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POSSIBLE IMPACT OF ATMOSPHERIC PARTICULATE MATTER AND INDOOR STAYING BEHAVIOUR IN WINTER ON SARS-COV-2 TRANSMISSION: AN EXPLORATORY REVIEW

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ABSTRACT

The COVID-19 pandemic caused by a zoonotic virus - Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) demands knowledge about the impact of environmental factors in the epidemiology of the disease. Lower air temperature and lower humidity could be associated with increased SARS-CoV-2 transmission like other human coronaviruses (HCoVs). The higher stability of SARS-CoV-2 in lower temperature is also reinforcing this assumption. In winter, the levels of atmospheric particulate matter (PM) remains significantly high which could act as a mechanical transport vector for SARS-CoV-2 apart from its role as a pollutant that causes inflammation in the lungs and contribute to the severity of COVID-19. Moreover, inhaling small airborne droplets is also a probable transmission route for SARS-CoV-2 and this could be significant during longer indoor staying behavior in winter. Asymptomatic and pre-symptomatic cases of SARS-CoV-2 are also evident. High population density in urban areas forces more people to share common space inside houses, thus creating a possible virogenic environment. It is postulated that the changes in human behavior, such as staying relatively more time indoors, and the increased stability of SARS-CoV-2 during the winter months along with higher atmospheric PM concentration may develop a favorable situation for SARS-CoV-2 transmission.

Keywords: SARS-CoV-2, Atmospheric Particulate Matter, Indoor Staying Behavior, Transmission Dynamics

INTRODUCTION

Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) causing COVID-19 disease has led to over 1.5 million deaths with more than 65 million confirmed cases around 220 countries since its emergence in Wuhan, China (WHO, 2020). Emergences of more evolved SARS-CoV-2 strains are possible and this could complicate the situation further (Chatterjee and Bhattacharya, 2020). The novelty of the virus demands knowledge about the impacts of environmental factors on its transmission dynamics (Bhattacharya *et al.*, 2020). Studies showed that in favorable climatic conditions air pollutants - such as particulate matter (PM) - could function as mechanical transporter of SARS-CoV-2, and likely facilitate the longevity of the virus (Martelletti and Martelletti, 2020; Conticini *et al.*, 2020 & Frontera *et al.*, 2020). Atmospheric PM (PM 2.5 and PM 10) level varies in different season and has been found to be the highest in winter (Vinitketkumnuen *et al.*, 2002). Lower air temperature and lower humidity can be associated with increased SARS-CoV-2 transmission (Chin *et al.*, 2020). Shortened half-life of SARS-CoV-2 at warmer temperatures and higher humidity (Chin *et al.*, 2020) along with the seasonality of other HCoVs such as HCoV-NL63 (Abdul-Rasool and Fielding, 2010), HCoV-HKU1 (Esper *et al.*, 2006), and flu viruses (Sooryanarain and Elankumaran, 2015) are indicative and reinforcing this assumption. Primarily seasonal coronaviruses (sCoVs) causing common cough and cold (viz. HCoV-229E, HCoV-OC43, HCoV-HKU1, and HCoV-NL63) in most temperate sites are found to be prevalent in winter months (Li *et al.*, 2020). In tropical countries, in winter people prefer to stay more indoors to be protected from the cold outside, thereby, increasing the possibilities of exposure to the infection in a confined indoor environment (Comunian *et al.* 2020 & WHO, 2020). This review will explore the possible association between PM levels in different seasons and SARS-CoV-2 transmission. Attempt has also been made to assess and analyze the impact of indoor staying behavior in winter on the transmission of SARS-CoV-2.

REVIEW OF LITERATURE

Atmospheric Particulate Matter and SARS Coronaviruses

Atmospheric PM is a heterogeneous mixture of solid and liquid particles suspended in the air with various sizes and chemical compositions (WHO, 2013). Domestic coal burning in stoves, used for winter domestic heating, and vehicular traffic are the key sources of PM (Jandacka and Durcanska, 2019). Being trapped in the nose, mouth, or throat PM can easily go through the lung and be absorbed in the blood circulation system (Dobaradaran *et al.*, 2016 & Marzouni *et al.*, 2017). It has been reported that atmospheric PM could act as a mechanical transport vector and carry viruses (Comunian *et al.*, 2020). SARS-CoV-2 could also get transmitted through air, where atmospheric PM can function as a carrier through the aerosol and in turn enhances the spread of the virus (Comunian *et al.*, 2020). Moreover, PM induces inflammation in lung cells, thus exposure to PM could intensify the susceptibility and severity of COVID-19. Angiotensin-converting enzymes 2(ACE2) receptor produces anti-inflammatory peptides and remains over-expressed during inflammation from the PM exposure. This over-expression can increase the probability of SARS-CoV-2 to penetrate the cells as the virus needs to bind with the ACE2 receptor to enter the cell (Comunian *et al.*, 2020 & Lin *et al.*, 2018).

