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1 Article

# 2 Ambient BTEX Concentrations During the COVID-19 3 Lockdown in a Peri-urban Environment (Orléans, France)

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17 **Abstract:** During the period from March 17<sup>th</sup> to May 10<sup>th</sup> 2020, France saw dramatic shifts in domes-  
18 tic, industrial and transport sectors as a national lockdown was introduced. So far, studies have  
19 generally focused on urban settings, by contrast, this work reports data for a periurban location. Air  
20 samples were collected and analyzed using a fully automated GC-MS-FID system in an air quality  
21 monitoring station situated in the suburbs of Orléans, France. Average concentrations of BTEX (ben-  
22 zene, toluene, ethylbenzene and xylenes) before, during and after lockdown, were  $402 \pm 143$ ,  $800 \pm$   
23  $378$  and  $851 \pm 445$  pptv, respectively. Diurnal variation in BTEX and correlations between each of its  
24 components were analyzed to determine its various sources. The toluene/benzene (T/B) and m,p-  
25 xylene/ethylbenzene (MP/E) ratios, photochemical ages were used to explore whether the BTEX  
were from local or more distant sources. Together with a host of complementary measurements  
including NO<sub>x</sub>, O<sub>3</sub>, black carbon, meteorological parameters and anthropogenic activities, we were  
able to make some inferences on the sources of BTEX. The results suggest that although anomalous  
local anthropogenic activity can lead to significant changes in BTEX concentrations, pollution levels  
in Orléans are mostly dependent on meteorological conditions, specifically whether the winds are  
coming from the Paris Region. It appears, based on these measurements, that the pollution in the  
Orléans area is very much tied to the nearby megacity of Paris, this may be true for other peri-urban  
sites with implications for city planning and pollution mitigation strategies.

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**Keywords:** BTEX; COVID-19; lockdown; Orleans; peri-urban

## 1. Introduction

The COVID-19 pandemic has resulted in reduced emissions into the atmosphere worldwide as a result of the actions taken to limit or even stop certain human activities, which are generally linked to transportation and industrial activities. In some locations, these measures led to substantial reductions in the emissions of important atmospheric pollutants such as nitrogen oxides (NO<sub>x</sub>), particulate matter (PM), and volatile organic compounds (VOCs) as reported by a number of studies around the globe. For example, Barré et al. [1] and Guevara et al. [2] reported emissions dropping by up to 60% for NO<sub>x</sub>, and up to 15% for non-methane volatile organic compounds (NMVOC) during the March/April 2020 lockdown in Europe while Shi and Brasseur [3] showed that the surface concentrations of PM<sub>2.5</sub> and NO<sub>2</sub> in China were reduced by 35% and 60%, respectively. It

is expected that the NO<sub>x</sub> levels decreased in urban areas during lockdown periods since they are major combustion by-products from vehicle emissions. Many other regions have recorded significant reductions in air pollution globally [4–6].

While NO<sub>x</sub> levels have generally decreased, NO<sub>x</sub> concentration from other sources and the concentrations of other species may not follow the same trends, especially for those emitted into the atmosphere through plants, agricultural, biomass burning and indoor activities. In addition, atmospheric pollution is not a linear “chemistry” [7,8]. The reduction of NO<sub>x</sub> alone does not necessitate a direct improvement of air quality, for example, lowering NO<sub>x</sub> emissions may lead to an increase of ozone levels depending on a number of factors such as the types of VOCs and their concentrations as well as the solar irradiation. In fact, a number of studies have reported an increase of ozone concentrations in various areas during the lockdown despite the reduction in the NO<sub>x</sub> levels [9,10].

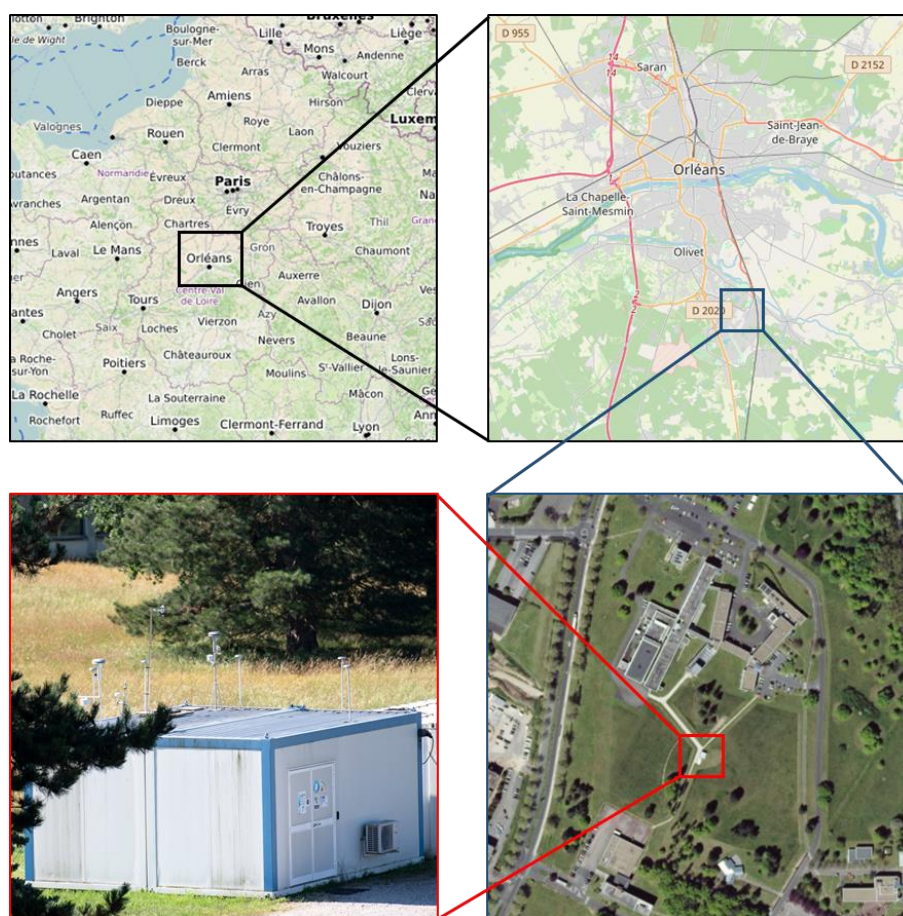
Atmospheric chemistry is complex; a complete understanding of the processes occurring and the resulting impacts on air quality and health require the knowledge of many parameters, not only the concentrations of NO<sub>x</sub> and PMs. More specifically, it requires the speciation of many other pollutants such as VOCs, which may play an important role in tropospheric ozone formation for example. Among the VOCs emitted into the atmosphere, the mono-aromatic hydrocarbons such as benzene, toluene, ethylbenzene, and xylene isomers (BTEX) are of special interest because of their role in the tropospheric chemistry and their adverse health effects such as asthma, dizziness, fatigue, and eye, nose, and throat irritation [11–13]. BTEX are emitted into the atmosphere from gasoline and diesel-powered automobiles, residential heating, industrial emissions and biogenic sources [14–17]. Once in the atmosphere, BTEX could react near the emission source or undergo transport depending on the atmospheric composition and meteorological conditions [18]. It is expected that the main degradation process in the gas phase during the day is the reaction with OH (hydroxyl radicals), resulting in a considerable contribution to photo-oxidant and secondary organic aerosol formation in the atmosphere [19]. The ratios of toluene/benzene (T/B) and m,p-xylene/ethylbenzene (MP/E) are considered to be useful indicators of atmospheric photochemical activity as well as the sources [20]. Assessing the impact of the lockdown on the BTEX atmospheric levels is important to the evaluation of the stay-at-home measures on the air quality during the pandemic period.

