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Is Particulate Matter of Air Pollution a Vector of Covid-19 Pandemic?

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SUMMARY

The COVID-19 pandemic is a severe respiratory disease caused by the emergence of a new coronavirus, SARS-CoV-2, that very quickly spread in the human population. Fine particulate matter (PM) generated from combustion engines have been described as toxic to human health. Recent events stressed that high concentrations of PM of air pollution might favor the spread of SARS-CoV-2. Autumn approaches, air pollution will be accentuated because of weather condition. The risk of a second outbreak of Covid-19 pandemic is highly probable. Elucidating the role of PM of air pollution in the spread of the virus is thus urgent and crucial.

The current COVID-19 outbreak has been caused by the emergence of a new coronavirus, SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2), that very quickly spread in human population. This COVID-19 outbreak was declared a pandemic by the World Health Organization (WHO) and continues to spread in the world after its emergence nine months ago. The expectation that rising temperatures in summer can reduce and even stop the spreading of the virus became unfortunately disillusioned. On February 20, 2020, the region of Lombardy in northern Italy declared its first cases of SARS-CoV-2. The region very quickly became the pandemic epicenter in Europe. Considering the heavy industrial development of this region, it was suggested that high air pollution may be a major factor in the aggressive spread of the virus.[1,2]

Fine particulate matter (PM) generated from combustion engines have been described as toxic to human health and the environment. A direct relationship has been established between respiratory diseases and PM generation in or around highly industrialized cities.[1,2] Recent events and consequent studies suggested that high concentrations of PM of air pollution might favor the spread of SARS-CoV-2. Scientific works from around the globe have discussed the likelihood that high concentrations of PM may have been one of the major causes for the important outbreak that has hit several industrialised regions such as Wuhan and northern Italy. The scientific community has thus been invited to pay more attention to airborne transmission of SARS-CoV-2. A recent paper by Bontempi refutes the above mentioned hypothesis, citing that no clear correlation exists between PM levels and the transport of SARS-CoV-2.[3] Navigating through such conflicting information highlights the need to provide concrete answers regarding the role of PM pollution amid this pandemic: is PM of air pollution a vector of COVID-19 pandemic? Do interactions between PM and SARS-CoV-2 affect the survival and infective power of the latter? Do resulting hybrid PM-virus particles represent a possible transmission route of the virus? (Figure 1) Elucidating the transmission factors that foster the spread of a viral infection is of prime importance to stop the viral outbreak and to improve the disease control. An insight into these questions is needed and can be applied to other viruses in general in order to determine their potential effect on the global human population.

Autumn is approaching, and air pollution will be accentuated because weather conditions. A second outbreak of COVID-19 is highly probable. The investigation of an efficient vaccine is still in progress. The present opinion article clearly underlines the possible relationship between the PM pollution and SARS-CoV-2 and other viral strains spreading. It aims at providing a warning to the general population and political deciders about the dangers of high pollution levels amid the current pandemic. It may also provide ideas to limit the propagation of COVID-19 and subsequently the fatalities related to contracting the virus. Finally, we envision that this opinion article will certainly attract particular interest from academia to pay more attention to the study of the possible relationship between the PM pollution and SARS-CoV-2 spreading.

Direct and Indirect Routes of Virus Transmission

The fast transmission of SARS-CoV-2 between individuals and the fact that the population is so easily infected

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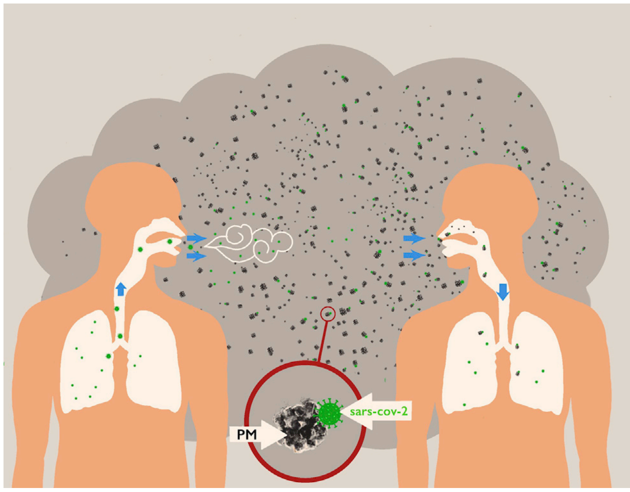


