



# Lockdown for CoViD-2019 in Milan: What are the effects on air quality?

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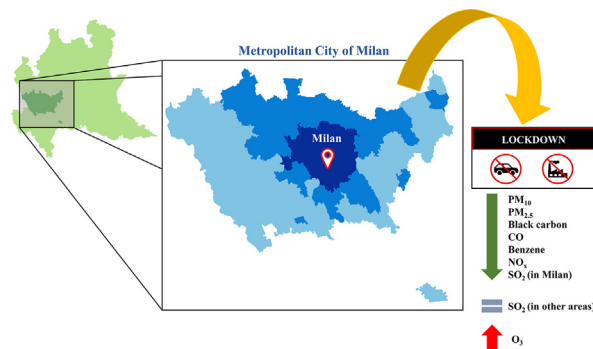
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## HIGHLIGHTS

- The effect of lockdown on air quality in Milan was assessed.
- The trends of 9 pollutants in meteorologically comparable periods were studied.
- Lockdown determined a significant reduction of PM<sub>10</sub>, PM<sub>2.5</sub>, BC, benzene, CO and NO<sub>x</sub>.
- SO<sub>2</sub> remained unchanged in the more peripheral areas.
- Part of the ozone increase was probably due to the lower NO measured during lockdown.

## GRAPHICAL ABSTRACT



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## ABSTRACT

Based on the rapid spread of the CoViD-2019, a lockdown was declared in the whole Northern Italy by the Government. The application of increasingly rigorous containment measures allowed to reduce the impact of the CoViD-2019 pandemic on the Italian National Health System but at the same time these restriction measures gave also the opportunity to assess the effect of anthropogenic activities on air pollutants in an unprecedented way. This paper aims to study the impact of the partial and total lockdown (PL and TL, respectively) on air quality in the Metropolitan City of Milan. As results, the severe limitation of people movements following the PL and the subsequent TL determined a significant reduction of pollutants concentration mainly due to vehicular traffic (PM<sub>10</sub>, PM<sub>2.5</sub>, BC, benzene, CO, and NO<sub>x</sub>). The lockdown led to an appreciable drop in SO<sub>2</sub> only in the city of Milan while it remained unchanged in the adjacent areas. Despite the significant decrease in NO<sub>2</sub> in the TL, the O<sub>3</sub> exhibited a significant increase, probably, due to the minor NO concentration. In Milan and SaA the increase was more accentuated, probably, due to the higher average concentrations of benzene in Milan than the adjacent areas that might have promoted the formation of O<sub>3</sub> in a more significant way.

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## 1. Introduction

In Italy, the first case of transmission of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes coronavirus disease 2019 (CoViD-19), was detected the 20th February 2020 in

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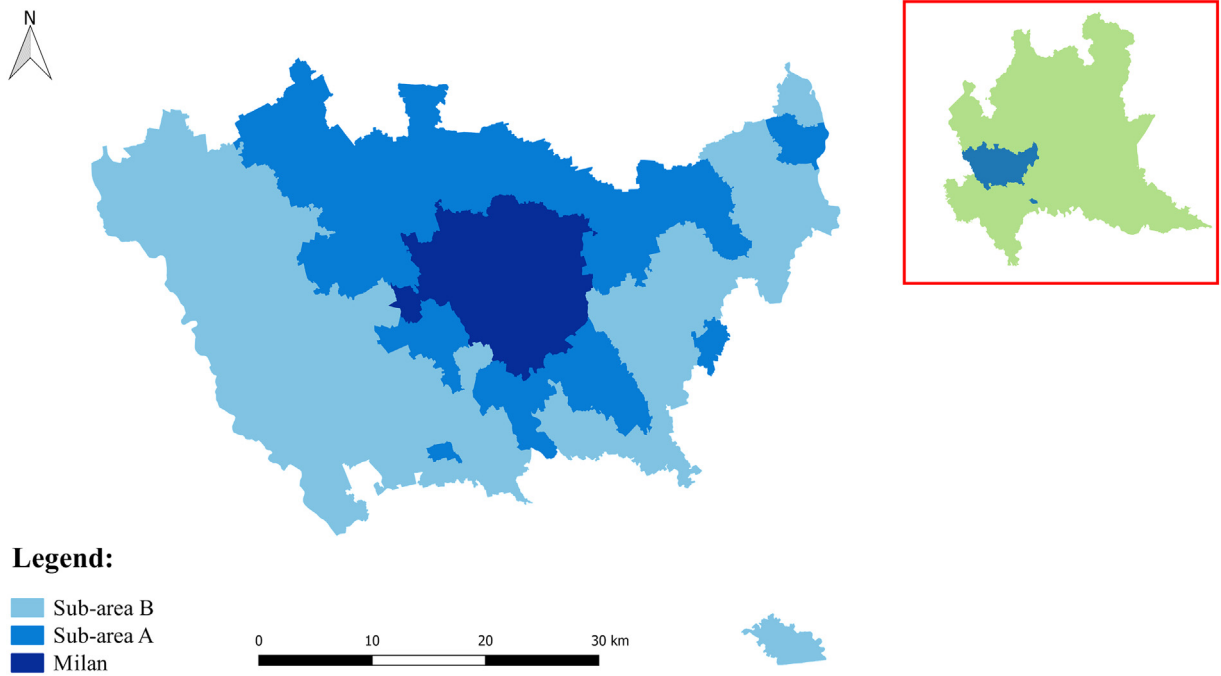


Fig. 1. Map of the Metropolitan City of Milan and its location in the Lombardy region. The sub-areas A and B used in the study are highlighted. Map realized with QGIS (2020).

Codogno (around 60 km from Milan) (Grasselli et al., 2020; Porcheddu et al., 2020). On the 21st February 2020, the total of cases identified by the health authorities in Lombardy was 34 (Lombardy Region, 2020). This prompted the Government to declare the area of the outbreak “red zone”, progressively limiting travel, social, cultural and economic activities of >50,000 people (DPCM, 2020a; IMH, 2020a). Due to the

rapid rise of infections, on the 23rd February 2020, a new ordinance from the authorities resulted in the closure of all schools and placed restrictions on social and economic activities throughout the Lombardy region (IMH, 2020b).

