



# Changes in the concentration and composition of urban aerosols during the COVID-19 lockdown

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## ABSTRACT

This work investigates the impact of COVID-19 restrictive measures on the mass concentrations of PM<sub>1</sub> and PM<sub>10</sub>, and their chemical components (water-soluble ions, organic and elemental carbon, and major and trace metals) at an urban site in the western Mediterranean. The evolution of gaseous pollutants (NO<sub>x</sub>, O<sub>3</sub> and some volatile organic compounds) was also analyzed. The concentrations measured during the lockdown in 2020 were compared to those obtained during the same period over the preceding five years. The average decrease in the levels of NO<sub>x</sub> and traffic-related volatile organic compounds was higher than 50 %, while O<sub>3</sub> concentrations did not exhibit significant variations during the study period. Our results show that temporal variations in PM<sub>1</sub> and PM<sub>10</sub> concentrations were strongly affected by the frequency of Saharan dust events. When these episodes were excluded from the analysis period, a 35 % decrease in PM<sub>1</sub> and PM<sub>10</sub> levels was observed. Traffic restrictions during the lockdown led to important reductions in the concentrations of elemental carbon and metals derived from road dust (e.g. Ca and Fe) and break wear (e.g. Cu). Regarding secondary inorganic aerosols, nitrate showed the largest reductions as a consequence of the drop in local emissions of NO<sub>x</sub>.

## 1. Introduction

Particulate matter (PM) is an air pollutant of major concern for human health since it is estimated that, only in Europe, exposure to PM<sub>2.5</sub> (particulate matter less than 2.5 μm in diameter) is responsible for almost 400,000 premature deaths per year (EEA, 2020). Recent research suggests that the health effects of PM<sub>2.5</sub> were mostly from PM<sub>1</sub> (particles smaller than 1 μm) (Kan, 2017).

Atmospheric PM is a complex mixture made up of hundreds of different chemical components both primary and secondary in nature. The concentrations of primary aerosols are mainly driven by emissions from sources, and of course by meteorological conditions (Guevara, 2016; Nicolás et al., 2020; Reizer and Juda-Rezler, 2016). However, the factors responsible for the variability of secondary PM, which nowadays dominates over primary PM in urban environments, are more complex to identify. The formation of secondary aerosols in the atmosphere partly depends on precursor emissions, but interdependencies and nonlinearities in atmospheric chemical reactions (many of which are not well understood) make difficult to predict the response of secondary aerosols to emission changes (Jiménez, 2016; Kroll et al., 2020).

The COVID-19 outbreak, identified in late 2019, led most governments to implement strict measures in their countries in an attempt to control the spread of the virus. In Spain, a nationwide lockdown was imposed on 14 March to maintain social distancing. All non-essential commercial and industrial activities were suspended, schools and universities closed and it was forbidden to move outside the place of residence. This strict lockdown was maintained until 18 May, when restrictions were gradually lifted. The shutdowns around the world have allowed researchers to study changes in air quality under unique conditions. Although a number of works on the effects of the COVID-19 lockdown on the concentrations of different atmospheric pollutants have been recently published (e.g. Donzelli et al., 2020; Filonchik et al., 2021; Goel et al., 2021; Viatte et al., 2021), to our knowledge, few studies regarding changes in PM composition during this period have been conducted (e.g. Altuwayjiri et al., 2021; Manchanda et al., 2021; Wang et al., 2021).

The present work is aimed at evaluating the impact of mobility restrictions during the COVID-19 lockdown on PM<sub>1</sub> and PM<sub>10</sub> components at a medium-sized Spanish city where traffic is the main anthropogenic source of air pollution. Data on PM<sub>1</sub> and PM<sub>10</sub> chemical composition

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during the strict lockdown in 2020 were compared with same period in previous years. These data are part of an ongoing campaign that started in early 2015 (Galindo et al., 2020).

## 2. Materials and methods

### 2.1. Sampling site and sample collection

Sampling was carried out in the center of Elche, a 190,000 inhabitants city located in southeastern Spain, close the Mediterranean Sea. There are no industrial activities nearby the study area so traffic can be considered as the main anthropogenic source of air pollutants in the city. The samplers were located on the first floor of a municipal office block, around 4.5 m above ground level. A detailed description of the sampling site can be found in Galindo et al. (2018).

