

1  
2  
3  
4 **1 Diurnal and seasonal variation of BTEX in the air of Monterrey, Mexico: preliminary study of sources**  
5 **2 and photochemical ozone pollution**  
6 **3**

7 4 CERÓN-BRETÓN J.G.<sup>1</sup>; CERÓN-BRETÓN, R. M.<sup>1</sup>; KAHL, J. D. W<sup>2</sup>; RAMÍREZ-LARA, E <sup>3</sup>;  
8 5 GUARNACCIA, C. <sup>4</sup>; AGUILAR-UCÁN C. A. <sup>1</sup>; MONTALVO-ROMERO, C. <sup>1</sup> ANGUEBES-  
9 6 FRANCESCHI, F. <sup>1</sup>; AND LÓPEZ-CHUKEN, U. <sup>2</sup>.

10 7 <sup>1</sup>Universidad Autónoma del Carmen, Facultad de Química, Calle 56 núm. 4 Esq. Ave. Concordia, Col. Benito  
11 8 Juárez. Ciudad del Carmen, Campeche, CP 24180, MEXICO.

12 9 <sup>2</sup> University of Wisconsin-Milwaukee, Department of Mathematical Sciences, P.O. Box 413  
13 10 Milwaukee, WI 53201, Wisconsin, USA.

14 11 <sup>3</sup> Universidad Autónoma de Nuevo León, Facultad de Ciencias Químicas, Av. Universidad S/N, Cd.  
15 12 Universitaria. San Nicolás de los Garza Nuevo León, CP 66451, MEXICO.

16 13 <sup>4</sup> University of Salerno, Industrial Engineering Department, Via Ponte don Melillo 84084, Fisciano, ITALY.

17 14  
18 15 Corresponding author: Julia Griselda Cerón Bretón, email: [jceron@pampano.unacar.mx](mailto:jceron@pampano.unacar.mx)  
19 16 <http://www.unacar.mx>  
20 17

1  
2  
3  
4 18 *Abstract:* - Atmospheric levels of BTEX were measured in an urban site located in Nuevo Leon, Mexico  
5 19 during summer and autumn, 2013. A total of 60 samples were collected using carbon packed cartridges at  
6 20 09:00 h, 12:00 h and 15:00 h, and then analyzed using gas chromatography with flame ionization detector.  
7 21 Meteorological parameters and criteria air pollutants were measured and correlated with BTEX by a Principal  
8 22 Component Analysis (PCA). The relative abundance of BTEX followed the order: benzene> toluene>  
9 23 ethylbenzene>p-xylene with mean concentrations of 55.24  $\mu\text{g m}^{-3}$ , 22.24  $\mu\text{g m}^{-3}$ , 6.94  $\mu\text{g m}^{-3}$  and 4.17  $\mu\text{g m}^{-3}$ ,  
10 24 respectively, during summer. Mean concentrations during autumn were 21.079  $\mu\text{g m}^{-3}$  for benzene, 3.648  $\mu\text{g}$   
11 25  $\text{m}^{-3}$  for toluene, 2.521  $\mu\text{g m}^{-3}$  for ethylbenzene and 2.115  $\mu\text{g m}^{-3}$  for p-xylene. All measured BTEX showed  
12 26 clear diurnal and seasonal patterns. The highest mean levels for benzene were obtained during the midday.  
13 27 Toluene, ethylbenzene and p-xylene showed the highest levels during afternoon period. BTEX levels were  
14 28 higher when wind blew from NE and ESE during summer and from ESE during autumn. The municipalities  
15 29 of Apodaca, and Guadalupe are located in these directions where important industries, high traffic volume,  
16 30 many oil and gas service stations and the biggest airport in this region are found. These sources could  
17 31 contribute to the BTEX concentrations measured during the sampling period.

18  
19  
20 32  
21 33 *Key-Words:* - BTEX, ozone, air pollution, Nuevo Leon, COVs.  
22 34

## 23 35 **1. Introduction**

24 36  
25 37 Volatile organic compounds (VOCs) play a critical role in atmospheric photochemical reactions and multi-  
26 38 phase processes (Calvert et al. 2002; Wang et al. 2010 a; Wang et al. 2010 b). VOCs can undergo reactions  
27 39 initiated by hydroxyl radicals (OH) to form peroxy radicals (RO<sub>2</sub>), which react rapidly with nitric oxide (NO)  
28 40 to form nitrogen dioxide (NO<sub>2</sub>), an essential step in the formation of ground level ozone (O<sub>3</sub>) (Calvert et al.  
29 41 2002). This pollutant is the main oxidant in the troposphere and is related to adverse effects on human health,  
30 42 vegetation and materials (Cerón et al. 2010 a; Cerón et al. 2010 b). VOCs are organic compounds with boiling  
31 43 points between 50-150°C. Within this group, there is a sub-group commonly called BTEX which includes  
32 44 benzene, toluene, ethylbenzene and xylenes. Anthropogenic activities are responsible for most of the VOCs  
33 45 emissions in and around heavily populated urban areas (Li et al. 2007; Wang et al. 2009; Apel et al. 2010). In  
34 46 cities like Mexico City and Los Angeles, approximately 45% of the total VOC emissions results from  
35 47 gasoline-related emissions, including a substantial portion of aromatic compounds such as benzene and  
36 48 toluene (Brown et al. 2007). These compounds are known to be toxic, genotoxic and carcinogenic, and play  
37 49 an important role in tropospheric chemistry due to their active participation in photochemical reactions. They  
38 50 are ozone precursors (Lu et al. 2006; Katsoyiannis et al. 2006; Hoque et al. 2008) and have multiple and  
39 51 diverse sources in urban areas (motor vehicle exhaust, incomplete combustion of fossil fuels and biomass, oil  
40 52 and gas service stations, cooking and heating processes, household products, and other industrial and human  
41 53 activities). In Mexico there is little information about BTEX levels in ambient air. Most of the studies have  
42 54 been focused on Mexico City (Arriaga et al. 1997; Bravo et al. 2002; Mugica et al. 2002; Ceron et al. 2013 a).  
43 55 Here we focus on San Nicolas de Garza, one of the twelve municipalities of the metropolitan area of  
44 56 Monterrey (MAM), which is the third largest city in Mexico and one of the country's most important urban  
45 57 and industrial centers. MAM is characterized by the presence of important education and research centers,  
46 58 business activities and industrial settlements. In this work we present BTEX measurements obtained in San  
47 59 Nicolás de los Garza during summer and autumn, 2013. The purpose of this field campaign was to  
48 60 characterize the BTEX present in the ambient air and identify the relationships among the measured variables  
49 61 using a PCA analysis (including criteria air pollutant concentrations and meteorological parameters), in order  
50 62 to infer the sources that could contribute to the BTEX observations.  
51 63

## 52 64 **2. Materials and Methods**

### 53 65 54 66 **2.1. Observation Site**

55 67  
56 68 The observation site is located near the urban center of Monterrey, Nuevo Leon, Mexico, inside the Chemistry  
57 69 School (Postgraduate Division building) of the Autonomous University of Nuevo Leon (25° 43' 30" N; 100°  
58 70 18' 48" W), at 500 masl. A detailed map of the site is presented in Figure 1. This municipality is located at the  
59 71 northeast of the MAM, and has a semi-arid warm climate (Bsh) according to the Köppen climatic

1  
2  
3  
4 72 classification modified by García (García 1990). Frontal systems coming from the north are common in this  
5 73 area. The specific observation site is located within an industrial, residential, educational and commercial  
6 74 area where there also are several avenues with high vehicular traffic volume.  
7 75

8 76 **Fig. 1** Location of the sampling site and the SIMAT air quality northeast station  
9 77

## 10 78 11 79 **2.2. Sampling Method** 12 80

13 81 A total of 60 samples were collected from July 3 to November 14, 2013, half during the summer season and  
14 82 half during autumn. Benzene (B), ethyl benzene (Ebz), toluene (T) and p-xylene (X) were determined in all  
15 83 ambient air samples. Samples were collected using glass tubes containing 226-01 Anasorb CSC (SKC) with  
16 84 the following features: length 70 mm; inner diameter 4.0 mm; outer diameter 6 mm packed in two sections  
17 85 with 100 mg and 500 mg of active carbon, separated by a glass wool section (Method INSHT MTA/MA-  
18 86 030/A92) (INSHT 1992; Cerón et al. 2013 b). The downstream end of the glass tube was connected to a  
19 87 calibrated flow meter. Ambient air was passed through the glass tubes at a flow rate of 200 ml min<sup>-1</sup> at 1.5-  
20 88 hour intervals. Samples with a sampling volume lower than 5 liters were discarded. Sampling was carried out  
21 89 using a Universal XR pump model PCXR4 (SKC), at three sampling periods (local time): B1 (morning, from  
22 90 09:00 to 10:30 h), B2 (midday, from 12:00 to 13:30 h) and B3 (afternoon, from 15:00 to 16:30 h). Prior to the  
23 91 main study, several pilot experiments were conducted to evaluate the suitability of the sampling procedure  
24 92 described here. These pilot experiments included the determination of appropriate sampling times. In addition,  
25 93 desorption efficiency (DE) was calculated for each glass tubes lot and for each analyte, and tubes with ED  
26 94 lower than 75% were discarded. After the exposure time, the adsorption tubes were labeled and capped tightly  
27 95 with PTFE caps and transferred to the laboratory in cold boxes. This procedure was applied to both clean and  
28 96 sample tubes for storage prior to use or analysis. Field blanks were transported to the field along with  
29 97 samplers and stored in the laboratory during the sampling period. Samples were analyzed within three weeks  
30 98 after sample collection.  
31 99

## 32 100 33 101 **2.3. Analytical Method** 34 102

35 103 Samples were extracted with 1 ml of CS<sub>2</sub> for each section of the sample tubes, and shaken for 30 s to assure  
36 104 maximum desorption. Extracted samples were analyzed using a TRACE GC Ultra gas chromatograph  
37 105 (Thermoscientific) and one flame ionization detector (FID; Thermoscientific Technologies, Inc) (Method  
38 106 INSHT MTA/MA-030/A92) (INSHT 1992). The analytical column used was a capillary column (57 m, 0.32  
39 107 mm i.d., 0.25 µm film thickness). The oven temperature program was initially set to 40 °C for 4 min, then  
40 108 increased at a rate of 5 °C/min up to 100 °C, and finally maintained for 10 min at 100 °C. The FID  
41 109 temperature was set to 250 °C using a hydrogen/air flame with constant flows of 35 ml min<sup>-1</sup> and 350 ml min<sup>-1</sup>  
42 110 for ultra-pure hydrogen and extra-dried air, respectively. The ultra-pure nitrogen carrier (99.999%) gas flow  
43 111 rate was 1 ml min<sup>-1</sup> (INSHT 1992). Four BTEX were investigated: benzene (B), p-xylene (X), ethylbenzene  
44 112 (Ebz) and toluene (T). Five-point calibration was performed using 99.98% Sigma-Aldrich analytical reagents  
45 113 at a concentration of 2 ppm for each BTEX. The established calibration curves for the four investigated BTEX  
46 114 were found to have R-square values of 0.999. Method detection limits (MDL) for each compound were  
47 115 calculated by multiplying the standard deviation obtained from seven replicate measurements of the first level  
48 116 of calibration by 3.14 (Student's t-value). The analytical results showed that the MDLs for B, Ebz, X, and T,  
49 117 were 0.0517, 0.0566, 0.0600, and 0.025 µg m<sup>-3</sup>, respectively. The amount of BTEX in blank samples was  
50 118 below the limit of detection for all compounds studied.  
51 119

## 52 120 **2.4. Monitoring of meteorological parameters and criteria air pollutants** 53 121

54 122 Wind conditions (speed and direction), relative humidity, temperature and barometric pressure were  
55 123 monitored from July 3 to November 14 using a Davis Vantage Pro II portable meteorological station located  
56 124 at the BTEX observation site. Wind frequency statistics were determined using WRPLOT software (Lakes  
57 125 Environmental). Criteria air pollutant (O<sub>3</sub>, NO, NO<sub>2</sub>, NO<sub>x</sub>, CO and SO<sub>2</sub>) concentrations measured by API

1  
2  
3  
4 126 Teledyne automatic analyzers were obtained from the Integrated System of Environmental Monitoring of the  
5 127 MAM (SIMAT) Northeast Station, located 5 km away at 25° 44' 42" N, 100° 15' 17" W, 500 masl. The  
6 128 BTEX and criteria pollutant sites are essentially co-located in terms of meteorological characteristics and air  
7 129 masses being sampled, pollution sources, population density, traffic volume and topography. Figure 1 shows  
8 130 both locations.  
9 131

