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Assessment of BTEX Concentrations in Air Ambient of Gas Stations Using Passive Sampling and the Health Risks for Workers

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Abstract

Gas stations are important emissions source of benzene (C_6H_6), toluene (C_7H_8), ethylbenzene (C_8H_{10}), and ortho, meta and para-xylene (C_8H_{10})—better known by the acronym BTEX. The objective of this study was to determine the concentrations of BTEX compounds in the ambient air of ten gas stations in the cities of Salvador and Feira de Santana, Bahia, Brazil and evaluate the health risks to workers. Passive samplers diffusive of the Radiello®, containing activated carbon as adsorbent, were used. The samplers were exposed for 8 h and then the analytes were recovered by chemical desorption with CS_2 and determined by GC-FID. The BTEX concentrations found in the ambient air of gas stations ranged from 46.72 - 435.43 μg·m^{-3} for benzene; 25.54 - 342.46 μg·m^{-3} for toluene, 7.10 - 30.07 μg·m^{-3} for ethylbenzene, 9.36 - 89.73 μg·m^{-3} for m, p-xylene and 9.79 - 52.29 μg·m^{-3} for o-xylene. The concentrations of toluene, ethylbenzene and xylenes found in gas stations were lower than the limits recommended by the US NIOSH and NR-15 of the Ministry of Labour of Brazil; however, it should be considered the risks due to chronic exposure of workers. Benzene concentrations in three gas stations were above the exposure limit recommended by NIOSH (3.20×10^2 μg·m^{-3}). Samplings were also held outdoors at 250 m of two gas stations. The total concentrations of the BTEX compounds were equal to 24.97 and 35.51 μg·m^{-3}, and benzene concentrations were about 3 - 4 times higher than the annual pattern of 5.0 μg·m^{-3} established by Union European, as tolerance limit for outside areas. These data confirm that the next areas of gas stations are subject to the effects of volatilization of these compounds. Additionally, the values found in the 10 gas stations for the cancer risk ranged from 4.06×10^{-5} - 3.78×10^{-4} (mean of 1.82×10^{-4}) for workers exposed to benzene for 30 years (acceptable limit equal 1.00×10^{-6}). The cancer risk is very high, because the values found are about 40 - 378 times above the acceptable limit and reinforce the need to adopt urgent measures to reduce or eliminate exposure of workers to the BTEX compounds. The average non-cancer risk to benzene, toluene, ethylbenzene and xylenes was 1.84, 5.76×10^{-3}, 4.59×10^{-3} and 1.37×10^{-1}, respectively (acceptable limit < 1). Only to benzene the average value of this risk is above 1, showing that workers are likely the adverse effects health due to exposure to benzene.

Keywords

BTEX, Gas Stations, Passive Sampling, Health Risk

1. Introduction

In recent decades, the global concern about the degradation of air quality has been increasing, and many studies have shown the impacts on the environment and human health resulting from gas emissions and potentially harmful particles into the atmosphere. In occupational environments, air pollution is directly related to the specific activities carried out on site and reaches direct way workers due to the long exposure time.

In Brazil, gas stations are establishments that play retailer resale activities of liquid fuels derivates petroleum, fuel alcohol and other automotive fuels, with equipment available for metering and the storage of fuels [1]. These activities, added with the high rate of evaporation fuels and evaporative losses from vehicle emissions are the main sources of change in the air quality in these occupational environments.

Gasoline is one of the most important petroleum fuels, and it is chemically composed of hydrocarbons containing 4 to 12 carbon atoms, which mainly belong to the classes of paraffins (normal and branched), olefins, naphthenes and aromatics [2]. The gasoline Brazilian type A is produced by refineries and delivered directly to the distributing companies, and the gasoline type C marketed in the gas stations is a mixture of gasoline type A with 27% v/v anhydrous ethyl alcohol used as additive and at most 1% v/v of benzene and 45% v/v aromatic hydrocarbons [3] [4].