On the 8th March 2020, on the basis of the rapid spread of the infections that reached 5963 cases in Lombardy and 6387 cases in all the

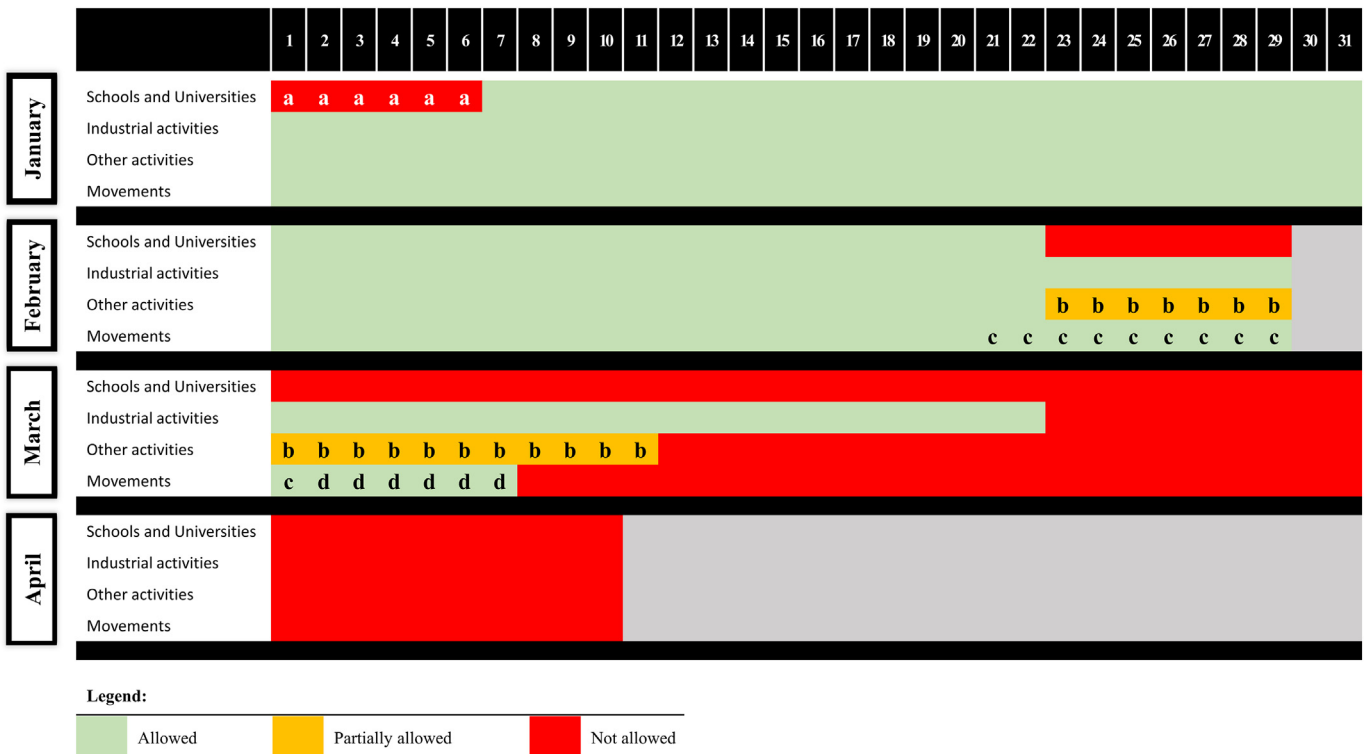


Fig. 2. Scheme of activities allowed and prohibited from the 1st of January 2020 to the 10th of April 2020 in MeCiMi. a: Christmas holidays; b: some activities (e.g. museums and cinemas) were closed; c: workplace closures, no public transports (in the nearby area of Codogno); d: stricter measures in Codogno (movements outside the area were not allowed).

Country (CPD, 2020; Lombardy Region, 2020), the Government adopted heavy containment measures in a large part of Northern Italy, including the whole Lombardy Region, declaring a partial lockdown (PL) and prohibiting all transfers if not necessary to reach the workplace or related to essential needs (DPCM, 2020b). In Lombardy and Milan, some businesses remained open with severe restrictions until March 11th while industrial activities remained open until the 23rd March 2020, when a total lockdown (TL) was imposed and only factories attributable to essential supply chains (e.g. food, pharmaceuticals, etc.) were authorized to remain operative (DPCM, 2020c, 2020d).

The application of increasingly rigorous and unprecedented containment measures allowed to flatten the contagion curve reducing the impact of the CoViD-2019 pandemic on the Italian National Health System and saving many lives (Anderson et al., 2020; Gatto et al., 2020; Gourinchas, 2020; Tobias, 2020). However, these restriction measures gave also the opportunity to reduce displacements and minimize industrial activities in an unprecedented way, creating unique conditions for assessing the effect of anthropogenic activities on air pollutants in one of the most polluted area of Italy and Europe: the Metropolitan City of Milan (MeCiMi) (Carugno et al., 2017; van Donkelaar et al., 2015).

This paper aims to study the impact of the lockdown imposed by the CoViD-19 pandemic on air quality in MeCiMi. Firstly, a reference period (CTRL) meteorologically comparable with PL and TL was identified

analysing the data of 22 meteorological control units. Then, in order to determine the trend of nine different air pollutants, the data of 18 air quality control units in the entire MeCiMi were studied and compared with CTRL data to detect how the lockdown was able to affect air quality in this area.