## 10 132 11 133 **2.5. Correlation and Principal Component Analysis (PCA)** 12 134

13 135 Pearson correlation analysis was applied to all data collected at the sampling site. To assess the relationships  
14 136 between BTEX concentrations, meteorological parameters and criteria air pollutants, a factor analysis  
15 137 (Principal Component Analysis) was applied using XLSTAT software (Statistics Package for Microsoft  
16 138 Excell).  
17 139

## 18 140 19 141 **3. Results and Discussion** 20 142

### 21 143 **3.1. Diurnal and seasonal variation** 22 144

23 145 Diurnal variation and descriptive statistics for the summer and autumn seasons can be observed in Fig 2.  
24 146 During the summer period, T, Ebz, and X showed similar diurnal patterns related to the prevailing ESE and  
25 147 ENE winds (see Section 3.2 Meteorological influence). The highest concentrations occurred during the  
26 148 afternoon (B3), decreasing during the midday (B2) and reaching the lowest values during the mornings (B1).  
27 149 B exhibited maximum concentrations during the midday (B2), decreasing during the afternoon (B3) and  
28 150 reaching the lowest values during the mornings (B1). During autumn, all BTEX components presented  
29 151 different diurnal behavior, probably due to variable wind conditions occurring during this season, transporting  
30 152 air masses from different sources located in diverse directions (See Section 3.2 Meteorological influence).  
31 153 BTEX concentrations during summer were higher than those during autumn, presumably due to seasonal  
32 154 differences in wind, temperature (higher during summer) and relative humidity (higher during autumn). The  
33 155 relative abundance of BTEX exhibited the following order during both sampling periods: B > T > Ebz > X.  
34 156 During summer the mean concentration levels were 55.24  $\mu\text{g m}^{-3}$ , 22.24  $\mu\text{g m}^{-3}$ , 6.94  $\mu\text{g m}^{-3}$  and 4.17  $\mu\text{g m}^{-3}$ ,  
35 157 respectively. During autumn the respective mean concentrations were 21.079  $\mu\text{g m}^{-3}$ , 3.648  $\mu\text{g m}^{-3}$ , 2.521  $\mu\text{g}$   
36 158  $\text{m}^{-3}$  and 2.115  $\mu\text{g m}^{-3}$ .  
37 159

38 159  
39 160 **Fig. 2** Diurnal variation and descriptive statistics for measured BTEX during the summer and autumn  
40 161 sampling periods. B1 (09:00-10:30 h), B2 (12:00-13:30 h) and B3 (15:00-16:30 h)  
41 162

42 163 Descriptive statistics and diurnal variation for criteria air pollutants and meteorological parameters are shown  
43 164 in Figures 3-4 for summer and autumn, respectively. NO<sub>2</sub>, NO<sub>x</sub>, O<sub>3</sub>, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub> and RH showed  
44 165 higher levels during autumn, while NO and Temperature were higher during summer. During summer season,  
45 166 NO<sub>2</sub>, PM<sub>2.5</sub>, T, and SO<sub>2</sub> showed a similar behavior with the highest levels during the afternoon (B3)  
46 167 decreasing during midday (B2) and showing the lowest values during the morning (B1). NO<sub>x</sub>, PM<sub>10</sub> and RH  
47 168 during summer showed the same diurnal pattern with the highest values during the morning period (B1) and  
48 169 the lowest levels during the afternoon period (B3). NO concentrations were higher during B2 period  
49 170 decreasing during the afternoon period (B3), and with the lowest levels during the morning period (B1). The  
50 171 highest levels of O<sub>3</sub> were found during the mornings (B1). During autumn NO, NO<sub>x</sub> and RH had the same  
51 172 pattern with the highest levels during the mornings (B1) and the lowest values during the afternoons (B3).  
52 173 PM<sub>10</sub> and SO<sub>2</sub> showed the highest concentrations during the midday period (B2) and the lowest values of  
53 174 concentration during the morning period (B1). PM<sub>2.5</sub>, Temperature and O<sub>3</sub> showed similar behavior with the  
54 175 lowest levels during the mornings, increasing during the midday and registering the highest values during the  
55 176 afternoons.  
56 177

57 178 **Fig. 3.** Descriptive statistics and diurnal variation for criteria air pollutants and meteorological parameters  
58 179 during summer season  
59  
60  
61  
62  
63  
64  
65

1  
2  
3  
4 180  
5 181 **Fig. 4.** Descriptive statistics and diurnal variation for criteria air pollutants and meteorological parameters  
6 182 during autumn season  
7 183

8 184 All BTEX measurements were made only during weekdays, therefore it was not possible to analyze the  
9 185 weekday/weekend effect. For criteria pollutants, a strong weekday/weekend signal was not evident except for  
10 186 an unexplained increase on November 9-10 (not shown), and a weekday when all criteria pollutants registered  
11 187 high values in comparison with the rest of weekdays of the period. This specific day was a holiday  
12 188 (November 1) which corresponds to an annual Mexican celebration called “Los Santos Difuntos”.  
13 189

### 14 190 **3.2. Meteorological influence**

15 191  
16 192 Wind speed, wind direction and meteorological influences for each air pollution sample during summer and  
17 193 autumn can be observed in Table 1. The wind conditions are used to identify the probable sources of the  
18 194 measured BTEX compounds. Prevailing winds during the whole period were from ESE and ENE. During  
19 195 summer, BTEX levels were generally higher when winds blew from ESE. During this season wind  
20 196 conditions were: 50% from ESE and 50% from ENE during the B1 period with wind speed values from 3.51  
21 197 to 12.5 km h<sup>-1</sup>; 70% from ESE and 30% from ENE during the B2 period with wind speed ranging from 3.73  
22 198 to 11.38 km h<sup>-1</sup>; and 90% from ESE during the B3 period with speed values from 6.45 to 11.51 km h<sup>-1</sup>.  
23 199 During autumn, wind conditions were variable and had the following characteristics: 40% from ENE, 30%  
24 200 from ESE, 20% from NNW, 10% from WSW during the B1 period (wind speed: 0.556-13.13 km h<sup>-1</sup>), 40%  
25 201 from ENE, 30% from ESE, 20% from NNE, 10% from NNW during the B2 period (2.37-11.92 km h<sup>-1</sup>) and,  
26 202 60% from ESE, 20% from ENE, 10% from NNW, and 10% from NNE during the B3 period (3.57-12.71 km  
27 203 h<sup>-1</sup>).  
28 204

29 205 **Table 1** Meteorological conditions and BTEX concentrations for each air pollution sample during summer  
30 206 and autumn. Individual samples discussed in the text are highlighted in bold.  
31 207

32 208 On July 11 2013 (Table 1) there was a peak for BTEX compounds during the B3 period (B: 137.52 µg m<sup>-3</sup>, T:  
33 209 97.18 µg m<sup>-3</sup>, Ebz: 14.32 µg m<sup>-3</sup>, and X: 15.15 µg m<sup>-3</sup>), with prevailing winds from ESE (wind speed: 10.67 m  
34 210 s<sup>-1</sup>). These wind conditions probably promoted pollutant transport from upwind sources. For the midday  
35 211 period (B2), B and T concentrations were higher when air masses came from the ENE, whereas Ebz and X  
36 212 levels were higher with ESE winds. During the summer afternoons, BTEX levels were generally higher when  
37 213 winds blew from ESE where the Guadalupe municipality is located. Anthropogenic sources are located  
38 214 throughout the MAM, as is typical of a large urban and industrial center, however, industrial activities and  
39 215 roads with high vehicular traffic are concentrated in the northeast and southeast zones. On the morning of  
40 216 October 30 an air pollution episode occurred, with BTEX levels reaching the highest values of the autumn  
41 217 period (B: 29.86 µg m<sup>-3</sup>, T: 4.35 µg m<sup>-3</sup>, and Ebz: 3.64 µg m<sup>-3</sup>) (See Table 1). Prevailing winds on this day  
42 218 were ENE. During the B1 period on this day the highest BTEX concentrations occurred with ENE winds.  
43 219 During B2 period, high BTEX concentrations occurred on November 1 with ENE winds (B: 27.45 µg m<sup>-3</sup>, T:  
44 220 11.99 µg m<sup>-3</sup>, Ebz: 6.20 µg m<sup>-3</sup> and X: 3.05 µg m<sup>-3</sup>). On October 24 and November 14, high levels of  
45 221 afternoon (B3) BTEX were found when winds blew from the ESE and ENE, respectively.  
46 222  
47 223

### 48 224 **3.3. Toluene to Benzene ratio (T/B ratio)**

49 225  
50 226 The T/B ratio has been commonly used as an indicator of traffic emissions. B and T are constituents of  
51 227 gasoline and are emitted into the atmosphere by motor vehicle exhaust. The T content of gasoline and motor  
52 228 vehicle exhaust is 3-4 times higher than the B content (Pekey and Yilma 2011). T/B values lower than 2-3 are  
53 229 characteristic of vehicular emissions in many urban areas worldwide (Elbir et al. 2007; Mugica et al. 2003;  
54 230 Rad et al. 2014), whereas values higher than 3 may indicate that BTEX levels could be associated with  
55 231 industrial facilities and area sources (evaporative emissions, painting, cooking processes, among others).  
56 232 During summer this ratio was between 0.108 and 0.835, being higher during the afternoon sampling period.  
57 233 For the autumn period, this ratio was between 0.012 and 0.383. These values are in agreement with typical  
58  
59  
60  
61  
62  
63  
64  
65

234 values of vehicular emissions reported for other urban areas, suggesting that this site was under the influence  
235 of mobile sources. The seasonal differences in T/B may be due to transport. In summer, winds were typically  
236 ESE. Winds were more variable in autumn, suggesting transport from sources in different directions. In  
237 addition, relative humidity (RH) was much higher during autumn and its correlation with T was negative and  
238 higher than during summer. Higher RH levels could have a wash-out effect on T concentrations and cause a  
239 drop in the T/B ratios during this period.

#### 242 **3.4. p-Xylene to Ethylbenzene ratio (X/Ebz ratio)**

244 The X/Ebz ratio is commonly used as an indicator of the photochemical age of air masses. A value of 3.6: 1 of  
245 this ratio has been established as a typical emission relation for these species (Keymeulen et al. 2001; Lee et  
246 al. 2002). This ratio is related to the atmospheric residence time of these pollutants: high values of indicate  
247 aged air masses (old emissions), and low values indicate fresh air masses (recent emissions). Kuntasal et al.  
248 (2005) used a value of 3.8 for this ratio. Fresh gasoline emissions provide values between 3.8 and 4.4 for this  
249 ratio. In this study, the combined summer and autumn period registered low values for this ratio, indicating  
250 that most of the air masses correspond to “fresh emissions”. A mean value of 0.4849 for this ratio was  
251 obtained for summer (B1: 0.4437; B2: 0.570; B3: 0.440). During autumn the mean value was 0.7529 (B1:  
252 0.777; B2: 0.207; B3: 1.249). Taken together, T/B and X/Ebz ratios, it can be suggested that these fresh  
253 emissions correspond to vehicular emission from mobile sources. The values for this ratio in the site under  
254 study are similar to those observed in other cities around the world such as Guangzhou in China (0.21) (Wang  
255 et al. 2003), Izmir in Turkey (0.45) (Muezzinoglu et al. 2001), Seoul in Korea (0.30) (Na and Kim 2001) and  
256 Valparaíso in Chile (0.33) (Toro et al. 2014).