Twenty-four hour PM<sub>1</sub> and PM<sub>10</sub> samples were collected from February 2015 using two Derenda 3.1 low volume samplers (2.3 m<sup>3</sup> h<sup>-1</sup>). The sampling frequency was three times a week, starting at midnight. Quartz fiber filters (47 mm diameter, AHLSTROM MK360) were used for sample collection.

Filters were weighed in quadruplicate before and after sampling on an Ohaus AP250D balance. All filters were conditioned in a temperature and humidity-controlled chamber (50 ± 5 %, 20 ± 1 °C) for at least 24 h before weighing. After the gravimetric determination of PM<sub>1</sub> and PM<sub>10</sub> mass concentrations, filters were stored in the fridge at 4 °C until chemical analyses.

In the present work, changes in the concentrations measured within the period from 14 March to 18 May between the years 2015 and 2020 were evaluated. Between 21 and 28 valid samples of both PM<sub>1</sub> and PM<sub>10</sub> were collected during each period.

### 2.2. Chemical analyses

The collected samples were analyzed for major and trace elements, elemental carbon (EC) and organic carbon (OC), and water-soluble ions using conventional analytical techniques.

For the elemental analysis an ARL Quant'X (Thermo Scientific Inc, USA) EDXRF spectrometer was used. A detailed description of the technique setup is given in Chiari et al. (2018). Then, 1.5 cm<sup>2</sup> punch from each filter was analyzed by the thermal-optical transmittance method using a Sunset Laboratory OC/EC analyzer (Sunset Laboratories Inc.) and the EUSAAR2 protocol. Finally, after extracting the remaining filter with ultrapure water in an ultrasonic bath, water-soluble ions (Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, NO<sub>3</sub><sup>-</sup>, C<sub>2</sub>O<sub>4</sub><sup>2-</sup>, Na<sup>+</sup>, NH<sub>4</sub><sup>+</sup>, Mg<sup>2+</sup>, K<sup>+</sup> and Ca<sup>2+</sup>) were measured by ion chromatography (Galindo and Yubero, 2017; Galindo et al., 2021).

### 2.3. Secondary organic carbon concentrations

The EC tracer method (Turpin and Huntzicker, 1995) was applied to OC and EC data in order to estimate the concentration of secondary organic carbon (SOC) in PM<sub>1</sub> and PM<sub>10</sub>. This approach is based on the assumption that primary OC (POC) and EC have similar combustion sources and, therefore, POC can be defined by,

$$POC = b \cdot EC + a \tag{1}$$

and the contribution of SOC can be estimated as,

$$SOC = OC - POC = OC - (b \cdot EC + a) \tag{2}$$

where *b* represents the primary OC emitted along with EC from combustion sources, while *a* is the noncombustion contribution to POC. The slope (*b*) and the intercept (*a*) of this line can be determined from the plots of OC vs. EC (Castro et al., 1999; Yubero et al., 2015).

## 2.4. Traffic, meteorological and gaseous pollutant data

Traffic data at the sampling site were supplied by the Elche Traffic Office. Hourly and daily concentrations of gaseous pollutants (NO<sub>x</sub> and O<sub>3</sub>) were obtained from a station of the Regional Air Quality Network located at a suburban area approximately 2 km west of the sampling site. Continuous measurements of ozone and nitrogen oxides are carried out using UV absorption and chemiluminescence monitors, respectively. From 2019, the concentrations of benzene, toluene and xylenes were also monitored by gas chromatography. The meteorological parameters were obtained from a semi-rural station of the regional network, about 3.5 km from our sampling site. During the studied years, the mean temperature between mid-March and mid-May ranged from 16.8 to 18.7 °C, while solar radiation varied between approximately 210 and 250 W m<sup>-2</sup>. The average relative humidity was around 60–75 %, and the wind speed between 1.2 and 1.7 m s<sup>-1</sup>.

## 3. Results and discussion

### 3.1. Traffic flows and meteorological variables

During the spring of the years 2015–2019, the average traffic flow at the sampling site was 7000–7500 vehicles per day on weekdays and 5,000–5,500 vehicles per day on Sundays. In contrast, during the strict lockdown in 2020 the average traffic intensity was reduced to around 2,000 vehicles per day on weekdays and 1,000 vehicles per day on Sundays. To illustrate differences in traffic volumes by hour, the average hourly number of vehicles passing the site during the month of April 2019 and 2020 is shown in Fig. 1. It can be observed that the decrease in traffic flows was highest during the afternoon and early morning.

