52 \pm 0.36 \mu\text{g}/\text{m}^{-3}$  and  $4.11 \pm 0.38 \mu\text{g}/\text{m}^{-3}$ , respectively. The authors suggest that the main sources of emissions were motor vehicles and the combustion of fuels with a high sulphur content (Cerón-Bretón *et al.*, 2021a).

On the other hand, (Esteves *et al.* 2015) measured BTEX concentrations in the city of Orizaba, Veracruz, and the carcinogenic risk levels of benzene, analysed by FID gas chromatography. The results suggested that the main contribution of BTEX was from vehicular sources. The cancer risk was  $68 \times 10^{-5}$ , exceeding the acceptable LTCR value of  $1 \times 10^{-6}$  for adults according to the US EPA.

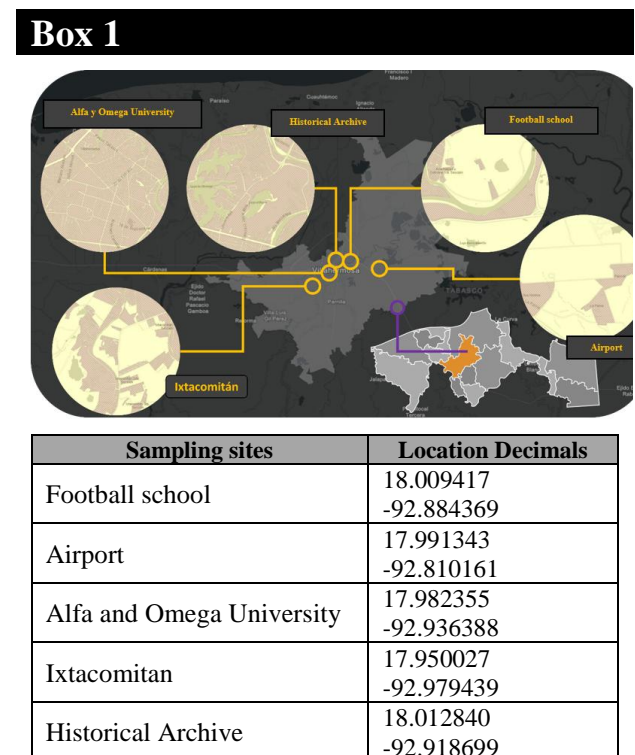
Passive sampling of BTEX allows concentrations to be measured at several sites at once. Its main advantages are its low cost, light weight (weighing 9 g), ease of use, no need for electricity or pumps, and its applicability both indoors and outdoors, even in remote or hard-to-reach areas.

## Methodology

### Study área

The state of Tabasco is located in the southeast of the Mexican Republic, between the geographical coordinates  $18^\circ 39'$  and  $17^\circ 15'$  north latitude and  $91^\circ 00'$  and  $94^\circ 07'$  west longitude. It borders the Gulf of Mexico and Campeche to the north. (INEGI, 2023). The Villahermosa Metropolitan Area, comprising Centro and Nacajuca, covers 2,100 km<sup>2</sup> and has 833,907 inhabitants. Its main activities are oil mining, trade, construction and services, which account for 73.0% of the state's GDP (Ministry of Economy, 2016).

The study area comprises five urban sites in the city of Villahermosa. These sites were selected based on certain criteria such as population density and their main socio-economic activities. Figure 1 shows a map of the location of the sampling sites and their coordinates.



**Figure 1**

Location and coordinates of sampling sites

Source: Own Elaboration

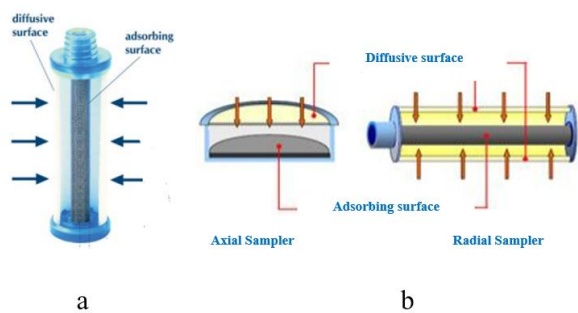
## Passive sampling of BTEX

Sampling was carried out using Sigma Aldrich® Radiello® passive samplers (Figure 2) developed by the Salvatore Maugeri Foundation (FSM) in Padua, Italy, in the mid-1990s ([sigma-aldrich.com/supelco](http://sigma-aldrich.com/supelco)) in accordance with European Standard EN 13528-2 (UNE, 2003). This type of passive sampler consists of a stainless steel adsorbent cartridge inserted into a microporous polyethylene membrane.