#### 259 **3.5. Ozone photochemical sensitivity**

261 The ozone photochemical sensitivity can be determined from an empirical approach based on the mean  
262 ambient mixing ratio of VOCs (in part per billion carbon) and NO<sub>x</sub> (in parts per billion by volume) (Geng et  
263 al. 2008; Jiménez and Baldasano 2004). According to EPA’s empirical kinetic modeling approach  
264 (EKMA)(Whitten et al. 1985), maximum afternoon ozone levels are dependent on the morning concentrations  
265 and mixing ratios of VOC and NO<sub>x</sub>. The morning VOC to NO<sub>x</sub> ratio can provide a useful starting point for  
266 evaluating the relative effectiveness of cost-efficient ozone precursor control strategies. A VOC to NO<sub>x</sub> ratio  
267 of 8 to 1 is often cited as an approximate decision point for determining the relative benefits of NO<sub>x</sub> vs VOCs  
268 controls. At low VOC to NO<sub>x</sub> ratios (< about 4 to 1), an area is considered to be VOC-limited., VOC  
269 reductions will be most effective in reducing ozone, and NO<sub>x</sub> controls may lead to ozone increases. At high  
270 VOC to NO<sub>x</sub> ratios (>about 15 to 1), an area is considered NO<sub>x</sub> limited and VOC controls may be ineffective.  
271 When VOC to NO<sub>x</sub> ratios are at intermediate levels (4 to 15), a combination of VOC and NO<sub>x</sub> reductions may  
272 be warranted. VOC to NO<sub>x</sub> ratios for the sampling site under study were 2.58 and 0.41 for summer and  
273 autumn seasons, respectively. According to these results, this site is in an ozone formation regime that is  
274 VOC-limited (Kang et al. 2004; Martilli et al. 2002; Neftel et al. 2002).

#### 276 **3.6. Reactivity and ozone production by individual VOCs**

278 The reactivity of VOCs is normally evaluated by estimating the ozone formation potential, or OFP (Carter  
279 1994; Carter and Heo 2012). The OFP is defined as,  $OFP_i = MIR_i \times C_i$ , where  $OFP_i$  is calculated from the  
280 maximum incremental reactivity scale ( $MIR_i$ ), according to values obtained from Carter and Heo 2012 (B:  
281 0.69; T: 3.88; Ebz: 2.93; X: 7.61) and the ambient concentration for each VOC ( $C_i$ ). The obtained values for  
282 OFP of each measured BTEX during summer season (expressed in  $\mu\text{g m}^{-3}$ ) were the following: B: 38.11; T:  
283 86.29; Ebz: 20.33; X: 31.73; whereas, OFP values obtained during autumn season were: B: 14.54; T: 14.15;  
284 Ebz: 7.8; X: 16.09. During summer season, the highest OFP values were obtained for B and T; whereas,  
285 during autumn period, X and B showed the highest values of OFP. Other studies have reported that X is the  
286 largest contributor to ozone formation potential (Alghamdi et al. 2014). These compounds could contribute

1  
2  
3  
4 287 significantly to the formation of ozone in the site under study. Summer showed higher OFP values than  
5 288 autumn, indicating that during this period photochemical activity was higher.

6 289 **3.7. Principal Component Analysis (PCA) and Pearson Correlation**

7  
8 290 The T/B ratios and X/Ebz ratios suggest that summer and autumn BTEX levels at the site under study were  
9 291 influenced in a dominant way by vehicular traffic emissions (see sections 3.3 and 3.4). However, PCA  
10 292 analysis can reveal more detailed information about the behavior of the studied pollutants. While BTEX  
11 293 ratios are used as markers of fresh, local traffic emissions, different gasoline formulations can result in  
12 294 different T/B ratios. These ratios must therefore be used with caution. In addition, low values for the T/B  
13 295 ratio may indicate the presence of other benzene sources in this area in addition to motor vehicle emissions. It  
14 296 is well known that BTEX have multiple sources. In the MAM study area, road transportation and area sources  
15 297 (evaporative emissions from solvents, storage tanks, coatings, fuel marketing and other miscellaneous  
16 298 sources) are the dominant sources of VOCs. The MAM Emissions Inventory for 2005 (SEMARNAT-INE,  
17 299 2005) reported that 48.3% of the total VOC emissions come from mobile sources, 43.5% from area sources  
18 300 and 8.2 % from industrial fixed sources. Therefore, it is necessary to investigate the relationship among BTEX  
19 301 and other pollutants and meteorological parameters in order to infer their probable additional sources. In  
20 302 addition Pearson correlation matrixes were constructed for each sampling period (B1, B2 and B3) for the  
21 303 summer and autumn seasons. Principal component analysis (PCA) was used to study the variability patterns  
22 304 present in this multivariate data set. A PCA model was developed for air pollutants (CO, NO<sub>x</sub>, NO, NO<sub>2</sub>, SO<sub>2</sub>,  
23 305 PM10, PM2.5, B, T, Ebz and X) and the meteorological parameters (temperature: Temp, barometric pressure:  
24 306 P, relative humidity: RH, wind direction: WD, and wind speed: WS). Table 2 shows the PCA loadings  
25 307 obtained for the morning (B1), midday (B2) and afternoon (B3) sampling periods during summer and autumn.

26  
27 308 The analysis of the summer data set for the B1 period gave three principal components (F1, F2 and F3) with  
28 309 eigenvalues greater than 0.5 expressing about 78.438% of the total variance. The loadings for these factors are  
29 310 shown in Table 2. F1 showed high factor loadings among CO, NO<sub>x</sub>, SO<sub>2</sub> and NO<sub>2</sub>, which could be associated  
30 311 with combustion sources (vehicular exhaust). F2 showed high factor loadings between O<sub>3</sub> and temperature,  
31 312 being an evidence of the photochemical activity during this period. BTEX had a poor correlation with the  
32 313 combustion tracers but good correlations each other with high factor loadings in F3, indicating that they  
33 314 probably had common sources different from vehicular emissions.

34  
35  
36 315 **Table 2** Eigenvalues and factor loadings for the summer and autumn data set during the three sampling  
37 316 periods

38  
39 317 Table 3 shows the Pearson correlation matrix for the B1 period during both summer and autumn. A  
40 318 significant positive correlation was found during summer among CO, NO<sub>x</sub>, NO<sub>2</sub>, SO<sub>2</sub> and WD, indicating that  
41 319 these compounds likely had a common origin (vehicular emissions). O<sub>3</sub> showed a significant negative  
42 320 correlation with NO and WS, indicating that the air during this period was rich on NO<sub>x</sub>, and that ozone  
43 321 probably originated via photochemical reaction of NO<sub>2</sub>. PM10 and PM2.5 showed a significant positive  
44 322 correlation, indicating common sources for these particulate pollutants. A good correlation between NO<sub>x</sub> and  
45 323 SO<sub>2</sub> indicates that these pollutants probably originated from common sources that implicate high temperature  
46 324 combustion processes of sulfur-containing fossil fuels. All BTEX showed no significant negative correlation  
47 325 with O<sub>3</sub> and good correlations among each other indicating that they may originate from common sources.  
48 326 BTEX did not have good correlations with temperature; this suggests that evaporative emissions were  
49 327 negligible during the summer period. However, BTEX did not correlate with either CO or SO<sub>2</sub>, indicating that  
50 328 neither vehicular emissions nor industrial sources contributed to the ambient levels of these compounds (this  
51 329 finding is not in agreement with the BTEX ratios analysis), they may have originated from area sources.

52 330 **Table 3** Pearson correlation matrix for B1 sampling period during summer and autumn seasons

53 331  
54 332 During summer for the B2 period, four components expressed about 89.218% of the total variance (Table 2).  
55 333 F1 was associated with ozone precursors, F2 showed high factor loadings for CO, NO<sub>x</sub>, NO<sub>2</sub> and SO<sub>2</sub>. These  
56 334 are all species emitted from combustion sources, i.e. vehicular exhaust in urban areas. F3 was associated with  
57 335 particulate matter with high factor loadings for PM10 and PM2.5. F4 was associated to B and T indicating that  
58 336 these compounds had common sources but different from vehicular emissions. It should be noted that BTEX

337 can be emitted from either vehicular exhaust or solvent use, and this can be evaluated using their correlation  
338 with the combustion tracer CO. During summer (B2), NO<sub>2</sub>, NO<sub>x</sub>, WD and SO<sub>2</sub> showed a significant positive  
339 correlation with CO, evidence that these pollutants could originate from mobile sources (Table 4). NO<sub>x</sub>  
340 correlated well with SO<sub>2</sub> indicating that at least partially, this pollutant had its origin in industrial sources and  
341 from the combustion of sulfur-containing fossil fuel. During this period, T and B correlated positively (r=  
342 0.732) indicating that they probably had common sources. A good correlation among Temperature and p-X  
343 indicates that this hydrocarbon could originate from evaporative emissions, a conjecture supported by the  
344 occurrence, during this period, of the highest mean ambient temperature (28.8°C). A negative correlation  
345 among O<sub>3</sub> with NO, CO and Ebz indicates that these last compounds could be precursors of tropospheric  
346 ozone in the site under study. O<sub>3</sub> is produced when primary pollutants such as NO<sub>x</sub> and VOCs (including  
347 BTEX) interact under the action of sunlight. The main atmospheric sink process for CO is by reaction with  
348 OH and this mechanism also makes CO a major precursor to photochemical ozone (Crutzen 1974). Negative  
349 correlations between B-CO, Ebz-NO<sub>x</sub>, X-NO can be evidence of photochemical activity and secondary  
350 pollutant production from reaction between BTEX and OH radicals.

351  
352 **Table 4** Pearson correlation matrix for B2 sampling period during summer and autumn seasons

353  
354 Four components were found for the summer data set during B3 period, expressing 88.106% of the total  
355 variance (Table 2). F1 is associated with photochemical activity with high factor loadings of O<sub>3</sub>, PM2.5, B, T,  
356 Ebz, X, SO<sub>2</sub> and Temperature. F2 included high factor loadings of CO (combustion tracer) and the four BTEX  
357 compounds, indicating that during this period, these VOCs could originate from combustion sources related to  
358 vehicular traffic. F3 included the pollutants CO, O<sub>3</sub>, NO<sub>2</sub> and SO<sub>2</sub>, and F4 was associated with particulate  
359 matter with high factor loadings of PM10 and PM2.5. Table 5 shows the Pearson correlation matrix for B3  
360 period during both summer and autumns. During summer (B3), BTEX components showed significant  
361 positive correlations, evidence that these compounds probably originated from common sources. NO  
362 correlated positively in a significant way with NO<sub>x</sub>, indicating that these pollutants also could have a common  
363 origin. NO<sub>2</sub> and NO<sub>x</sub> showed a significant positive correlation with CO, indicating that they probably had their  
364 origin in vehicular sources. NO, NO<sub>x</sub>, CO, and BTEX showed a negative significant correlation with O<sub>3</sub>,  
365 indicating that during this period all these compounds were ozone precursors. B, T, Ebz and X showed  
366 moderate correlations with SO<sub>2</sub> during this period suggesting that at least partially, industrial sources could  
367 influence the BTEX levels in the study area. Ebz was negatively correlated with relative humidity, indicating  
368 that the wash-out phenomenon could be the most important removal process for this compound as MAM  
369 typically receives about 300 mm of rain during the summer.

370  
371 **Table 5** Pearson correlation matrix for the B3 sampling period during summer and autumn seasons

372  
373 During the B1 period for autumn, three principal components were found, which explained 70.931% of the  
374 total variance (Table 2). F1 was associated with combustion sources (vehicular exhaust) with high factor  
375 loadings for CO, NO<sub>x</sub>, NO, NO<sub>2</sub>, PM10, PM2.5, Ebz and SO<sub>2</sub>. F2 showed high factor loadings for B and O<sub>3</sub>,  
376 indicating that this compound could act as an ozone precursor during this period. Finally, F3 suggested that B  
377 could originate from evaporative emissions. Table 3 shows the Pearson correlation matrix for the B1 period  
378 during autumn. CO, NO, NO<sub>2</sub>, PM10 and SO<sub>2</sub> correlated with each other, indicating that this group of  
379 pollutants probably had a common origin, i.e. gasoline and fuel containing sulfur vehicle emissions. Ebz had  
380 good correlations with NO<sub>x</sub> (r= 0.686), NO (r= 0.684), NO<sub>2</sub> (r= 0.578), PM10 (0.532), and SO<sub>2</sub> (r=0.539) but  
381 did not show a good correlation with CO. This suggests that Ebz might have source contributions different  
382 than vehicle emissions. PM10 and PM2.5 showed an influence of wind speed (r= -0.606 and r= -0.658)  
383 indicating that particulate matter could be associated with nearby sources (WS for this period ranged from  
384 0.55 to 13.12 km h<sup>-1</sup>). B correlated significantly with temperature (r=0.617), indicating that this hydrocarbon  
385 could originate from evaporative emissions. RH was negatively correlated with all measured air pollutants.  
386 This behavior suggest that high concentrations of water vapor partially remove pollutants from the atmosphere  
387 by means of chemical reaction (acid rain) or condensation (promoting deposition) (Felipe-Sotelo, 2006).