We report in the present work measurements of the concentrations of BTEX levels in a peri-urban area in France. The main objectives are: (1) to determine real time BTEX concentrations before, during and after the period of COVID-19 lockdown in Orléans, France; (2) to rationalize the obtained results based on the concentrations of secondary pollutants such as NO<sub>x</sub> and O<sub>3</sub>, particulate matter and black carbon and (3) to investigate the effect of meteorological parameters such as wind speed, wind direction, and temperature on the diurnal BTEX variations during the studied period.

## 2. Materials and Methods

### 2.1. Sampling Site

As shown in Fig. 1, the sampling site is positioned within the campus of the Centre National de la Recherche Scientifique (CNRS) about 10 km south from Orléans city center (47°50'17"N, 1°56'39"E). Orléans is the capital of the Centre-Val de Loire region, located in central France about 120 kilometers southwest of Paris, with a population of 300 thousand inhabitants. The site is close to a forest belt, and farms. There are no obstructing buildings around the sampling site within 50 m. The measurements reported in this study were made during the period from Feb. 26<sup>th</sup> to May 31<sup>st</sup> in 2020.



**Figure 1.** Location of the sampling site at the CNRS-campus in Orléans, France.

## 2.2. Instrumentation

### 2.2.1. BTEX Measurements

An automated online gas chromatographic system (GC-FID, AirmoVOC C6–C16 Chromatotec®) was used for in situ BTEX measurements with a time resolution of 40 min. Ambient air was sampled continuously from an inlet mounted at a height of 4 m above the ground through a Teflon tube (length 2.5 m, diameter 1/4 inch) at a  $16 \text{ L min}^{-1}$  bypass flow, and then entered the trap at a flow rate of  $45 \text{ mL min}^{-1}$  through a heated stainless-steel tube (length  $\sim 1.5 \text{ m}$ , diameter 1/8 inch). This sampling setup could ensure a short residence time in the sampling line and improve the sampling efficiency of the C6–C16 VOCs. The volume of air samples was 1350 ml for a 30 min sampling period. The trap was heated to  $380^\circ\text{C}$  within 4 min. VOCs were thermally desorbed and injected into capillary columns (analytical column: MXT 30 CE, film thickness:  $1 \mu\text{m}$ , id:  $0.28 \text{ mm}$ , length:  $30 \text{ m}$ ) with  $\text{H}_2$  around  $3$  to  $4 \text{ mL min}^{-1}$  for separation before detection. The temperature ramp of the capillary column (a plot of temperature vs time is provided in Figure. A1 in the supporting information) was set as follows: increased from  $38^\circ\text{C}$  to  $50^\circ\text{C}$  at a rate of  $2^\circ\text{C min}^{-1}$ ; increased to  $80^\circ\text{C}$  in 3 min; increased to  $220^\circ\text{C}$  at a rate of  $15^\circ\text{C min}^{-1}$ , then went to  $230^\circ\text{C}$  at a rate of  $2^\circ\text{C min}^{-1}$ ; finally reached  $269^\circ\text{C}$  at a rate of  $9^\circ\text{C min}^{-1}$  and held for 3 min. A flame ionization detector (FID) set at  $200^\circ\text{C}$  was used for quantification.

The accuracy of the system (quantification and identification) was controlled every 12h using an automatic calibration system, which is equipped with four internal permeation tubes containing four internal standards (benzene, n-butane, n-decane, and n-hexane). The detection limits for benzene, toluene, ethylbenzene, m, p-xylene, and o-xylene were  $\sim 5 \text{ pptv}$ .

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### 2.2.2. NO<sub>x</sub>, O<sub>3</sub>, PM<sub>10</sub> and BC measurements

The concentrations of ozone (O<sub>3</sub>), NO<sub>x</sub> (include NO and NO<sub>2</sub>), black carbon (BC), and particulate matter with a diameter less than 10 μm (PM<sub>10</sub>) were provided by the air quality monitoring agency at the Centre-Val de Loire region by Lig'Air (<http://www.ligair.fr/>). These species were monitored at the same location as the BTEX measurements reported in the present work. Ambient air was sampled continuously from separate Teflon tubes (diameter 1/4 inch) at a height of 1 m above the roof of the container and about 4 m from the ground. BC was measured continuously at 1-min intervals using an aethalometer (AE33 model, Magee Scientific). The O<sub>3</sub> and NO–NO<sub>x</sub> concentrations were continuously monitored by UV absorption (Thermo Scientific™ Model 49i) and chemiluminescence (Thermo Scientific™ Model 42i), respectively. A DIGITEL DHA-80 high volume aerosol sampler was also used for PM<sub>10</sub> sampling. Most of data processing and figures were performed using the R software environment [21] and particularly the Openair package, designed by Carslaw et al. [22].