Figure 1. Schematic Representation of the Potential Role of PM as Vectors of SARS-CoV-2

alleviated questions regarding the transmission routes and viability of SARS-CoV-2 in contrast with other viruses. Aerosol mode constitutes a major transport and transmission route of viruses in general. Gormley et al. showed that a building's sanitary plumbing system constitutes a route of pathogen cross-transmission. In their recreated full-scale test-rig, they noticed that the turbulence caused by a toilet discharge was sufficient to aerosolise pathogens, thus opening a way for their transmission from one part of the building to another through U-traps.[4] The stability of pathogens in aerosol form has been extensively described in the literature. One particular study by Van Doremalen et al. confirmed the viability of MERS-CoV in aerosol form under different environmental conditions. It was also reported that when generated by an infected camel in a confined space, virus-loaded aerosols constitute a transmission route of the virus to humans.[5]

The airway transmission of viruses goes beyond aerosol form. In fact, aerosols sediment eventually onto inert surfaces (fomites), thus initiating an indirect transmission route. In their recent work, Van Doremalen et al. extensively discussed the viability of SARS-CoV-1 and SARS-CoV-2 on inert surfaces such as plastic, metal, and wood. They found that both viruses remain viable and infectious for hours in aerosol mode and for days when deposited onto surfaces.[6] It is known that ambient temperature and humidity conditions favor a long stability of SARS-coronaviruses in aerosol and on fomites.

In short, the works mentioned above state that aerosols possibly constitute both direct and indirect transmission routes of viruses to humans. Viruses retain their viability and infectiousness when in aerosol form or on the surfaces of fomites, including fine sediment-based PM. However, no studies on the interaction of viruses with PM, neither in aerosol mode nor on surfaces, have been reported to date. Questions regarding the interaction of SARS-CoV-2 with PM, its viability and its contagiousness remain unanswered and should be addressed. First, it is necessary to provide insight on PMs and their accompanied health hazards prior to addressing any existing relationship between PM and viruses.

Exposure to PM and Accompanied Health Risks

Fine PM generated from combustion processes are typically composed of carbon atoms and their mean average size lies below 10 μm (PM_{10}). Their formation/aggregation mechanisms have been extensively described in the literature and their release into the atmosphere has been directly linked to health hazards. For instance, Maître et al. investigated the effect of PM inhalation from polluted urban air on coronary diseases. They stated that particles smaller than 10 μm are deposited in the airways when inhaled whereas finer particles (<2.5 μm) may reach the pulmonary alveoli, accumulate there, or even pass directly into the blood circulation and have vascular effects (<0.1 μm).[7] Recent works by Conticini et al.[8] and Borro et al.[9] claimed that a subject's exposure to both $PM_{2.5}$ and PM_{10} leads to a chronic inflammatory stimulus that weakens the cilia and upper airways defenses and increases the number of potential "virus" docking sites on the surface of respiratory cells, thus favoring infectivity. It is therefore clear that PM exposure weakens the biological barriers, rendering the host more vulnerable toward external agressors. Is there an interaction between PM and external aggressors such as viruses? Could such an interaction result in a PM-virus hybrid, and would this hybrid be a vector of the virus?

Is PM of Air Pollution a Vector of COVID-19 Pandemic?