The stainless steel cartridge (adsorption surface) contains 300 mg of activated carbon and measures 60 mm in length and 5.8 mm in diameter (30–50 mesh). The microporous polyethylene membrane (pore size 5 µm), also called the diffuser body, has a diffusion surface 60 mm long by 16 mm in outer diameter, with a diffusion rate of 80 mL min<sup>-1</sup>.

The diffusion of contaminants is parallel to the radius of the cartridge, which is why it has been called a radial diffusion sampler. These passive samplers have greater capacity and higher sampling rates compared to traditional passive samplers. (Cerón-Bretón *et al.*, 2025; Pennequin-Cardinal *et al.*, 2005).

### Box 2



**Figure 2**

a) Radiello model. b) Axial and radial design of passive samplers

Source: (Sigma-Aldrich, 2025)

A total of 80 samples were collected during the dry (T1) and rainy (T2) seasons of 2024. Each of the Radiello devices was left exposed for two weeks and then analysed using gas chromatography with flame ionisation detection.

## Chromatographic análisis

The analytes were recovered from the Radiello® cartridges by chemical desorption, adding two millilitres of carbon disulphide (CS<sub>2</sub>), and were subjected to an ultrasonic bath for 10 minutes at a temperature of 10°C (Cerón-Bretón *et al.*, 2021b). The MTA/MA-030/A92 method of the Spanish National Institute for Safety and Hygiene was used for the chemical analysis. The chromatographic analysis of the collected samples was carried out at the Gas Chromatography Research Laboratory of the Faculty of Chemistry of the Autonomous University of Carmen. The gas chromatograph used was a Thermoscientific TRACE GC Ultra Gas Chromatograph with a flame ionisation detector (FID) that uses extra-dry air and ultra-high purity hydrogen and ultra-pure nitrogen as carrier gas and a 30 m x 0.25 mm ID TR-5 capillary column, Methyl type fused silica with a film thickness of 0.25 µm.

## Analysis of meteorological parameters: Wind roses and trajectory models

Wind roses were constructed using NOAA's Windrose software (NOAA ARL website) to determine the influence of prevailing winds at the study site for the selected seasons, as well as to establish whether there is a correlation between meteorological parameters and the concentrations obtained for BTEX compounds. Based on data from the National Oceanic and Atmospheric Administration (NOAA), the regressive trajectories of air masses will be analysed using the HYSPLIT trajectory model. These trajectories show the transport and dispersion of pollutants originating from various sources.

## Statistical análisis

This was performed using the Excel XLSTAT statistical package, version 2019. The non-parametric Friedman test ( $\alpha = 0.05$ ) statistical tools were used to evaluate the existence of significant differences between sampling seasons and the concentrations obtained from BTEX, as well as to determine whether these values come from the same population or not, and thus be able to infer whether there is seasonal or spatial variation. Principal Component Analysis (PCA) was also performed to explain the variance and determine the structure of the data set.

The information obtained from the PCA is used to identify whether a contaminant is secondary or primary, or to identify the specific source of the contaminants. For descriptive statistics, box plots were created to visualise the concentrations, means, maximums and averages of the measured contaminants; in this way, it is easy to identify which contaminant has the highest average concentrations and even if any patterns occurred during sampling.

### Health risk assessment

The carcinogenic potential of benzene is widely known (Vega-Campa *et al.*, 2023). The European Union recommends an annual limit of  $5 \mu\text{g m}^{-3}$  for benzene in ambient air and a minimal risk level for cancer by inhalation (MRL of 1 in 10,000), while the US EPA sets a value of 4.0 ppbv for this pollutant (US EPA, 2012). In this study, the methodology proposed by (Zhang *et al.* 2015) was used to determine daily exposure (E), lifetime cancer risk (ILTCR) and cancer non-risk potential (HQ).

### Assessment of the carcinogenic risk of benzene

An individual's daily exposure by inhalation can be calculated as:

$$E = \frac{C \times IRa \times Da}{BW} \quad [1]$$

Where:

$E$  = is the daily exposure by inhalation in mg/kg per day.

$C$  = is the average concentration of benzene in  $\text{mg/m}^3$ .

$IRa$  = is the inhalation rate for an adult ( $0.83 \text{ m}^3 \text{ h}^{-1}$ ) (US EPA, 1998).

$Da$  = is the duration of exposure for an adult (24 hr/day).

$BW$  = is the average adult body weight (65 kg).

The lifetime cancer risk (LTCR) is calculated as:

$$LTCR = E \times SF \quad [2]$$

Where:

$LTCR$  = is the lifetime cancer risk.

$SF$  = is the slope factor ( $2.98 \text{ E}^{-02} \text{ kg day/mg}$ ).