Among the aromatic hydrocarbons present in gasoline are compounds benzene (C_6H_6), toluene (C_7H_8), ethylbenzene (C_8H_{10}), and ortho, meta and para-xylenes (C_8H_{10})—known by the acronym BTEX. These compounds are emitted to the atmosphere by the vehicle fleet (fossil fuel combustion and evaporative losses), gas stations (distribution and storage of fuels) and industrial processes [5] [6] [7], and are classified as priority environmental pollutants because of the high toxicity and mobility [8]. Among the BTEX compounds, benzene is considered the most dangerous and has become one of the most intensely regulated substances in the world to be classified as carcinogenic to humans (group 1) by the International Agency for Research on Cancer-IARC [9]. The WHO estimated that benzene concentration of 1.7 μg·m^{-3} can cause leukemia in 10 cases per 1 million people [10].

Health effects from exposure to compounds BTEX depend on the dose and duration of exposure as acute or chronic effects. Chronic exposure primarily to benzene can lead to neurological, endocrine, immunological and hematological disorders such as aplastic anemia and myeloid leukemia. The increased incidence of reproductive problems and birth defects, including cleft lip is also associated with exposure to benzene [8] [11] [12] [13]. In gas stations, adverse health effects of workers are reported due to acute exposure to BTEX, such as headache, cough, fatigue, skin irritation and eyes, nausea, dizziness, depression and asthma [14] [15] [16].

Few recent studies on emissions of BTEX in gas stations have been reported in the world, to evaluate the air quality in these establishments [17] [18] [19] [20] and the health risks to workers associated with these compounds [5] [15] [21] [22] [23] [24] [25], but no study has been carried out previously in the Bahia state, Brazil. In addition, most of the work uses active air sampling techniques, where a vacuum pump is used to suck air into the sampling device. The application of such techniques is often ineffective, mainly due to the high cost of equipment and the need for continuous supply of electricity [26].

Passive sampling is based on physical processes such as diffusion and permeation, without involving the active movement of air through the sampler, not requiring suction pump to force air to be sampled. The application of passive samplers when compared to conventional active techniques also has other advantages, such as simple, small and portable, easy handling and transportation to places of difficult access, and the use by workers in occupational environments. They do not need to use pumps and electricity. These features make these samplers suitable for applications in air monitoring indoor and outdoor environments [27] [28] [29].

This study aims to determine the BTEX concentrations in the air of gas stations using passive samplers, and evaluate the health risks to workers caused by exposure to these compounds. In addition, two external locations were chosen to 250 m of gas stations to verify the influence of these compounds in the surrounding areas.

2. Materials and Methods

2.1. Description of the Study Areas

The data were collected in 10 gas stations in the cities of Salvador, the state capital of Bahia and in Feira de Santana located 100 km from the Salvador city (**Figure 1**). Among these, two gas stations near highways (S1 and S2), four in commercial areas (S3, S4, S6 and S7) and four in residential areas (S5, S8, S9 and S10). Sampling occurred after request to the respective managers of gas stations for access to the physical space, through the terms of agreement previous and research intent. Two external locations at 250 m of S5 and S7 gas stations designated L1 250 and L2 250, and close to hospitals, medical centers, schools,