To answer this question, we have proceeded in analyzing literature works that were dedicated to establishing a relationship between PM and SARS-CoV-2. One specific region has made headlines when it came to establishing such a correlation: Lombardy, northern Italy. The region of Lombardy is an industrial hub where metal products, textile, wood, and wood products are manufactured. Industrial activities and the transport sector participate in releasing high levels of PM with varying diameters (PM_{10}, $PM_{2.5}$) and other pollutants (NO_x, SO_x, etc.). Public accessible data show that the annual average concentration of PM_{10} was 52.5 $\mu g/m^3$ in Milan (the capital of the region) and 45.4 $\mu g/m^3$ in other densely populated areas of

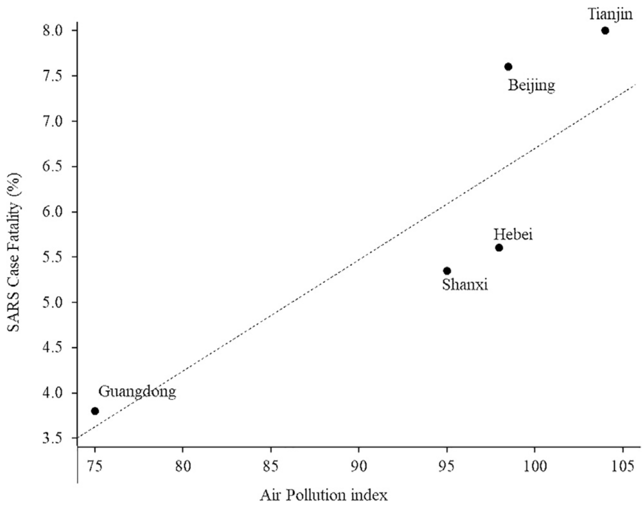


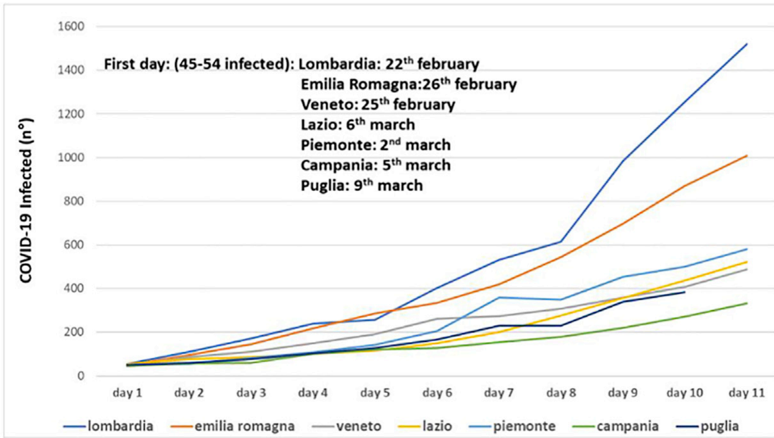
Figure 2. The Correlation and Association between Short-Term Exposure to Ambient Air Pollution and Case Fatality of SARS in People's Republic of China
Air polluion Index values versus SARS Case Fatality yields in Tianjin, Beijing, Hebei, Shanxi, and Guangdong provinces.[11]

Lombardy. Furthermore, 95% of daily values recorded in Milan exceeded the limit of 20 μg/m^3. Italy is definitely not the only country where high air pollution levels have been recorded. Data collected from industrial cities in the world (e.g., Warsaw, Lanzhou, Hong Kong, Seoul, Chicago, and Pittsburg) follow similar trends to those of Lombardy. A recent work by Conticini et al. stated that communities living in polluted areas (such as Lombardy and Emilia Romagna) are more predisposed to die of Covid-19 because of a weakened health status. They claimed that a subject's exposure to both $PM_{2.5}$ and PM_{10} leads to systemic inflammation. This leads to a chronic inflammatory stimulus that weakens the cilia and upper airways defenses and facilitate virus invasion by allowing virus reaching lower airways.[8] In this respect, Borro et al. confirmed that prolonged exposition to $PM_{2.5}$ of the population in north Italy promotes a pro-inflammatory milieu in the airways, which further increases the number of potential SARS-CoV-2 docking sites on the surface of respiratory cells, thus favoring infectivity. It is true that PMs affect the health status of subjects, exposing them to a high risk of contracting the virus.[9]