The slope factor for inhalation of toxic substances ( $SF$ ) is when the carcinogenic effect of exposure is considered linear.

An SF value of  $2.98 \text{ E}^{-02} \text{ kg day/mg}^{-1}$  was considered for benzene in accordance with (US EPA, 2014). The values determined will be compared with the permissible limit values established by the US EPA and the WHO. The non-carcinogenic risk of benzene will be measured as a hazard quotient (HQ), calculated as:

$$HQ = \frac{C}{RfC} \quad [3]$$

Where:

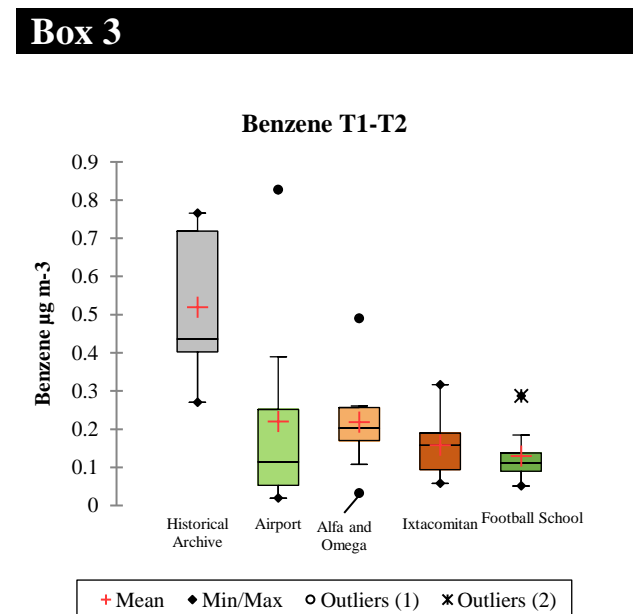
$C$  = is the daily intake ( $\mu\text{m}^{-3}$ )

$RfC$  = This is the inhalation reference concentration proposed by the US EPA for benzene ( $0.03 \mu\text{g m}^{-3}$ ), toluene ( $5 \mu\text{m}^{-3}$ ), ethylbenzene ( $1 \mu\text{m}^{-3}$ ) and xylene ( $0.1 \mu\text{m}^{-3}$ ) (US EPA, 2002).

## Results

### Descriptive statistics for BTEX

During seasons T1 and T2, benzene showed the highest average concentrations at the Historical Archive Site with  $0.5188 \mu\text{g m}^{-3}$ , a maximum of  $0.7658 \mu\text{g m}^{-3}$  and a minimum of  $0.2703 \mu\text{g m}^{-3}$ . The Football School site had the lowest concentrations of this toxic contaminant, with an average of  $0.1292 \mu\text{g m}^{-3}$ , a maximum of  $0.2864 \mu\text{g m}^{-3}$ , and a minimum of  $0.0510 \mu\text{g m}^{-3}$  (Figure 3).



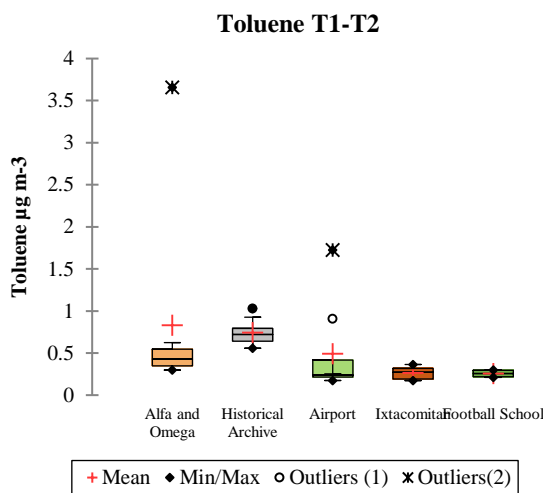
**Figure 3**

Descriptive statistics for benzene seasons T1-T2

Source: Own Elaboration

In the case of toluene, the descriptive statistics are shown in Figure 4. The site with the highest concentrations in both seasons was Alfa y Omega, with an average of  $0.8307 \mu\text{g m}^{-3}$  and maximum and minimum values of  $3.6581$  and  $0.2978 \mu\text{g m}^{-3}$ , respectively. The site Escuela de futbol had the lowest concentrations, with an average of  $0.2562 \mu\text{g m}^{-3}$ , very similar to the site Ixtacomitán, with an average of  $0.2651 \mu\text{g m}^{-3}$ .