### 2.2.3. Meteorological data

The meteorological data were used from Orléans-Bricy air base station (<https://www.infoclimat.fr/>) due to missing data for several weeks during lockdown.

## 3. Results and discussions

### 3.1. Data Overview

The measurement period (Feb. 26<sup>th</sup> to May 31<sup>st</sup> 2020) was divided in three regimes (a) before lockdown (Feb. 26<sup>th</sup> – Mar. 16<sup>th</sup>), (b) during lockdown (Mar. 17<sup>th</sup> – May 10<sup>th</sup>) and (c) after lockdown (May 11<sup>th</sup> – May 31<sup>st</sup>). Average BTEX mixing ratios along with their associated arithmetic mean and interquartile range (IQR) in each period are listed in Table 1. Benzene and ethylbenzene were the most abundant BTEX compounds throughout the study period. On average, the highest concentrations of BTEX were observed during and after the lockdown.

**Table 1.** Average mixing ratios (pptv) of BTEX for each period (before, during and after lockdown) in Orléans, France (SD: Standard deviation, IQR: interquartile range).

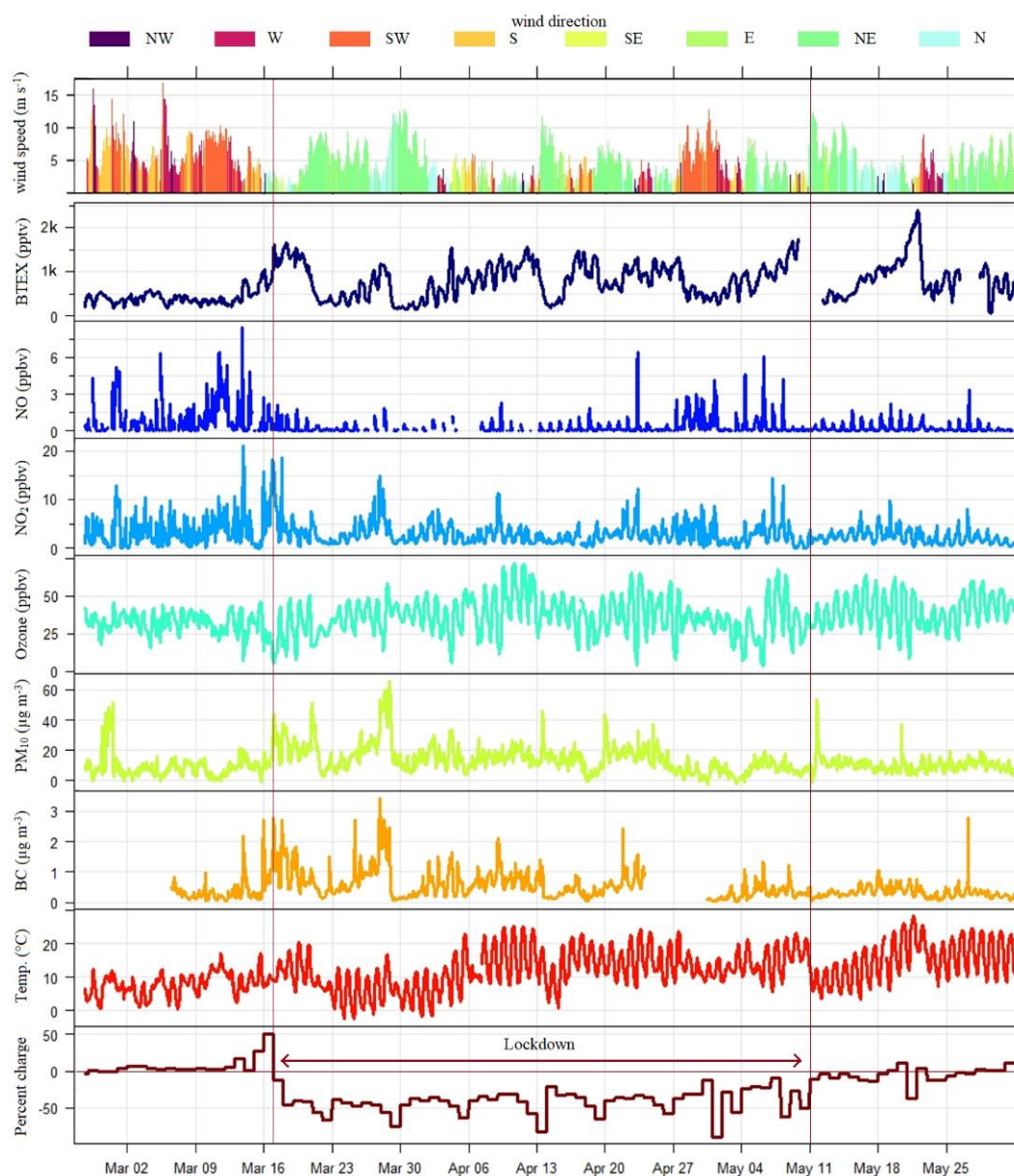
	Before lockdown		Lockdown		After lockdown	
	Feb. 26 <sup>th</sup> - Mar. 16 <sup>th</sup>		Mar. 17 <sup>th</sup> - May 10 <sup>th</sup>		May 11 <sup>th</sup> - May 31 <sup>st</sup>	
	Mean ± SD	IQR	Mean ± SD	IQR	Mean ± SD	IQR
N° samples	620		1860		595	
Benzene	83 ± 48	30	271 ± 143	233	280 ± 163	191
Toluene	56 ± 36	32	121 ± 80	112	118 ± 63	79
Ethylbenzene	99 ± 37	47	172 ± 80	125	205 ± 113	121
m,p-xylene	86 ± 29	37	124 ± 59	92	122 ± 58	76
o-xylene	79 ± 20	27	113 ± 49	65	128 ± 64	59
Total BTEX	402 ± 143	155	800 ± 378	626	851 ± 445	523

The temporal variations of BTEX, NO, NO<sub>2</sub>, O<sub>3</sub>, PM<sub>10</sub>, BC, temperature at this site, and meteorological parameters (wind speed in m s<sup>-1</sup> and wind direction in a color-coded way) during the measurement period are illustrated in Figure. 2. Furthermore, the relative changes in daily regional mobility data from the Google Community Mobility Reports (<https://www.google.com/covid19/mobility/>) were also used for this analysis (the bottom of Figure. 2). The reports chart movement trends over time by geography, across different categories of places such as retail and recreation, groceries and pharmacies, parks, transit stations, workplaces, and residential. These reports are created with aggregated, anonymized sets of data from users who have turned on the Location History setting, which is off by default. This provides a breakdown by category (grocery stores, parks, residential, workplaces, transit stations, and retail) in changes to daily movement at a regional level.