The traffic data analysis indicates that anthropogenic emissions of air pollutants at the sampling site were similar during the period 2015–2019, while a marked reduction occurred in 2020. Therefore, in order to assess the impact of changes in emissions following lockdown restrictions on pollutant concentrations, it is necessary to discard any significant influence of weather conditions. For this, meteorological data were compared using the Krustal-Wallis test. The results suggest that meteorological parameters (temperature, relative humidity, solar radiation and wind speed) during the spring of 2020 (14 March–18 May) were not statistically different from those of the preceding five years. Consequently, changes in pollutant levels during the lockdown cannot be attributed to the year-to-year variability in weather patterns.

### 3.2. Particulate matter and gaseous pollutants

Fig. 2 shows box plots of PM<sub>1</sub>, PM<sub>10</sub>, NO<sub>x</sub> and O<sub>3</sub> concentrations between 14 March and 18 May for each year of study. Of the studied

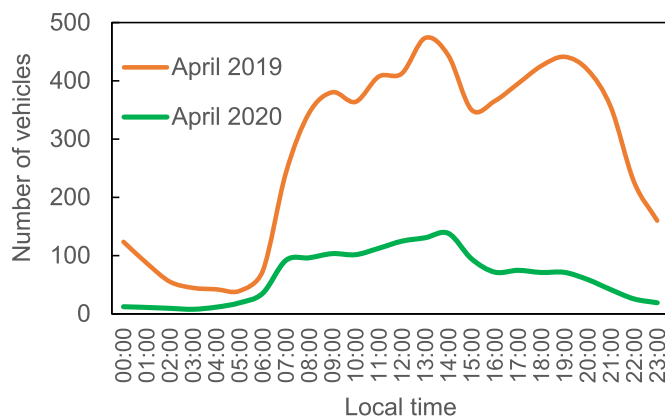
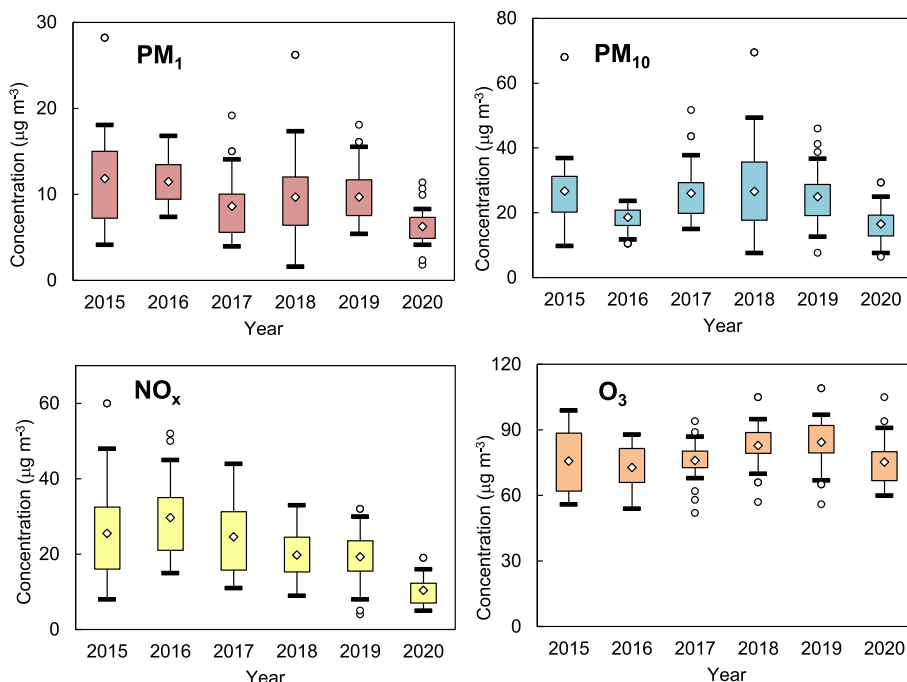


Fig. 1. Mean diurnal variation of traffic flow rate near the sampling site on April 2019 and April 2020.