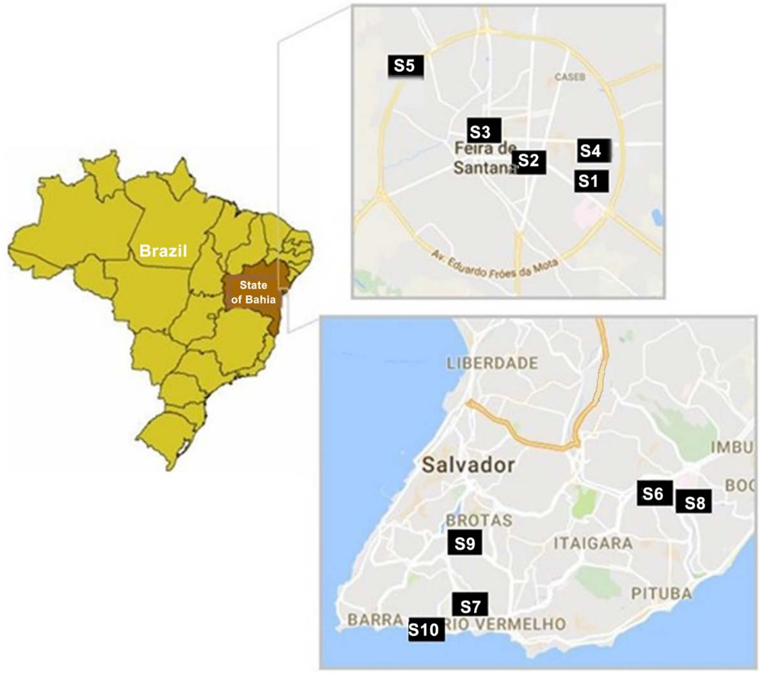

Figure 1. Location of gas stations in the Salvador and Feira de Santana cities, Bahia, Brazil.

universities and/or residences were also chosen for sampling in order to check the dispersion of BTEX compounds in the areas surrounding the gas stations.

2.2. Sample Collection and Analytical Method

The compounds BTEX sampling in the gas stations were performed using passive samplers diffusive Radiello® patented by the Foundation Salvatore Maugeri (http://www.radiello.com), comprising a cylindrical diffusive surface composed of microporous polyethylene having thickness of 1.7 mm, medium porosity 25 ± 5 μm, and a diffusive path of 18 mm and a adsorbent surface comprises a cylindrical stainless steel mesh, opening 100 mesh and a diameter of 5.8 mm, filled with approximately 530 ± 30 mg of activated carbon with particle size 35 - 50 mesh.

The passive samplers were exposed in gas stations near the supply pumps, in local free barriers, not to hinder the dispersion of air to the passive samplers, with height of approximately 2 m, for periods of 8 h (hours daily of workers). After this time the samplers were removed, identified, properly wrapped in parafilm, packed in box thermic with ice and immediately transported to the laboratory.

The analytes were subsequently recovered by desorption chemical with 1.0 mL of carbon disulfide (CS_2) in an ultrasound bath Bransonic 3510 R-MT with ice water (T ≈ 10˚C) to avoid any possibility of evaporation of BTEX or CS_2 for 10 min with manual agitation every 2 min to ensure that the solvent keep in touch with the analytes contained in the cartridge. For determination of the compounds BTEX was used gas chromatography (GC) with ionization detection

(FID), under the following analytical conditions: gas chromatograph (Agilent), Model 7820, using a HP-5 Agilent column (5% phenyl, 95% dimethylpolysiloxane), with 30 m length × 0.32 mm ID × 0.25 μm thick film, the initial temperature was maintained at 40˚C for 3 min, then high to 140˚C at a heating rate of 8˚C min^{-1} and raised to 220˚C at a heating rate of 20˚C min^{-1} lasting for 4.5 min at this temperature; injector with flow division (split) in the ratio 1:20, using as carrier gas helium at a rate of 1.5 $mL·min^{-1}$ and nitrogen as make-up gas, with the arrival of both the detector at a flow rate of 30 $mL·min^{-1}$, the flame detector maintained with synthetic air at 300 $mL·min^{-1}$ and hydrogen at 30 $mL·min^{-1}$.

Calibration curves were constructed using with a standard mixture UST HC BTEX MIX (2000 $μg·mL^{-1}$ in methanol, Sigma-Aldrich) for obtaining a response signal (peak area in the chromatogram) as a function of concentration known of standard. The curves were composed of 7 points (0.7 to 20 $μg·mL^{-1}$) having the following correlation coefficients: benzene (R = 0.9993), toluene (R = 0.9987), ethylbenzene (R = 0.9996), m, p-xylene (R = 0.9996) and o-xylene (R = 0.9998). The precision of the method was evaluated by triplicate standard mixture of BTEX in three different levels, and results expressed in terms of relative standard deviation were less than 5%.