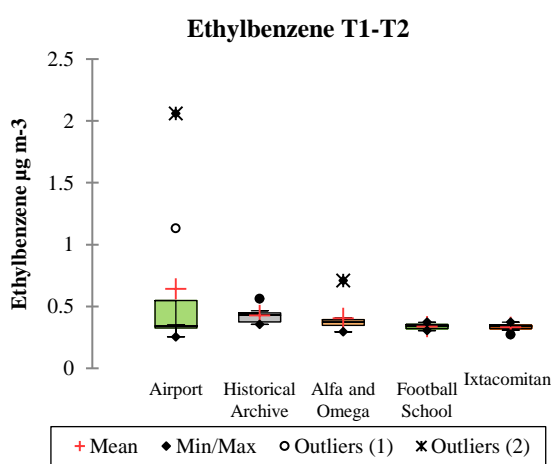
**Box 4**



**Figure 4**  
Descriptive statistics for toluene seasons T1-T2.  
Source: Own Elaboration

Figure 5 shows the descriptive statistics for ethylbenzene for both seasons T1 and T2. It can be seen that the airport had the highest concentrations, with an average of  $0.6411 \mu\text{g m}^{-3}$ , a minimum value of  $0.2551 \mu\text{g m}^{-3}$ , and a maximum value of  $2.0606 \mu\text{g m}^{-3}$ .

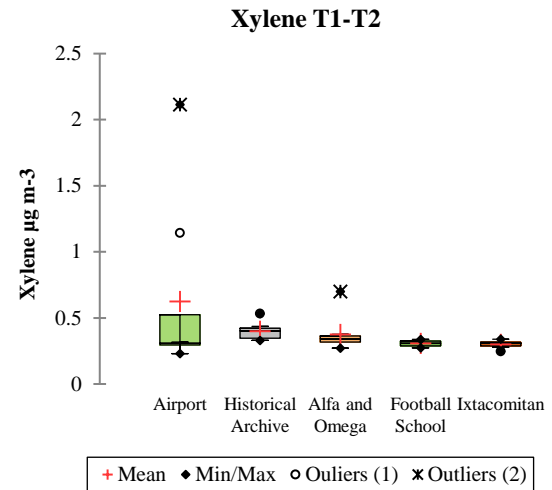
**Box 5**



**Figure 5**  
Descriptive statistics for ethylbenzene seasons T1-T2.  
Source: Own Elaboration

Xylene also had its highest concentrations at the Airport site, with an average of  $0.6254 \mu\text{g m}^{-3}$  and a minimum and maximum of  $0.2298$  and  $2.1153 \mu\text{g m}^{-3}$ , respectively, as shown in Figure 6.

**Box 6**



**Figure 6**  
Descriptive statistics for Xylene seasons T1-T2.  
Source: Own Elaboration

**Bivariate Analysis and Principal Component Analysis**

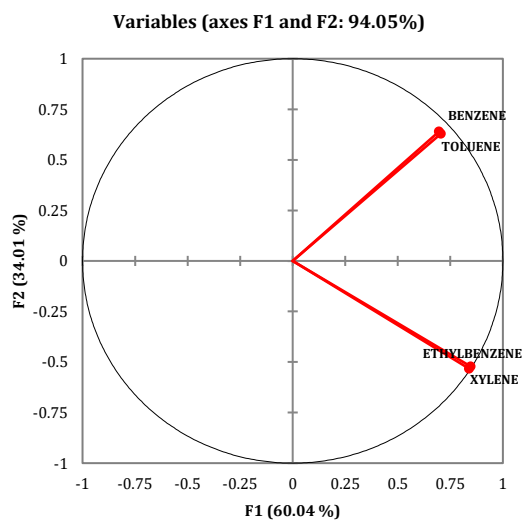
Spearman's correlation matrices were constructed as a bivariate analysis technique to identify relationships between the different BTEX measured, as well as principal component analysis (PCA) to identify groups of variables. Table 1 shows Spearman's correlation matrix and PCA for BTEX concentrations at all sites measured.

**Box 7**

**Table 1**  
Spearman correlation matrix and PCA for BTEX concentrations for all sites measured during the dry and rainy seasons

