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Effects of air pollution on the potential transmission and mortality of COVID-19: A preliminary case-study in Tarragona Province (Catalonia, Spain)

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ABSTRACT

The number of studies published on COVID-19 in recent months is certainly impressive. However, there are still important gaps to know a great number of characteristics of this disease. Among these, some potential ways of transmission of the SARS-CoV-2 and the different reasons for the severity of the disease in different people. Various studies have suggested that certain air pollutants could be increasing the transmission of the coronavirus, as well as the risks of COVID-19 incidence and mortality. In the present preliminary case-study conducted in Tarragona Province (Catalonia, Spain), we studied the potential association of COVID-19 with PM₁₀, NO₂ and O₃, as well as the differences in the incidence and lethality of this disease. This Province is divided into two “health regions”: Camp de Tarragona, with an important industrial complex, and Terres de l’Ebre, with a great agricultural component. In spite of the notable limitations of the current study, our preliminary findings indicate that the industrialized/urban areas of Tarragona Province show a higher incidence and mortality of COVID-19 than the agricultural/rural zones. These -and previous- results would highlight the importance of conducting specific investigations focused on directly assessing whether air pollutants such as particulate matter can act as carriers of the SARS-CoV-2. If confirmed, the recommendation on keeping the “social distance” (1.5-2 m) might need to be adapted to this situation.

Keywords: COVID-19; air pollutants; transmission; lethality; Tarragona Province (Catalonia, Spain)

1. Introduction

Officially, COVID-19 started in Wuhan (China) in December 2019 and its rapid widespread throughout the world drove to the declaration of the pandemic in March 2020 (WHO, 2020a). In September 17, 2020, the number of global confirmed cases and deaths was 29.4 million and 931,321, respectively (WHO, 2020b).

COVID-19 is associated with the Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV-2). SARS-CoV-2 can be transmitted by human-to-human contact (i.e., through the respiratory droplets emitted by an infected person while coughing, sneezing and/or exhaling to an uninfected person) (WHO, 2020b; Huang et al., 2020; Xu et al., 2020; Lai et al., 2020). Hence, the higher the number of personal contacts, the higher the chances of being infected by SARS-CoV-2. In fact, metropolitan areas, such as New York, in the United States, as well as Madrid and Barcelona, in Spain, or Milan, in Italy, were/have been specially impacted by COVID-19 outbreak.

In addition to this well-characterized pathway of SARS-CoV-2 transmission, the potential role of certain environmental pollutants on the transmission and lethality of this coronavirus is not well-known yet, being currently subject of a number of investigations. In relation to this, we recently reviewed more than 20 scientific articles, which have been published between March and June 2020. The review was aimed at assessing the role of environmental pollution on SARS-CoV-2 transmission and severity (Domingo et al., 2020). The preliminary detection of SARS-CoV-2 in particulate matter (PM) strengthened the associative hypothesis between PM and COVID-19, suggesting that inhalation of PM might be a potential pathway of transmission (Setti et al., 2020). In turn, higher ambient CO concentration is a risk factor for increased transmissibility of the novel coronavirus (Lin et al., 2020). Although Coccia (2020) stated accelerated transmission dynamics of COVID-19 is due to mainly to the mechanism of “air pollution-to-human transmission” (airborne viral infectivity) rather than “human-to-human transmission, Espejo et al. (2020) concluded that too little is known about the current pandemic to evaluate whether there is an association between environment and positive COVID-19 cases.

On the other hand, it is well established that exposure to air pollutants (i.e., PM, NO₂, O₃) increases the incidence and/or severity of respiratory and cardiovascular diseases. Hence, in a COVID-19 outbreak context, individuals chronically exposed to

relatively higher concentrations of certain air pollutants might suffer more severe and serious forms of COVID-19, with a more complicated recovery than those subjects chronically exposed to lower pollutant concentrations (Sciomer et al., 2020; Frontera et al., 2020a), and with air pollution relate comorbidities (Sharma and Balyan, 2020). Most of these investigations have been focused on the most characteristic urban pollutants such as PM, NO₂ and O₃. Copat et al. (2020) recently reviewed investigations focused on the role of PM and NO₂ in COVID-19 spread and lethality. They stated the significant limitations for direct comparison of results, and the need of more studies to strengthen scientific evidences and support firm conclusions. However, major findings highlight the important contribution of PM_{2.5} and NO₂ as triggering of the COVID-19 spread and lethality, and with a less extent also PM₁₀. However, the potential impact of pollutants typically emitted by harmful industrial facilities, such as volatile organic compounds (VOCs) or polycyclic aromatic hydrocarbons (PAHs) among others, on the transmission and severity of COVID-19, remains unexplored.

The purpose of the present study was to investigate the potential association of COVID-19 with various air pollutants (PM₁₀, NO₂ and O₃) and to assess the potential differences in the incidence and lethality of COVID-19 in two health regions of Tarragona Province (Catalonia, Spain). The population included in these health regions live in zones in Tarragona County, an area where the largest petrochemical complex of Southern Europe is placed (Nadal et al., 2006), and Terres de l'Ebre, an agricultural area of Southern Catalonia.