2.3. Health Risks Calculation

The risk assessment is used to estimate the potential carcinogen and non-carcinogen adverse health effects [30]. The risks were calculated based on recommended reference doses and in working conditions of the workers of the gas stations studied (**Table 1**). The cancer risk was calculated based on the Equation (1):

$$\text{Cancer Risk}\left(\text{CR}\right)=\text{CDI}_{\text{L}}\times\text{SF} \quad (1)$$

Table 1. Description of the variables used in the calculation of cancer and non-cancer risks.

Variable	Description	Value	Unit
CA	Contaminant concentration	---	$mg·m^{-3}$
IR	Inhalation rate, adult	0.83	$m^3·h^{-1}$
ED	Exposure duration, adult	8	$hours·day^{-1}$
EF	Exposure frequency	48	$week·year^{-1}$
L	Length of exposure	30	years
ATL	Average lifetime	75	years
BW	Bodyweight	70	kg
NY	Number of days per year	365	days
D	Days of work	6	days
$SF_{Benzene}$	Slope factor	0.029	$mg·kg^{-1}·day^{-1}$
$RfD_{Benzene}$	Reference dose to benzene	0.00855	$mg·kg^{-1}·day^{-1}$
$RfD_{Toluene}$	Reference dose to toluene	1.43	$mg·kg^{-1}·day^{-1}$
$RfD_{Ethylbenzene}$	Reference dose to ethyl benzene	0.286	$mg·kg^{-1}·day^{-1}$
RfD_{Xylene}	Reference dose to xylene	0.029	$mg·kg^{-1}·day^{-1}$

where CDI_L is the chronic daily intake average life time calculated based on the Equation (2) and SF is the slope factor (the slope of the dose-response curve at very low exposures). According to the Integrated Risk Information System (IRIS) the slope factor for benzene is equal 0.029 mg $kg^{-1}\cdot day^{-1}$ [31]. A cancer risk >1.00 × 10^{-6} was considered carcinogenic effects and a value ≤1.00 × 10^{-6} was considered an acceptable level.

$$CDI_L = \frac{CA \times IR \times ED \times D \times EF \times L}{BW \times ATL \times NY} \quad (2)$$

The non-cancer risk is expressed in terms of the hazard quotient (HQ). The HQs were calculated based on the following Equation:

$$HQ = \frac{CDI_Y}{RfD} \quad (3)$$

where CDI_Y is the chronic daily intake average yearly and RfD is the reference dose (a level below which adverse health effects are not likely to occur) [30]. Values RfDs for benzene, toluene, ethylbenzene and xylene were showed in Table 1 [31] [32] [33] [34]. A value of HQ > 1 was considered adverse non-carcinogenic effects and a value of HQ ≤ 1 was considered acceptable level.

3. Results and Discussion

3.1. Concentrations of BTEX Compounds in the Air of Gas Stations and External Sites

The concentrations of BTEX compounds present in the air in the gas stations are shown in Figure 2. The variation of the results can be attributed to the different conditions in each gas station as: sales volume of gasoline, flow of cars, heavy traffic nearby and meteorological parameters.

A previous study shows that sold gasoline volume is one of the variables that can affect the BTEX concentrations in the air of gas stations, because during the