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The data “percent charge in the grocery and pharmacy” was used to perform the comparisons along the studied period.



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162 **Figure 2.** Time series of hourly BTEX (pptv, y axis of BTEX 1k=1×10<sup>3</sup>), NO (ppbv), NO<sub>2</sub> (ppbv), O<sub>3</sub> (ppbv), PM<sub>10</sub> (µg m<sup>-3</sup>),  
163 Black Carbon (µg m<sup>-3</sup>) and Temperature (°C) in Orléans during the studied period, with daily “percent change in the  
164 grocery and pharmacy”, and meteorological parameters (wind speed in m s<sup>-1</sup>, wind direction in a color-coded way).

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### 3.2. Diurnal variation and correlations

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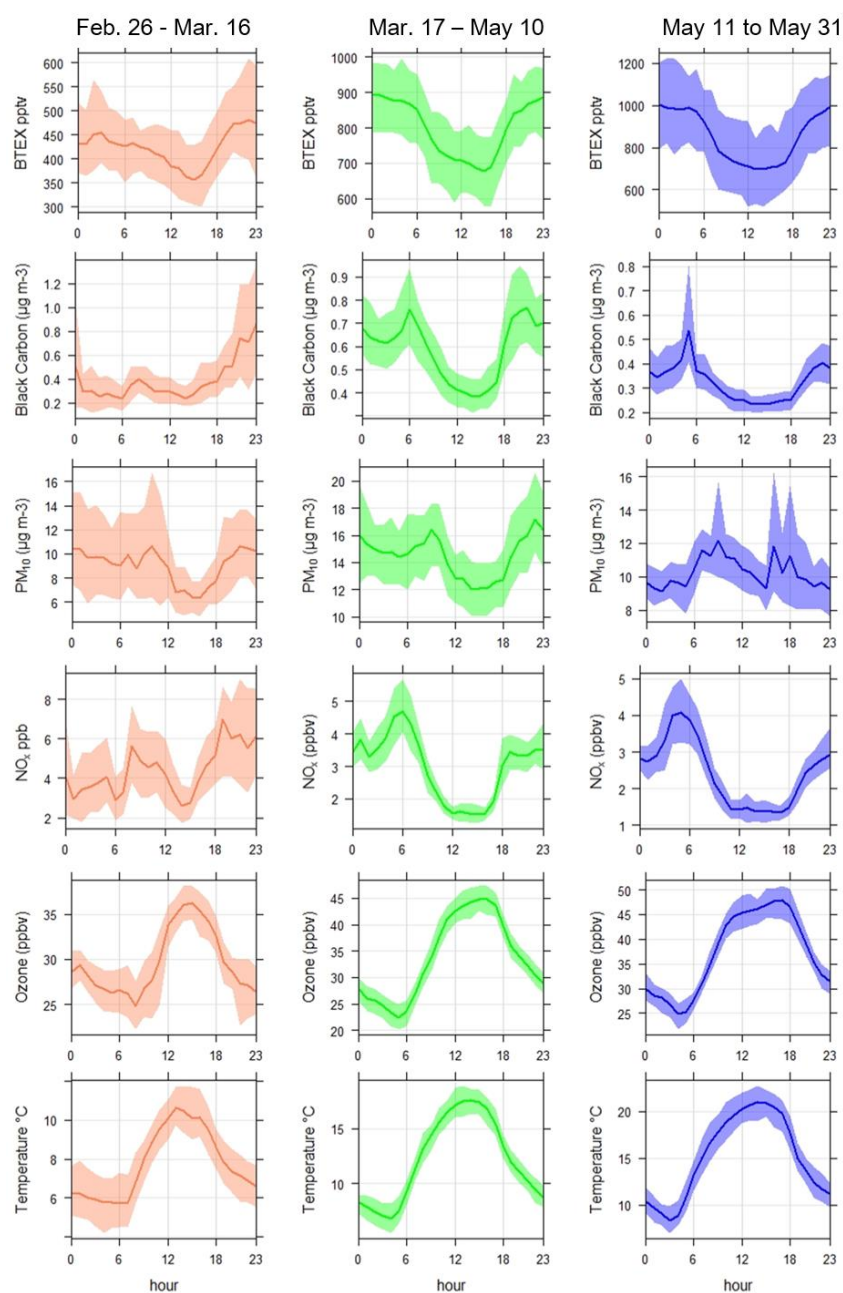
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The study of diurnal variations of air pollutants could provide valuable information about the sources, transport and chemical formation/destruction of such pollutants. The diurnal variations of the BTEX, BC, PM<sub>10</sub>, NO<sub>x</sub> and O<sub>3</sub> during the present study are shown in Figure. 3. (a series of diurnal variations in benzene, toluene, ethylbenzene, m,p-xylene and o-xylene mixing ratios before, during and after lockdown provided in the supporting information, Figure. A2)



**Figure 3.** Diurnal variations in BTEX, BC, PM<sub>10</sub>, NO<sub>x</sub>, O<sub>3</sub> and temperature before, during and after lockdown. The shaded area represent 95% confidence interval in mean.

BTEX concentrations have been observed to be generally higher during the night than daytime. The concentrations-time profiles show a decrease of the total BTEX from around 6 am to around 3 pm in the three periods. This is likely to result from a combination of effects such as photochemical reactions, an increase in the atmospheric mixing depth and/or a reduction in emission rates [23]. During the afternoon, an increase in concentration is observed around 3 pm. This increase is observed markedly during the period before the lockdown, which could be attributed to traffic emissions and home heating fuels consumed in winter in the late afternoon. High values were recorded also during rush hours in the morning and late afternoon before and after the lockdown. These feature was less clear during lockdown, revealing the possible contribution from the traffic emissions during periods before and after the lockdown.