388  
389 The analysis of the autumn data set for B2 period gave three principal components, explaining 73.884 % of  
390 the total variance (Table 2). F1 was associated to combustion tracers (vehicular exhaust) with high factor  
391 loadings of CO, NO<sub>x</sub>, NO, NO<sub>2</sub>, PM10, PM2.5, T, Ebz, X and SO<sub>2</sub>. F2 included B and Ebz and F3 showed



1  
2  
3  
4 392 high factor loadings for X, WD and Temperature, indicating that probably this compound could also originate  
5 393 from evaporative emissions. The following correlations: T-CO ( $r=0.530$ ), T-NO<sub>x</sub> ( $r=0.844$ ), T-NO ( $r=0.827$ ),  
6 394 Ebz-NO<sub>x</sub> ( $r=0.555$ ) Ebz-NO ( $r=0.551$ ), X-NO<sub>x</sub> ( $r=0.640$ ), X-NO ( $r=0.561$ ), X-NO<sub>2</sub> ( $r=0.703$ ) and T-PM10  
7 395 ( $r=0.659$ ) indicate that this group of pollutants originated from common sources (vehicular emissions) (Table  
8 396 4). CO and B were negatively correlated with ozone indicating that both played an important role in the  
9 397 formation of tropospheric ozone during this period. B-Ebz and T-X showed significant correlations suggesting  
10 398 that they probably had sources in common (Table 4). WS showed negative correlation with NO<sub>x</sub>, NO, PM10,  
11 399 PM2.5 and Ebz, indicating that all these pollutants may be associated with nearby sources. Once again, RH  
12 400 played an important role in the wash-out of pollutants in the site under study during this sampling period as  
13 401 MAM typically receives nearly 400 mm of rain during the autumn. During B3 period for autumn (Table 2),  
14 402 three components were necessary to explain 72.117% of the total variance in the data set. F1 was associated  
15 403 with combustion sources (vehicular exhaust) with high factor loadings for CO, NO<sub>x</sub>, NO, NO<sub>2</sub>, PM10,  
16 404 PM2.5, Ebz and SO<sub>2</sub>. F2 showed high factor loadings for B, T, RH and temperature indicating that at least  
17 405 during this period these BTEX could originate from evaporative emissions. F3 showed the highest loadings  
18 406 for B, wind speed and wind direction; this could indicate that probably B could have been transported from  
19 407 regional sources. The Pearson correlation matrix for the B3 period during autumn is shown in Table 5. Once  
20 408 again, the influence of vehicular emissions was evident from the high correlations with CO: NO<sub>x</sub>-CO  
21 409 ( $r=0.695$ ), NO-CO ( $r=0.731$ ), NO<sub>2</sub>-CO ( $r=0.579$ ), PM10-CO ( $r=0.506$ ), Ebz-CO ( $r=0.742$ ), B-CO ( $r=0.47$ )  
22 410 and T-CO ( $r=0.46$ ). In addition high correlations between T-NO, T-NO<sub>x</sub>, Ebz-NO<sub>x</sub> and Ebz-NO<sub>2</sub> were found.  
23 411 O<sub>3</sub> correlated in a moderate way with CO and NO, indicating that these pollutants could act at least partially  
24 412 as ozone precursors during this period. NO<sub>x</sub>, PM10, PM2.5 and T showed a moderate influence of the wind  
25 413 conditions ( $r > -0.5$ ), indicating that nearby sources could influence their levels during this period (WS: 3.5-  
26 414 12.72 km h<sup>-1</sup>; prevailing WD: ESE (60%).  
27 415  
28 416

#### 29 417 **4. Conclusion**

30  
31 418 B and T showed the highest concentrations in the study site. B concentrations were higher than those reported  
32 419 in other large cities whereas, the levels of T, Ebz and X were similar to those reported for other cities around  
33 420 the world. All measured BTEX compounds showed a clear diurnal and seasonal pattern with the highest  
34 421 concentrations during summer. Diurnal patterns for BTEX were similar during summer but changed in  
35 422 autumn. The seasonal change in diurnal pattern was due to meteorology: summer winds were predominantly  
36 423 ESE, while autumn winds were more variable. Other meteorological differences include lower temperatures  
37 424 and higher relative humidities in autumn. According to the prevailing winds, the municipalities of Apodaca  
38 425 and Guadalupe (which contain important industries, high traffic volume, many oil and gas service stations,  
39 426 and the biggest airport in the region) could influence BTEX concentrations found in this site during the  
40 427 sampling period. According to the VOC to NO<sub>x</sub> ratio analysis, the study area is VOC-limited. This implies  
41 428 that VOCs are sparse and NO<sub>x</sub> is abundant. Calculated OFP values showed that benzene, toluene and p-xylene  
42 429 were the BTEX species that could contribute to the formation of ozone in the study area, especially during  
43 430 high solar radiation (higher photochemical activity) periods. T/B and X/Ebz ratios showed that BTEX were  
44 431 influenced by fresh vehicular emissions, however BTEX ratios must be used with caution. PCA analysis  
45 432 confirmed the relative importance of vehicular sources only for the autumn season. During summer, this  
46 433 analysis suggested that additional sources beyond traffic related emissions could influence the levels of  
47 434 BTEX. The ratios, Pearson correlations and PCA analysis reported here provide preliminary information  
48 435 about the probable sources of VOCs in the study area but do not provide conclusive evidence about the source  
49 436 types and their contributions. A more complete understanding of BTEX source identification requires the  
50 437 application of a more robust tool such as receptor modeling.

51 438

#### 52 439 *References:*

53 440 Apel E C, Emmons L K, Karl T, Flocke F, et al. (2010) Chemical evolution of volatile organic compounds in  
54 441 the outflow of the Mexico City Metropolitan Area. *Atmos. Chem. Phys* 10: 2353-2376.  
55 442 Alghamdi M A, Khoder M, Abdelmaksoud A S, Harrison R M, Hussein T, Liharainen H, Al-Jeelani H,  
56 443 Goknil M H, Shabbaj I I, Almeahadi F M, Hyvarinen A P, Hameri K (2014) Seasonal and diurnal  
57 444 variations of BTEX and their potential for ozone formation in the urban background atmosphere of

- 1  
2  
3  
4 445 the coastal city Jeddah, Saudi Arabia. Air Quality, Health and Atmosphere DOI 10.1007/s11869-014-  
5 446 0263-x.  
6 447 Arriaga C J, Martinez V G, Escalona S S, Martínez C H (1997) Volatile Organic Compounds in the  
7 448 atmosphere of MZMC. In: García C L and Varela H J (Eds) Atmospheric Pollution, El Colegio  
8 449 Nacional, México, D.F. Mexico, pp. 26-38.  
9 450 Bravo A H, Sosa E R, Sánchez A P, Bueno E, González R L (2002) Concentrations of benzene and toluene in  
10 451 the atmosphere of the southwestern area at the Mexico City Metropolitan Zone. Atmos. Environ  
11 452 36:3843-3849.  
12 453 Brown S G, Frankel A, Hafner H R (2007) Source apportionment of VOCs in the Los Angeles Area using  
13 454 positive matrix factorization. Atmos. Environ 41: 227-237.  
14 455 Calvert J G, Atkinson R, Becker K H, Kamens R M, Seinfeld J H, Wallington T J (2002) The mechanisms  
15 456 of atmospheric oxidation of Aromatic Hydrocarbons. Oxford University Press, New York, N.Y.  
16 457 Carter W P L (1994) Development of ozone reactivity scales for volatile organic-compounds. J Air Waste  
17 458 Manage 44:881-899.  
18 459 Carter W P L, Heo G (2012) Development of revised SPARC aromatics mechanisms. Final Report to  
19 460 California Air Resources Board Contracts No. 07-730 and 08-326  
20 461 Cerón- Bretón J G, Cerón-Bretón R M, Rangel-Marrón M, Carballo-Pat C G, Villarreal-Sánchez G X,  
21 462 Uresti-Gómez A Y (2013 a) Diurnal variation of BTX levels in ambient air of one urban site located  
22 463 at the southeast of Mexico City during two seasons in 2013. International Journal of Energy and  
23 464 Environment 7: 261-271.  
24 465 Cerón Bretón J G, Cerón Bretón R M, Ramírez Lara E, Rojas Domínguez L, Vadillo Sáenz M S, Guzmán  
25 466 Lara J L (2013 b) Measurements of atmospheric pollutants /aromatic hydrocarbons, O<sub>3</sub>, NO<sub>x</sub>, NO,  
26 467 NO<sub>2</sub>, CO and SO<sub>2</sub>) in ambient air of a site located at the northeast of Mexico during summer 2011.  
27 468 WSEAS Transactions on Systems 12 (2): 55-66.  
28 469 Cerón Bretón J G, Cerón Bretón R M, Rangel Marrón M, Vargas Cáliz C et al. (2010 a) Effects of simulated  
29 470 tropospheric ozone on foliar nutrients levels (Ca<sup>2+</sup>, Mn<sup>2+</sup>, Mg<sup>2+</sup> and K<sup>+</sup>) of three woody species of  
30 471 high commercial value typical from Campeche, Mexico. WSEAS Transactions on Environment and  
31 472 Development 6 (11): 731-743.  
32 473 Cerón Bretón J G, Cerón Bretón R M, Guerra Santos J J, Córdova Quiroz A Ve et al. (2010 b) Effects of  
33 474 simulated tropospheric ozone on soluble proteins and photosynthetic pigments levels of four woody  
34 475 species typical from the Mexican Humid Tropic. WSEAS Transactions on Environment and  
35 476 Development 6 (5): 335-344.  
36 477 Crutzen J (1974) Photochemical reactions initiated by and influencing ozone in unpolluted tropospheric air.  
37 478 Tellus 26:47-56.  
38 479 Felipe-Sotelo M, Gustems L, Hernández I, Terrado M, Tauler R (2006) Investigation of geographical and  
39 480 temporal distribution of tropospheric ozone in Catalonia (North-East Spain) during the period 2000-  
40 481 2004 using multivariate data analysis methods. Atmospheric Environment 40: 7421-7436.  
41 482 García E (1990) Climas, 1: 4000 000. IV.4.10 (A). Atlas Nacional de México, vol. II. Instituto de Geografía,  
42 483 UNAM, Mexico.  
43 484 Geng FH, Tie XX, Xu JM, Zhou GQ, Peng L, Gao W, Tang X, Zhao CS (2008) Characterizations of ozone,  
44 485 NO<sub>x</sub>, and VOCs measured in Shanghai, China. Atmos Environ 42:6873-6883.  
45 486 Hoque R R, Khillare P S, Agarwal T, Shridhar V, Balachandran S (2008) Spatial and temporal variation of  
46 487 BTEX in the urban atmosphere of Delhi, India. Sci. Total Environ 392: 30-40.  
47 488 INSHT Method MTA/MA-030/A92 (1992) Aromatic hydrocarbons determination in air (benzene, toluene,  
48 489 ethylbenzene, p-xylene, 1, 2, 4-trimethyl-benzene): Adsorption in activated carbon/gas  
49 490 chromatography method, Social and Ocupacional Affairs Office, Spain.  
50 491 Jiménez P, Baldasano JM (2004) Ozone response to precursor controls in very complex terrains: use of  
51 492 photochemical indicators to assess O<sub>3</sub>- NO<sub>x</sub>-VOC sensitivity in the northeastern Iberian Peninsula. J  
52 493 Geophys Res-Atmos 109.  
53 494 Kang DW, Aneja VP, Mathur R, Ray JD (2004) Observed and modeled VOC chemistry under high  
54 495 VOC/NO<sub>x</sub> conditions in the Southeast United States national parks. Atmos Environ 38:4969-4974.  
55 496 Katsoyiannis A, Leva P, Kotzias D (2006) Determination of volatile organic compounds emitted from  
56 497 household products, The case of velvet carpets. Fresenius Environ. Bull 15:943-949.  
57  
58  
59  
60  
61  
62  
63  
64  
65