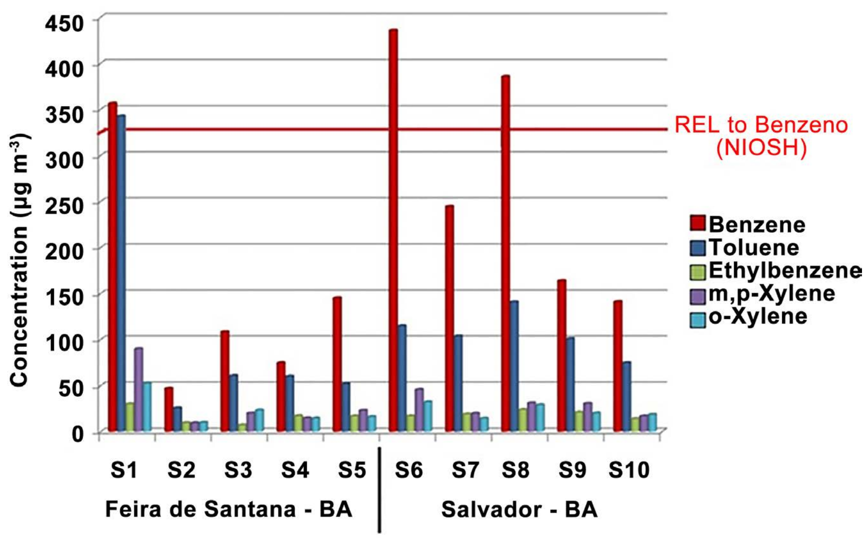

Figure 2. Average BTEX concentrations (µg·m^{-3}) in ambient air of the gas stations studied.

process of supply, saturated air stream with gasoline vapor is released from automobile fuel tank, and the air volume is exactly equal to the volume of gas supplied, which may have a decisive influence on air pollution in these establishments [35].

In this study could not get the exact volume of gas marketed at each gas station due to market competition and only an estimated sale was informed. Thus, higher total concentrations of BTEX (871.82, 644.84 and 609.86 μg·m^{-3}, respectively) found in gas stations S1, S6 and S8 are compatible with the fact that these have the largest marketed gas volumes (>500,000 L·month^{-1}).

In Brazil, the current law that treats of gas stations (CONAMA Resolution 273/2000) [1] only establishes guidelines for environmental licensing and provides for the prevention and control of pollution, focusing on possible accidents involving fires and leaks into the ground and in groundwater, but no reference is made to air pollution. For occupational environments, as gas stations, are used the tolerance limits stipulated in the Regulatory Standard Number 15 (NR 15) of the Ministry of Labor-unhealthy activities and operations [36], as shown in **Table 2**. A Brazilian national agreement stipulates that after 1 January 1997 it is forbidden to use benzene for any activity, except in industries and laboratories that produce or use it in chemical synthesis, chemical analysis and in petroleum fuels. Thus, in this study for benzene was used recommended exposure limit (REL) by the National Institute for Occupational Safety and Health (NIOSH) [37] (**Table 2**).

The toluene, ethylbenzene and xylenes concentrations found in the air of the gas stations in this study did not exceed the limits stipulated by NIOSH and NR-15 (**Table 2**). However, comparing the concentrations of benzene (compound carcinogen group 1 by IARC) found in the gas stations S1, S6 and S8 (356.27; 435.43 and 385.40 μg·m^{-3}, respectively), with the limit of exposure recommended by NIOSH for this compound (3.20×10^2 μg·m^{-3}), it is verified that the concentrations are above this limit (**Figure 2**), contributing to increase the cancer risk among workers.

This study was conducted during the months of November/2015 to March/2016, in the summer period with average temperatures ranging between 26.5˚C - 29.2˚C. The literature reports that elevated temperatures in the summer may increase the exposure risk to BTEX compounds among workers the gas stations due to the high evaporation of these compounds [35].

Table 2. Maximum, minimum and average BTEX concentrations (μg·m^{-3}) in ambient air of the gas stations and exposure limits established by NIOSH and NR-15.

BTEX	Maximum	Minimum	Average	NR-15	NIOSH
Benzene	435.43	46.72	211.87	0	3.20×10^2
Toluene	342.46	25.54	107.50	2.90×10^5	3.75×10^5
Ethyl benzene	30.07	7.10	17.48	3.40×10^5	4.35×10^5
Xylenes	9.36	89.73	26.50	3.40×10^5	4.35×10^5

Comparing the BTEX concentration levels obtained in this study with other cities in Brazil and the world (**Figure 3**), the values found these compounds were generally higher those obtained in Rio de Janeiro/Brazil [18], but much smaller those obtained in Bangkok/Thailand [15], Ardabil/Iran [20] and Murcia/Spain [35]. These variations can be attributed to differences in the composition of the fuels used in other countries, and the influence of seasonal and/or weather local factors. The comparison between different studies is difficult due to the use of different experimental conditions, sampling and analysis methods. In the study conducted in the Rio de Janeiro city [18] the authors affirm that the obtained BTEX concentrations were lower than those found in gas stations from other countries, because the Brazilian gasoline is mixed with 27% v/v of anhydrous ethanol, what contributes to change the volatility of BTEX and reducing emissions of these compounds to the atmosphere, which certainly can be considered as an advantage of the gasoline marketed in Brazil.

