The Influence of Atmospheric Particulate on the Second Wave of CoViD-19 Pandemic in Emilia-Romagna (Italy): Some Empirical Findings

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Abstract. While the role played by air pollution and meteorological conditions on SARS-Cov-2 transmission is still subject of a scientific controversy, we have extended our analysis on this association by studying the impact of particulate on the beginning of the second wave in Emilia-Romagna (Italy), in the period October-November 2020. Again, we found many clues in favour of this hypothesis, with new results that shed a particular light on the time varying effect of the particulate on the virus spread. Specifically, we found a strong magnitude of correlation between the PM10 particulate and CoViD-19 infections, peaking at 6–7th day lags for contagions, while this magnitude drops to a medium level value with 9–11th day lags. This is of special interest, if we consider that the specialized literature suggests a median CoViD-19 incubation period of almost 6 days before that infected people display symptoms.

Keywords: CoVid-19 · Atmospheric Particulate · Pearson's correlation · Second Wave · Emilia Romagna (Italy)

1 Introduction

The link between the spread of the coronavirus disease 2019 (CoViD-19) and air pollution represents a questioned issue that has raised divergent views in the scientific community [1]. Many have argued that co-factors, such as quality of air and particulate matter in particular, may have played a role, yielding a number of negative CoViD-19 outcomes, including infections, deaths, and even excessive mortality rates. The motivations which are the basis of this hypothesis are that: i) fine particulate may work as a viral vector in the transmission of the

virus and ii) it may facilitate the infection of the respiratory system, by disrupting the pulmonary defense system.

This hypothesis has also provided a plausible explanation to the reason why the virus has spread so unbalanced across different geographical areas in the world, even within the same countries.

Being the Po Valley, in Northern Italy, one of the most polluted areas in Europe, and also a hotspot for the first wave of the contagion, it has been the subject of several studies with the aim to understand the role of environmental pollution in influencing the spread of the virus during the pandemic. Some of those studies have corroborated this hypothesis, finding that a rise in the atmospheric level of the particulate was concomitant with the increase in the viral infection counts [2]. Among these studies, one has already shown the existence of a correlation between daily lagged values of particulates (precisely, PM2.5 and PM10) and adverse CoViD-19 outcomes, in all the provinces of the region of Emilia-Romagna in Northern Italy, during the first wave [3].

Italy's response to CoViD-19, that had allowed to contain the pandemic during that first wave, unfortunately broke down with the advent of the summer vacations and exposed the country to a second wave which surpassed the first one in intensity, starting in October 2020 and peaking around mid of November 2020 [4]. This dramatic situation, however, has offered the opportunity to investigate, again, on the hypothesis of the environmental pollution as a driver for viral transmission, also during the second wave.

In this context, this study has investigated the association between the CoViD-19 daily infection cases registered in the period 1 October - 12 November 2020 and the daily average lagged values of the PM10 pollutant, in all the nine provinces of the Emilia-Romagna region, in Italy.

The reminder of the paper is structured as follows. The next Section present the methodology adopted in our study, along with the main results we have achieved. Finally, Section 3 concludes the paper with some considerations.

2 Methodology and Results

The association, subject of this study, has been tested by exploiting the statistical hypothesis testing method based on the Pearson's correlation coefficient.

In particular, we computed the value of the Pearson's coefficient *r* by comparing two data time series. The first one is given by the infection counts registered on a given day *X* during the second wave of the pandemic (with *X* belonging to the temporal interval: 1 October - 12 November 2020), while the second one is the amount of pollution measured on day *X* - *n*, where the lag *n* was chosen from two different intervals: **A** = [8, 7, 6, 5, 4] and **B** = [12, 11, 10, 9], based on the literature which suggests a median CoViD-19 incubation period of almost 6 days before that infected people display symptoms [5].

To summarize the main results of this study: they have confirmed a strong magnitude of correlation between the PM10 particulate and CoViD-19 infections, peaking at 6–7th day lags for contagions, with Pearson's *r* coefficient ranging from approx. 0.6 to approx. 0.8, and a *p value* always less than 0.001, for eight out of the nine provinces in the investigated regions (except for Piacenza).

Instead, this magnitude drops to a medium level value with 9–11th day lags, where the Pearson's *r* coefficients range from approx. 0.3 to approx. 0.5; not only, but in many of those cases the *p value* display an unstable behavior.

These empirical findings seem to be of particular relevance as they are corroborated by similar results on the time varying effect of the particulate found by other authors during the first wave in a different European region [6].