2. Materials and methods

2.1. COVID-19 data

The daily number of confirmed positive cases (diagnosed by either Polymerase Chain Reaction (PCR) or rapid test) between March 8, 2020, and May 10, 2020, were obtained from the open data portal from the Government of Catalonia (<https://analisi.transparenciacatalunya.cat>). The number of confirmed fatalities caused by COVID-19 during the same period was provided by the Catalan Health System Observatory (<http://observatorisalut.gencat.cat/en/inici/index.html>). Tarragona Province is divided into 2 “health regions”, 4 “health sectors” (HS) and 45 “basic health areas”

(BHA) (Table 1 and Figure 1). Both, confirmed positive cases and fatalities, were downloaded at BHA scale in order to achieve an optimal adjustment with the data on environmental pollutants. Finally, COVID-19 data were adjusted to the total population living in Tarragona Province in 2019, which are published by the Statistical Institute of Catalonia (<https://www.idescat.cat/?lang=en>).

2.2. Environmental pollution data

Time series data of daily average air pollutants PM₁₀, NO₂ and O₃ were obtained from the open data portal from the Government of Catalonia (<https://analisi.transparenciacatalunya.cat>). The average chronic exposure to these pollutants was estimated by using data covering from January 1, 2014 to December 31, 2019. In turn, to assess exposure to these pollutants during the COVID-19 outbreak, weekly average air concentrations were calculated considering data from March 14, 2020 to May 8, 2020.

2.3. Statistical analysis

SPSS 25.0 was used for statistical assessment. Pearson test was applied to examine the association between environmental concentrations of PM₁₀, NO₂ and O₃ and COVID-19 confirmed cases and fatalities. Both Pearson coefficient and correlation significance ($p < 0.05$) were calculated.

3. Results and discussion

3.1. Incidence of COVID-19: Tarragona County vs Terres de l'Ebre

In the same way as in other recent studies, the ongoing epidemic trend in Province of Tarragona showed strong regional differences in the spread of COVID-19 cases. The distribution of the reported number of positive cases at BHA scale is depicted in Figure 2. The most impacted BHA was Tarragonès-Baix Penedès, followed – at a notable distance – by Baix Camp-Priorat, Terres de l'Ebre and Alt Camp-Conca de Barberà (Figure 2a). This tendency coincides with the distribution of inhabitants, showing that the higher the number on inhabitants, the higher the number of reported

COVID-19 positive cases. Therefore, in order to minimize the difference between the number of inhabitants at each BHA, the absolute number of confirmed positive cases was normalized according to the number of inhabitants for BHA populations (Figure 2b). Thus, it was further evidenced that Tarragonès-Baix Penedès was the most highly impacted HS by COVID-19, while Terres de l'Ebre was not so affected.

3.2. Mortality of COVID-19: Tarragona County vs Terres de l'Ebre

The mortality of COVID-19 presented geographical differences (Figure 3). Figure 3a shows the distribution of the number of fatalities at BHA scale. Tarragonès-Baix Penedès is the most affected HS, followed by Baix Camp-Priorat, Terres de l'Ebre and Alt Camp-Conca de Barberà. This trend follows a similar pattern to that of the confirmed cases, indicating again that the higher the number of inhabitants, the higher the number of confirmed cases, and consequently, the higher the mortality cases. Although the differences between BHA decreased when the mortality was normalized to the number of inhabitants (Figure 3b), the pattern of incidence was the same for the 4 HS. Finally, the lethality of SARS-CoV-2 was calculated as here indicated: $Lethality = \frac{\text{number of COVID-19 fatalities}}{\text{number of COVID-19 cases}}$ (Figure 4). It was found that SARS-CoV-2 was more lethal in Baix Camp-Priorat and Tarragonès-Baix Penedès than in Terres de l'Ebre and Alt Camp-Conca de Barberà.

3.3. Association between the incidence of COVID-19 and the air concentrations of PM_{10} , NO_2 and O_3

The temporal evolution of the COVID-19 confirmed cases versus the weekly average PM_{10} concentrations in 4 localities of Tarragona Province (Tarragona, Reus, Vila-seca and Amposta) is depicted in Figure 5. Data are given from one month before the declaration of state of alarm in Spain (March 14, 2020) until the start of the de-escalation (May 4, 2020), just after the lockdown. Even though the present data must be interpreted with great caution, a concentration peak of PM_{10} might have caused a peak in the number of COVID-19 positive cases one and two weeks later. Although the current PM_{10} concentrations are much lower than those reported in the North of Italy, our findings are in agreement with Bontempi (2020), who already hypothesized that

PM₁₀ might be a carrier of COVID-19. It was based on the fact that episodes of high PM₁₀ concentrations were correlated to the increase in the number of infection COVID-19 cases -after two weeks- during the lockdown in several regions of Italy (Bontempi, 2020). Similarly, Coccia (2020) also reported a positive correlation with the frequency of daily PM₁₀ exceedances.

Figure 6 shows the statistical correlation between the number of COVID-19 cases and the weekly average PM₁₀ concentrations during the same week, the previous week and two weeks before in Tarragona Province (Tarragona, Reus, Vila-seca and Amposta). The number of COVID-19 cases correlated significantly with the average concentrations of PM₁₀ the week before only in the cities of Reus and Amposta. It might be hypothesized that COVID-19 incidence significantly correlated with PM₁₀ in Reus and Amposta because both localities are affected by a typical urban contamination, while Tarragona and Vila-seca have a mixture of pollution sources (urban and industrial). On the other hand, Setti et al. (2020a) reported that the effect of the dust on the spread of COVID-19 is significant when the PM₁₀ concentration is over 50 µg/m³. The levels of PM₁₀ in the sampling sites of the present study are much lower than this threshold, which could explain the poor correlation between PM₁₀ and the number of COVID-19 cases of the current survey. Anyhow, the potential role of PM₁₀ as a carrier of SARS-CoV-2 must be confirmed at lab scale, with the detection of the coronavirus in PM₁₀. In relation to this, Setti et al. (2020b) recently detected SARS-CoV-2 in PM₁₀ sampled in Bergamo (Italy) during the lockdown, confirming PM₁₀ and COVID-19 might have not only an associative, but also a casuistry relationship.