The reasons among BTEX species have been widely used as an indicator to provide information on the different emission sources of these compounds. Thus, the ratios of toluene/benzene (T/B), m, p-xylenes/benzene (m, p-X/B) and o-xylene/benzene (o-X/B) was used to confirm the source of BTEX. The results obtained show T/B values in the range of 0.37 - 0.96, values of m, p-X/B in the range of 0.05 - 0.25 and values of o-X/B in the range of 0.04 - 0.21. These values are in agreement with those cited by other authors who also evaluated the BTEX levels at gas stations [17] [18] [35], showing that BTEX emissions at gas stations studied come mainly from evaporative fuel emissions. An analysis of the coefficients of linear correlation (R) between species, showed R values higher than 0.8769, indicating a good linear correlation between BTEX compounds, indicating that these have the same origin.

The Brazilian Environmental Law (CONAMA Resolution 003/1990) [38] associated with air pollution in outdoors does not define standards for BTEX

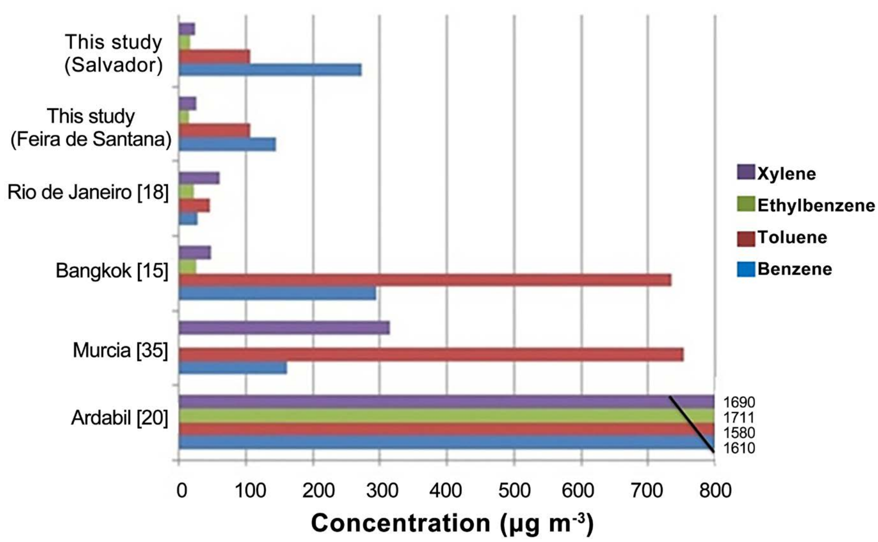

Figure 3. Comparison of the average BTEX concentrations (µg·m^{-3}) reported to gas stations in different sites.

compounds. The external areas (L1 250 and L2 250) located at 250 m of S5 and S7 gas stations had BTEX total concentration values equal to 24.97 and 35.51 $\mu g \cdot m^{-3}$, respectively, being that for benzene the concentrations were 3 - 4 times higher what annual standard of 5.0 $\mu g \cdot m^{-3}$ established by the European Union by Directive 2008/50/EC [39], as tolerance limit for external areas (**Figure 4**). In these places there are in the vicinity of the gas stations, hospitals including maternity hospitals, medical centers, schools, universities and/or residences. In Brazil, no restrictions regarding the location of gas stations allowing the installation these establishments close to residential areas and commercial. These data reinforce the need to review the current Brazilian legislation, both to restrict the installation of gas stations mainly near these areas, as set standards for the BTEX compounds for external and occupational areas.