Several scientists demonstrated seasonal patterns in PM 2.5 concentrations which remain highest during the winters followed by pre-monsoon, post-monsoon, and monsoon seasons, and PM10 which also remains much higher in winters as compared to the other seasons (Vinitketkumnuen *et al.*, 2002; Devraj *et al.*, 2019). The higher PM levels in urban areas in winter are significant in the context of SARS-CoV-2 transmission as a positive correlation has been drawn by investigators between the case incidences and atmospheric PM concentrations (Zhu *et al.*, 2020). Moreover, during the 2003 SARS outbreak in China, a positive association was also seen between the SARS case-fatality rate and pollution measures (Cui *et al.*, 2003).

Indoor Staying Behavior in Winter and its Possible Association with SARS-CoV-2

The likely airborne transmission of SARS-CoV-2 by the dissemination of aerosol, like many respiratory viruses, particularly in indoor settings with poor ventilation has been deliberated and discussed by many authors (WHO, 2020; Kohanski *et al.*, 2020; Comunian *et al.*, 2020). In a room setting, emission of moist droplets from mouth and nose are influenced by the initial velocity of release. These droplets begin to evaporate, their size decreases, and eventually become small enough to re-circulate in the air (Kohanski *et al.*, 2020; Comunian *et al.*, 2020). People prefer to stay indoors in winter with the windows and doors closed most of the time. Comparison between developed countries and developing countries shows that the population density in urban areas is much higher in the developing countries and a significant percentage of people live in slums as well (World Bank, 2020 a, b). This suggests that the number of people sharing common space inside houses in these areas is more than usual, which thus brings more people together in close contact in poorly ventilated settings. It has been perceived in experimental studies that air re-circulation in public transports such as buses can increase the risk of SARS-CoV-2 infection owing to its possible airborne transmission mechanism (Shen *et al.*, 2020). In urban and suburban areas of developing countries, most people do not have private transport, which forces them to avail public transportations. These vehicles having several people inside and the windows closed in winter create a propitious situation for viral transmission through airborne pathways, inevitably increasing the chances of viral infection.

Seasonal Prevalence of Human Coronaviruses

HCoV-OC43, -229E, -NL63, and -HKU1 that causes upper and lower respiratory tract infections (Bhattacharya *et al.*, 2020) are known for their seasonal prevalence. Studies revealed that these coronaviruses are up to 10 folds more prevalent during the winter months in comparison to summers (Neher *et al.*, 2020). A similar pattern has been observed for the SARS-CoV, as the virus was most prevalent and had peak transmission at a mean temperature of 16.9˚C with mean relative humidity of 52.2% (Yuan *et al.*, 2006). The community transmission of SARS coronavirus during the 2003 epidemic in the subtropical cool environment can be attributed to its better stability at low temperature and low humidity (Chan et al., 2011). The role of temperature and humidity in the stability of SARS-CoV-2 has also been demonstrated by several groups of investigators (Biryukov *et al.*, 2020; Chin *et al.*, 2020). Experimental results provide evidence that SARS-CoV-2 decayed more rapidly when either humidity or temperature was increased (Biryukov et al., 2020; Chin *et al.*, 2020; Bhattacharya *et al.*, 2020). Chin *et al.*, 2020 reported that SARS-CoV-2 is highly stable at 4˚C with a log-unit reduction of 0.7 after 14 days of incubation and when the temperature was increased to 70˚C the time for inactivation reduced only to 5 minutes. Furthermore, the half-life of SARS-CoV-2 at room temperature (24°C), ranges from 6.3 to 18.6 hours depending on the relative humidity (Biryukov et al., 2020) with the half-life in aerosol being approximately about 1.1-1.2 hours (Zhu *et al.*, 2020). During the winters the ultraviolet radiation from direct sunlight is much less (Thieden *et al.*, 2006) in comparison to summer. This in turn may increase the prevalence of SARS-CoV-2, especially in aerosol, as experimentally UV radiation has been found to be effective in inactivating SARS-CoV-2 (Ratnesar-Shumate *et al.,* 2020).

DISCUSSION

The significance of viral transmission via aerosol has been profoundly discussed in respect of the SARS-CoV-2 transmission dynamics. Several investigators apprehended possible links between air pollution and the transmission of SARS-CoV-2, owing to the ability of atmospheric PM to act as a mechanical carrier of SARS-CoV-2 (Setti *et al.*, 2020; Conticini *et al.*, 2020; Brandt *et al.*, 2020). Pollution-induced inflammation has also been considered as a putative factor to increase the severity and symptoms of SARS-CoV-2 infection (Comunian *et al.*, 2020). The Italian regions Lombardy and Emilia Romagna, with the highest air pollutions level, were the focused points of the SARS-CoV-2 outbreak in Italy and recorded the highest SARS-CoV-2 lethality (Conticini *et al.*, 2020). Furthermore, a significant positive correlation has been found between morbidity and mortality of COVID-19 and high pollution levels in cities of China's Hubei province, the epicenter of the SARS-CoV-2 outbreak (Brandt *et al.*, 2020). Comparative analysis of PM concentrations at different months also validates the fact that PM concentration in the air remains significantly higher in the winter season (Vinitketkumnuen *et al.*, 2002; Devraj *et al.*, 2019). Considering this association between winter and high PM concentration possibilities arise that SARS-CoV-2 transmission can be facilitated in winter by the increased atmospheric PM concentrations. Similar associations of higher prevalence of influenza virus in winter due to higher atmospheric PM have been made by many investigators (Liang *et al.*, 2014; Murtas and Russo, 2019). However, this assumption requires further validation through experimental studies and field evidences.