Figure 7 shows the statistical correlation between the regional distribution of COVID-19 cases per habitant (%) and the average concentration of PM₁₀, NO₂ and O₃ during the outbreak period, as well as considering also the mean levels of these air pollutants found in the period 2014-2019. Positive correlations were observed between the incidence of COVID-19 and the exposure to PM₁₀ and NO₂, both during the period 2014-2019 and during the outbreak. However, this correlation was significant only for NO₂. In contrast, we found a negative correlation between COVID-19 incidence and O₃ levels, but being only significant in the case of the chronic exposure (2014-2019) to O₃. These results agree with those recently reported by Fattorini and Regoli (2020), Zoran et al. (2020 a,b), Zhu et al. (2020) and Bashir et al. (2020) for these air pollutants, excepting O₃. Similarly, Jiang et al. (2020) also reported a negative correlation between

exposure to O₃ and the incidence of COVID-19. In fact, the concentrations of NO₂ and O₃ usually correlate negatively (Rovira et al., 2020; Munir et al., 2011).

3.4. Association between the mortality of COVID-19 and the air concentrations of PM₁₀, NO₂ and O₃

The potential association between chronic exposure to PM₁₀, NO₂ and O₃ (average concentration of PM₁₀, NO₂ and O₃ during 2014-2019) and the number of fatalities was statistically assessed (Figure 8). As occurred with the number of COVID-19 cases, a positive correlation was found between the mortality of COVID-19 and the chronic exposure to PM₁₀ and NO₂, but in this case, there was no statistical significance. In turn, a non-significant negative correlation was noticed between O₃ levels and COVID-19 mortality. There is scientific evidence that NO₂, O₃ and PM induces hyper-expression of pro-inflammatory interleukins, being NO₂ a common marker of air pollution and/or industrial activity, which – in turn – is associated with morbidity and mortality (He et al., 2020). The results of the current study support such scientific evidence regarding exposure to NO₂ and PM₁₀ and the number of fatalities/inhabitant, but not with respect to O₃ exposure. In relation to recent reports on the association between air pollution and COVID-19 fatalities, Yao et al. (2020) found a correlation between exposure to PM₁₀ and the COVID-19 case fatality rate, while Ogen (2020) reported that >80% of fatalities of COVID-19 were associated to NO₂>100 µmol/m². In contrast, Zoran et al. (2020 a,b) and Bashir et al. (2020) found that PM₁₀ and NO₂ negative correlated with COVID-19 fatalities. A similar negative correlation seems to occur in the association between PM_{2.5} and the number of COVID-19 deaths. Thus, Frontera et al. (2020b) reported a positive correlation between exposure to PM_{2.5} and the number of fatalities, while Adhikari and Yin (2020) and Bashir et al. (2020) could not find any relationship between them. In turn, Vasquez-Apestegui et al. (2020) also supported the association between PM_{2.5} exposure and COVID-19 fatalities, but not with the fatality rate. With respect to Catalonia, recently Saez et al. (2020) have not discarded that there are biological mechanisms that explain, at least in part, the association between long-term exposure to air pollutants and COVID-19. However, they hypothesized that the spatial spread of COVID-19 in that entire region would be mainly to the different ease with which some people, the hosts of the virus, are infecting others.

4. Conclusions

Firstly, we want to highlight that this is certainly a preliminary case-study with some important limitations. It makes difficult a proper data analysis and the consequent interpretation of results, as well as drawing clear conclusions. These limitations include: i) the low number of air quality stations to monitor air pollutants across the area of study (Tarragona Province, Catalonia, Spain), ii) these stations are not uniformly distributed throughout Tarragona Province, iii) the air pollutants here assessed (PM₁₀, NO₂ and O₃) are not regularly analyzed in all the air quality stations, and iv) COVID-19 fatalities at BHA do not include those occurred in nursing homes, which -doubtless- meant a very high number.

Bearing the above in mind, our preliminary findings indicate that Tarragonès-Baix Penedès experienced the highest incidence and mortality of COVID-19 in Tarragona Province, while the lowest rates occurred in Terres de l'Ebre and Alt Camp-Conca de Barberà. However, it must be taken into account that the density of population is higher in the HS of Tarragonès-Baix Penedès than in Terres de l'Ebre. It means a higher probability of person-to-person contact, and consequently, of being infected. Moreover, it is important to note that there is a large petrochemical industrial complex located in Tarragona County, whose harmful emissions might have a potential role on the health status of the individuals living in the neighborhood. Hence, individuals living in the surroundings of such industrial areas might already have a stressed respiratory system. Consequently, these subjects might be in worse conditions to face the COVID-19, suffering the more lethal form, when infected not only by SARS-CoV-2, but also by other potential respiratory viral infections (Domingo and Rovira, 2020). Although this is right now only a hypothesis, we do believe that it is certainly worthy of being investigated in deep. In summary, the current health and air pollution data of Tarragona Province are still preliminary to conclude whether chronic exposure to certain air pollutants is a significant reason to cause a higher incidence/severity of COVID-19. However, these and previous results would highlight the importance of conducting specific studies focused on directly assessing if air pollutants such as PM can act as carriers of the SARS-CoV-2. If confirmed, the recommendation on keeping the "social distance" (1.5-2.0 m) might need to be adapted to this situation. In addition, we also suggest to conduct specific health surveys at local level, which include those

individuals, who due to their usual places of residence, are potentially affected by the air pollutants emitted by the petrochemical industries.