Before we show these results in details, it is worth reminding that a very common empirical classification for interpreting the strength of a correlation by using the Pearson's *r* coefficient suggests that values less than 0.20 represent a very weak correlation, 0.20 to 0.39 represent a weak correlation, 0.40 to 0.59 a medium correlation, 0.60 to 0.79 a strong correlation, while 0.80 or greater is a very strong correlation. Despite the attention with which those values should be managed, it is commonly accepted that higher absolute values for *r* and smaller associated *p values* have the meaning of a robust distance from a null hypothesis of no correlation [7].

The following two Tables 1 and 2 display, respectively: the Pearson's *r* coefficient for all the days in the **A** temporal interval and the associated *p values*.

For a better visual comprehension of the magnitude of the association, in Table 1 we have put in evidence all the *r* values above 0.6 (strong or very strong) using a dark grey background of the cells, while

for all values of *r* from 0.40 to 0.59 (medium) we used a light grey. The same as above was done in Table 2 for all the *p values* below 0.0001.

Table 1. Correlation between CoViD-19 spread and PM10 - Pearson's *r* coefficient. Day lags 8-4.

Province	Day 8th	Day 7th	Day 6th	Day 5th	Day4th
Bologna	0.61002	0.65945	0.62994	0.57674	0.56594
Ferrara	0.58364	0.61271	0.55860	0.50462	0.51837
Forlì-Cesena	0.66084	0.70124	0.70816	0.67757	0.67337
Modena	0.57602	0.62150	0.61529	0.56182	0.56236
Parma	0.59699	0.65012	0.67515	0.62365	0.62365
Piacenza	0.42790	0.49571	0.52424	0.49621	0.61705
Ravenna	0.69767	0.74090	0.72859	0.66957	0.64159
Reggio E.	0.56007	0.60908	0.61789	0.57798	0.57647
Rimini	0.76540	0.78566	0.79719	0.76405	0.75318

Table 2. *p-value*. Day lags: 8-4.

Province	Day 8th	Day 7th	Day 6th	Day 5th	Day 4th
Bologna	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ferrara	<0.0001	<0.0001	<0.0001	0.0006	0.0004
Forlì-Cesena	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Modena	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Parma	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Piacenza	0.0042	0.0007	0.0003	0.0007	<0.0007
Ravenna	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Reggio E.	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Rimini	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

The following two Tables 3 and 4 show, instead: the Pearson's *r* coefficient for all the days in the **B** temporal interval and the associated *p values*. In Table 3, we used the same colors as above (dark grey, light grey) to highlight strong/very strong and medium levels of correlation, respectively, while the light grey In Table 4 emphasize *p values* below 0.0001.

Table 3. Correlation between CoViD-19 spread and PM10 - Pearson's *r* coefficient. Day lags: 12-9

Province	Day 12th	Day 11th	Day 10th	Day 9th
Bologna	0.35535	0.43657	0.47860	0.52103
Ferrara	0.48144	0.53633	0.54891	0.55864
Forlì-Cesena	0.36961	0.51331	0.57531	0.60970
Modena	0.41553	0.49650	0,50167	0.50186
Parma	0.37126	0.43649	0.46308	0.50205
Piacenza	0.27939	0.31956	0.33102	0.34839
Ravenna	0.50601	0.59245	0.64274	0.65928
Reggio E.	0.34744	0.42799	0.45161	0.48109
Rimini	0.53434	0.66206	0.71231	0.73043

Table 4. *p-value.* Day lags: 12-9.

Province	Day 12th	Day 11th	Day 10th	Day 9th
Bologna	0.0194	0.0034	0.0012	0.0003
Ferrara	0.0011	0.0002	0.0001	<0.0001
Forlì-Cesena	0.0147	0.0004	<0.0001	<0.0001
Modena	00056	0.0007	0.0006	0.0006
Parma	0.0142	0.0034	0.0018	0.0006
Piacenza	0.0696	0.0367	0.0301	0.0221
Ravenna	0.0005	<0.0001	<0.0001	<0.0001
Reggio Emilia	0.0024	0,0042	0.0024	0.0011
Rimini	0.0002	<0.0001	<0.0001	<0.0001

3 Conclusions

The link between the spread of CoViD-19 and air pollution represents a questioned issue that has raised divergent views. Nonetheless, we have found many clues in favour of this hypothesis both in a previous data analysis of the so-called first wave in the Italian region of Emilia Romagna and also with this new study focused on the beginning of the second wave in the same Italian region, in the period October-November 2020.

These latest findings shed a light on the time varying effect of the particulate. In particular, we found a strong magnitude of correlation

between the PM10 particulate and CoViD-19 infections, peaking at 6–7th day lags for contagions, while this magnitude drops to a medium level value with 9–11th day lags.

Further to these latest results, our efforts to study the complex dynamics behind the spread of this virus are still continuing with the hope that they can inform policy-makers [9-12].

To conclude, it is the turn of the data: at the time of our study, they were all available on Italian governmental sites [13, 14]. All our experiments are reproducible using those data.

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