**Fig. 2.** Box plots of PM and gaseous pollutants in the centre of Elche during the study period. Boxes represent the 25th and 75th percentiles and white diamonds the mean value. Error bars outside the box represent 1.5-times the interquartile range. Small circles represent possible outliers.

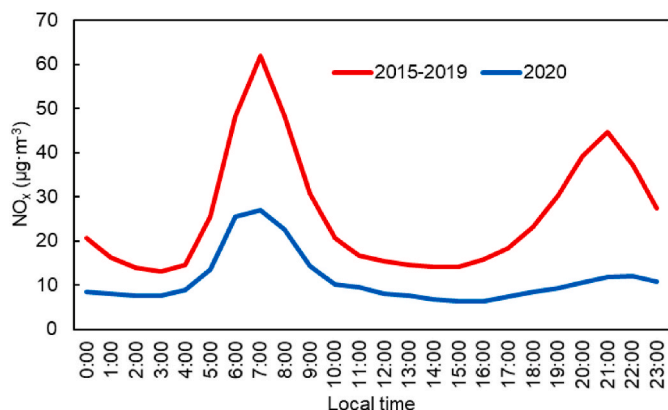
pollutants, NO<sub>x</sub> levels showed the highest reduction during the 2020 lockdown period compared with the same period in previous years. The average NO<sub>x</sub> concentration between 14 March and 18 May of 2020 ( $10.4 \pm 3.8 \mu\text{g m}^{-3}$ ) was around 60 % lower than the mean value during the same period for the years 2015–2019 ( $23.5 \pm 10.1 \mu\text{g m}^{-3}$ ). This reduction can be clearly attributed to a decrease in NO<sub>x</sub> emissions due to traffic restrictions during the lockdown, as confirmed by the daily variation in NO<sub>x</sub> concentrations shown in Fig. 3. It can be observed that the maximum reduction in the levels of nitrogen oxides occurred around 9 p.m., coinciding with the maximum reduction in the traffic volume. Equivalent results were previously reported at many other urban sites around the world (Baldasano, 2020; Donzelli et al., 2020; Elshorbany et al., 2021; Filonchik and Peterson, 2020; Liu et al., 2020).

Similarly to NO<sub>x</sub>, the concentrations of traffic-related volatile organic compounds, such as benzene, toluene and xylenes (Galindo et al., 2016; Lu et al., 2017) decreased during the lockdown in 2020 compared with the same span in 2019, as observed in other studies (Jianxin et al., 2021). For example, the mean concentration of toluene (the most abundant of the measured hydrocarbons) during the

quarantine in 2020 ( $0.9 \pm 0.6 \mu\text{g m}^{-3}$ ) was half that measured during the same time period in 2019 ( $1.9 \pm 0.9 \mu\text{g m}^{-3}$ ). This difference was statistically significant at a confidence level of 99 % ( $p < 0.01$ ).

Ozone concentrations did not show any clear trend during the study period. In fact, a significant impact of restrictive measures on ozone levels registered in 2020 was not observed at all. Some studies have reported increases in O<sub>3</sub> concentrations during shutdown periods that were attributed to reductions in NO emissions (Liu et al., 2020; Wyche et al., 2021). It is well known that NO rapidly reacts with O<sub>3</sub> to produce NO<sub>2</sub>; therefore, a reduction in NO levels would lead to an increase in ozone concentrations. However, as indicated in previous works, ozone production depends not only on the levels on NO<sub>x</sub>, but also on the concentrations of VOCs, and this dependence is complex and non-linear (Kroll et al., 2020; Mazzuca et al., 2016). Therefore, the effects of variations in precursor emissions on ozone levels are not straightforward. In fact, previous works have also reported a limited impact of the lockdown on O<sub>3</sub> concentrations in many urban areas despite the decrease in NO<sub>x</sub> emissions (Donzelli et al., 2020; Elshorbany et al., 2021; Manchanda et al., 2021; Menut et al., 2020). This could be due to the regional nature of this pollutant, which makes it less sensitive to local variables (Menut et al., 2020).