PMs have been previously labeled as possible virus vectors. Reche et al. identified the presence of viruses in marine aerosols and Saharan dust and measured viruses to bacteria ratios in both types of aerosols (52-fold to 28-fold, respectively). They showed that ratios of viruses were the highest in marine aerosols and that air masses directly affected their proportion and residence time in the atmosphere.[10] Cui et al. utilized publicly accessible data on SARS statistics and air pollution indices collected in multiple Chinese CITIES. They demonstrated a direct correlation between SARS-CoV-1 case fatalities and short-term exposure to ambient air pollution and hypothesized that exposure to air pollutants, such as PM_{10}, might not only influence the prognosis of SARS but also lead to increased risk of death (Figure 2).[11]

These findings alimented an emerging mindset where an association between exposure to air pollution and COVID-19 infection seemed inevitable. A position paper published by Setti et al. claimed that the rapid spread of COVID-19 observed in selected regions of northern Italy is supposedly related to PM_{10} pollution because of airborne particles able to serve as carrier of pathogens. Their claims were based on the analysis of compiled meteorological data (satellite and surface collected) and COVID-19 data (infections, fatality cases, etc.) collected in the Lombardy region of northern Italy (Figure 3).[1,2] As a result, a cascade of works based on data analysis have emerged from around the world as to address the question at hand. In particular, works conducted by Wu et al. and Travaglio et al. analyzed data collected in the United States[12] and England[13] and showed positive associations/correlations between the exposure to different air pollutants and the number of Covid-19 infections and fatalities. Without any doubt, these studies put into light a correlation between air pollutants and COVID-19 cases while stopping short of establishing pollutants as vectors of SARS-CoV-2, which in fact is the question at hand. This has been clearly stated by Bontempi in his analysis of data collected in Lombardy and Piedmont regions where a high number of cases was registered. The study showed that cities that suffered from the most severe event of PM_{10} pollution (Torino and Alessandria), in the 20 days before the Italian sanitary crisis, had low infection cases (0.01% and 0.03%, evaluated on total population on March 12). Bontempi concluded that "direct correlations between…high quantities of PM10 and the diffusion of COVID-19 are not evident."[3]

All the above-mentioned studies focus on the analysis of medical data and meteorological factors and data. While some of them label PM of air pollution as vectors of viruses, it is clear that data analysis has, in this case, its limitations in proving the role of PM in particular and air pollutants in general as vectors of infectious SARS-CoV-2. Even though studies showed that genetic material of SARS-CoV-2 might be associated with PM obtained from highly infected areas, none of them investigated whether the virus was infectious or not. In addition, no study of virus-PM surface interactions have been conducted to date. As mentioned in most of the literature works discussed in this



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C	69	56	53	25	18	40	nd	nd	nd	58	25	21	44	33	33	63	50	39	43	27	45	54	59	72	76	34	66	nd	nd
D	88	58	56	13	18	39	68	69	82	68	34	38	80	50	40	71	73	61	54	22	74	51	49	67	84	35	28	24	35
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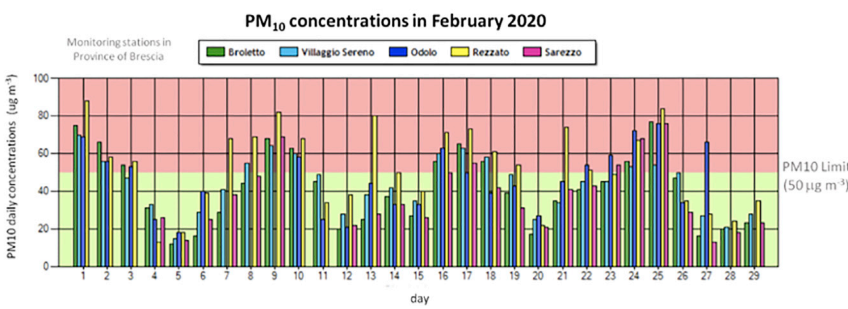

Figure 3. Potential Correlation between the Concentration of PM_{10} and the Spread of Covid-19 Cases in Italy

(A) Infection spread trends in Northern and Southern regions in Italy and (B) PM_{10} concentration levels and limit value exceedances in Province of Brescia in February 2020.[1,2]

article, there is an urgent need for experimental and *in vitro* results that could confirm or disprove if PM are indeed vectors of SARS-CoV-2 in particular, and viruses in general.