Moreover, a strong correlation coefficient ( $r = 0.83$ ) was obtained for ethylbenzene / xylene isomers before the lockdown (Figure. 4 a). This fact suggests that both compounds

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could be emitted from the gasoline vehicles and stations [24]. Toluene is also widely used as a solvent in paint manufacture, the production of adhesives and glues, while benzene emissions could be mainly due to wintertime domestic heating combustion in France [25]. During the lockdown (Figure. 4 b), the high correlations among all the BTEX suggests that the contributions are likely to be emitted by the same sources. The correlation becomes even stronger after the lockdown period as shown by Figure 4 c, which indicates that the source of BTEX were becoming increasingly homogenous.

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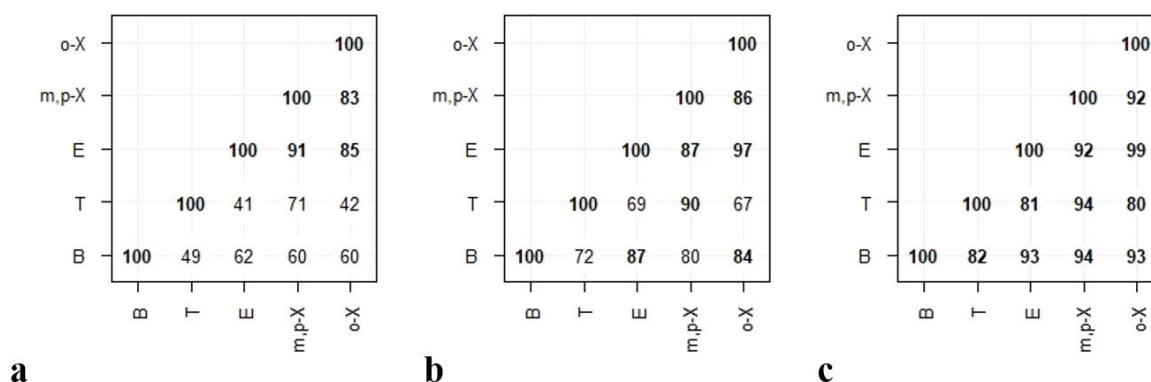
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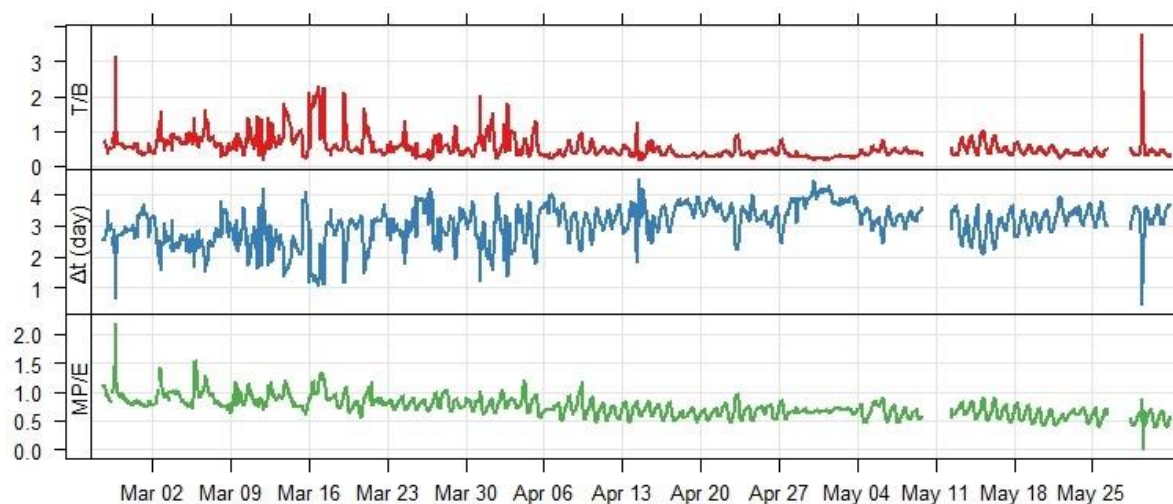
**Figure 4.** Correlation coefficients in percentage between Benzene, Toluene, Ethylbenzene, m,p-Xylene and o-Xylene (a) before, (b) during and (c) after the lockdown.

### 3.3. BTEX ratios assessment

The Toluene/Benzene ratio (T/B) is often used in BTEX source apportionment studies [26]. It is a tool for characterizing the distance from (and age of) vehicular emission sources. While toluene emissions are associated with traffic and industries, benzene from these sources has been reduced as a consequence of gasoline regulations. The principal source of benzene in France is therefore likely to be residential heating [27].

It can be observed in Figure. 5 that the T/B ratio falls below 1 in general, with some higher values observed in the first week of lockdown. This suggests that there were no major changes in BTEX sources during our study period, which is surprising, given the decrease in transport activities and the change in the population's daily routines during lockdown. When the location of the measurement site in Orléans is considered in relation to potential BTEX sources in Paris, the T/B ratios < 1 that we observe are broadly consistent with the measurements of Salameh [28], who show that in suburban sites such as Melun and other locations on the outskirts of Paris, T/B ratios are close to 1. Nevertheless, it is possible that a significant contribution of the benzene concentration comes from residential heating as mentioned above..





**Figure 5.** Variation of toluene / benzene (T/B), photochemical age of the air ( $\Delta t$ ), and m, p-xylene / ethylbenzene (MP/E) concentration ratios in the observation site during the entire measurement period.