It has been found that sharing indoor space could be a major risk factor in the transmission of SARS-CoV-2 (Allen and Marr, 2020) and could be ascribed to the airborne transmission of the virus. Apart from the widely recognized transmission via larger respiratory droplets and direct contact, inhaling small airborne droplets is also a probable transmission route for SARS-CoV-2 (Morawska *et al.*, 2020; WHO, 2020). During the winters this mode of transmission can be more significant due to the prolonged indoor stay of humans by compulsion. Moreover, high population density with a significant percentage of slum living people (World Bank, 2020b) in urban areas of developing countries could also increase the risk of infection. High population density indicates more number of people sharing a single household or living space, which in turn may create a congenial situation for the establishment of a virogenic environment during the winters. The higher case incidences of COVID-19 in urban areas of India than in rural areas could also be attributed to the population density (V *et al.*, 2020). Furthermore, the stability of SARS-CoV-2 for extended periods on surfaces under indoor conditions has been well demonstrated (Ratnesar-Shumate *et al.*, 2020). Transmission of SARS-CoV-2 from asymptomatic and pre-symptomatic persons has been reported, but to what extent and the transmission routes are not yet fully understood (Gao *et al.*, 2020). During the winters, common cold or influenza are commonly prevalent with symptoms like sneezing and coughing (Acharya and Thapa, 2016). Co-infection of patients with both influenza and SARS-CoV-2 has been found (Konala *et al.,* 2020). Owing to longer indoor stay in winter, the pre-symptomatic and asymptomatic persons if any could also unknowingly transmit the virus to others. The possibility of SARS-CoV-2 transmission from asymptomatic and pre-symptomatic individuals during indoor staying is a matter of great concern, hence requires a comprehensive scientific investigation in order to formulate the preventive strategies. Airborne transmission risk also gets influenced by aerosol properties, virus-specific, and host-specific factors (Kohanski *et al.*, 2020) which are beyond the scope of this review. During the winters, people tend to stay more indoors, and hence deprive themselves of reasonable sunlight, which may lead to vitamin D deficiency. This deficiency may weaken the immune system (Acharya and Thapa, 2016). Prevalence of several respiratory diseases such as influenza, tuberculosis, cystic fibrosis has been linked with Vitamin D deficiency and compromised immunity (Hughes and Norton, 2009; Acharya and Thapa, 2016). A similar association has been reported between the COVID-19 and Vitamin D as well (Marik *et al.*, 2020; Grant *et al.*, 2020; Radujkovic *et al.*, 2020). Almost all of the HCoVs are prevalent during the winters owing to their high stability at low temperature and humidity (Biryukov *et al.*, 2020; Chin *et al.*, 2020) in different bio-geographical regions. It is postulated that the changes in human behavior, such as staying relatively more time indoors, and the increased stability of SARS-CoV-2 in winter along with higher atmospheric PM concentration may create a congenial environment for SARS-CoV-2 transmission.

CONCLUSION

The seasonality of HCoVs including the SARS-CoV is a known phenomenon for many years. However, the seasonal prevalence of the novel coronavirus (SARS-CoV-2) is not yet evidenced. In winter, the PM remains closer to the surface with higher concentrations than usual. This situation prevails especially in urban areas. The increased PM concentration favors SARS-CoV-2 transmission. Atmospheric PM not only causes lung infections but also amplifies the severity of COVID-19 and enhances the possible transmission of the virus through aerosols. The airborne transmission has been evidenced during previous coronavirus epidemics (SARS-CoV and MERS-CoV). Airborne transmission by dissemination of aerosol is proposed as a route of SARS-CoV-2 transmission, especially in poorly ventilated settings. Indoor staying behavior in winter forces people to be in closed and poorly ventilated environments which create conducive situations for disease transmission. The spread of human coronaviruses is more serious in urban areas, and the higher population density could be one of the reasons behind this. Nevertheless, the magnitude of COVID-19 cases may vary even in winter months in different regions of the world as the above-mentioned factors are not the only drivers of the disease. We conclude that in winter, higher PM concentrations and increased indoor staying behavior, specially in urban areas, could create a transmission-friendly situation for SARS-COV-2 and can contribute as important drivers in the COVID-19 disease epidemiology.

Conflict of Interest

The authors declare that they have no conflict of interest.

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