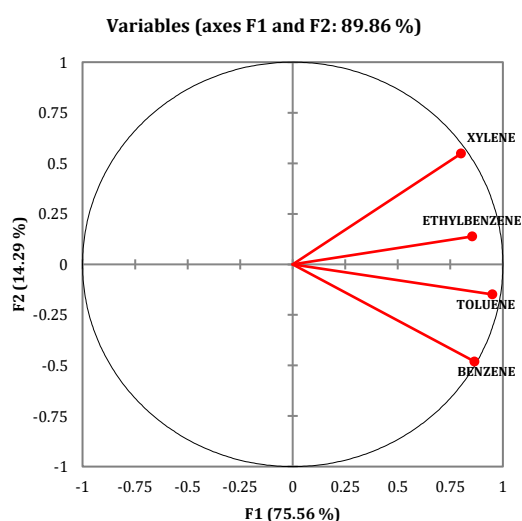
Variables	Benzene	Toluene	Ethylbenzene	Xylene
Football School				
Benzene	<b>1</b>	<b>0.786</b>	0.262	0.238
Toluene	<b>0.786</b>	<b>1</b>	0.238	0.286
Ethylbenzene	0.262	0.238	<b>1</b>	<b>0.976</b>
Xylene	0.238	0.286	<b>0.976</b>	<b>1</b>

Values in bold are different from 0 with a significance level of  $\alpha=0.05$ .



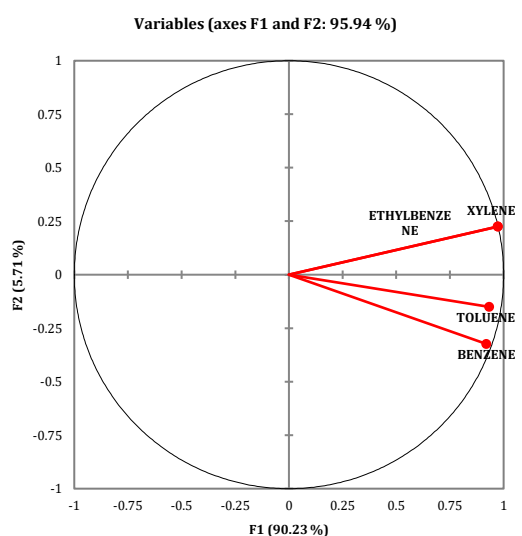
Variables Football School	Benzene	Toluene	Ethylbenzene	Xylene
Benzene	1	<b>0.881</b>	0.643	0.452
Toluene	<b>0.881</b>	1	0.690	0.714
Ethylbenzene	0.643	0.690	1	0.643
Xylene	0.452	0.714	0.643	1

Values in bold are different from 0 with a significance level of  $\alpha=0.05$ .



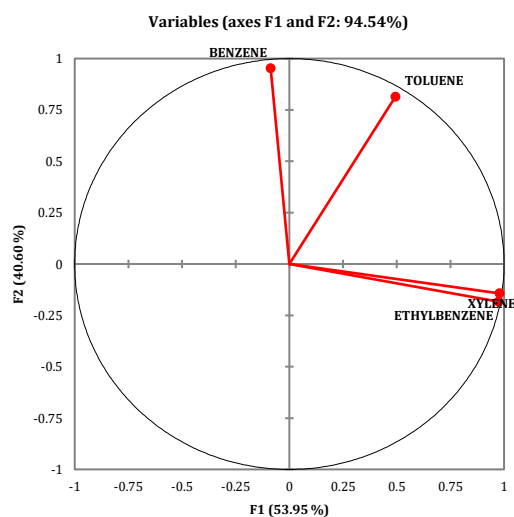
Variables Football School	Benzene	Toluene	Ethylbenzene	Xylene
Benzene	1	<b>0.833</b>	<b>0.833</b>	<b>0.833</b>
Toluene	<b>0.833</b>	1	<b>0.857</b>	<b>0.857</b>
Ethylbenzene	<b>0.833</b>	<b>0.857</b>	1	<b>1.000</b>
Xylene	<b>0.452</b>	<b>0.714</b>	<b>0.643</b>	1

Values in bold are different from 0 with a significance level of  $\alpha=0.05$ .



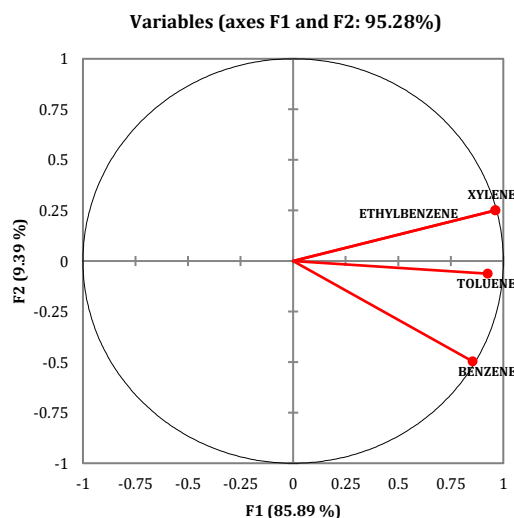
Variables Football School	Benzene	Toluene	Ethylbenzene	Xylene
Benzene	1	0.643	-0.238	-0.190
Toluene	0.643	1	0.310	0.333
Ethylbenzene	-0.238	0.310	1	<b>0.976</b>
Xylene	-0.190	0.333	<b>0.976</b>	1

Values in bold are different from 0 with a significance level of  $\alpha=0.05$ .