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List of Tables and Figures

Table 1. Population of the Tarragona Province according to the respective Health Sectors and Basic Health Areas

Health Region (HR)	Health Sector (HS)	Basic Health Area (BHA)	Population*
Camp de Tarragona	Alt Camp-Conca de Barberà	Alt Camp Est	11,740
		Alt Camp Oest	6,199
		Montblanc	15,889
		Valls Urbà	27,188
	Baix Camp-Priorat	Cambrils	33,406
		Cornudella	2,184
		Falset	6,669
		La Selva del Camp	7,207
		Les Borges del Camp	6,614
		Mont-roig del Camp	12,737
		Reus 1	13,418
		Reus 2	26,980
		Reus 3	22,528
		Reus 4	21,334
		Reus 5	27,552
		Riudoms	12,566
		Vandellòs i Hospitalet de l'Infant	5,786
		Tarragonès-Baix Penedès	Baix Penedès Interior
	Calafell		24,162
	Constantí		6,703
	El Morell		12,039
	El Vendrell		46,709
	Salou		25,975
	Tarragona 1		14,729
	Tarragona 2		27,854
	Tarragona 3		30,377
	Tarragona 4		16,212
	Tarragona 5		16,539
	Tarragona 6		19,632
	Tarragona 7		11,451
	Tarragona 8		15,552
	Torredembarra		35,912
	Vila-seca	21,793	
Terres de l'Ebre	Terres de l'Ebre	Amposta	30,659
		Deltebre	11,673
		Flix	7,438
		Aldea-Camarles-L'Ampolla	10,251
		L'Ametlla de Mar - El Perelló	9,140
		Móra la Nova - Móra d'Ebre	13,968
		Sant Carles de la Ràpita	23,739
		Terra Alta	11,015
		Tortosa 1-est	23,146
		Tortosa 2-oest	23,495
		Ulldecona	11,964

*Source: Statistical Institute of Catalonia (<https://www.idescat.cat/?lang=en>).

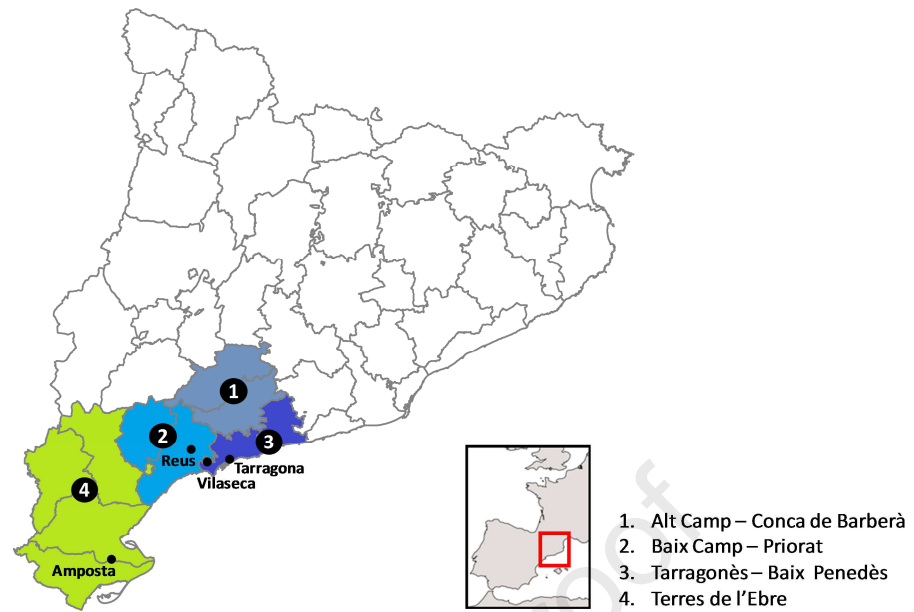


Figure 1. Location of the 4 Health Sectors (HS) of Tarragona Province. Sectors 1, 2 and 3 belong to the “Camp de Tarragona” Health Region (HR).