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1. Setti, L., Passarini, F., de Gennaro, G., Di Gilio, A., Palmisani, J., Buono, P., Fornari, G., Perrone, M.G., Piazzalunga, A., Barbieri, P., et al. (2020). Evaluation of the Potential Relationship between Particulate Matter (PM) Pollution and COVID-19 Infection Spread in Italy, http://www.simaonlus.it/wpsima/wp-content/uploads/2020/03/COVID_19_position-paper_ENG.pdf.

2. Setti, L., Passarini, F., De Gennaro, G., Barbieri, P., Perrone, M.G., Piazzalunga, A., et al. (2020). Potential role of particulate matter in the spreading of COVID-19 in Northern Italy: first observational study based on initial epidemic diffusion. BMJ Open *10*, e039338.

3. Bontempi, E. (2020). First data analysis about possible COVID-19 virus airborne diffusion due to air particulate matter (PM): The case of Lombardy (Italy). Environ. Res. *186*, 109639.

4. Gormley, M., Aspray, T.J., Kelly, D.A., and Rodriguez-Gil, C. (2017). Pathogen cross-transmission via building sanitary plumbing systems in a full scale pilot test-rig. PLoS ONE *12*, e0171556.

5. van Doremalen, N., Bushmaker, T., and Munster, V.J. (2013). Stability of Middle East respiratory syndrome coronavirus (MERS-CoV) under different environmental conditions. Euro Surveill. *18*, 20590.

6. van Doremalen, N., Bushmaker, T., Morris, D.H., Holbrook, M.G., Gamble, A., Williamson, B.N., Tamin, A., Harcourt, J.L., Thornburg, N.J., Gerber, S.I., et al. (2020). Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1. N. Engl. J. Med. *382*, 1564–1567.

7. Maitre, A., Bonneterre, V., Huillard, L., Sabatier, P., and de Gaudemaris, R. (2006). Impact of urban atmospheric pollution on coronary disease. Eur. Heart J. *27*, 2275–2284.

8. Conticini, E., Frediani, B., and Caro, D. (2020). Can atmospheric pollution be considered a co-factor in extremely high level of SARS-CoV-2 lethality in Northern Italy? Environ. Pollut. *261*, 114465.

9. Borro, M., Girolamo, P.D., Gentile, G., Luca, O.D., Preissner, R., Marcolongo, A., Ferracuti, S., and Simmaco, M. (2020). Evidence-Based Considerations Exploring Relations between SARS-CoV-2 Pandemic and Air Pollution: Involvement of PM2.5-Mediated Up-Regulation of the Viral Receptor ACE-2. Int. J. Environ. Res. Public Health *17*, 5573.

10. Reche, I., D'Orta, G., Mladenov, N., Winget, D.M., and Suttle, C.A. (2018). Deposition rates of viruses and bacteria above the atmospheric boundary layer. ISME J. *12*, 1154–1162.

11. Cui, Y., Zhang, Z.-F., Froines, J., Zhao, J., Wang, H., Yu, S.-Z., and Detels, R. (2003). Air pollution and case fatality of SARS in the People's Republic of China: an ecologic study. Environ. Health *2*, 15.

12. Wu, X., Nethery, R.C., Sabath, B.M., Braun, D., and Dominici, F. (2020). Exposure to air pollution and COVID-19 mortality in the United States: A nationwide cross-sectional study. medRxiv. https://doi.org/10.1101/2020.04.05.20054502.

13. Travaglio, M., Yu, Y., Popovic, R., Selley, L., Leal, N.S., and Martins, L.M. (2020). Links between air pollution and COVID-19 in England. medRxiv. https://doi.org/10.1101/2020.04.16.20067405.