Variables Football School	Benzene	Toluene	Ethylbenzene	Xylene
Benzene	1	<b>0.762</b>	0.714	0.714
Toluene	<b>0.762</b>	1	<b>0.833</b>	<b>0.833</b>
Ethylbenzene	0.714	<b>0.833</b>	1	<b>1.000</b>
Xylene	0.714	<b>0.833</b>	<b>1.000</b>	1

Values in bold are different from 0 with a significance level of  $\alpha=0.05$ .



Source: Own Elaboration

Spearman's correlation analysis revealed positive and significant relationships between BTEX compounds at most sites, indicating common emission sources associated with fossil fuel combustion and vehicular traffic. At the Football School and the Airport, the strongest correlations were between pairs such as benzene-toluene ( $r = 0.786$ ) and ethylbenzene-xylene ( $r = 0.976$ ), linked to mobile sources (vehicles and aircraft) (Mugica-Álvarez *et al.*, 2020). At Alfa y Omega and the Historical Archive, high and uniform correlations reflected a single dominant source: heavy urban traffic.

In contrast, Ixtacomitán showed a differentiation of benzene from other compounds, suggesting additional sources such as domestic combustion or waste burning. This differential pattern of benzene is consistent with its greater chemical stability and ability to remain in the atmosphere longer (ATSDR, 2019). Principal component analysis (PCA) identified patterns of variation and dominant sources of BTEX compounds at the five sites. In general, two main groups were distinguished: one associated with vehicular traffic and the other with diffuse or industrial emissions. At the Football School and Ixtacomitán, mixtures of mobile and industrial sources were observed, while at the Airport, Alfa y Omega and Archivo Histórico, a single vehicular source, linked to urban or air traffic, predominated. The high explained variances (60–90%) in the first components confirm that fossil fuel combustion is the main cause of BTEX presence in the areas studied.

### Urban Containment Perimeters

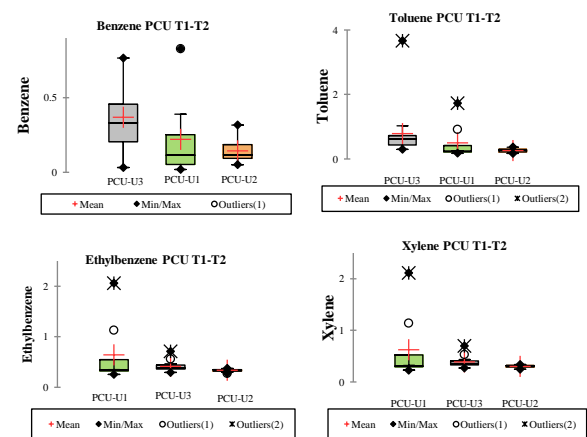
To determine the portion of the population exposed to these toxic contaminants at each site, a general classification of Urban Containment Perimeters (PCU) was made as follows U1: Areas with the highest concentration of jobs and economic activities, representing the consolidated core of the city. U2: Areas with basic services such as water and drainage, where housing development is promoted near the U1 perimeter; and finally U3: Areas of urban expansion adjacent to the consolidated areas (U1 and U2), delimited according to the population size of the city (SEDATU, 2018).

The points to highlight are that the Football School Site was classified as (U3) as it is located in a conurbation with a high influx of people and the presence of agricultural and livestock activities. The main access is by motorised transport, which increases the potential for vehicle emissions. The Airport site, classified as (U2), is located outside the urban area but has a significant urban impact due to the high number of daily users and its proximity to residential neighbourhoods and the Yumka tourist park. It is an area with high mobility and constant traffic flow. The Alfa y Omega site (U1) is a fully urbanised and consolidated area with a high concentration of services and businesses: shopping centres, petrol stations and parks.

It is an area of intense economic and social activity, with heavy vehicle and pedestrian traffic. The Ixtacomitán site (U3) is located on the southwestern outskirts of the city and is predominantly residential with little commercial activity but close to a busy transport route, making it a potential point for capturing emissions. Finally, the Archivo Histórico (U2) site is located very close to the city centre, with a wide range of services and urban activities and facing one of the busiest roads, which contributes to exposure to pollutants.

Taken together, the five sites show an urban gradient ranging from consolidated areas (U1) to peripheral areas (U3), allowing for a comparison of BTEX concentrations according to the degree of urbanisation and human activity (Figure 7).