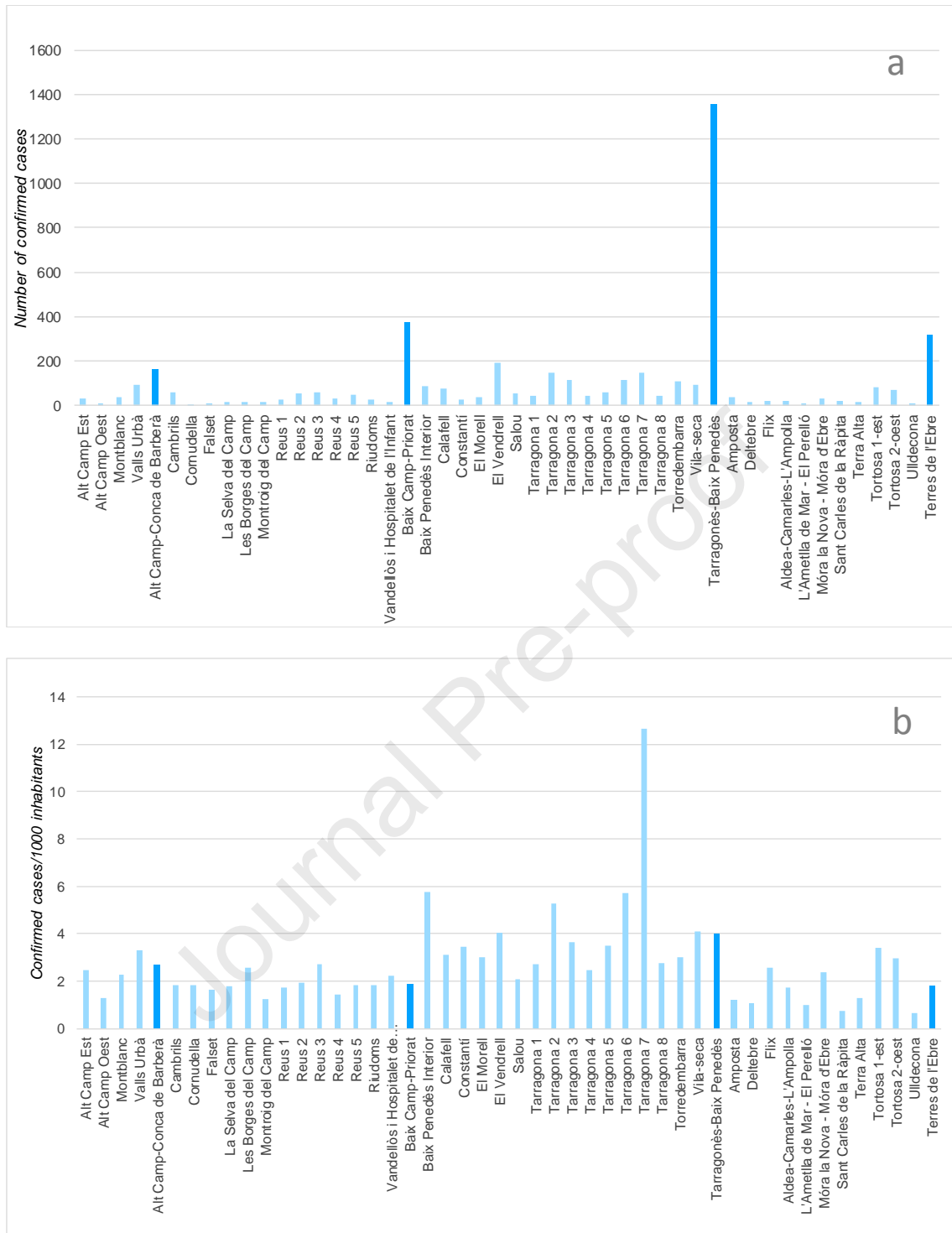


Figure 2. Confirmed cases (a), and confirmed cases/1,000 inhabitants (b), at BHA (light blue) and HS (dark blue) scale.



Figure 3. Confirmed fatalities (a), and confirmed fatalities/10,000 inhabitants (b), at BHA (light red) and HS (dark red) scale.

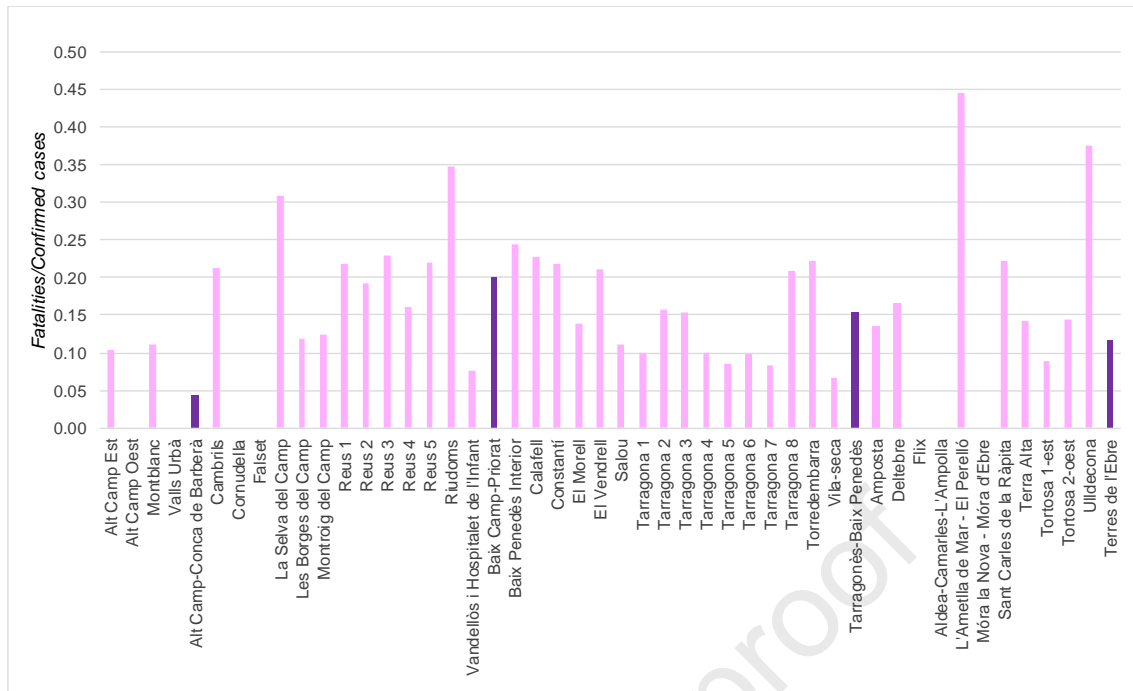


Figure 4. Lethality (mortalities/confirmed cases) of SARS-CoV-19 at BHA (light purple) and HS (dark purple) scale