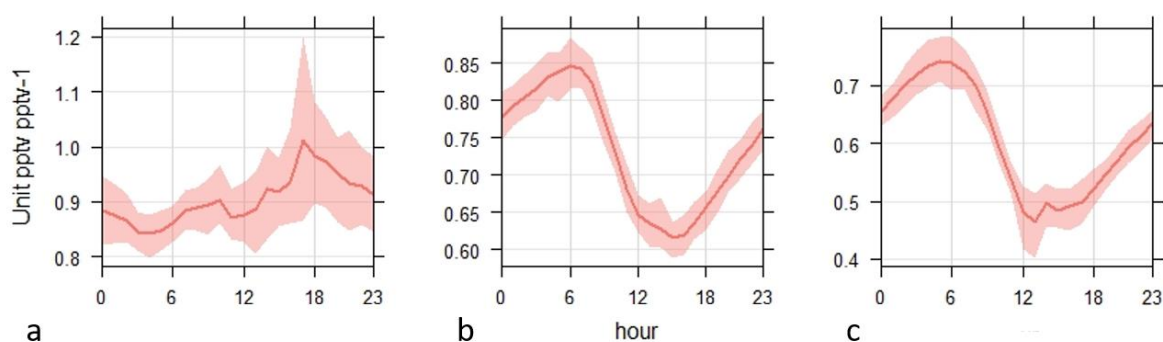
In this study, the photochemical age was used to estimate the origin of the air masses. Its definition depends on the fact that the more reactive chemicals are consumed faster than the less reactive ones, so that as an air mass ages there are systematic changes in concentration ratios [29]. The T/B ratio in the sampled air as described by Roberts [30]:

$$\Delta t = \frac{1}{[\text{OH}](k_{\text{toluene}} - k_{\text{benzene}})} \times \left[ \ln \left( \frac{[\text{toluene}]_t}{[\text{benzene}]_t} \right) - \ln \left( \frac{[\text{toluene}]_0}{[\text{benzene}]_0} \right) \right] \quad (1)$$

where  $k_{\text{toluene}}$  and  $k_{\text{benzene}}$  are the rate coefficients for the reaction with OH ( $k_{\text{toluene}} = 5.63 \times 10^{-12}$  and  $k_{\text{benzene}} = 1.22 \times 10^{-12}$  at 298 K in  $\text{cm}^3 \text{ molecule}^{-1} \text{ s}^{-1}$  [31].  $[\text{OH}]$  is the average concentration of the OH radical ( $2.1 \times 10^6 \text{ molecule cm}^{-3}$ , [32]). The initial emission ratio of T/B was set to 1.69 (Initial value of B/T = 0.59), it was taken from Airparif station, which is located on the roof of the main Airparif building, close to busy roads, in the Paris city center [33].

It can be seen from Figure. 5 that when the T/B ratio increases, the photochemical age decreases. For example, on the evening of Mar. 13<sup>th</sup> and the early morning of Mar. 16<sup>th</sup>, it is as low as 1.37 and 1.14 days, respectively. This suggests that the pollutants are fresher and the source of the pollution is relatively close to the site (100–300 km). In most of the observation period, the photochemical age is more than 3 days, indicating that long-distance air transport could contribute to the air pollution in this region (> 500 km).

The m,p-xylene to ethylbenzene (MP/E) ratio could also be used to evaluate the age of air parcels and as an indicator for the photochemical age of the VOCs in the atmosphere. The xylenes are more reactive towards the OH radical than ethylbenzene so the low ratio of MP/E could be used as an indication of an aged air parcel. Relatively constant MP/E ratios ranging from 2.8 to 4.6 with a mean value of 3.5 due to near traffic exhaust emissions have been previously reported [34]. MP/E ratio along the studied period is presented in Figure. 5. MP/E ratios average shows a quite small but noticeable difference before (0.87), during (0.72) and after (0.59) the lockdown. The values in the three periods suggest a rather aged air parcel, and the decreasing trend is an expected effect due to the increase in solar radiation as the spring season approaches. During and after lockdown the variation in the MP/E ratio reaches its maximum value before sunrise and its minimum at mid-afternoon (Figure. 5), in agreement with what is expected for a photochemically aged air parcel [35]. On the other hand, before the lockdown, this cyclical variation in the MP/E ratio between day and night is not clearly observed, this may be due to the different emission sources during winter (Figure. 6). Figure. 2 shows that the prevailing wind direction changed significantly after the first period. This is likely to have also a strong effect, transporting air from different locations with different distance.



**Figure 6.** Diurnal variations in MP/E ratio (a) before, (b) during and (c) after the lockdown.

### 3.4. Impact from community mobility and meteorological effects on the measured BTEX

In order to get a better understanding of the BTEX sources we made a series of supporting measurements including meteorological information,  $O_3$ ,  $NO$ ,  $NO_2$ ,  $PM_{10}$  and  $BC$ . For this purpose, we investigated correlations over 4 episodes taken from the whole period of investigation: before lockdown (Feb. 26<sup>th</sup> - Mar. 12<sup>th</sup>), declared lockdown (Mar. 13<sup>th</sup>, Mar. 15<sup>th</sup>, Mar. 16<sup>th</sup>), lockdown (Mar. 17<sup>th</sup> - May 10<sup>th</sup>) and after the lockdown (May 11<sup>th</sup> - May 31<sup>st</sup>). Figure. 7 shows correlation coefficient between BTEX,  $O_3$ ,  $NO$ ,  $NO_2$ ,  $PM_{10}$ ,  $BC$  and temperature ( $T$ ) for each period.

BTEX average concentrations were relatively low before lockdown, with an average mixing ratio around  $402 \pm 143$  pptv. Nevertheless, on March 13<sup>th</sup> and 15<sup>th</sup> to 16<sup>th</sup>, two higher concentration peaks of BTEX were detected, with about 820 pptv and 1040 pptv, respectively. To better understand the possible causes and identify the main contribution sources for these particular events, correlation coefficients were calculated using the corresponding data of these particular days as shown in Figure. 7b. From this figure, it can be seen that a high positive correlation ( $r = 0.90$ ) between  $BC$  and  $NO_2$ , but BTEX didn't correlate very well with either of them ( $r = 0.51$  with  $NO_2$  and  $r = 0.63$  with  $BC$ ), suggesting that it could be another source besides fuels and/or biomass burning [36,37].