### Box 8



**Figure 7**

BTEX Urban Containment Perimeters (PCU) for seasons T1 and T2

Source: Own Elaboration

The results obtained show clear spatial and temporal variability in BTEX concentrations within the Urban Containment Perimeters (PCU-U1, U2 and U3). During the dry season (T1), higher BTEX concentrations were observed, especially in PCU-U3, which corresponds to areas with higher vehicle density and intensive commercial activity. This is consistent with previous studies conducted in tropical urban environments, where lower relative humidity and greater atmospheric stability during the dry season favour the accumulation of volatile organic compounds (VOCs) due to lower vertical dispersion (Bretón *et al.*, 2018).

During the rainy season (T2), the average concentrations of all compounds decrease, especially in PCU-U2, which can be attributed to increased precipitation and greater atmospheric turbulence, which promote the removal and dilution of pollutants.

However, specific peaks were recorded at specific sites (such as PCU-U1) that could be associated with local mobile sources or fugitive hydrocarbon emissions related to service stations and automotive workshops.

Statistical analysis of normality applied to BTEX (benzene, toluene, ethylbenzene and xylenes) concentrations in the PCU-U1, PCU-U2 and PCU-U3 areas during seasons T1 and T2 revealed that the data do not follow a normal distribution, as indicated by the p-values obtained in the Shapiro-Wilk, Anderson-Darling, Lilliefors and Jarque-Bera tests. From an environmental perspective, this variability suggests the existence of intermittent emission sources or external influences such as weather conditions and urban and industrial activity patterns that significantly alter the levels of these pollutants in the air. The non-normal behaviour of the data also shows that the dispersion and accumulation processes of these compounds are neither constant nor uniform.

In terms of meteorology, wind roses were created and a higher average wind speed was identified in the dry season (2.83 m/s) compared to the rainy season (2.32 m/s). This analysis allows us to infer the predominant direction of air mass transport and, therefore, to estimate the possible origin of the BTEX compounds detected. At most sites (Airport, Alfa y Omega, Ixtacomitán, and Escuela de Fútbol), winds come from the east-northeast ( $56^{\circ}$ – $64^{\circ}$ ) during the dry season, with high resulting vectors (35–38%), indicating a defined and stable prevailing direction. Under these conditions, it is likely that the compounds detected originate from sources located to the east and northeast of the city, where there are high-traffic roads and light industrial areas.

### BTEX ratios

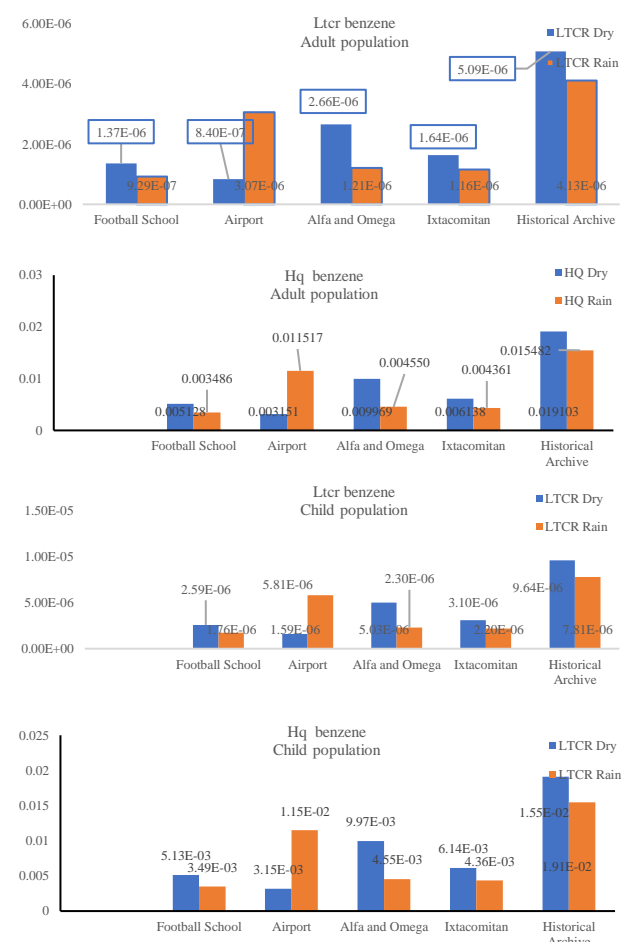
The toluene/benzene (B/T) and xylene/ethylbenzene (X/E) ratios are calculated to determine the probable origin of BTEX at a specific site. Ratios (B/T) with values lower than 2-3 are specific to sites with a high influence of motor vehicle traffic (Elbir *et al.*, 2006).