The results for PM levels are more difficult to interpret. On the one hand, atmospheric aerosols include both directly emitted particles from natural and anthropogenic sources, and secondary components formed by chemical reactions. On the other hand, once in the atmosphere, the aerosol mass concentration and chemical composition change continuously through a series of physical and chemical processes (Fuzzi et al., 2015). For instance, it has been shown that the occurrence of episodic events, such as Saharan dust outbreaks, affects the concentration and composition of PM (Galindo et al., 2020; Reizer and Juda-Rezler, 2016). In fact, the reason for the low average concentration of PM<sub>10</sub> in 2016 was that no Saharan dust event was recorded on the sampling days between mid-March and mid-May that year. When average PM<sub>10</sub> concentrations measured in 2016 and 2020 were compared, no statistical differences were detected. However, when those days under the influence of Saharan dust outbreaks were excluded from the analysis (Table 1), mean PM<sub>10</sub> levels in both periods were statistically different



**Fig. 3.** Hourly mean concentrations of NO<sub>x</sub> between mid-March and mid-May for 2015–2019 and 2020.

**Table 1**

Average PM concentrations between 14 March and 18 May excluding Saharan dust outbreaks for the years 2015–2020.

	PM <sub>1</sub>					N	PM <sub>10</sub>				
	N	Mean	SD	Min	Max		Mean	SD	Min	Max	
2015	17	10.2	4.0	4.2	15.2	17	21.8	6.5	9.8	32.1	
2016	22	11.5	2.7	7.4	16.8	23	18.6	3.4	10.5	23.7	
2017	21	7.8	2.9	4.0	15.0	23	24.0	6.1	15.0	37.8	
2018	22	8.4	3.9	1.6	17.4	21	21.6	9.1	7.6	42.5	
2019	25	9.2	3.2	5.4	18.1	25	23.5	7.8	7.6	45.9	
2020	20	5.9	2.1	1.8	10.7	20	14.1	3.9	6.3	22.4	

( $p < 0.001$ ). On average, PM<sub>10</sub> concentrations decreased by approximately 35 % during the 2020 lockdown compared to the same period over the preceding 5-years.

Regarding the PM<sub>1</sub> fraction, its concentrations were less affected by Saharan dust episodes and similar results were obtained whether or not these events were considered. The concentration of PM<sub>1</sub> during the lockdown in 2020 experienced a similar reduction as that of PM<sub>10</sub> when compared with the mean concentration over the same period during previous years.

Differently from nitrogen oxides, for which a significant reduction was generally observed due to traffic restrictions during the lockdowns, results for PM in different countries and types of stations are uneven. Some studies have reported substantial decreases in PM<sub>10</sub> and/or PM<sub>2.5</sub> levels during lockdown periods (Donzelli et al., 2021; Filonchik and Peterson, 2020; Jianxin et al., 2021; Liu et al., 2020), while others point to moderate reductions (Gualteri et al., 2020; Menut et al., 2020) or even increases in PM concentrations compared to pre-lockdown values (Gualteri et al., 2020; Sbai et al., 2021). A possible reason for the limited impact of the lockdowns on PM levels in many cities of the world is that reduction in traffic emissions has been counterbalanced by increases in emissions from residential heating (Altuwajjiri et al., 2021; Gualteri et al., 2020; Sbai et al., 2021). The fact that, in our study area, traffic is the main anthropogenic source of PM and biomass burning does not account for a significant fraction of the emissions during this period of the year (Galindo et al., 2021), may explain the observed reductions in aerosol concentrations.

In the following sections, the effect of lockdown measures on PM<sub>1</sub> and PM<sub>10</sub> chemical components is analyzed. Those days affected by Saharan dust outbreaks have been removed to avoid misleading results.

### 3.3. Water-soluble ions

Average concentrations of water-soluble ions during the lockdown in 2020 and the same span in the previous five years are presented in Table 2. As previously reported (Galindo et al., 2020), ammonium concentrations were higher in PM<sub>1</sub> than in PM<sub>10</sub> as a consequence of the loss of NH<sub>4</sub>Cl formed from the reaction of NH<sub>4</sub>NO<sub>3</sub> with NaCl in the PM<sub>10</sub> filter.

Both in PM<sub>1</sub> and PM<sub>10</sub> calcium concentrations showed a strong

**Table 2**

Mean concentrations of water-soluble species ( $\mu\text{g m}^{-3}$ ) between 14 March and 18 May over the period 2015–2020.