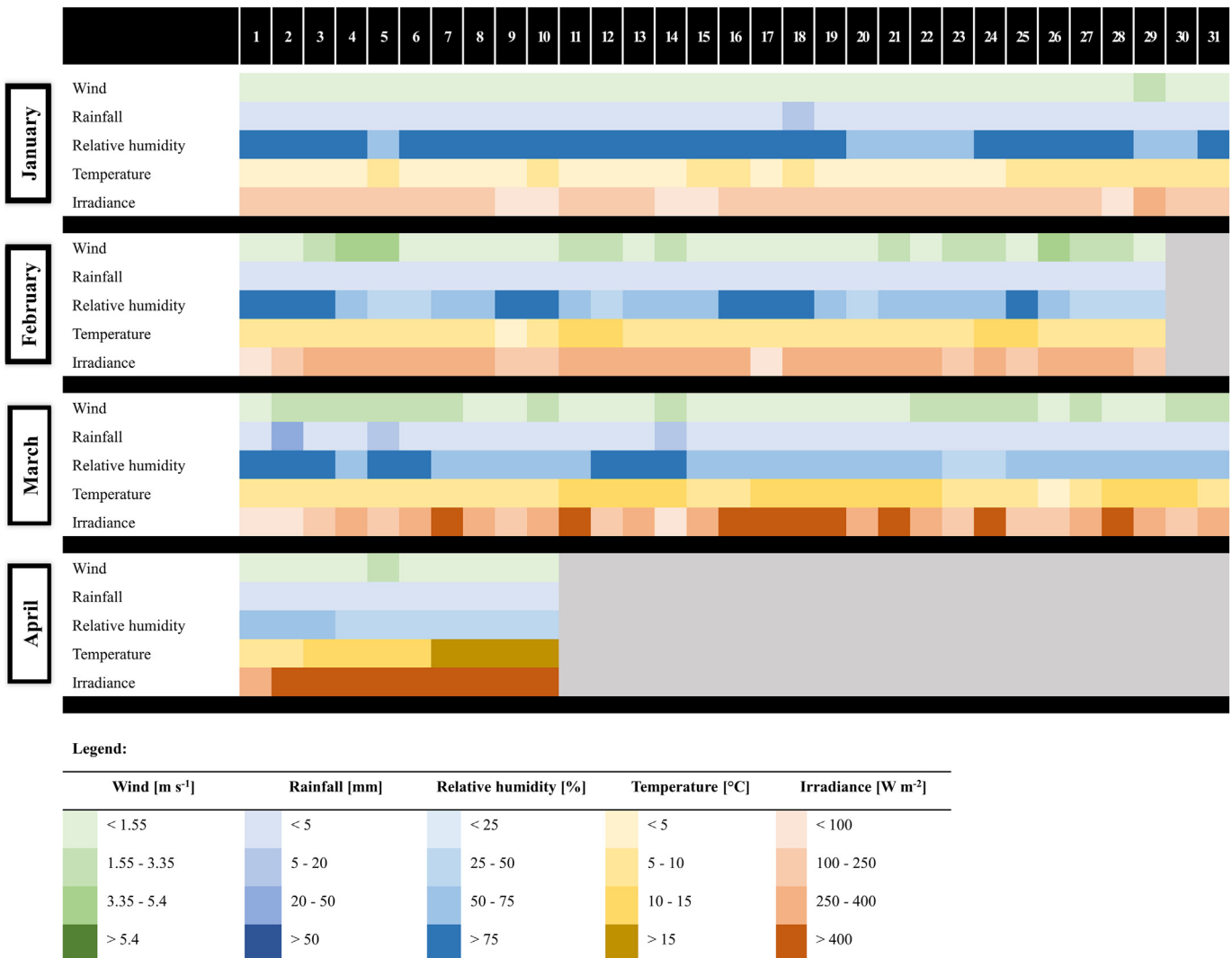
**2. Methods**

*2.1. Area of the study*

According to the most recent available data (1.1.2019), MeCiMi had over 3,250,000 inhabitants and an area higher than 1500 km<sup>2</sup> (CMM, 2020) where Milan represents the main municipality. In this study, the other municipalities were divided into two groups based on population density (PD): sub-area A (SaA), with PD higher (or equal) than 1200 ab km<sup>-2</sup> and sub-area B (SaB), with PD lower than 1200 ab km<sup>-2</sup>, to consider the heterogeneity of the conditions within the remaining area. In Fig. 1, the map of the MeCiMi and its location in the Lombardy region is reported.

*2.2. Meteorological data collection and processing*

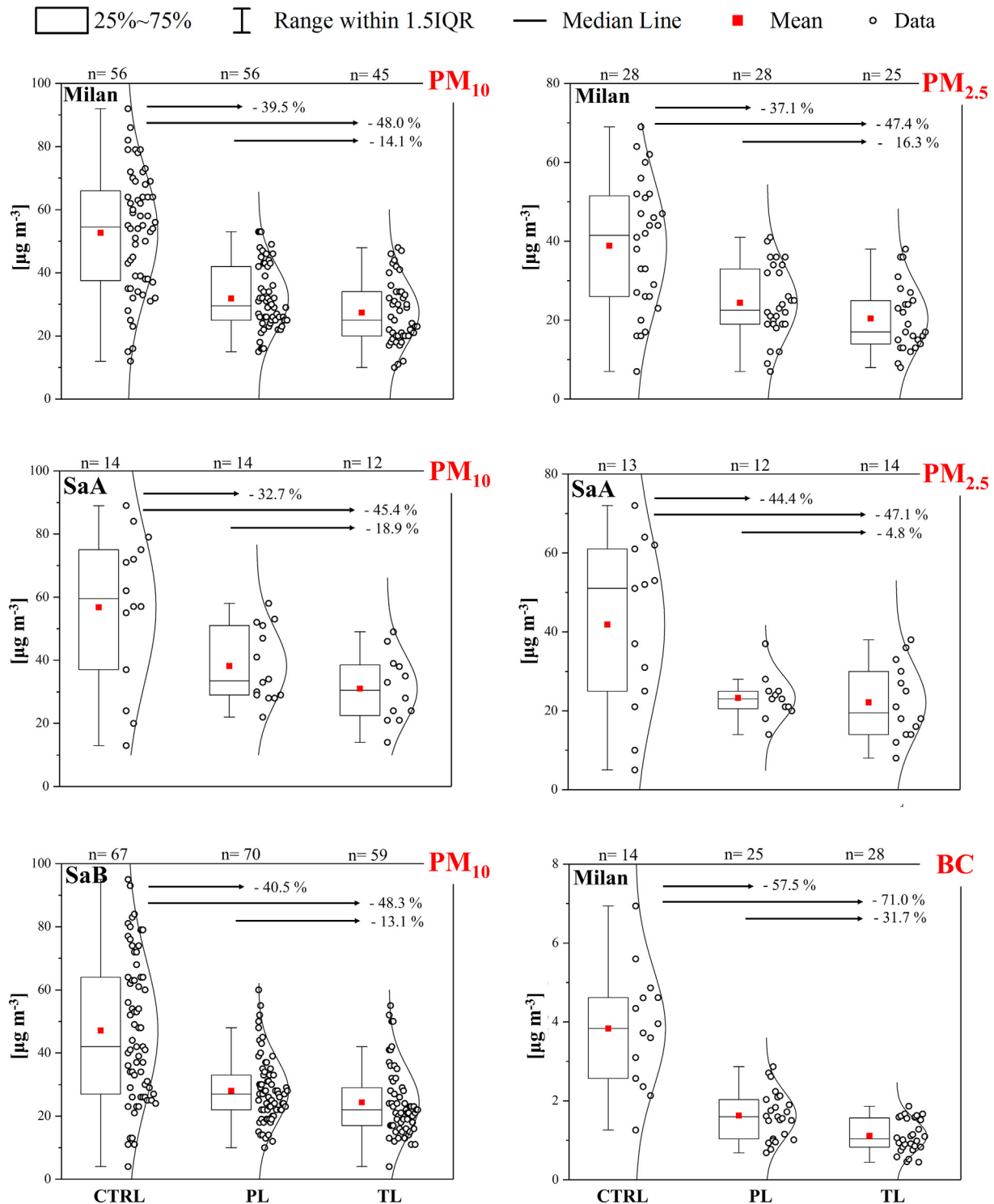
Data on wind speed, rainfall, relative humidity, temperature, and solar irradiance for the entire MeCiMi, have been collected by the local