Compounds BTEX concentrations obtained in areas externals at 250 m from gas stations in this study were compatible to values obtained in Rio de Janeiro [18] and Murcia [40] in similar studies confirming the dispersion these pollutants emitted from gas stations to nearby areas. Other study reports that people in the vicinity of these establishments have an increased cancer risk 3% - 21% [41], confirming the influence of the emission of BTEX for upcoming sites.

3.2. Health Risks Assessment

The results of cancer risk (CR) and non-cancer risk (HQ) for workers using the BTEX concentrations in the air of the gas stations in this study, in the 30-year period are shown in **Table 3**. It is noted that except benzene, other compounds showed a non cancer risk lower than 1 (HQ < 1), indicating that no adverse health effect of workers will be observed during the exposure time. In contrast, HQ values for benzene is above 1 in 7 of the 10 gas stations (70%), revealing adverse health effects of workers due exposure to benzene emitted of the gas stations.

The values found for cancer risk in 10 gas stations are range from 4.06×10^{-5} - 3.78×10^{-4} (mean of 1.82×10^{-4}) for workers exposed to benzene by 30 years are above the acceptable limit by the USEPA equal 1.00×10^{-6} (**Table 3**). These

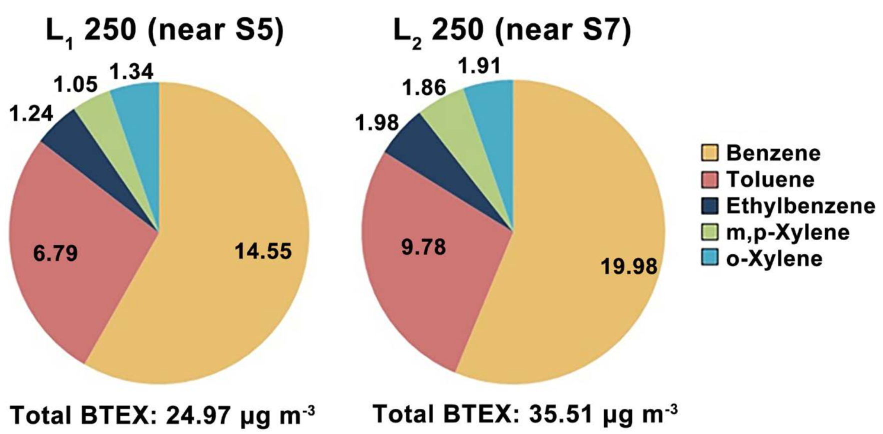

Figure 4. BTEX concentrations ($\mu g \cdot m^{-3}$) in outdoors at 250 m from gas stations.

Table 3. Risks assessment due to exposure to the BTEX compounds of workers in gas stations studied.