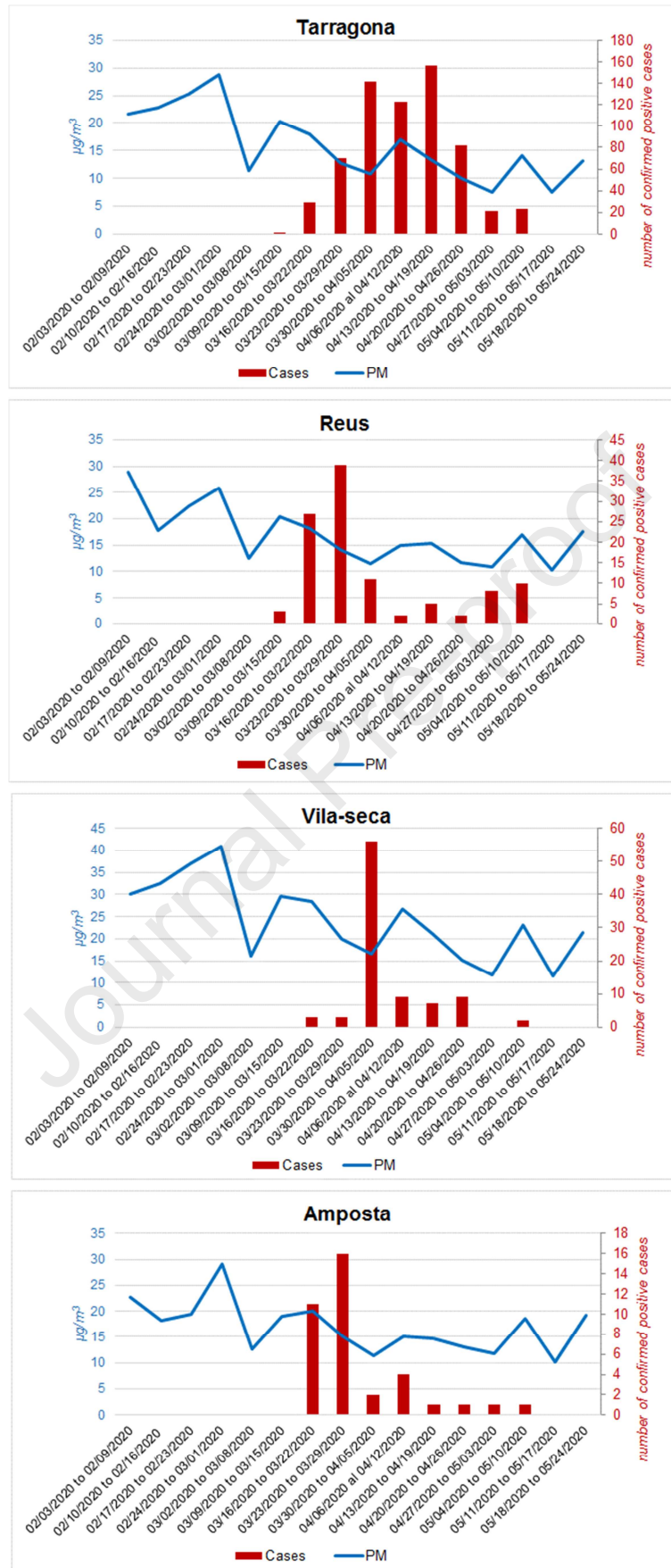


Figure 5. COVID-19 confirmed cases *versus* concentrations of PM₁₀ in 4 locations of Tarragona Province.