During the same period, the warm weather would suggest that it is less likely that the burning of wood for home heating represented a significant source, however, given the extremely different daily schedules of people during this timeframe, it remains possible that residential heating was a contributing factor. Considering these facts, BTEX concentration increase during these episodes could be related to transportation emissions rather than other sources. This may be linked to the announcement of official measures to be implemented in order to prevent the spread of COVID-19 on Mar. 12<sup>th</sup>. Similarly, for Mar. 15<sup>th</sup> and 16<sup>th</sup> with the order from the French Government to close all non-essential public places and businesses, including restaurants, cafes, shops, and entertainment venues from Mar. 14<sup>th</sup> in order to limit social movements. To support this hypothesis, the Google Community Mobility Reports data for Friday 13<sup>th</sup>, Sunday 15<sup>th</sup> and Monday 16<sup>th</sup> of March were also used. From these data, displayed in Figure. 2, it is possible to observe a substantial increase in the mobility of people (percent change) on the same dates where the maximum concentrations of BTEX were observed. Considering this, it could be speculated that most of the emissions detected during Mar. 13<sup>th</sup>, 15<sup>th</sup> and 16<sup>th</sup> were strongly related to the local use of transport vehicles on an elevated scale to visit pharmacies and grocery stores.

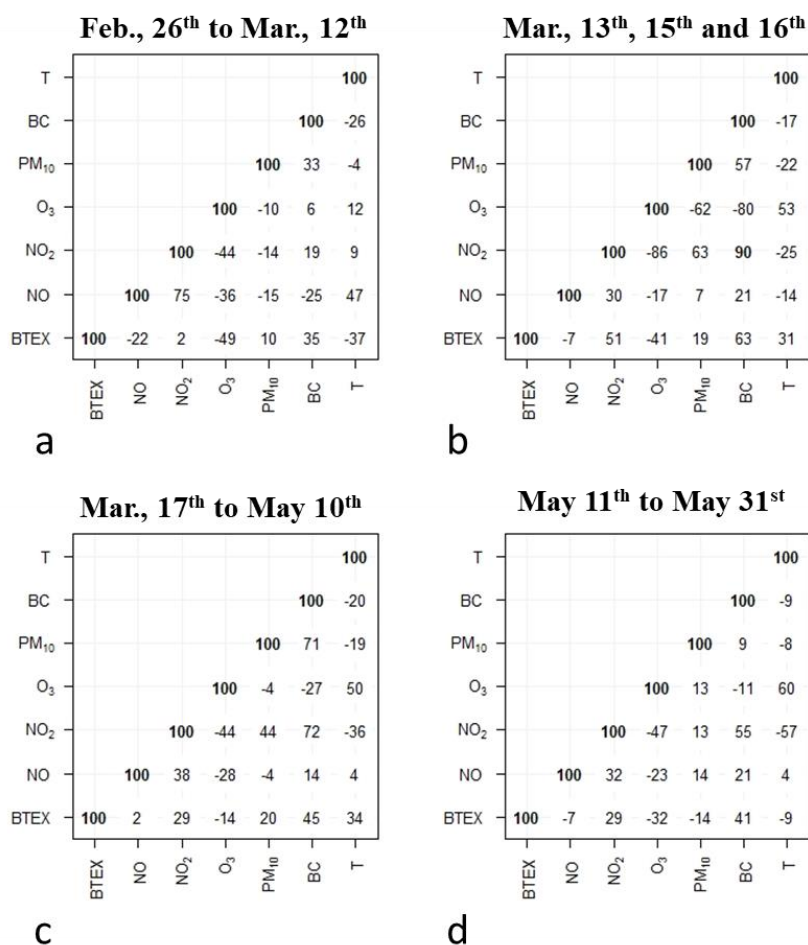
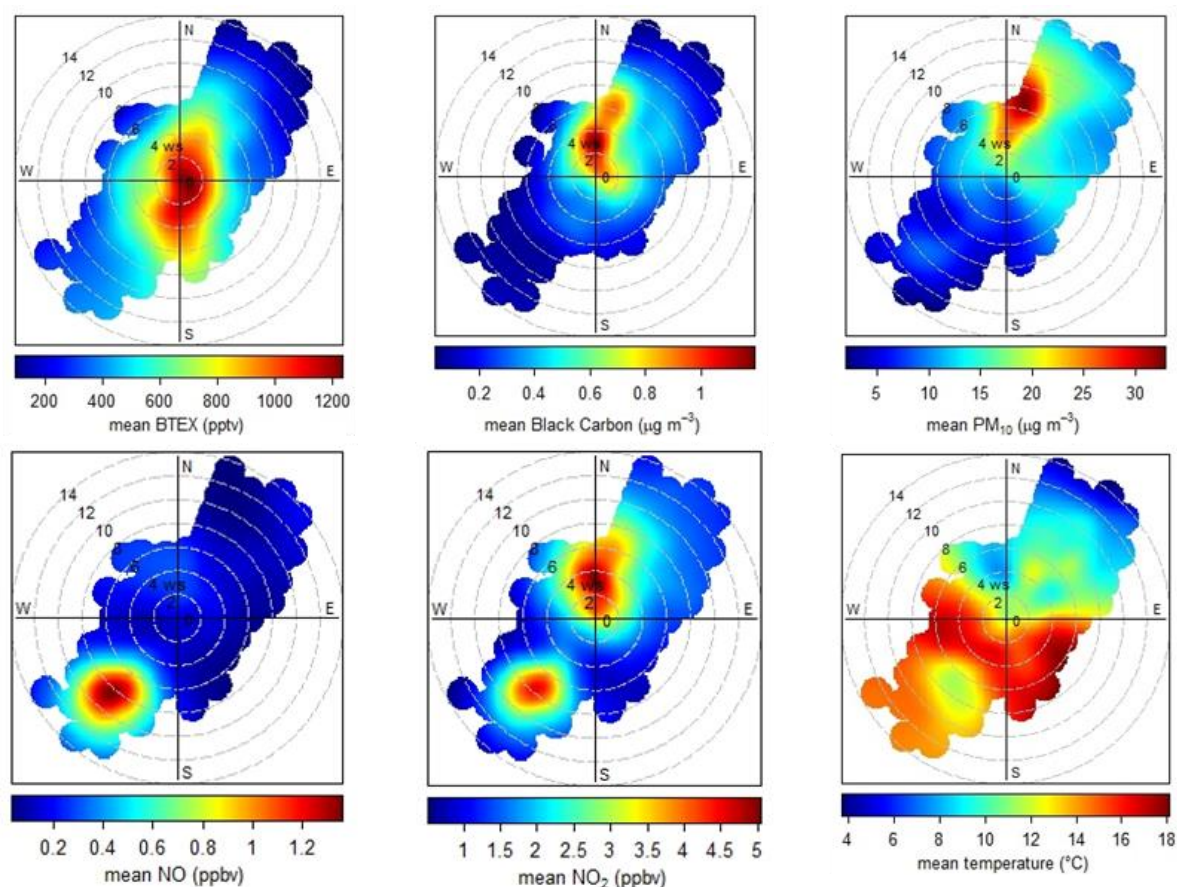