	PM <sub>1</sub>						PM <sub>10</sub>					
	2015	2016	2017	2018	2019	2020	2015	2016	2017	2018	2019	2020
Cl <sup>-</sup>	0.28	0.29	0.21	0.11	0.09	—	0.82	0.61	0.98	0.69	1.04	0.33
NO <sub>3</sub> <sup>-</sup>	0.96	1.22	0.30	0.21	0.32	0.10	2.71	2.58	2.34	1.71	2.04	0.94
SO <sub>4</sub> <sup>2-</sup>	1.51	1.72	1.28	1.30	1.26	0.88	2.13	2.14	2.38	2.11	1.91	1.22
C <sub>2</sub> O <sub>4</sub> <sup>2-</sup>	0.11	0.13	0.07	0.07	0.08	0.07	0.19	0.17	0.15	0.14	0.15	0.12
Na <sup>+</sup>	0.18	0.19	0.12	0.08	0.11	—	0.64	0.75	0.98	0.74	1.09	0.55
NH <sub>4</sub> <sup>+</sup>	0.76	1.00	0.49	0.41	0.45	0.39	0.68	0.88	0.42	0.39	0.42	0.22
K <sup>+</sup>	0.14	0.11	0.16	0.13	0.11	0.07	0.16	0.13	0.27	0.19	0.18	0.08
Mg <sup>2+</sup>	0.03	0.04	0.02	0.02	0.03	0.01	0.13	0.14	0.15	0.11	0.18	0.08
Ca <sup>2+</sup>	0.39	0.53	0.26	0.40	0.44	0.11	1.29	1.23	1.49	1.43	1.29	0.48

\*Data on sodium and chloride for 2020 are not included since most concentrations were below the detection limit.

### 3.4. Elemental and organic carbon

Elemental carbon (EC) is considered a good indicator of traffic emissions (Jones and Harrison, 2005); however, in places where biomass burning is widely used for residential heating, a significant fraction of EC can be attributed to this source (Klejnowski et al., 2017). As already mentioned, biomass combustion is not a major source of PM in the study area; therefore, an important reduction in EC concentrations was expected as a consequence of traffic restrictions during the lockdown. The evolution of carbonaceous aerosols from 2015 to 2020 for the period between 14 March and 18 May is shown in Fig. 4.

EC concentrations showed a strong reduction in the spring of 2020 compared with the average values for the preceding years. As for calcium, the magnitude of the EC decrease was much greater than that observed for PM. EC concentrations in PM<sub>1</sub> and PM<sub>10</sub> during the lockdown were 65 % and 50 % lower, respectively, than the average value for the years 2015–2019. These results are in line with those obtained in previous works for black carbon (BC) (Collivignarelli et al., 2020; Evangeliou et al., 2021; Goel et al., 2021), although they differ from the outcomes reported for other regions, where BC concentrations increased during the lockdowns (Altwayjiri et al., 2021; Evangeliou et al., 2021). Increases in BC levels in these regions have been attributed to enhanced residential combustion as people stayed at home.

Organic carbon (OC) is a dominant component of atmospheric PM, especially of the fine and submicron fractions (Lee et al., 2015; Ram et al., 2012). At the sampling site OC accounts for around 40 % and 20 %, respectively, of PM<sub>1</sub> and PM<sub>10</sub> mass concentrations (Galindo et al., 2019). OC concentrations decreased around 30 %, both in PM<sub>1</sub> and PM<sub>10</sub>, as a consequence of the lockdown. This value is similar to those calculated for PM and approximately half those of EC. A reduction in OC levels was expected since traffic is a major source of organic aerosols in the study area (Galindo et al., 2021). Lockdown restrictions have been previously associated with a decrease in OC concentrations (Altwayjiri et al., 2021), although the reduction was lower than that reported here.