- 1  
2  
3  
4 498 Keymeulen R, Gögényi M, Héberger K, Priksane A, Lagenhove H V (2001) Benzene, toluene, ethylbenzene  
5 499 and xylenes in ambient air and *Pinus sylvestris* L. needles: a comparative study between Belgium,  
6 500 Hungary and Latvia. Atmos. Environ 35: 6327-6335.
- 7 501 Kuntasal O O, Karman D, Wang D, Tuncel S, Tuncel G (2005) Determination of volatile organic  
8 502 compounds in microenvironments by multibed adsorption and short-path thermal desorption  
9 503 followed by gas chromatographic-mass spectrometric analysis. Journal of Chromatography A 1099:  
10 504 43-54.
- 11 505 Lakes Environmental, WRPLOT View version 7.0: Wind Rose Plots for Meteorological Data,  
12 506 <http://www.weblakes.com/products/wrplot/index.html>.
- 13 507 Lee S C, Chiu M Y, Ho K, Zou S C, Wang X (2002) Volatile organic compounds (VOCs) in urban  
14 508 atmosphere of Hong Kong. Chemosphere 48: 375-382.
- 15 509 Li G H, Zhang R Y, Fan J W, Tie X X (2007) Impacts of biogenic emissions on photochemical ozone  
16 510 production in Houston, Texas. J. Geophys. Res 112:1-12.
- 17 511 Lu H, Wen S, Feng Y, Wang X, et al. (2006) Indoor and outdoor carbonyl compounds and BTEX in the  
18 512 hospitals of Guangzhou, China. Sci. Total Environment 368:574-584.
- 19 513 Martilli A, Nefel A, Favaro G, Kirchner F, Sillman S, Clappier A (2002) Simulation of the ozone formation  
20 514 in the northern part of the Po Valley. J Geophys Res-Atmos 107.
- 21 515 Muezzinoglu A, Odabasi M, Onat L (2001) Volatile organic compounds in the air of Izmir, Turkey. Atmos  
22 516 Environ 35:753-760
- 23 517 Mugica V, Vega E, Ruiz H, Sánchez G, Reyes E, Cervantes A (2002) Photochemical reactivity and sources  
24 518 of individual VOCs in Mexico City, In: Brebbia C A and Martin-Duque J F (Eds) Air Pollution X,  
25 519 WIT PRESS, London, U.K, pp. 209-217.
- 26 520 Mugica V, Ruiz M E, Watson J, Chow J (2003) Volatile Aromatic Compounds in Mexico City atmosphere:  
27 521 Levels and Source apportionment. Atmosfera 16: 5-27.
- 28 522 Na K, Kim YP (2001) Seasonal characteristics of ambient volatile organic compounds in Seoul, Korea.  
29 523 Atmos Environ 35:2603-2614.
- 30 524 Nefel A, Spirig C, Prevot ASH, Furger M, Stutz J, Vogel B, Hjorth J (2002) Sensitivity of photooxidant  
31 525 production in the Milan Basin: an overview of results from a EUROTRAC-2 Limitation of Oxidant  
32 526 Production field experiment. J Geophys Res-Atmos 107.
- 33 527 Pekey B, Yilma H (2011) The use of passive sampling monitor spatial trends of volatile organic compounds  
34 528 (VOCs) at one industrial city of Turkey. Microchemical Journal 9 (2): 213-219.
- 35 529 Rad H D, Babaci A A, Goudarzi G, Angali K A, Ramezani Z, Mohammadi M M (2014) Levels and sources  
36 530 of BTEX in ambient air of Ahvaz metropolitan city. Air Quality, Atmosphere and Health, DOI  
37 531 10.1007/s11869-014-0254-y.
- 38 532 SEMARNAT. INE. Secretaría de Medio Ambiente y Recursos Naturales (2008) Programa De Gestión Para  
39 533 Mejorar La Calidad Del Aire Del Área Metropolitana De Monterrey 2008-2012. México.
- 40 534 Statisticks Package for Microsoft Excell (XLSTAT), <http://www.xlstat.com/es>.
- 41 535 Toro RA, Donoso C S, Seguel A, Morales R G E S, Leiva M A G (2014) Photochemical ozone Pollution in  
42 536 the Valparaíso, Chile. Air Qual Atmos Health 7: 1-11.
- 43 537 Wang ZH, Zhang SY, Lu SH, Bai YH (2003) Screenings of 23 plant species in Beijing for volatile organic  
44 538 compound emissions. Chin J Environ Sci 24:7-12.
- 45 539 Wang M, Zhu T, Zheng J, Zhang R Y, Zhang S Q, Xie X X, Han Y Q, Li Y (2009) Use of a mobile  
46 540 laboratory to evaluate changes in on-road air pollutants during the Beijing 2008 summer Olympics.  
47 541 Atmos. Chem. Phys 9: 8247-8263.
- 48 542 Wang L, Khalizov A F, Zheng J, Xu W, Ma Y, Lal V, Zhang R, (2010) Atmosphere nanoparticles formed  
49 543 from heterogeneous reactions of organics. Nat. Geosci. 3: 238-242.
- 50 544 Wang L, Lal V, Khalizov A F, Zhang R, (2010) Heterogeneous chemistry of alkylamines with sulfuric acid:  
51 545 implications for atmospheric formation of alkylammonium sulfates. Environ. Sci. Technol 44: 2461-  
52 546 2465.
- 53 547 Whitten G Z, Hogo H, Yonkow NR, Johnson R G, Meyers T C (1985) Application of the empirical kinetic  
54 548 modeling approach to urban areas Volume III. U.S. Environmental Protection Agency- Office of Air  
55 549 and Radiation, Report EPA-450/4-81-005c: 1-107.

Table 1

[Click here to download Table: Table 1.doc](#)

SP	a) SUMMER 2013						b) AUTUMN 2013					
	Date	WD/MWS (km h <sup>-1</sup> )	BTEXC μg m <sup>-3</sup>				Date	WD/ MWS (km h <sup>-1</sup> )	BTEXC μg m <sup>-3</sup>			
			B	T	Ebz	X			B	T	Ebz	X
B1	03/07	ESE/5.5.	30.5	16.7	3.8	0.9	22/10	NNW/13.1	23.9	ND	1.3	ND
B2		ESE/9.6	45.2	13.8	2.3	ND		NNW/10.2	12.6	ND	1.6	ND
B3		ES/10.4	34.6	11.8	3.4	0.1		NNW/6.9	19.3	1.7	1.6	ND
B1	05/07	ENE/4.3	47.3	16.5	7.6	1.8	24/10	ENE/4.4	21.2	2.4	4.4	4.7
B2		ESE/9.9	38.3	32.0	12.6	5.1		ESE/11.9	19.4	ND	2.0	ND
B3		ESE/10.0	93.3	49.2	16.5	12.0		<b>ESE/12.7</b>	<b>26.9</b>	<b>3.5</b>	<b>1.6</b>	<b>2.0</b>
B1	09/07	ENE/5.5	75.9	36.1	13.6	8.5	28/10	ESE/4.2	28.2	1.3	1.8	ND
B2		ESE/9.4	44.7	22.0	11.9	4.7		ESE/7.1	23.6	0.2	2.6	ND
B3		ESE/10.4	61.1	28.8	13.0	7.5		ESE/8.8	16.9	2.3	1.7	ND
B1	11/07	ENE/3.5	28.5	6.2	3.1	ND	30/10	<b>ENE/2.8</b>	<b>29.8</b>	<b>4.3</b>	<b>3.6</b>	<b>ND</b>
B2		ESE/11.0	38.9	13.4	3.6	ND		NNE/2.3	29.3	3.4	5.5	0.2
B3		<b>ESE/10.7</b>	<b>137.5</b>	<b>97.1</b>	<b>14.3</b>	<b>15.1</b>		ESE/6.3	18.0	ND	1.3	ND
B1	15/07	ESE/6.3	44.9	4.8	3.7	ND	01/11	WSW/0.5	33.3	ND	4.3	1.3
B2		ESE/11.4	40.8	4.6	7.4	6.6		<b>ENE/4.4</b>	<b>27.4</b>	<b>11.9</b>	<b>6.2</b>	<b>3.0</b>
B3		ESE/10.6	43.8	4.2	7.9	8.4		ESE/4.6	24.7	ND	4.1	ND
B1	17/07	ESE/9.5	79.0	26.2	6.0	2.7	05/11	NNW/4.1	15.5	ND	1.5	ND
B2		ENE/9.7	89.6	37.3	5.9	0.6		ENE/2.5	12.8	ND	1.9	ND
B3		ESE/11.1	31.6	13.2	4.9	1.3		ESE/8.9	16.1	ND	1.3	ND
B1	18/07	ENE/7.5	33.9	14.8	4.5	0.8	08/11	ENE/2.5	18.3	ND	1.33	ND
B2		ESE/10.5	52.0	20.5	4.6	0.7		ENE/5.1	12.6	ND	1.9	ND
B3		SE/6.5	29.6	13.7	3.8	1.0		ENE/4.9	16.0	ND	1.8	ND
B1	22/07	ENE/5.5.	43.0	8.9	3.6	ND	11/11	ENE/5.6	14.9	ND	2.9	ND
B2		ENE/3.7	110.4	45.4	8.3	5.0		ESE/7.1	19.9	0.9	2.3	ND
B3		ESE/11.5	50.5	18.2	6.2	3.2		ESE/6.4	21.2	2.3	2.6	ND
B1	23/07	ESE/4.6	44.1	11.2	4.1	0.1	12/11	ESE/12.7	18.4	1.7	1.8	ND
B2		ESE/7.3	87.7	21.5	6.2	2.8		NNE/4.2	22.7	4.5	2.3	ND
B3		ESE/11.3	41.4	12.9	4.2	0.6		NNE/4.5	23.5	3.3	1.8	ND
B1	26/07	ESE/12.5	54.4	26.6	6.1	5.3	14/11	ESE/5.3	20.5	3.4	2.1	ND
B2		ENE/4.5	51.2	19.4	6.9	6.1		ENE/2.7	23.7	7.4	2.5	0.5
B3		ESE/8.1	51.9	18.8	6.8	6.3		<b>ENE/3.5</b>	<b>20.5</b>	<b>7.8</b>	<b>2.7</b>	<b>ND</b>

SP: Sampling period; MWS: Mean Wind Speed; BTEXC: BTEX Concentrations; WD: Wind Direction; ND: non detected

Table 2

[Click here to download Table: Table 2.doc](#)

Variables	B1 Sampling period			B2 Sampling period				B3 Sampling period			
	F1	F2	F3	F1	F2	F3	F4	F1	F2	F3	F4
CO	0.7 <sup>S</sup> 0.6 <sup>A</sup>			0.5 <sup>S</sup> 0.5 <sup>A</sup>	0.7 <sup>S</sup>			0.6 <sup>A</sup>	0.6 <sup>S</sup>	0.6 <sup>S</sup>	
NO <sub>x</sub>	0.9 <sup>S</sup> 0.9 <sup>A</sup>			0.9 <sup>A</sup>	0.7 <sup>S</sup>			0.9 <sup>A</sup>			
NO	0.9 <sup>A</sup>			0.8 <sup>S</sup> 0.9 <sup>A</sup>				0.8 <sup>A</sup>			
O <sub>3</sub>		0.7 <sup>S</sup> -0.6 <sup>A</sup>						0.5 <sup>S</sup>	0.5 <sup>A</sup>	0.5 <sup>S</sup>	
NO <sub>2</sub>	0.9 0.8 <sup>A</sup>			0.9 <sup>A</sup>	0.8 <sup>S</sup>			0.8 <sup>A</sup>		0.7 <sup>S</sup>	
PM <sub>10</sub>	0.8 <sup>A</sup>	0.6 <sup>S</sup>		0.8 <sup>A</sup>		0.7 <sup>S</sup>		0.7 <sup>A</sup>	0.7 <sup>A</sup>	0.5 <sup>A</sup>	0.5 <sup>S</sup>
PM <sub>2.5</sub>	0.5 <sup>A</sup>			0.5 <sup>A</sup>		0.8 <sup>S</sup> -0.6 <sup>A</sup>		0.5 <sup>S</sup> 0.6 <sup>A</sup>	0.7 <sup>A</sup>		0.5 <sup>S</sup>
B		0.6 <sup>A</sup>	0.6 <sup>S</sup> 0.5 <sup>A</sup>		0.8 <sup>A</sup>		0.73 <sup>S</sup>	0.6 <sup>S</sup>	0.7 <sup>S</sup> -0.7 <sup>A</sup>		
T			0.7 <sup>S</sup>	0.8 <sup>A</sup>			0.75 <sup>S</sup>	0.7 <sup>A</sup>	0.7 <sup>S</sup>		
Ebz	0.6 <sup>A</sup>		0.7 <sup>S</sup>	0.6 <sup>A</sup>	0.6 <sup>A</sup>			0.5 <sup>S</sup> 0.7 <sup>A</sup>	0.7 <sup>S</sup>		
X			0.5 <sup>S</sup>	0.5 <sup>A</sup>		0.5 <sup>A</sup>		0.5 <sup>S</sup>	0.7 <sup>S</sup>		
SO <sub>2</sub>	0.9 <sup>S</sup> 0.8 <sup>A</sup>			0.5 <sup>A</sup>	0.9 <sup>S</sup> -0.5 <sup>A</sup>		0.19 <sup>S</sup>	0.5 <sup>S</sup> 0.6 <sup>A</sup>		0.7 <sup>S</sup>	
WS			0.5 <sup>A</sup>	0.9 <sup>S</sup>							
WD	0.5 <sup>S</sup>		0.7 <sup>A</sup>	0.7 <sup>S</sup>		0.7 <sup>A</sup>			-0.5 <sup>A</sup>		
Temperature		0.9 <sup>S</sup>	0.6 <sup>A</sup>			0.7 <sup>A</sup>		0.9 <sup>S</sup>		0.8 <sup>A</sup>	
RH		0.4 <sup>A</sup>		0.6 <sup>S</sup>	0.5 <sup>A</sup>						