**Fig. 3.** Daily average wind speed, rainfall, relative humidity, temperature, and solar irradiance in daylight hours from the 1st of January 2020 to the 10th of April 2020.

environmental protection agency (ARPA Lombardia, 2020a). All meteorological control units located in Milan (7), SaA (7), and SaB (8) were used (Table S1) for obtaining meteorological data from the 1st of January 2020 to the 10th of April. From the hourly temperature and solar irradiance data, the average daily temperature and solar irradiance in daylight hours were calculated. Daily averages of each single parameter

were classified in 4 categories in order to better compare their values. In March 28–29, 2020, a phenomenon of transport of dust to the Po Valley was reported by the local environmental protection agency (ARPA Lombardia, 2020b). The values of  $PM_{10}$  in these days were excluded from the analysis, in order to consider only significant and comparable data.



**Fig. 4.** Daily average concentration of  $PM_{10}$ ,  $PM_{2.5}$ , and BC in Milan, SaA, and SaB during CTRL, PL, and TL periods. The percentages indicate the variations between the periods. Boxplots represent the distance between the first and third quartiles while whiskers are set as the most extreme (lower and upper) data point not exceeding 1.5 times the quartile range from the median. Black curves represent the normal distributions of the data.

### 2.3. Air quality data collection and processing

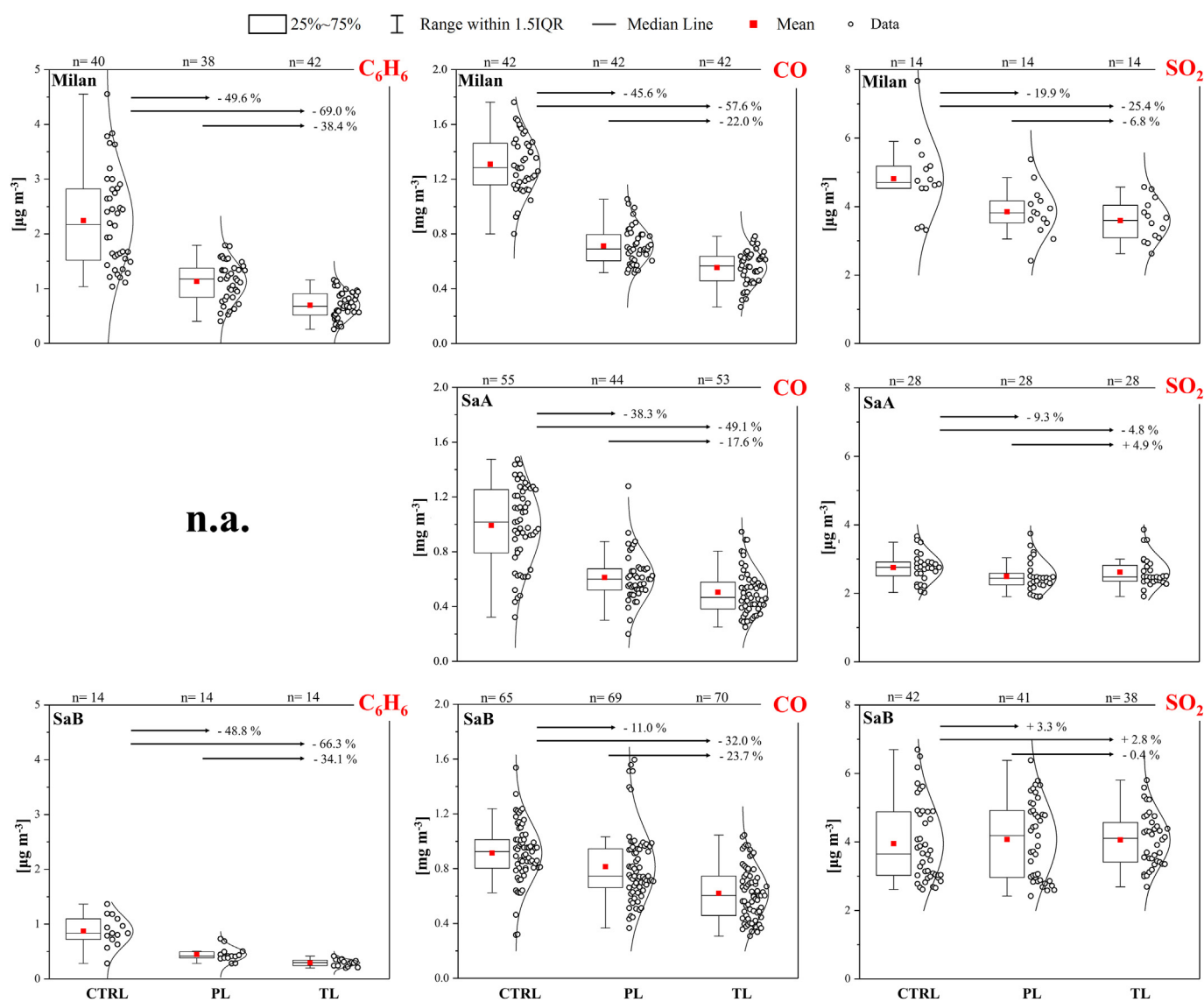
Data collected on the particulate matter with a diameter of  $<10\ \mu\text{m}$  ( $\text{PM}_{10}$ ) and  $2.5\ \mu\text{m}$  ( $\text{PM}_{2.5}$ ), black carbon (BC), benzene ( $\text{C}_6\text{H}_6$ ), carbon monoxide (CO), sulphur dioxide ( $\text{SO}_2$ ), nitrogen dioxide ( $\text{NO}_2$ ), total nitrogen oxides ( $\text{NO}_x$ ), ozone ( $\text{O}_3$ ) and ammonia ( $\text{NH}_3$ ) for the entire MeCiMi, were obtained from the local environmental protection agency (ARPA Lombardia, 2020c). All air quality control units located in Milan (5), SaA (6), and SaB (7) were selected and used (Table S2) for obtaining data in three 14-days periods: CTRL (from February 7, 2020 to February 20, 2020 chosen after the analysis of meteorological data as described in Section 3.1), PL (from March 9, 2020 to March 22, 2020), and TL (from March 23, 2020 to April 5, 2020). The daily averages (24 h) of the air pollutants for each area were calculated and the relative percentage variation of the average concentrations throughout the periods was examined.