Figure 7. Correlation coefficient in percentage between BTEX, NO, NO<sub>2</sub>, O<sub>3</sub>, PM<sub>10</sub>, BC and temperature (T) for each period (before, declared, during and after lockdown).

During the lockdown, social mobility decreased significantly as it can be seen from the relative changes in the Mobility Reports (Figure. 2). At the same time, NO concentrations also showed a progressive decrease, which is likely to be associated with the reduction of local traffic emissions. However, BTEX concentrations showed multiple elevated episodes during the lockdown period. From the correlation coefficients shown in Figure. 7, it is possible to observe that this increase does not correlate with the NO concentration ( $r = 0.02$ ), weakly correlated with NO<sub>2</sub> ( $r = 0.29$ ), and only shows a moderate correlation with black carbon ( $r = 0.45$ ). Besides, from Figure. 2, it is possible to observe that wind direction changed markedly in the region, from southwest before lockdown to northeast during the lockdown.

To consider a possible effect of these variables, polar plots of each pollutant and temperature against wind direction were constructed in Figure. 8, where each factor is plotted as a function of wind speed and wind direction. The dominant wind direction came from the northeast 43.1% of the time, which was most frequent during the lockdown. Other wind directions were: north 15%, east 8.7%, southeast 5.2%, south 8.1%, southwest 12%, west 5.8% and northwest 2%.

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**Figure 8.** Polar plots of BTEX, NO, NO<sub>2</sub>, O<sub>3</sub>, PM<sub>10</sub>, BC and temperature (T) for lockdown (from Mar. 17<sup>th</sup> to May 10<sup>th</sup>); ws = wind speed (m s<sup>-1</sup>).

For NO and NO<sub>2</sub>, polar plot representations clearly show that maximum concentrations were observed for winds blowing from the southwest. The southwest of the site is located near a traffic intersection, gas station and provincial road, which would indicate very local sources.

Another area with high NO<sub>2</sub> concentration was found in the north, which has a similar situation for BC and PM<sub>10</sub>. It is noted that the site is located in the south of Orléans (distance 6 km from city center) and south west of Paris (distance 90 km), and that the major source of volatile organic compounds during wintertime in the Paris region is wood burning [38]. Hence, impact of biomass or coal burning emissions, especially during the lockdown, was clearly evidenced on NO<sub>2</sub>, BC and PM<sub>10</sub> atmospheric concentrations.

Concerning the BTEX mixing ratios, the probability to observe high concentrations decreased with the wind speed. Higher concentrations were associated with a speed ranging between 0 and 4 m s<sup>-1</sup>, lower concentrations of all pollutants were observed when the wind speed was greater than 12 m s<sup>-1</sup>, intuitively, this result indicates that the high wind speed plays a role in “cleaning up” the air over the measurements site area.

#### 4. Conclusions

The ambient levels and possible sources of atmospheric BTEX during the lockdown period in Orléans are reported in this study. The variation of the mean BTEX concentration suggests that besides source strength, the seasonal and diurnal variations of atmospheric BTEX in periurban areas also strongly depend on meteorological conditions and photochemical activity.

T/B ratios are generally low (<1) at the site during all three periods. In contrast to the observations of Salameh [28], which focused on the Paris area, we find that temperature



is not a strong determinant of T/B, which suggests that evaporation rates are not the major control on this ratio in our study, and that photochemical age may be playing a more important role. Previous observations in Parisian suburbs such as Melun [28] find T/B ratios of approximately 1, which is similar to our own observations and suggests that we are observing a more aged air mass in line with the overall findings of the MEGAPOLI campaign [28].

Surprisingly, the overall BTEX mixing ratios were in general at their highest (~ 1 ppb) during the lockdown period, a time when we would expect to have the lowest volumes of traffic, which is supported by the Google Community mobility reports. Some of this effect is likely to be caused by meteorological conditions, where a change in the prevailing wind direction from SW to NE occurred near the onset of lockdown, suggesting that Orléans during this time could be more affected by plumes from the Paris megacity. It is noted that the overall concentrations are lower than those observed in Paris, as would be expected from photochemical losses as well as mixing and diffusion during the transport process. Changes to daily routines that could result in increases of residential heating emissions could also explain elevated BTEX mixing ratios during lockdown, although it is noted that the meteorological conditions during this time were generally warmer than the period that preceded lockdown. This hypothesis is supported on some days by the higher loading of BC and PM<sub>10</sub> observed during lockdown, which could be attributable to a wood smoke source.

In addition to the BTEX measurements, we present a suite of supporting measurements including NO<sub>x</sub>, O<sub>3</sub>, PM<sub>10</sub>, BC and meteorological data. In general, we didn't observe strong correlations between these parameters and BTEX, suggesting that their respective sources could be different.

Even though we can be sure of changes in emission sources during the lockdown period, we find that the highest ambient pollution levels occurred during a time of national inactivity. Given that BTEX are considered to be dominated by traffic [25], and that local traffic volumes were reduced during the lockdown, we conclude therefore that ambient pollution levels in Orléans are strongly connected with the neighboring Paris region, which may be true of other suburban and peri-urban sites around the globe. Furthermore, if the higher BTEX episodes observed during lockdown are indeed related to more local sources of residential heating, then this implies that emission control of wood burning should be prioritized.

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