**S: SUMMER; A: AUTUMN**

Table 3

[Click here to download Table: Table 3.doc](#)

Variables	B1 SAMPLING PERIOD;							S: SUMMER;		A: AUTUMN						Temperature
	CO	NO <sub>x</sub>	O <sub>3</sub>	NO	NO <sub>2</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	B	T	Ebz	X	SO <sub>2</sub>	WS	WD	RH	
CO	1.00															
NO <sub>x</sub>	<b>0.75<sup>S</sup></b> <b>0.58<sup>A</sup></b>	1.00														
O <sub>3</sub>	0.10 <sup>S</sup> -0.39 <sup>A</sup>	0.35 <sup>S</sup> -0.23 <sup>A</sup>	1.00													
NO	0.27 <sup>S</sup> <b>0.56<sup>A</sup></b>	0.35 <sup>S</sup> <b>0.97<sup>A</sup></b>	<b>-0.53<sup>S</sup></b> -0.31 <sup>A</sup>	1.00												
NO <sub>2</sub>	<b>0.72<sup>S</sup></b> <b>0.51<sup>A</sup></b>	<b>0.96<sup>S</sup></b> <b>0.88<sup>A</sup></b>	<b>0.53<sup>S</sup></b> -0.02 <sup>A</sup>	0.08 <sup>S</sup> <b>0.76<sup>A</sup></b>	1.00											
PM <sub>10</sub>	-0.58 <sup>S</sup> <b>0.59<sup>A</sup></b>	-0.11 <sup>S</sup> <b>0.78<sup>A</sup></b>	0.49 <sup>S</sup> <b>-0.55<sup>A</sup></b>	-0.14 <sup>S</sup> <b>0.80<sup>A</sup></b>	-0.078 <sup>S</sup> <b>0.60<sup>A</sup></b>	1.00										
PM <sub>2.5</sub>	0.10 <sup>S</sup> 0.26 <sup>A</sup>	0.34 <sup>S</sup> <b>0.54<sup>A</sup></b>	0.25 <sup>S</sup> -0.04 <sup>A</sup>	0.12 <sup>S</sup> 0.48 <sup>A</sup>	0.33 <sup>S</sup> <b>0.57<sup>A</sup></b>	<b>0.68<sup>S</sup></b> <b>0.55<sup>A</sup></b>	1.00									
B	-0.28 <sup>S</sup> 0.29 <sup>A</sup>	<b>-0.56<sup>S</sup></b> 0.23 <sup>A</sup>	-0.23 <sup>S</sup> <b>-0.62<sup>A</sup></b>	-0.38 <sup>S</sup> 0.20 <sup>A</sup>	-0.48 <sup>S</sup> 0.26 <sup>A</sup>	-0.16 <sup>S</sup> 0.44 <sup>A</sup>	-0.31 <sup>S</sup> -0.21 <sup>A</sup>	1.00								
T	0.02 <sup>S</sup> 0.04 <sup>A</sup>	-0.08 <sup>S</sup> 0.02 <sup>A</sup>	-0.02 <sup>S</sup> -0.38 <sup>A</sup>	-0.13 <sup>S</sup> 0.06 <sup>A</sup>	-0.05 <sup>S</sup> -0.07 <sup>A</sup>	-0.15 <sup>S</sup> 0.20 <sup>A</sup>	-0.17 <sup>S</sup> -0.02 <sup>A</sup>	<b>0.78<sup>S</sup></b> 0.15 <sup>A</sup>	1.00							
Ebz	0.07 <sup>S</sup> 0.26 <sup>A</sup>	-0.25 <sup>S</sup> <b>0.68<sup>A</sup></b>	-0.15 <sup>S</sup> -0.38 <sup>A</sup>	-0.19 <sup>S</sup> <b>0.68<sup>A</sup></b>	-0.21 <sup>S</sup> <b>0.57<sup>A</sup></b>	-0.12 <sup>S</sup> <b>0.53<sup>A</sup></b>	0.006 <sup>S</sup> -0.06 <sup>A</sup>	<b>0.72<sup>S</sup></b> 0.47 <sup>A</sup>	<b>0.83<sup>S</sup></b> 0.28 <sup>A</sup>	1.00						
X	-0.30 <sup>S</sup> -0.13 <sup>A</sup>	-0.49 <sup>S</sup> 0.03 <sup>A</sup>	-0.05 <sup>S</sup> 0.06 <sup>A</sup>	-0.38 <sup>S</sup> 0.22 <sup>A</sup>	-0.41 <sup>S</sup> -0.36 <sup>A</sup>	-0.13 <sup>S</sup> 0.01 <sup>A</sup>	-0.32 <sup>S</sup> -0.17 <sup>A</sup>	<b>0.61<sup>S</sup></b> -0.45 <sup>A</sup>	<b>0.61<sup>S</sup></b> -0.06 <sup>A</sup>	<b>0.70<sup>S</sup></b> 0.01 <sup>A</sup>	1.00					
SO <sub>2</sub>	<b>0.76<sup>S</sup></b> <b>0.54<sup>A</sup></b>	<b>0.86<sup>S</sup></b> <b>0.95<sup>A</sup></b>	0.49 <sup>S</sup> -0.01 <sup>A</sup>	-0.11 <sup>S</sup> <b>0.90<sup>A</sup></b>	<b>0.95<sup>S</sup></b> <b>0.89<sup>A</sup></b>	-0.19 <sup>S</sup> 0.63 <sup>A</sup>	0.24 <sup>S</sup> <b>0.63<sup>A</sup></b>	-0.39 <sup>S</sup> -0.02 <sup>A</sup>	-0.04 <sup>S</sup> -0.03 <sup>A</sup>	-0.17 <sup>S</sup> <b>0.53<sup>A</sup></b>	-0.35 <sup>S</sup> 0.02 <sup>A</sup>	1.00				
WS	0.31 <sup>S</sup> 0.004 <sup>A</sup>	-0.14 <sup>S</sup> -0.40 <sup>A</sup>	<b>-0.74<sup>S</sup></b> 0.34 <sup>A</sup>	0.34 <sup>S</sup> -0.34 <sup>A</sup>	-0.25 <sup>S</sup> -0.46 <sup>A</sup>	<b>-0.56<sup>S</sup></b> <b>-0.60<sup>A</sup></b>	-0.34 <sup>S</sup> <b>-0.65<sup>A</sup></b>	0.24 <sup>S</sup> -0.20 <sup>A</sup>	0.11 <sup>S</sup> -0.23 <sup>A</sup>	0.15 <sup>S</sup> -0.33 <sup>A</sup>	-0.16 <sup>S</sup> 0.29 <sup>A</sup>	-0.14 <sup>S</sup> -0.34 <sup>A</sup>	1.00			
WD	<b>0.71<sup>S</sup></b> 0.39 <sup>A</sup>	<b>0.57<sup>S</sup></b> 0.03 <sup>A</sup>	-0.006 <sup>S</sup> 0.32 <sup>A</sup>	0.08 <sup>S</sup> 0.01 <sup>A</sup>	<b>0.58<sup>S</sup></b> 0.08 <sup>A</sup>	-0.42 <sup>S</sup> -0.15 <sup>A</sup>	-0.03 <sup>S</sup> -0.25 <sup>A</sup>	-0.16 <sup>S</sup> 0.07 <sup>A</sup>	0.06 <sup>S</sup> -0.08 <sup>A</sup>	-0.04 <sup>S</sup> -0.20 <sup>A</sup>	-0.32 <sup>S</sup> -0.01 <sup>A</sup>	<b>0.70<sup>S</sup></b> 0.07 <sup>A</sup>	<b>0.54<sup>S</sup></b> <b>0.58<sup>A</sup></b>	1.00		
RH	-0.38 <sup>S</sup> <b>-0.60<sup>A</sup></b>	-0.48 <sup>S</sup> <b>-0.65<sup>A</sup></b>	<b>-0.57<sup>S</sup></b> 0.007 <sup>A</sup>	0.48 <sup>S</sup> <b>-0.65<sup>A</sup></b>	<b>-0.65<sup>S</sup></b> <b>-0.54<sup>A</sup></b>	-0.09 <sup>S</sup> -0.48 <sup>A</sup>	-0.33 <sup>S</sup> -0.23 <sup>A</sup>	0.17 <sup>S</sup> -0.17 <sup>A</sup>	-0.02 <sup>S</sup> -0.07 <sup>A</sup>	0.040 <sup>S</sup> -0.25 <sup>A</sup>	0.025 <sup>S</sup> -0.14 <sup>A</sup>	<b>-0.76<sup>S</sup></b> <b>-0.63<sup>A</sup></b>	0.48 <sup>S</sup> -0.02 <sup>A</sup>	-0.27 <sup>S</sup> <b>-0.70<sup>A</sup></b>	1.00	
Temperature	-0.40 <sup>S</sup> 0.05 <sup>A</sup>	-0.17 <sup>S</sup> 0.03 <sup>A</sup>	<b>0.62<sup>S</sup></b> 0.008 <sup>A</sup>	<b>-0.71<sup>S</sup></b> -0.03 <sup>A</sup>	0.02 <sup>S</sup> 0.18 <sup>A</sup>	0.47 <sup>S</sup> 0.12 <sup>A</sup>	0.16 <sup>S</sup> -0.45 <sup>A</sup>	0.10 <sup>S</sup> <b>0.61<sup>A</sup></b>	0.09 <sup>S</sup> -0.03 <sup>A</sup>	0.04 <sup>S</sup> 0.44 <sup>A</sup>	0.36 <sup>S</sup> -0.29 <sup>A</sup>	0.08 <sup>S</sup> -0.11 <sup>A</sup>	<b>-0.79<sup>S</sup></b> -0.09 <sup>A</sup>	-0.43 <sup>S</sup> 0.17 <sup>A</sup>	<b>-0.66<sup>S</sup></b> -0.10 <sup>A</sup>	1.00

Table 4

[Click here to download Table: Table 4.doc](#)