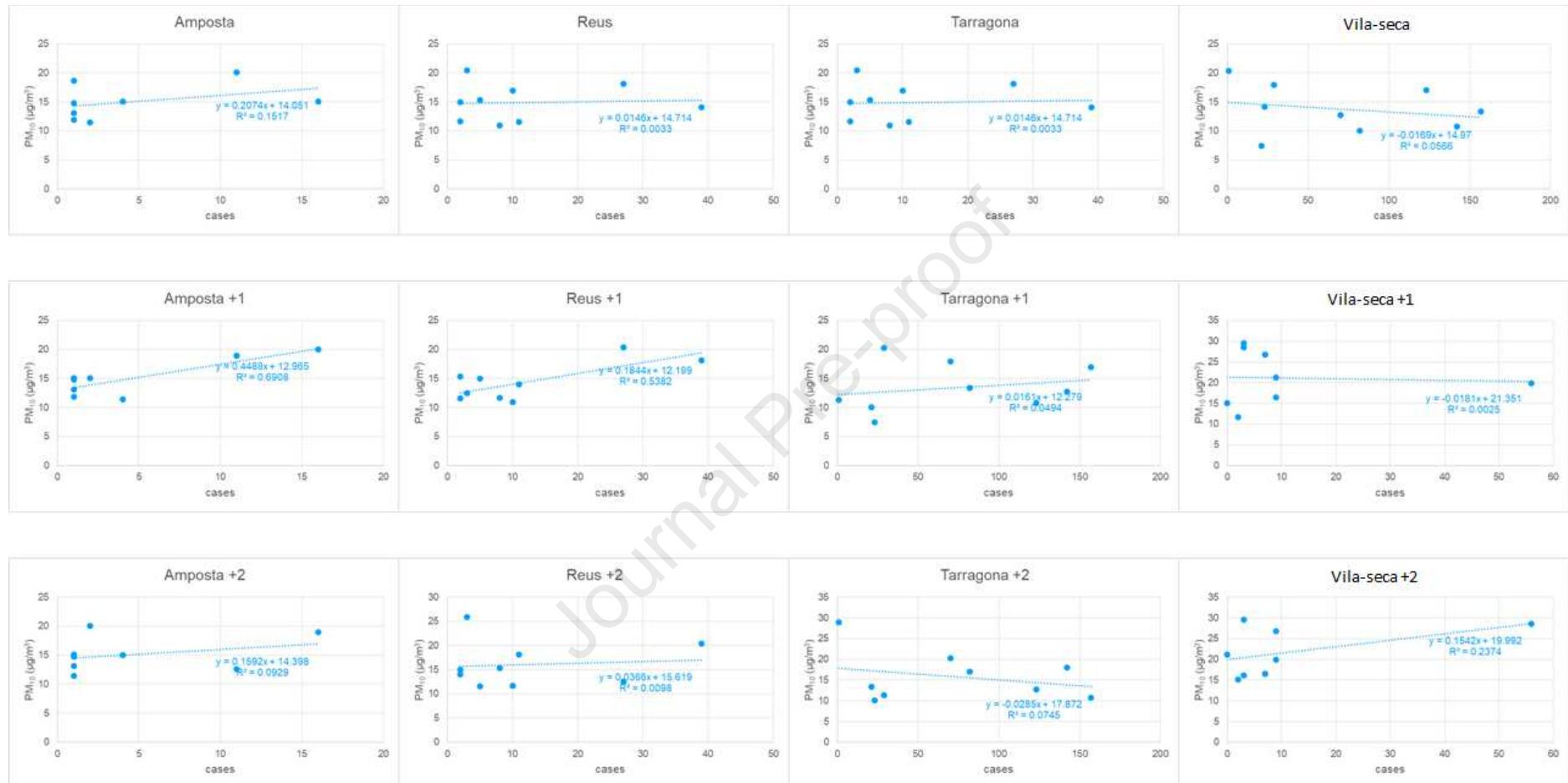


Figure 6. Number of COVID-19 cases versus weekly average concentrations of PM₁₀ on that week, one week (+1) and two weeks before (+2) in various localities of Tarragona Province.

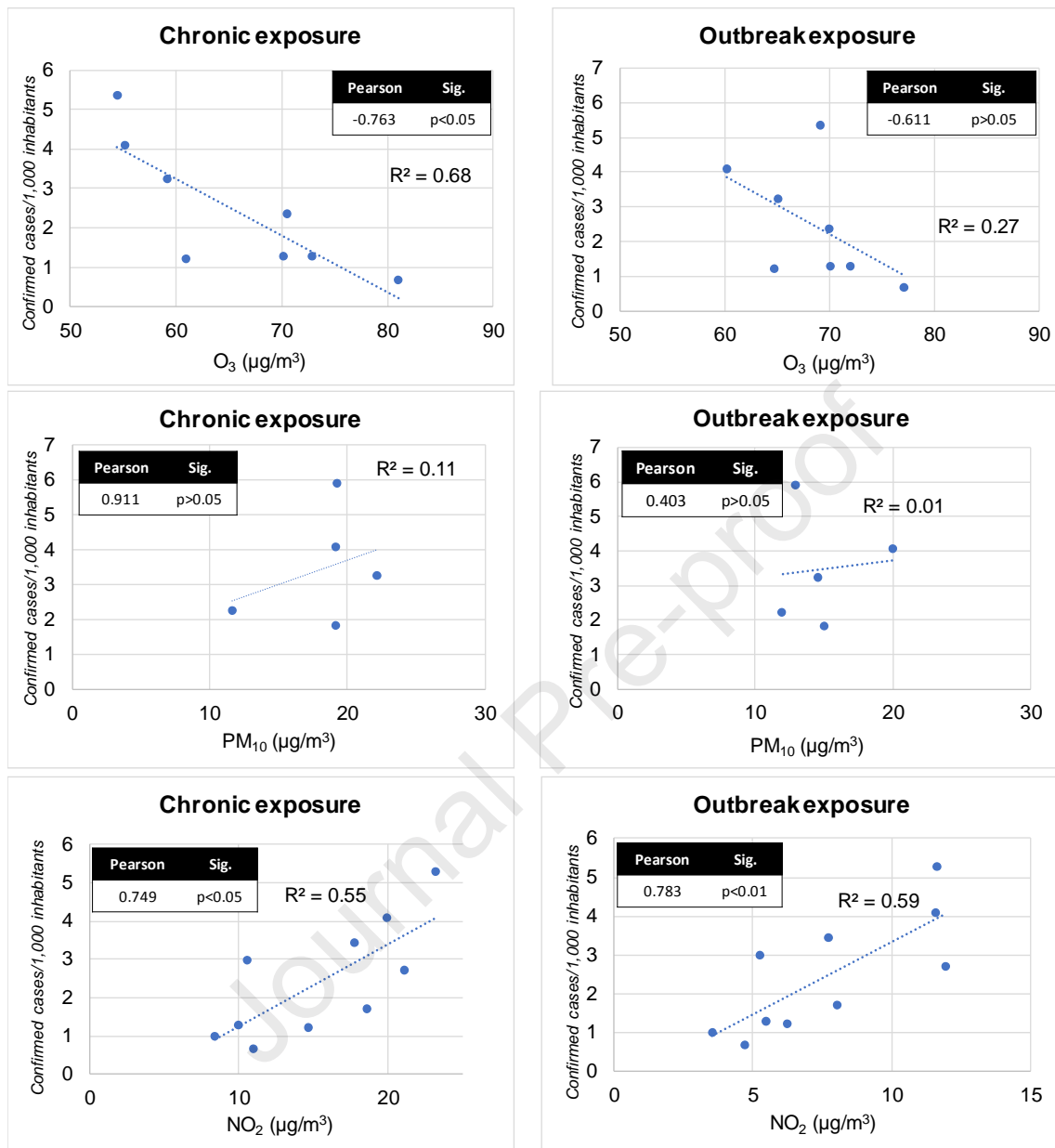


Figure 7. Correlation between chronic (2014-2019) and outbreak (COVID-19) exposure to O₃, PM₁₀ and NO₂ and the incidence of COVID-19 (confirmed cases/inhabitant).