The (X/E) ratio is used to deduce the photochemical age of air masses, and thus to determine whether they are local and from fresh emissions (values  $<4.4$ ), or from regional aged air masses (Keymeulen *et al.*, 2001). For the dry season at all sampling sites, the average B/T ratio was 2.529, and for the rainy season, it was 2.946, indicating that the recorded BTEX emissions probably originated from vehicular sources. On the other hand, for the X/E ratio, the averages for all sites in the dry season were 0.920 and 0.922 for the rainy season, indicating that the measured BTEX concentrations were from fresh, local emissions.

### Health risk assessment análisis

The cancer risk index was calculated as a result of benzene exposure for the adult and child population living in the study area. The lifetime cancer risk (LTCR) values at the five study sites for seasons T1 and T2 are shown in Figure 8.

#### Box 9



**Figure 8**

LTCR and HQ values for the five study sites for benzene inhalation for adults and children during both study seasons

Source: Own Elaboration

The lifetime cancer risk (LTCR) values obtained for the five study sites, both in the adult and child populations, show significant variations between the dry and rainy seasons, being higher in the dry season for all sites, except for the airport site, which had higher values in the rainy season. According to international guidelines, the reference value established for LTCR is  $1 \times 10^{-6}$ , while the WHO reference value is  $1 \times 10^{-5}$ . The average LTCR for benzene in the adult population in both seasons was  $3.20459 \times 10^{-5}$  and for children  $8.2885 \times 10^{-03}$ , showing that there is a risk for both populations as they exceed the established limits.

The HQ values for the different compounds are below the threshold of 1.0 at all sites and for both seasons, indicating a non-carcinogenic risk. However, slight increases in HQ are observed at the study sites during the dry season and at sites with higher vehicular or industrial activity.

## Conclusions

The study on BTEX in Villahermosa, Tabasco showed notable spatial and temporal differences. It was observed that the highest concentrations were recorded at the airport and the historical archive, mainly associated with heavy traffic and urban activities, while the football school and Ixtacomitán presented low levels and greater dispersion of pollutants. Weather conditions had a direct influence, as higher concentrations were detected during the dry season due to lower atmospheric dispersion, and during rainfall, precipitation and humidity reduced average concentration levels.

Statistical analysis (Spearman and PCA) confirmed that toluene, ethylbenzene and xylenes share a common vehicular source, while benzene also comes from stationary or industrial sources. In terms of health risk, the carcinogenic risk from benzene exceeded the EPA and WHO reference values, representing a potential danger to the population, especially during the dry season; the other compounds did not show an immediate risk, but they did show a cumulative risk.

The results obtained highlight the urgent need to incorporate BTEX compounds into national air quality monitoring systems, given their potential adverse effect on human health.

It is also recommended to strengthen vehicle emission management and area source control strategies, promote the use of clean fuels, and conduct continuous environmental monitoring campaigns in medium-sized cities such as Villahermosa, where urbanisation and vehicular traffic are critical factors in pollution.

## Declarations

### Conflict of interest

The authors declare that they have no conflict of interest. They have no known financial interests in Competencia or personal relationships that could have influenced the information reported in this chapter.

### Contribution of the authors

*Uc-Chi, Martha Patricia:* was responsible for writing the introduction and graphic summaries. She carried out the analysis of the data obtained.

*Cerón-Bretón, Julia Griselda:* was responsible for writing the discussion of the results.

*Cerón-Bretón, Rosa María:* was responsible for writing the conclusions and references. She also participated in the final revisions of the book chapter.

*Silis-Esquivel, Jhoanna:* was responsible for writing the results and preparing the tables and figures.

### Availability of data and materials

The data are available upon request at: [muc@pampano.unacar.mx](mailto:muc@pampano.unacar.mx)

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### Abbreviations

ACP	Principal Component Analysis
ATSDR	Agency for Toxic Substances and Disease Registry
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CONAPO	National Population Council Government

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COVs	Volatile organic compounds	
FSM	Salvatore Maugeri Foundation	
GC-FID	Gas chromatography with flame ionisation detector	
HQ	Hazard Quotient	
HYSPLIT	Hybrid Lagrangian Trajectories	Single-Particle Integrates
INEGI	National Institute of Statistics and Geography	
LTCR	Lifetime cancer risk	
MRL	Minimal Risk Level	
NOAA	National Oceanic and Atmospheric Administration	
OMS	World Health Organisation	
PCU	Urban Containment Perimeters	
US EPA	United States Environmental Protection Agency	
XLSTAT	Statistical Software for Excel	

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