The data regarding the estimation of the sources of  $\text{PM}_{10}$ ,  $\text{PM}_{2.5}$ , BC, CO,  $\text{SO}_2$ ,  $\text{NO}_2$  and  $\text{NO}_x$  were obtained from the regional inventory of emissions from Lombardy (INEMAR, 2017). For each area (Milan, SaA and SaB), data were aggregated in 5 categories representative of the sources of emissions: energy sector, household heating, industrial

sector, transports, and agriculture and livestock. Referred to a reference period, these data were used to explain the inhomogeneity of changes in air pollution during the lockdown in the three areas.

### 2.4. Lockdown periods determination

In Fig. 2, the legislative measures issued by the authorities were taken into account in order to identify the periods of PL and TL, for a rapid comparison. The measures of restriction on the neighbouring areas that might have had an influence on the presence of traffic in the MeCiMi, and therefore on the quality of the air, were also considered, such as the creation of the red zone in the nearby Codogno area ( $> 50,000$  inhabitants) (IMH, 2020a). The chosen period for the PL is from the 9th to 22nd of March 2020, when schools and universities were completely closed and movements in a large part of northern Italy were limited only to strictly essential needs and to reach the workplace (DPCM, 2020b, 2020d). The days from the 23rd of March to 5th of April have been identified as indicative of the TL, since the implementation of more rigid measures that have forced the closure of almost all production activities and therefore a further limitation of movements (DPCM, 2020c).



**Fig. 5.** Daily average concentration of benzene ( $\text{C}_6\text{H}_6$ ), CO, and  $\text{SO}_2$  in Milan, SaA, and SaB during CTRL, PL, and TL periods. The percentages indicate the variations between the periods. Boxplots represent the distance between the first and third quartiles while whiskers are set as the most extreme (lower and upper) data point not exceeding 1.5 times the quartile range from the median. Black curves represent the normal distributions of the data. n.a.: not available.