Variables	B2 SAMPLING PERIOD; S: SUMMER; A: AUTUMN															
	CO	NO <sub>x</sub>	O <sub>3</sub>	NO	NO <sub>2</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	B	T	Ebz	X	SO <sub>2</sub>	WS	WD	RH	Temperature
CO	1.00															
NO <sub>x</sub>	<b>0.64<sup>S</sup></b> <b>0.59<sup>A</sup></b>	1.00														
O <sub>3</sub>	-0.11 <sup>S</sup> -0.47 <sup>A</sup>	0.23 <sup>S</sup> -0.06 <sup>A</sup>	1.00													
NO	0.27 <sup>S</sup> <b>0.69<sup>A</sup></b>	0.40 <sup>S</sup> <b>0.98<sup>A</sup></b>	-0.72 <sup>S</sup> -0.19 <sup>A</sup>	1.00												
NO <sub>2</sub>	<b>0.56<sup>S</sup></b> 0.46 <sup>A</sup>	<b>0.87<sup>S</sup></b> <b>0.98<sup>A</sup></b>	<b>0.64<sup>S</sup></b> 0.09 <sup>A</sup>	-0.08 <sup>S</sup> <b>0.93<sup>A</sup></b>	1.00											
PM <sub>10</sub>	<b>-0.57<sup>S</sup></b> <b>0.57<sup>A</sup></b>	-0.03 <sup>S</sup> <b>0.79<sup>A</sup></b>	0.41 <sup>S</sup> -0.04 <sup>A</sup>	-0.17 <sup>S</sup> <b>0.83<sup>A</sup></b>	0.05 <sup>S</sup> <b>0.73<sup>A</sup></b>	1.00										
PM <sub>2.5</sub>	-0.14 <sup>S</sup> 0.15 <sup>A</sup>	0.23 <sup>S</sup> <b>0.51<sup>A</sup></b>	0.07 <sup>S</sup> 0.14 <sup>A</sup>	0.21 <sup>S</sup> 0.47 <sup>A</sup>	0.13 <sup>S</sup> <b>0.54<sup>A</sup></b>	<b>0.77<sup>S</sup></b> <b>0.52<sup>A</sup></b>	1.00									
B	<b>-0.61<sup>S</sup></b> 0.11 <sup>A</sup>	-0.28 <sup>S</sup> 0.40 <sup>A</sup>	0.20 <sup>S</sup> <b>-0.52<sup>A</sup></b>	-0.21 <sup>S</sup> 0.44 <sup>A</sup>	-0.19 <sup>S</sup> 0.34 <sup>A</sup>	0.24 <sup>S</sup> 0.33 <sup>A</sup>	-0.20 <sup>S</sup> -0.16 <sup>A</sup>	1.00								
T	-0.27 <sup>S</sup> <b>0.53<sup>A</sup></b>	-0.14 <sup>S</sup> <b>0.84<sup>A</sup></b>	0.16 <sup>S</sup> 0.13 <sup>A</sup>	-0.14 <sup>S</sup> <b>0.82<sup>A</sup></b>	-0.07 <sup>S</sup> <b>0.83<sup>A</sup></b>	-0.05 <sup>S</sup> <b>0.65<sup>A</sup></b>	-0.36 <sup>S</sup> 0.33 <sup>A</sup>	<b>0.73<sup>S</sup></b> 0.19 <sup>A</sup>	1.00							
Ebz	-0.10 <sup>S</sup> 0.12 <sup>A</sup>	<b>-0.54<sup>S</sup></b> <b>0.55<sup>A</sup></b>	-0.05 <sup>S</sup> -0.20 <sup>A</sup>	-0.37 <sup>S</sup> <b>0.55<sup>A</sup></b>	-0.39 <sup>S</sup> <b>0.53<sup>A</sup></b>	0.01 <sup>S</sup> <b>0.52<sup>A</sup></b>	-0.10 <sup>S</sup> -0.007 <sup>A</sup>	-0.04 <sup>S</sup> <b>0.78<sup>A</sup></b>	0.37 <sup>S</sup> 0.49 <sup>A</sup>	1.00						
X	-0.09 <sup>S</sup> 0.29 <sup>A</sup>	-0.38 <sup>S</sup> <b>0.64<sup>A</sup></b>	<b>0.57<sup>S</sup></b> 0.27 <sup>A</sup>	<b>-0.89<sup>S</sup></b> <b>0.56<sup>A</sup></b>	0.05 <sup>S</sup> <b>0.70<sup>A</sup></b>	0.06 <sup>S</sup> 0.32 <sup>A</sup>	-0.20 <sup>S</sup> 0.09 <sup>A</sup>	-0.19 <sup>S</sup> 0.01 <sup>A</sup>	-0.15 <sup>S</sup> <b>0.57<sup>A</sup></b>	0.43 <sup>S</sup> 0.32 <sup>A</sup>	1.00					
SO <sub>2</sub>	<b>0.72<sup>S</sup></b> 0.34 <sup>A</sup>	<b>0.68<sup>S</sup></b> <b>0.56<sup>A</sup></b>	<b>0.56<sup>S</sup></b> 0.07 <sup>A</sup>	-0.26 <sup>S</sup> <b>0.56<sup>A</sup></b>	<b>0.88<sup>S</sup></b> <b>0.54<sup>A</sup></b>	-0.19 <sup>S</sup> 0.42 <sup>A</sup>	-0.06 <sup>S</sup> <b>0.67<sup>A</sup></b>	-0.41 <sup>S</sup> -0.22 <sup>A</sup>	-0.22 <sup>S</sup> <b>0.52<sup>A</sup></b>	-0.19 <sup>S</sup> -0.09 <sup>A</sup>	0.32 <sup>S</sup> 0.30 <sup>A</sup>	1.00				
WS	<b>0.61<sup>S</sup></b> -0.06 <sup>A</sup>	0.24 <sup>S</sup> <b>-0.59<sup>A</sup></b>	-0.71 <sup>S</sup> 0.03 <sup>A</sup>	0.63 <sup>S</sup> <b>-0.57<sup>A</sup></b>	-0.06 <sup>S</sup> -0.59 <sup>A</sup>	<b>-0.60<sup>S</sup></b> <b>-0.71<sup>A</sup></b>	-0.25 <sup>S</sup> -0.72 <sup>A</sup>	-0.20 <sup>S</sup> -0.42 <sup>A</sup>	-0.14 <sup>S</sup> -0.35 <sup>A</sup>	-0.15 <sup>S</sup> <b>-0.61<sup>A</sup></b>	-0.54 <sup>S</sup> -0.09 <sup>A</sup>	0.06 <sup>S</sup> -0.27 <sup>A</sup>	1.00			
WD	<b>0.74<sup>S</sup></b> 0.12 <sup>A</sup>	0.44 <sup>S</sup> -0.23 <sup>A</sup>	-0.28 <sup>S</sup> 0.27 <sup>A</sup>	0.30 <sup>S</sup> -0.26 <sup>A</sup>	0.32 <sup>S</sup> -0.20 <sup>A</sup>	-0.48 <sup>S</sup> -0.27 <sup>A</sup>	-0.24 <sup>S</sup> -0.39 <sup>A</sup>	-0.32 <sup>S</sup> -0.46 <sup>A</sup>	-0.35 <sup>S</sup> 0.12 <sup>A</sup>	-0.28 <sup>S</sup> -0.17 <sup>A</sup>	-0.16 <sup>S</sup> 0.20 <sup>A</sup>	0.46 <sup>S</sup> -0.40 <sup>A</sup>	<b>0.78<sup>S</sup></b> 0.49 <sup>A</sup>	1.00		
RH	-0.23 <sup>S</sup> -0.38 <sup>A</sup>	-0.21 <sup>S</sup> -0.18 <sup>A</sup>	-0.70 <sup>S</sup> -0.11 <sup>A</sup>	<b>0.60<sup>S</sup></b> -0.23 <sup>A</sup>	<b>-0.55<sup>S</sup></b> -0.11 <sup>A</sup>	-0.17 <sup>S</sup> -0.37 <sup>A</sup>	-0.22 <sup>S</sup> -0.12 <sup>A</sup>	0.47 <sup>S</sup> 0.40 <sup>A</sup>	0.39 <sup>S</sup> -0.43 <sup>A</sup>	-0.03 <sup>S</sup> 0.03 <sup>A</sup>	<b>-0.71<sup>S</sup></b> -0.24 <sup>A</sup>	<b>-0.69<sup>S</sup></b> <b>-0.55<sup>A</sup></b>	<b>0.52<sup>S</sup></b> -0.04 <sup>A</sup>	0.13 <sup>S</sup> -0.19 <sup>A</sup>	1.00	
Temperature	-0.35 <sup>S</sup> -0.04 <sup>A</sup>	-0.25 <sup>S</sup> 0.02 <sup>A</sup>	<b>0.64<sup>S</sup></b> 0.18 <sup>A</sup>	<b>-0.68<sup>S</sup></b> 0.01 <sup>A</sup>	0.09 <sup>S</sup> 0.02 <sup>A</sup>	0.48 <sup>S</sup> 0.27 <sup>A</sup>	0.30 <sup>S</sup> -0.40 <sup>A</sup>	-0.16 <sup>S</sup> 0.20 <sup>A</sup>	-0.14 <sup>S</sup> 0.05 <sup>A</sup>	0.28 <sup>S</sup> <b>0.52<sup>A</sup></b>	0.72 <sup>S</sup> 0.36 <sup>A</sup>	0.15 <sup>S</sup> -0.38 <sup>A</sup>	<b>-0.86<sup>S</sup></b> -0.09 <sup>A</sup>	<b>-0.67<sup>S</sup></b> 0.24 <sup>A</sup>	-0.78 <sup>S</sup> -0.26 <sup>A</sup>	1.00

Table 5

[Click here to download Table: Table 5.doc](#)