	Benzene			Toluene			Ethylbenzene			Xylenes		
Gas stations	CDI_L	HQ	CR	CDI_L	HQ	CR	CDI_L	HQ	CR	CDI_L	HQ	CR
	($mg \cdot kg^{-1} \cdot dia^{-1}$)			($mg \cdot kg^{-1} \cdot dia^{-1}$)			($mg \cdot kg^{-1} \cdot dia^{-1}$)			($mg \cdot kg^{-1} \cdot dia^{-1}$)		
S1	1.07×10^{-2}	3.13	3.09×10^{-4}	1.03×10^{-2}	1.84×10^{-2}	-	9.00×10^{-4}	7.89×10^{-3}	-	4.25×10^{-3}	3.68×10^{-1}	-
S2	1.40×10^{-3}	4.10×10^{-1}	4.05×10^{-5}	7.65×10^{-4}	1.37×10^{-3}	-	2.84×10^{-4}	2.49×10^{-3}	-	5.73×10^{-4}	4.96×10^{-2}	-
S3	3.24×10^{-3}	9.50×10^{-1}	9.40×10^{-5}	1.82×10^{-3}	3.25×10^{-3}	-	2.13×10^{-4}	1.86×10^{-3}	-	1.29×10^{-3}	1.12×10^{-1}	-
S4	2.23×10^{-3}	6.55×10^{-1}	6.47×10^{-5}	1.80×10^{-3}	3.21×10^{-3}	-	5.11×10^{-4}	4.48×10^{-3}	-	8.74×10^{-4}	7.55×10^{-2}	-
S5	4.34×10^{-3}	1.27	1.26×10^{-4}	1.55×10^{-3}	2.77×10^{-3}	-	5.03×10^{-4}	4.41×10^{-3}	-	1.17×10^{-3}	1.01×10^{-1}	-
S6	1.30×10^{-2}	3.82	$3{,}78 \times 10^{-4}$	3.44×10^{-3}	6.16×10^{-3}	-	5.06×10^{-4}	4.43×10^{-3}	-	2.32×10^{-3}	2.01×10^{-1}	-
S7	7.31×10^{-2}	2.14	2.12×10^{-4}	3.10×10^{-3}	5.56×10^{-3}	-	5.64×10^{-4}	4.95×10^{-3}	-	1.02×10^{-3}	8.83×10^{-2}	-
S8	1.15×10^{-2}	3.38	3.35×10^{-4}	4.21×10^{-3}	7.55×10^{-3}	-	7.11×10^{-4}	6.23×10^{-3}	-	1.80×10^{-3}	1.55×10^{-1}	-
S9	4.90×10^{-3}	1.44	1.42×10^{-4}	3.02×10^{-3}	5.40×10^{-3}	-	6.26×10^{-4}	5.48×10^{-3}	–	1.51×10^{-3}	1.31×10^{-1}	-
S10	4.22×10^{-3}	1.24	1.22×10^{-4}	2.23×10^{-3}	4.00×10^{-3}	-	4.17×10^{-4}	3.65×10^{-3}	-	1.06×10^{-3}	9.13×10^{-2}	-
Average		1.84	1.82×10^{-4}		5.76×10^{-3}			4.59×10^{-3}			1.37×10^{-1}	
SD		1.21	1.19×10^{-4}		4.79×10^{-3}			1.74×10^{-3}			9.15×10^{-2}	

results show that the cancer risks are very high in all gas stations because the values found are 40 - 378 times above the limit, reinforcing the need to adopt measures to minimize these risks as mandatory use of personal protective equipment (PPE) by workers, accompanied by oversight by agencies responsible and carrying out monitoring of personal exposure. Furthermore, as suggested in other study [18] the use of self-service and vapor recovery technology systems during the supply of the cars not yet implemented in Brazil would help to reduce or eliminate the exposure of workers to BTEX compounds in gas stations. Similar results for cancer risk were reported by other authors [15], which determined the cancer risk for workers in gas stations in Bangkok/Thailand equal to 1.75×10^{-4} to exposure period also of 30 years.

The USEPA [42], by cancer risk assessment, estimates that an exposed individual to benzene levels between 13 - 45 $\mu g \cdot m^{-3}$, the risk of developing cancer, particularly leukemia, is 1/1000. Benzene concentrations in the samples collected in gas stations in this study are 2 to 10 times larger than these levels confirming the most likely risk of workers of contracting cancer.

4. Conclusions

Concentrations of BTEX compounds found showed that gas stations are potentially dangerous places, especially considering exposure to benzene. The toluene, ethylbenzene and xylenes concentrations found in the air of the gas stations did not exceed the limits established by national and international agencies. The benzene concentrations exceeded the limit of exposure recommended by NIOSH in three gas stations. The continued exposure to these compounds mainly to benzene causes a physiological accumulation promoting long term damage such as cancer, mutations and cellular changes.

The values obtained in two areas externals near of gas stations showed benzene concentrations 3 - 4 times higher than annual standard of 5.0 $\mu g \cdot m^{-3}$ established by the European Union, confirming the dispersion of pollutants emitted from gas stations to nearby areas.

The estimated cancer risk is very high, because the values found in the gas stations are about 40 - 378 times above the acceptable limit set by the USEPA and reinforce the need to adopt urgent measures to reduce or eliminate the exposure of workers to BTEX compounds.

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