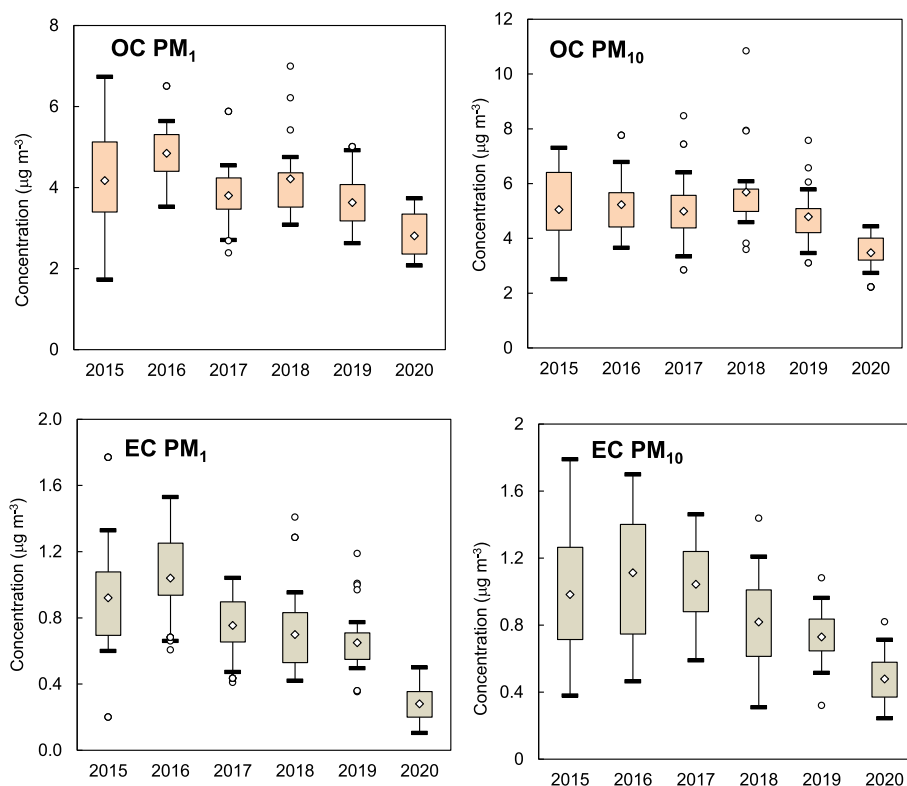
Average primary and secondary OC concentrations during the study period are shown in Table 3. Both POC and SOC levels were lowest in 2020. The decrease in traffic emissions due to mobility restrictions during the lockdown can explain the reduction in atmospheric POC concentrations. However, traffic is also a main source of precursors of secondary organic aerosols (i.e. volatile and semi-volatile organic compounds), which also explains the lower SOC concentrations in 2020 compared to the previous five years. Our results contrast with those of a recent study that reported a higher photochemical formation of secondary organic aerosols during the lockdown caused by an increase in O<sub>3</sub> concentrations (Meng et al., 2021). As described in section 3.1, traffic restrictions at the study area did not seem to have an impact on ozone, which could modify the oxidizing capacity of the atmosphere during the lockdown.

### 3.5. Major and trace elements

The concentrations of major and trace elements during the study period are presented in Table 4. As indicated in a previous study at the same location (Galindo et al., 2020), good correlations between calcium concentrations analyzed by ion chromatography and ED-XRF were

**Table 3**  
Average POC and SOC concentrations ( $\mu\text{g m}^{-3}$ ) between 14 March and 18 May over the period 2015–2020.

	PM <sub>1</sub>		PM <sub>10</sub>	
	POC	SOC	POC	SOC
2015	2.67	1.50	3.17	1.89
2016	2.87	1.96	3.43	1.81
2017	2.41	1.40	3.29	1.71
2018	2.32	1.90	2.84	2.85
2019	2.24	1.39	2.66	2.13
2020	1.65	1.16	2.16	1.32



**Fig. 4.** Box plots of OC and EC concentrations in the centre of Elche during the study period. Boxes represent the 25th and 75th percentiles and white diamonds the mean value. Error bars outside the box represent 1.5-times the interquartile range. Small circles represent possible outliers.

**Table 4**

Results of the elemental analysis (in ng m<sup>-3</sup>) of PM<sub>1</sub> and PM<sub>10</sub> samples between 14 March and 18 May over the period 2015–2020.<sup>a</sup>

	PM <sub>1</sub>						PM <sub>10</sub>					
	2015	2016	2017	2018	2019	2020	2015	2016	2017	2018	2019	2020
K	59	67	56	53	38	23	146	125	180	162	148	89
Ca	262	355	161	177	171	42	1212	1006	1259	1169	1062	403
Ti <sup>b</sup>	—	—	—	—	—	—	13	9	13	14	12	9
Mn	4	5	5	4	5	3	11	9	12	12	12	8
Fe	87	98	70	70	73	47	335	259	371	345	335	156
Ni	5	6	6	5	4	3	9	8	10	9	9	4
Cu	6	7	6	5	4	4	16	13	18	16	16	7
Zn	12	15	10	12	10	8	21	22	21	23	19	13

<sup>a</sup> Concentrations below detection limit were replaced by detection limit.