### 3. Results and discussion

#### 3.1. Meteorological data analysis for reference period selection

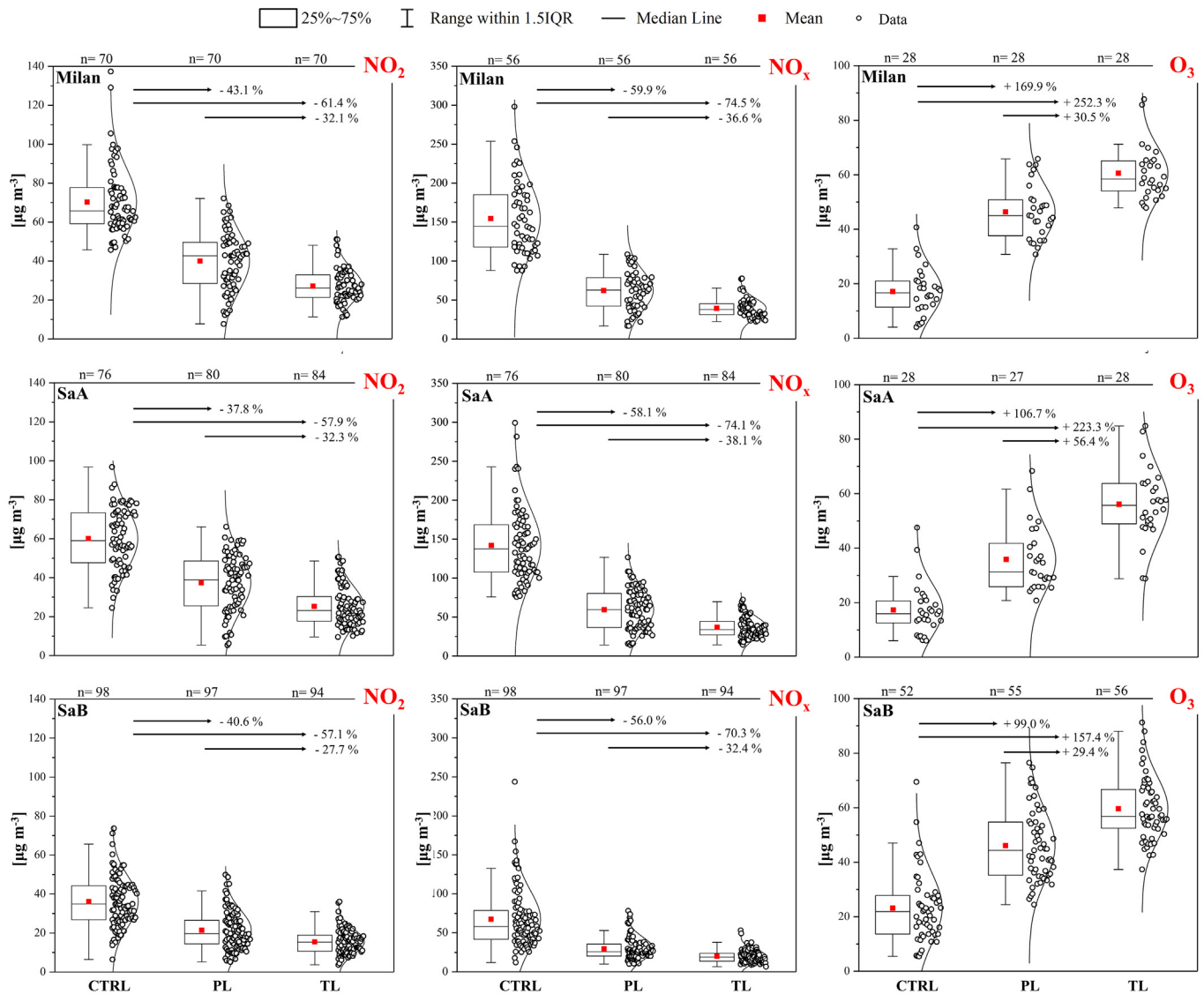
The meteorological data were sorted in climatically homogeneous reference periods for the comparison of the different scenarios, namely, no limitations, considered PL and TL. This aspect is essential considering that weather phenomena have a massive influence on air quality (Baklanov et al., 2016; Borge et al., 2019; Demuzere et al., 2009; Jhun et al., 2015; Zhao et al., 2019). January was not considered suitable for the identification of the reference period due to the high relative humidity, and low average temperatures (Table S3), different conditions than PL and TL which would have led to an imbalance in the comparison of some polluting agent trends (e.g. PM<sub>10</sub> and SO<sub>2</sub>) due to the massive use of heating systems (Barrington-Leigh et al., 2019; Pillarisetti et al., 2019). As shown in Fig. 3, in February temperature, relative humidity, wind, precipitation and average solar irradiance in the daylight hours were similar to those of March. Therefore, the CTRL period was chosen in the first part of February (from 7 to 20) next to the closing time of schools and universities and exhibiting comparable meteorological

conditions with PL and TL (Table S4). Furthermore, in the CTRL period an almost total absence of rainfall was reported, as in the PL and TL, thus preventing an overestimation of the air quality (Fig. 3).

#### 3.2. Air quality monitoring

##### 3.2.1. Particulate

Although highly variable, the concentration of PM<sub>10</sub> in the CTRL period was comparable (mean: 47.1–56.8  $\mu\text{g m}^{-3}$ ) in all the three areas of the MeCiMi demonstrating complete homogeneity among the data of Milan, its conurbation and rural areas with lower population density (Fig. 4). Moreover, the effects of PL and TL were similar in all three MeCiMi sections. In the PL phase, the reduction of PM<sub>10</sub> was between 32.7% (SaA) and 40.5% (SaB). It was likely attributable to the significant reduction in vehicular traffic given by the transfers restrictions imposed by the Authorities considering that transports represent the main source of PM<sub>10</sub> in Milan and in the whole MeCiMi (40.7–45%) (Fig. S1). The TL period marked a further overall decrease in PM<sub>10</sub> of 13.1%–18.9% compared to the PL. This result can be partially attributed to the stop of industrial activities that allowed reducing direct emissions



**Fig. 6.** Daily average concentration of O<sub>3</sub>, NO<sub>2</sub>, and NO<sub>x</sub> in Milan, SaA, and SaB during CTRL, PL, and TL periods. The percentages indicate the variations between the periods. Boxplots represent the distance between the first and third quartiles while whiskers are set as the most extreme (lower and upper) data point not exceeding 1.5 times the quartile range from the median. Black curves represent the normal distributions of the data.

and, consequently, decrease workers' transfers. In both periods, the contribution given by the reduction of building heating cannot be neglected. Although the average temperature of CTRL period was comparable with that registered in the PL and TL (Table S4), it should be considered that in the MeCiMi, as reported by Lombardy emissions inventory (Fig. S1), household heating counts for a 22.5–28.8% of the total  $PM_{10}$  emitted. So even a slight reduction due to the closure of several offices might have influenced the overall value.

Regarding  $PM_{2.5}$ , despite the absence of data relating to the SaB, in Milan and SaA, the concentration decreased from the CTRL period to the PL phase (37.1% - 44.4%) is clear (Fig. 4). Compared to an average concentration in the CTRL period of around  $40 \mu g m^{-3}$ , both in Milan and in the hinterland  $PM_{2.5}$  concentrations were almost halved in the TL phase (47.1–47.4%). As for  $PM_{10}$ , these results can be attributed: (i) in the PL phase mainly to the reduction of vehicular traffic (primary  $PM_{2.5}$ ) and (ii) in the TL phase also to the reduction of emissions from industrial activities. The low reduction from the PL to the TL period can also be caused to the relatively low contribution of the industrial sector in  $PM_{2.5}$  emissions in Milan and in SaA (15.3% and 25.9%, respectively) (Fig. S1). The reduction of  $PM_{2.5}$  in PL and TL can be also attributed to the simultaneous reduction in the concentration of other pollutants such as  $NH_3$  (Fig. S2), volatile organic compounds (e.g. benzene) (Section 3.4), and  $NO_x$  (Section 3.6) which act as precursors to the formation of secondary  $PM_{2.5}$  (Chen et al., 2017; Han et al., 2018). As in the case of  $PM_{10}$ , the influence of the reduction of other combustion processes due to domestic heating cannot be excluded as household heating in MeCiMi determines the 28–34.5% of the total  $PM_{2.5}$  emission (Fig. S1).