B3 SAMPLING PERIOD; S: SUMMER; A: AUTUMN																
Variable s	CO	NO <sub>x</sub>	O <sub>3</sub>	NO	NO <sub>2</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	B	T	Ebz	X	SO <sub>2</sub>	WS	WD	RH	Tempera - ture
CO	1.00															
NO <sub>x</sub>	<b>0.50<sup>S</sup></b> <b>0.69<sup>A</sup></b>	1.00														
O <sub>3</sub>	-0.23 <sup>S</sup> -0.44 <sup>A</sup>	<b>0.50<sup>S</sup></b> 0.16 <sup>A</sup>	1.00													
NO	0.33 <sup>S</sup> <b>0.73<sup>A</sup></b>	<b>0.85<sup>S</sup></b> <b>0.81<sup>A</sup></b>	<b>-0.86<sup>S</sup></b> -0.42 <sup>A</sup>	1.00												
NO <sub>2</sub>	0.44 <sup>S</sup> <b>0.57<sup>A</sup></b>	<b>0.60<sup>S</sup></b> <b>0.95<sup>A</sup></b>	0.35 <sup>S</sup> -0.01 <sup>A</sup>	0.10 <sup>S</sup> <b>0.60<sup>A</sup></b>	1.00											
PM <sub>10</sub>	-0.37 <sup>S</sup> <b>0.50<sup>A</sup></b>	-0.26 <sup>S</sup> <b>0.66<sup>A</sup></b>	0.43 <sup>S</sup> 0.03 <sup>A</sup>	-0.37 <sup>S</sup> 0.46 <sup>A</sup>	0.05 <sup>S</sup> <b>0.67<sup>A</sup></b>	1.00										
PM <sub>2.5</sub>	-0.43 <sup>S</sup> -0.04 <sup>A</sup>	-0.29 <sup>S</sup> 0.49 <sup>A</sup>	-0.05 <sup>S</sup> 0.26 <sup>A</sup>	-0.07 <sup>S</sup> 0.34 <sup>A</sup>	-0.45 <sup>S</sup> <b>0.50<sup>A</sup></b>	<b>0.60<sup>S</sup></b> <b>0.67<sup>A</sup></b>	1.00									
B	0.16 <sup>S</sup> 0.47 <sup>A</sup>	-0.32 <sup>S</sup> 0.22 <sup>A</sup>	-0.05 <sup>S</sup> -0.16 <sup>A</sup>	-0.13 <sup>S</sup> 0.08 <sup>A</sup>	-0.41 <sup>S</sup> 0.27 <sup>A</sup>	-0.10 <sup>S</sup> -0.05 <sup>A</sup>	0.41 <sup>S</sup> -0.44 <sup>A</sup>	1.00								
T	0.21 <sup>S</sup> 0.46 <sup>A</sup>	-0.18 <sup>S</sup> 0.62 <sup>A</sup>	-0.11 <sup>S</sup> -0.17 <sup>A</sup>	-0.01 <sup>S</sup> <b>0.80<sup>A</sup></b>	-0.32 <sup>S</sup> 0.44 <sup>A</sup>	-0.14 <sup>S</sup> 0.46 <sup>A</sup>	0.45 <sup>S</sup> 0.32 <sup>A</sup>	<b>0.97<sup>S</sup></b> 0.08 <sup>A</sup>	1.00							
Ebz	0.27 <sup>S</sup> <b>0.74<sup>A</sup></b>	-0.37 <sup>S</sup> <b>0.86<sup>A</sup></b>	-0.17 <sup>S</sup> -0.21 <sup>A</sup>	-0.12 <sup>S</sup> <b>0.60<sup>A</sup></b>	<b>0.51<sup>S</sup></b> <b>0.86<sup>A</sup></b>	-0.15 <sup>S</sup> <b>0.60<sup>A</sup></b>	0.24 <sup>S</sup> 0.35 <sup>A</sup>	<b>0.83<sup>S</sup></b> 0.45 <sup>A</sup>	<b>0.75<sup>S</sup></b> 0.27 <sup>A</sup>	1.00						
X	0.16 <sup>S</sup> -	-0.31 <sup>S</sup> -	-0.19 <sup>S</sup> -	-0.07 <sup>S</sup> -	-0.48 <sup>S</sup> -	-0.18 <sup>S</sup> -	0.24 <sup>S</sup> -	<b>0.89<sup>S</sup></b> -	<b>0.80<sup>S</sup></b> -	<b>0.91<sup>S</sup></b> -	1.00					
SO <sub>2</sub>	0.44 <sup>S</sup> 0.27 <sup>A</sup>	0.30 <sup>S</sup> <b>0.61<sup>A</sup></b>	0.49 <sup>S</sup> 0.006 <sup>A</sup>	-0.52 <sup>S</sup> <b>0.65<sup>A</sup></b>	0.21 <sup>S</sup> <b>0.50<sup>A</sup></b>	-0.02 <sup>S</sup> 0.29 <sup>A</sup>	-0.13 <sup>S</sup> <b>0.56<sup>A</sup></b>	0.49 <sup>S</sup> 0.03 <sup>A</sup>	0.41 <sup>S</sup> <b>0.54<sup>A</sup></b>	0.49 <sup>S</sup> 0.39 <sup>A</sup>	0.49 <sup>S</sup> -	1.00				
WS	<b>0.61<sup>S</sup></b> 0.16 <sup>A</sup>	0.10 <sup>S</sup> <b>0.70<sup>A</sup></b>	<b>-0.50<sup>S</sup></b> -0.01 <sup>A</sup>	0.29 <sup>S</sup> 0.49 <sup>A</sup>	-0.23 <sup>S</sup> <b>0.71<sup>A</sup></b>	-0.42 <sup>S</sup> <b>0.65<sup>A</sup></b>	-0.27 <sup>S</sup> <b>0.73<sup>A</sup></b>	0.24 <sup>S</sup> 0.33 <sup>A</sup>	0.24 <sup>S</sup> -	0.34 <sup>S</sup> 0.45 <sup>A</sup>	0.28 <sup>S</sup> -	0.06 <sup>S</sup> 0.28 <sup>A</sup>	1.00			
WD	<b>0.82<sup>S</sup></b> -0.04 <sup>A</sup>	<b>0.53<sup>S</sup></b> 0.30 <sup>A</sup>	-0.30 <sup>S</sup> -0.12 <sup>A</sup>	0.42 <sup>S</sup> 0.35 <sup>A</sup>	0.36 <sup>S</sup> 0.23 <sup>A</sup>	-0.13 <sup>S</sup> <b>0.60<sup>A</sup></b>	-0.40 <sup>S</sup> <b>0.71<sup>A</sup></b>	-0.07 <sup>S</sup> 0.10 <sup>A</sup>	-0.03 <sup>S</sup> <b>0.52<sup>A</sup></b>	0.07 <sup>S</sup> 0.24 <sup>A</sup>	-0.07 <sup>S</sup> -	0.07 <sup>S</sup> 0.47 <sup>A</sup>	<b>0.70<sup>S</sup></b> 0.36 <sup>A</sup>	1.00		
RH	0.11 <sup>S</sup> -0.13 <sup>A</sup>	<b>0.59<sup>S</sup></b> 0.06 <sup>A</sup>	<b>-0.73<sup>S</sup></b> -0.02 <sup>A</sup>	<b>0.78<sup>S</sup></b> 0.02 <sup>A</sup>	-0.06 <sup>S</sup> 0.07 <sup>A</sup>	<b>0.55<sup>S</sup></b> -0.21 <sup>A</sup>	-0.21 <sup>S</sup> 0.01 <sup>A</sup>	-0.37 <sup>S</sup> 0.08 <sup>A</sup>	-0.24 <sup>S</sup> 0.01 <sup>A</sup>	-0.32 <sup>S</sup> 0.15 <sup>A</sup>	-0.37 <sup>S</sup> -	-0.67 <sup>S</sup> -0.33 <sup>A</sup>	0.24 <sup>S</sup> 0.29 <sup>A</sup>	0.21 <sup>S</sup> 0.02 <sup>A</sup>	1.00	
Tempera - ture	-0.48 <sup>S</sup> -0.10 <sup>A</sup>	-0.71 <sup>S</sup> 0.35 <sup>A</sup>	<b>0.63<sup>S</sup></b> 0.15 <sup>A</sup>	-0.74 <sup>S</sup> <b>0.58<sup>A</sup></b>	-0.22 <sup>S</sup> 0.18 <sup>A</sup>	<b>0.56<sup>S</sup></b> 0.30 <sup>A</sup>	0.40 <sup>S</sup> -0.06 <sup>A</sup>	0.39 <sup>S</sup> 0.06 <sup>A</sup>	0.24 <sup>S</sup> -0.54 <sup>A</sup>	0.34 <sup>S</sup> 0.08 <sup>A</sup>	0.43 <sup>S</sup> -	0.44 <sup>S</sup> -0.55 <sup>A</sup>	-0.47 <sup>S</sup> 0.19 <sup>A</sup>	-0.54 <sup>S</sup> 0.01 <sup>A</sup>	-0.88 <sup>S</sup> -0.33 <sup>A</sup>	1.00



Figure 1

[Click here to download Figure: Figure 1.doc](#)

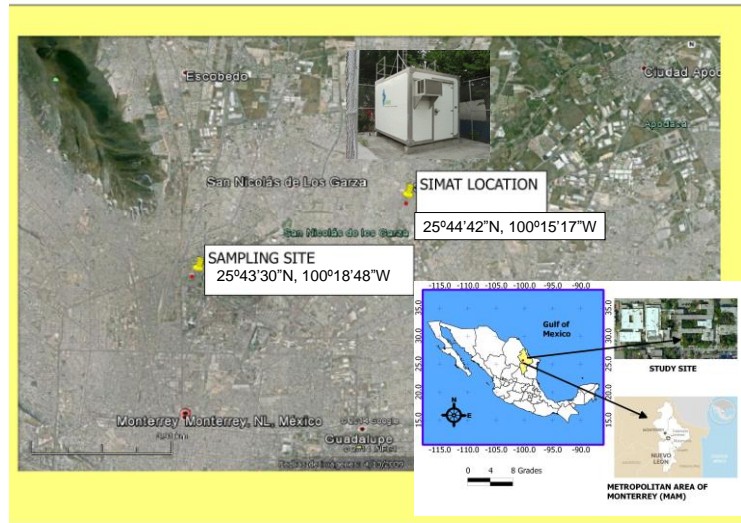


Figure 2

[Click here to download Figure: Figure 2.doc](#)

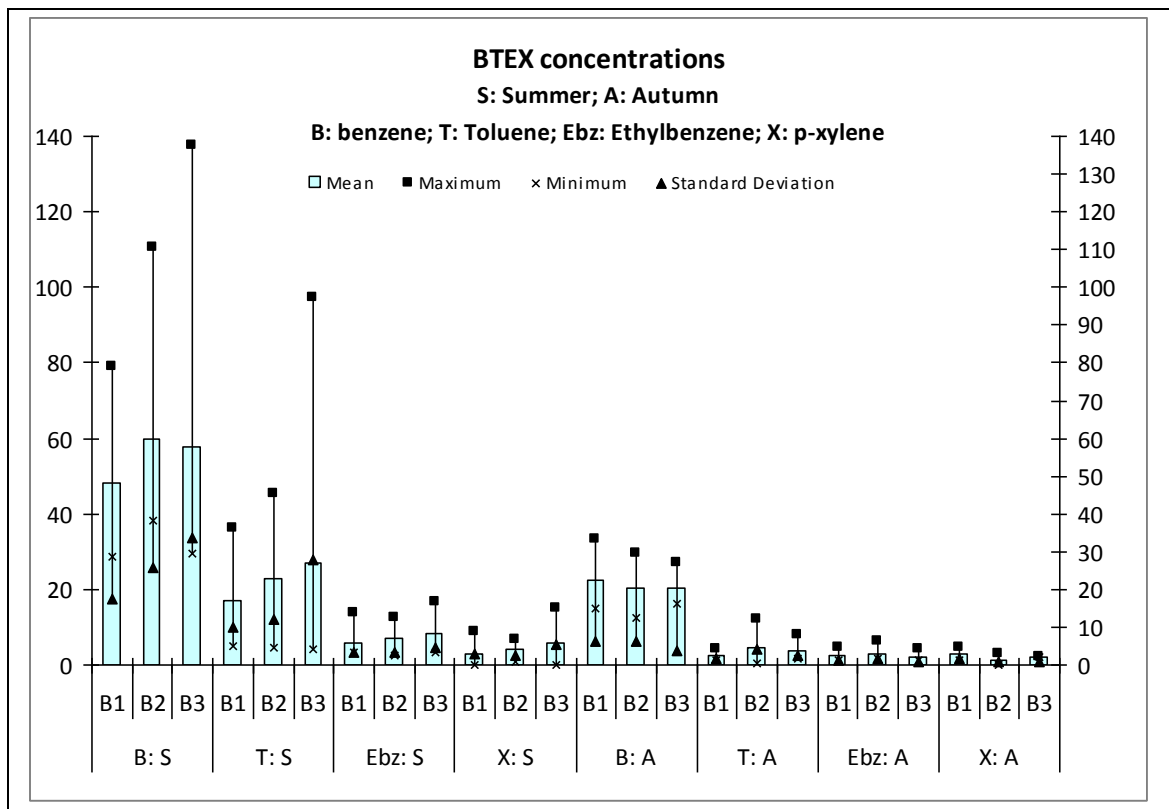


Figure 3

[Click here to download Figure: Figure 3.doc](#)

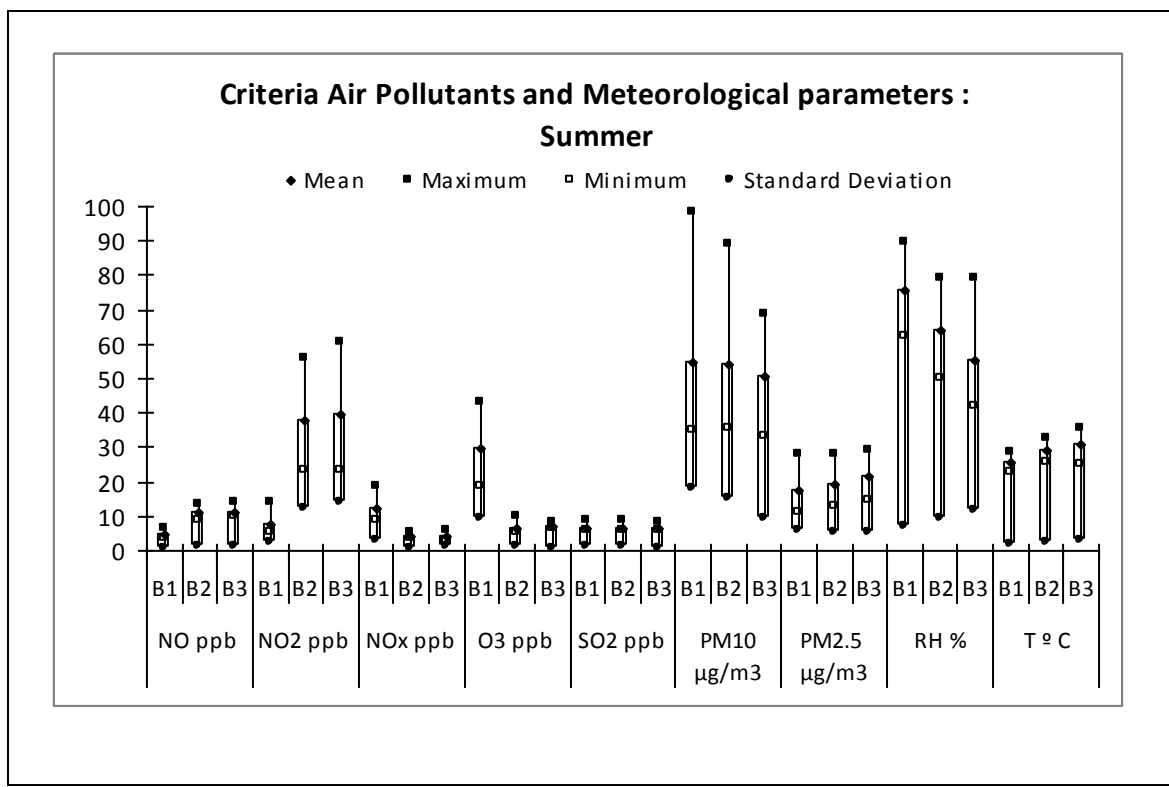


Figure 4

[Click here to download Figure: Figure 4.doc](#)