<sup>b</sup> The percentage of data above the detection limit for PM<sub>1</sub> was lower than 70 %.

found in both in PM<sub>1</sub> (slope = 1.19, r<sup>2</sup> = 0.71) and PM<sub>10</sub> (slope = 1.05, r<sup>2</sup> = 0.93), indicating that calcium is generally present as soluble salts.

The concentrations of crustal elements, particularly K, Ca and Fe, were significantly reduced in 2020 compared with the preceding years. Average levels of these components in both PM<sub>1</sub> and PM<sub>10</sub> were between 40 % and 80 % lower in 2020 with respect to the average values for the preceding five years. In urban areas, these metals are mainly emitted by road dust resuspension (Piscitello et al., 2021). Therefore, the observed reduction is undoubtedly due to the remarkable decrease in traffic volumes during the lockdown. Cu, commonly used as a tracer of break wear (Piscitello et al., 2021), showed a 54 % decrease in the PM<sub>10</sub> fraction during the spring of 2020 compared to the previous five-year mean. A comparable reduction in Ni concentrations was also observed, suggesting that traffic may be a source of this metal in the city of Elche. Ni has been associated with emissions from road dust resuspension and break wear (Almeida et al., 2020; Lawrence et al., 2013). The good correlations obtained in PM<sub>10</sub> between Ni and elements used as markers of road dust (K, Ca and Fe; r = 0.66–0.82), and between Ni and Cu (r = 0.73) support that non-exhaust traffic emissions are the most likely source of this metal at the sampling point.

Other traffic-related metals, such as Mn (emitted from road dust resuspension and break wear; Almeida et al., 2020; Piscitello et al., 2021) and Zn (derived from tyre wear; Lawrence et al., 2013) experienced a reduction of approximately 35 % in PM<sub>10</sub> during the 2020 lockdown. Regarding Ti, the observed decrease was lower than for the other metals. Although this element is present in road dust (Almeida et al., 2020), significant increases in Ti concentrations at the study area were mainly associated with Saharan dust events (Galindo et al., 2018).

#### 4. Conclusions

Mobility restrictions imposed by countries to reduce the spread of COVID-19 has allowed the scientific community to study changes in air quality under unprecedented circumstances. In this work, we analyze the effect of the lockdown on the concentrations of gaseous and particulate pollutants in the city Elche (southeastern Spain), where traffic is the main local source of air pollutants. The levels measured during COVID-19 pandemic restrictions were compared to the values during the same period over the previous five years.

Daily traffic at the sampling site was reduced by up to ~70 % during the lockdown, leading to a strong decrease in the emissions of vehicle-related pollutants. As a consequence, the concentrations of gaseous pollutants emitted by vehicle exhaust, such as NO<sub>x</sub> and volatile organic compounds, were significantly reduced (>50 %). Despite the drop in NO<sub>x</sub> emissions, an increase in ozone concentrations was not observed.

Restrictive measures produced a similar decrease of PM<sub>10</sub> levels to the absence of Saharan dust outbreaks. In fact, the average PM<sub>10</sub> concentration during the lockdown was similar to that measured during the same period in 2016, on which none of the sampling days was affected by African dust transport. When Saharan dust events were excluded from the analysis, the decrease in PM<sub>10</sub> levels during the 2020 shutdown

period compared to the previous five-year mean was 35 %, similar to the value calculated for PM<sub>1</sub>. The concentrations of traffic-related PM components, such as elemental carbon (generated by exhaust emission), crustal elements (e.g. Ca, K, Fe, emitted by road dust resuspension), and metals derived from break wear (e.g. Cu and Ni) showed large decreases during the lockdown (between 40 % and 80 %). Unexpectedly, the levels of marine species were also significantly reduced during the spring of 2020, which was attributed to a lower contribution of vehicle-induced resuspension of sea-salt particles deposited on the road. Among secondary inorganic ions, nitrated exhibited the highest decrease due to the drop in NO<sub>x</sub> emissions from traffic.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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