BC is produced by the incomplete combustion of carbonaceous fossil fuels, biomass and vegetation, representing a unique primary tracer for combustion emissions. BC is strongly recalcitrant and, given its low mobility, it tends to have a lognormal dispersion within 200 m from the traffic source, thus being considered by many studies as an excellent indicator of air quality in urban environments (Ali et al., 2020; Invernizzi et al., 2011). Compared to the CTRL period, the percentage reduction was 57.5% and 71%, in the PL and TL respectively (Fig. 4). As the major source in Milan is represented by the traffic (as well as other minor BC combustion sources, including household heating and cooking are possible) (Fig. S1) (Invernizzi et al., 2011; Mousavi et al., 2019), these

results confirm the identification of the reduction of traffic in PL and TL as the main source of the reduction of  $PM_{10}$  and  $PM_{2.5}$  in the city of Milan. In fact, a progressive reduction in the mileage of all vehicles has been estimated, reaching 75% in the TL period (ARPA Lombardia, 2020b).

Further data about the composition of particulate matter, in terms of polycyclic aromatic hydrocarbons (single molecules and their ratios), nitro-compounds, metals and semimetals might lead to a more accurate description of the phenomena, due to the possibility of highlight the emissions profiles of various activities. Besides, a detailed analysis of the vehicular park composition might provide additional information about possible particulate sources in the studied periods (Ferretti et al., 2019).

### 3.3. Benzene

Compared to the CTRL period, the concentration of benzene in PL decreased by 49.6% and 48.8% in Milan and SaB, respectively (no data are available for SaA). This decrease is more consistent if the TL period is compared with CTRL. In this case, the reduction exceeds 65% for both the scenarios (Fig. 5). The CTRL value referred to the whole MeCiMi ( $1.9 \pm 0.26 \mu g m^{-3}$ ) is in line with the benzene values in the months February and March, for the three-year period 2016–2018 ( $1.5\text{--}4.0 \mu g m^{-3}$ ) (ARPA Lombardia, 2018, 2017, 2016). The PL allowed to obtain very lower average concentrations:  $31.9 \pm 1.9 \mu g m^{-3}$  and  $22.1 \pm 1.2 \mu g m^{-3}$  in PL and TL, respectively. Volatile organic compounds (VOCs), including benzene, are mainly produced by vehicular traffic and other incomplete combustion processes that PL and TL have increasingly limited. Furthermore, the lower concentration of benzene detected in the SaB compared to Milan can be highlighted. This could be due to the lower concentration of vehicular traffic due to the lower PD.

### 3.4. Carbon monoxide and sulphur dioxide

In MeCiMi, the effect of PL on CO concentration was not homogeneous. The largest reduction was measured in the city of Milan (57.6%), followed by the SaA (49.1%) and SaB (32%) (Fig. 5). Indeed, the main sources of CO emissions are incomplete combustion processes (e.g. traffic, household heating) (INEMAR, 2017) and in which differ for

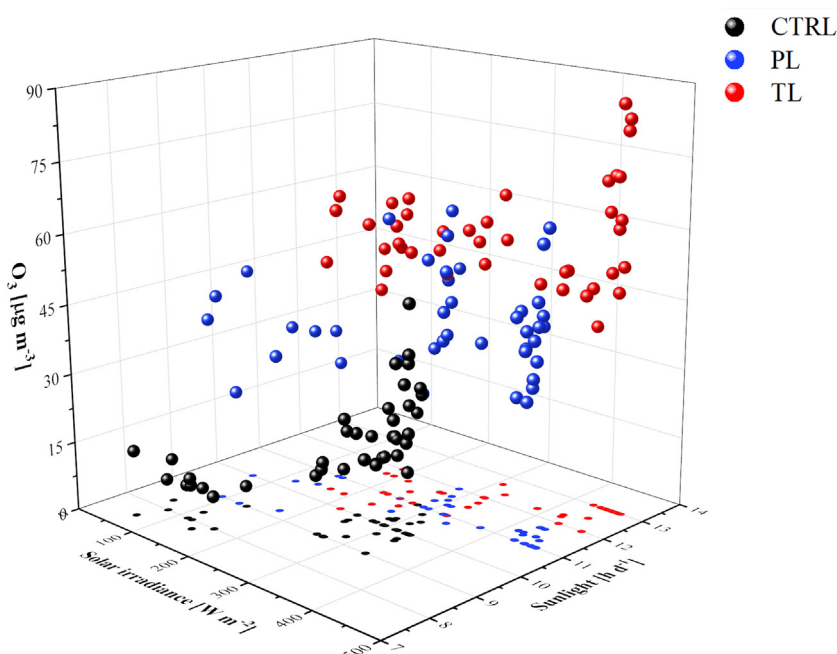


Fig. 7. Daily average concentration of  $O_3$  as function of daily hours of sunlight and average solar irradiance during daylight hours in CTRL, PL, and TL periods.

the various areas of MeCiMi (Fig. S1). While in Milan it is possible to estimate that during the reference period the traffic contributes 78.8% to the emission of CO, in SaA and SaB this percentage drops to 74.6% and 55.5%, respectively. These aspects confirm the greater impact in terms of CO reduction of the reduction of vehicular traffic and transport in the city of Milan than in the other two adjacent areas. The further reduction of CO in the transition from PL to TL is not attributable only to the closure of the industries. In fact, this sector has a minimal percentage impact on CO emissions in MeCiMi (1.4–3.5%) (Fig. S1). Instead, it is reasonable to attribute this result to a combination of causes: (i) further decrease in vehicular traffic and (ii) a reduction in the use of household heating due to the closure of many workplaces for the TL.

In Milan, SO<sub>2</sub> underwent a more marked reduction from the period of CTRL to PL (19.9%) and a lower decrease from PL to TL (6.8%). Overall, it diminished by an average of 25.4% between the period of CTRL and the TL (Fig. 5), while in SaA and SaB it remained substantially unchanged. The emissions of power plants, heating systems, and some industrial processes represent the main sources of SO<sub>2</sub> (INEMAR, 2017). The sum of these three contributions is the source of 70–90% of SO<sub>2</sub> emissions in the whole MeCiMi. In Milan, heating systems mainly contribute (51.6%) while in SaA and SaB industries (85.1% and 53.4%, respectively) (Fig. S1). The trend of reduction from CTRL to TL in Milan can be partially attributed to a reduction of heating due to the closure of workplaces (e.g. offices) which, instead, had lower influence in the other two areas. However, it should be noted that the number of data relating to the city of Milan is limited (1 control unit): further data would be required in order to carry out a more accurate assessment.