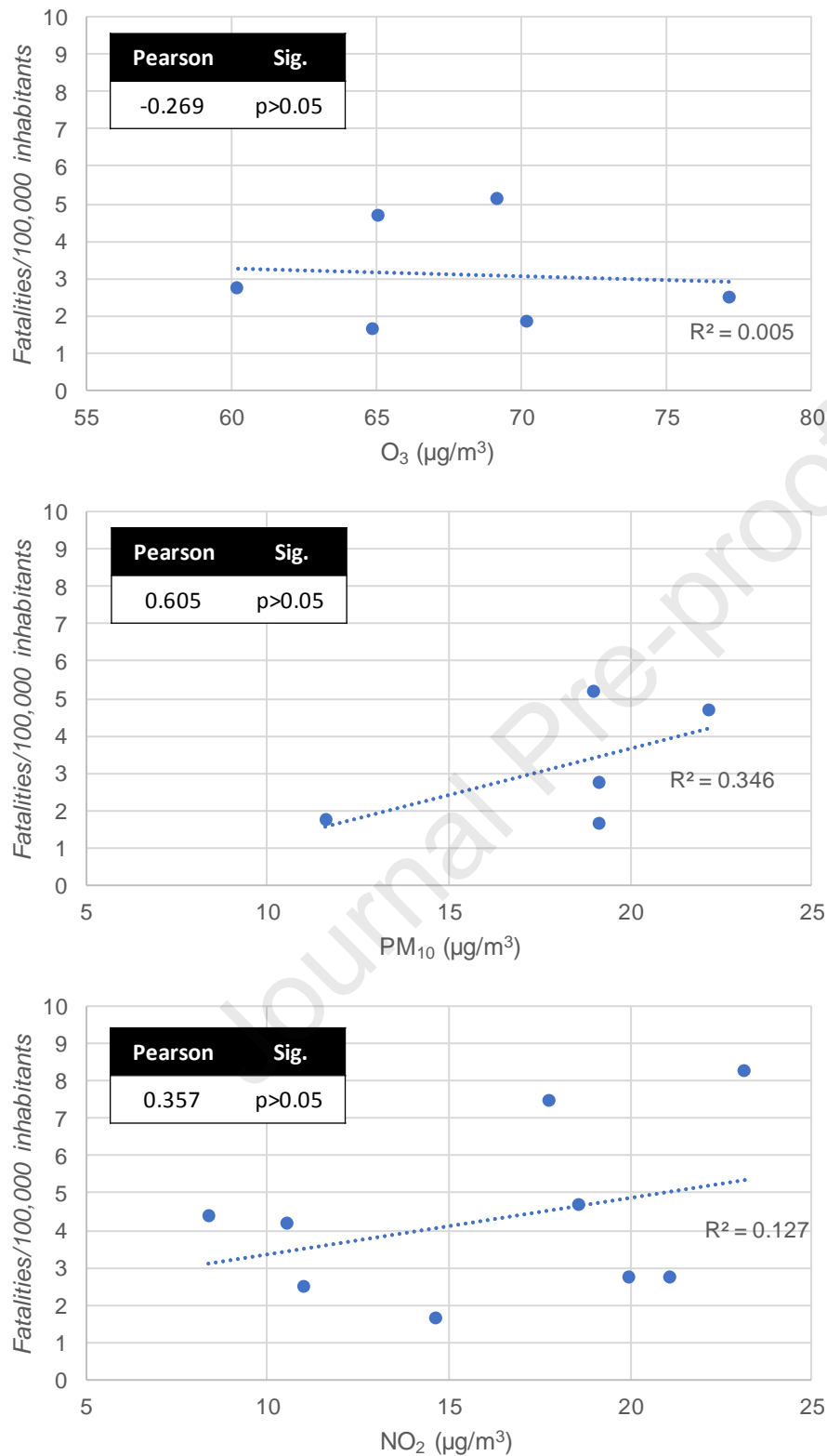


Figure 8. Correlation between chronic (2014-2019) exposure to O₃, PM₁₀ and NO₂ and the mortality of COVID-19 (confirmed cases/inhabitant).

3 to 5 bullet points (maximum 85 characters, including spaces, per bullet point).

- COVID-19 seems to be more severe in urban/industrial areas than in those rural
- A threshold of PM ($50 \mu\text{g}/\text{m}^3$) might determine its correlation with COVID-19
- Social distance recommendation might need to be adapted

Journal Pre-proof

Montse Marquès: Conceptualization, Methodology, Formal analysis, Writing-Original draft;
Joaquim Rovira: Conceptualization, Methodology, Formal analysis, Writing-Review&Editing,
Funding acquisition; **Martí Nadal:** Conceptualization, Methodology, Writing-Review&Editing;
José Luis Domingo: Conceptualization, Writing-Review&Editing, Supervision, Project
administration.

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Declaration of interests

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.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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