### 3.5. Nitrogen oxides

The PL and TL determined a drastic drop in the concentration of NO<sub>x</sub> and NO<sub>2</sub> in all the areas covered by the study (Fig. 6). This aspect becomes even more evident if we also make a comparison with the data of previous years. In the 2016–2018 three-year period, the average concentration of NO<sub>2</sub> in MeCiMi in February and March was in fact around 50–60 µg m<sup>-3</sup> and 45–50 µg m<sup>-3</sup>, respectively (ARPA Lombardia, 2018, 2017, 2016). These values are similar to those recorded in the reference period (53.4 ± 2.6 µg m<sup>-3</sup>) but far higher than the PL (31.9 ± 1.9 µg m<sup>-3</sup>) and TL (22.1 ± 1.2 µg m<sup>-3</sup>).

Traditionally, the main source of NO<sub>x</sub> is vehicular traffic which in MeCiMi accounts for 68.6% - 72.1% in the emission of these pollutants, followed by building heating (10.4% - 18.7%) and industrial processes (7.6% - 14.9%) (Fig. S1). In fact, during CTRL period, the highest concentrations of NO<sub>2</sub> and NO<sub>x</sub> were recorded precisely in Milan and in the SaA. The lower concentrations recorded in the three areas could be attributed to the prescriptions imposed with the PL and, later, made more rigid, when the TL minimized transfers, and consequently, the emissions from vehicular traffic.

A preliminary study carried out between the 9th and the 29th of March 2020 by the local environmental protection agency already identified the traffic reduction following the lockdown as the main cause of NO<sub>x</sub> concentration lowering in Lombardy (ARPA Lombardia, 2020b). Furthermore, the reductions recorded in MeCiMi agree with the results obtained in the lockdown period imposed by CoViD-19 in Barcelona (from 47.0 to 51.4%) (Tobías et al., 2020), and confirmed by Copernicus satellite system which highlighted the substantial reduction of tropospheric NO<sub>2</sub> in Milan (with a reduction of 47 ± 15%) when compared with March 2019 (ESA, 2020).

### 3.6. Ozone

Compared to the CTRL period, O<sub>3</sub> exhibited a more marked increase in Milan and SaA and lower in SaB despite the significant decrease in NO<sub>2</sub> (Fig. 6). The growth of O<sub>3</sub> is usual during spring and summer owing to higher solar radiation (in terms of intensity and daily duration), which promotes the photolysis of NO<sub>2</sub> (Escudero et al., 2019;

Wang et al., 2020). Fig. 7 shows the dependence of the concentration of O<sub>3</sub> in CTRL, PL and TL on solar radiation and daylight hours. The increase in daylight hours (from 9.5 ± 0.2 h in the CTRL period to 12 ± 0.2 h in the TL period) might appear a crucial factor causing higher O<sub>3</sub> concentrations. However, this aspect is not sufficient to explain the data. In fact, in MeCiMi, from 2016 to 2018 the average concentration of O<sub>3</sub> in February and March was 10–20 µg m<sup>-3</sup> and 30–40 µg m<sup>-3</sup>, respectively. These values are similar with those recorded in the reference period (20.1 ± 2.1 µg m<sup>-3</sup>) and in PL (43.7 ± 2.4 µg m<sup>-3</sup>) but very lower than TL (59.0 ± 2.1 µg m<sup>-3</sup>). The significant lowering of the NO concentration in TL, which, in turns, reacts with O<sub>3</sub>, could lead to obtain the higher O<sub>3</sub> concentrations than the average.

Furthermore, in TL, the presence of benzene in major average concentrations in Milan than in SaB (Fig. 5) surely yielded to a greater O<sub>3</sub> formation. Since VOCs emissions are mainly ascribable to vehicular traffic and industrial combustion (EEA, 2019; Huang et al., 2011; Man et al., 2020), strongly minimized in TL, it might be concluded that also the other VOCs acted as benzene.

## 4. Conclusions

In this paper the effect of lockdown on air quality in MeCiMi was assessed. The severe limitation of people movements following the PL and the subsequent TL resulted in a significant reduction of pollutants concentration mainly due to vehicular traffic: PM<sub>10</sub>, PM<sub>2.5</sub>, BC, benzene, CO, and NO<sub>x</sub>. For CO, the reduction was specifically appreciable in the city of Milan where vehicular traffic represents the primary source of these emissions in a marked manner. The lockdown led to an appreciable drop in SO<sub>2</sub> only in the city of Milan while it remained unchanged in the SaA and SaB. This specific reduction in Milan can be partially attributed to the decrease of heating, due to the closure of workplaces, factor playing a minor role in the other two areas. However, further data are required in order to carry out a more accurate evaluation. Despite the significant decrease in NO<sub>2</sub> in TL, ozone exhibited a significant increase, probably, due to the minor NO concentration. The more accentuated increase in Milan and SaA was, probably, due to the higher average concentrations of benzene in Milan than the adjacent areas that may have promoted the formation of O<sub>3</sub> in a more significant way.

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.scitotenv.2020.139280>.

### CRediT authorship contribution statement

**Maria Cristina Collivignarelli:** Conceptualization, Methodology, Supervision, Validation, Writing - original draft, Writing - review & editing. **Alessandro Abbà:** Methodology, Validation, Visualization, Writing - original draft, Writing - review & editing. **Giorgio Bertanza:** Methodology, Validation, Writing - original draft, Writing - review & editing. **Roberta Pedrazzani:** Data curation, Formal analysis, Validation, Writing - original draft, Writing - review & editing. **Paola Ricciardi:** Visualization, Writing - original draft, Writing - review & editing. **Marco Carnevale Miino:** Conceptualization, Data curation, Formal analysis, Methodology, Supervision, Validation, Writing - original draft, Writing - review & editing.

### 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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