

# Is it time to consider shreds of epidemiological and environmental evidence associated with high transmission of COVID-19?

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## ABSTRACT

Novel coronavirus named COVID-19 that emerged in late December from Wuhan affected almost the entire globe. Recent studies provided new insight into the high transmission of the disease. This review explores the current evidence of epidemiological and environmental factors associated with high transmission of COVID-19. Even transmission and symptoms found among cats, dogs, ferrets, and tiger suggested low species barrier of the virus. The airborne transmission was found even up to 4 m, and fecal transmission with virus particles and RNA in sewage and wastewater suggests rethinking containment strategies. However, temperature, humidity, and pollution were also associated with transmission and mortality trends of COVID-19. To better mitigate and contain the current pandemic, it is a need of hours to consider the recent shreds of evidence to prevent further spread and require detailed investigations of these evidences by extensive epidemiological and meteorological studies.

**Keywords:** Airborne, animals, asymptomatic, COVID 19, humidity, Mers coronavirus, novel corona virus, pollution, SARS-Cov-2, sewage, temperature

## Introduction

A novel human coronavirus emerged as an epidemic in Wuhan, China, in late December. On 11 February 2020, WHO officially named the coronavirus disease 2019 (COVID-19), and the coronavirus study group of the International Committee suggested naming it as SARS-CoV-2.<sup>[1]</sup> It has become a pandemic now. As of 27 May 2020, nearly 64,820,412 cases and 14,98,303 deaths have been reported worldwide.<sup>[2]</sup>

Coronaviruses are enveloped, single-stranded, positive-strand RNA viruses, pathogenic for both animals and humans. In

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recent decades, two other novel coronaviruses (SARS-CoV and MERS-CoV) had spread as epidemics to 37 and 27 countries worldwide, respectively. Both viruses are zoonotic and have a low capacity for sustained community transmission. However, it was observed in 2003 for SARS and 2014–17 for MERS that a significant proportion of cases were asymptomatic. Even 229E, OC43, NL63, and HKU1 are well adapted to humans but SARS-CoV and MERS-CoV viruses are not as well adapted, and thus, spread to mainly in a zoonotic reservoir, with occasional spread into the susceptible humans, possibly through an intermediate host species, facilitating for genetic recombination, resulting in novel viruses. Recombination of CoV in camels, resulting in a dominant MERS lineage and caused human outbreaks in 2015.<sup>[3]</sup> Additionally, the phylogenetic analysis concludes that bats might be the real host

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of SARS-CoV-2, sold at the seafood market in Wuhan, China. It might represent an intermediate host of the virus in human outbreaks.<sup>[4]</sup> After laboratory analysis, it is well established that both SARS-CoV and SARS-CoV-2 enter into the cell through the angiotensin-converting enzyme-2 receptor that is host and tissue specific. In humans, ACE2 receptors are present in lung and small intestine epithelial tissue, where the virus primarily replicates and produces infection. In Wuhan, the initial clinical presentation of cases was lower respiratory tract infection with fever, dry cough, and dyspnea.<sup>[5]</sup> It is well proven that SARS-CoV-2 can be transmitted through the respiratory tract, digestive system, and mucosal surfaces such as conjunctiva and saliva. In Beijing, serial samples of 82 COVID-19 patients from throat swabs, sputum, urine, and stool were collected and found that viral load was higher in sputum sample followed by throat swab, nasal swab, and stool sample, maximum at around 5–6 days after onset of symptom.<sup>[6]</sup>

### **Pet and wild animals as a potential intermediate host for SARS-Cov-2?**

Bats are most likely ecological reservoirs for SARS-CoV-2, but it is believed that this virus crossed the species barrier to humans from any other intermediate animal host. A domestic food animal, a wild animal, or a domesticated wild animal could be the intermediate animal host, but it has not been identified.<sup>[4]</sup> In the Wuhan outbreak, it was found that SARS-CoV-2 antibodies were present in 14.7% of cats, suggesting that cats' infection could be because of transmission from humans during the outbreak. Wuhan and other affected regions might have infected (SARS-CoV-2) cat populations.<sup>[7,8]</sup> March 2020, a pet cat in Belgium and similar cases of two dogs and pet cat in Hong Kong were found positive for SARS-CoV-2 but remained asymptomatic. Further, on April 5, 2020, a tiger (wild cat) was also positive for SARS-CoV-2 at Bronx Zoo, New York. These animals might have contracted the virus from the infected person in their surroundings. Cats are the most susceptible host than ferrets, but both can transmit the infection to other cats and ferrets but are less likely to produce disease.<sup>[9]</sup> Moreover, one study found that cats can transmit SARS-CoV-2 through respiratory droplets as, after inoculation of SARS CoV-2 in cats, viral RNA was present in the upper respiratory tract of all cats, and viral replication and clinical symptoms were found in both ferrets and cats, even transmission of infection found between cats. However, no evidence of cats to human transmission was recorded.<sup>[8]</sup> After some days, suddenly, authorities of Shenzhen city, China, announces to stop dogs and cats' meat consumption in the city. The reasons are not clear but might be a possible threat of these animals' virus transmission potential, which prompted China's authorities to ban wild animals' trade.<sup>[10]</sup> On 8 April 2020, Centers for Disease Control and Prevention (CDC) updated that pets have other types of coronaviruses, like canine and feline coronaviruses, affecting them only, not humans, and are not linked to the present COVID-19 outbreak. CDC also did not declare any evidence to conclude that imported animals or related products risk spreading COVID-19 in the United States.<sup>[11]</sup> On

the other hand, as of 9 April 2020, the OIE-World Organization of Animal Health commented on the current evidence that COVID-19 has emerged from an animal source. Data from the genetic sequence revealed a close relative of other coronaviruses circulating in *Rhinolophus* bat populations. Now it has spread to humans, possibly through infected animals.<sup>[9,5]</sup> In view of the spread of COVID-19 infection, the Government of India, Ministry of Environment, Forest and Climate Change, had issued an advisory for preventive measures to stop the transmission and spread of the virus from animal to humans and vice versa, in National Parks, Sanctuaries, and Tiger Reserves.<sup>[12]</sup> In Hong Kong, one pet dog has been investigated for COVID-19 infection after exposure to COVID-19 affected family and quarantined after getting positive reports on two separate occasions. However, the dog does not show any clinical signs and symptoms. This incidence also reflects the picture of human to the virus's animal transmission.<sup>[13]</sup> All evidence suggested that SARS-Cov-2 can cross the species barrier and human-to-human transmission is more usual and virulent.<sup>[5]</sup> Some pet and wild animals have been infected, who live in close contact with humans if they have any respiratory symptoms, needs detailed surveillance. Large-scale serological epidemiologic investigations of susceptible animals are required for better containment of possible virus transmission among the community.

### **Food contamination and fecal shedding of the virus as possible threats**

SARS-CoV-2 can spread directly from human to human through droplets produced by coughs or exhales of COVID-19 case that reach to healthy person's nose and mouth in hospital and family settings through direct contact or as droplets.<sup>[6,14,15]</sup> SARS-CoV-2 can remain viable for up to 3 h in the air, 72 h on stainless steel and plastic, up to 4 h on copper, and nearly 24 h on cardboard and can spread infection through contact of contaminated objects and airborne.<sup>[14]</sup> Moreover, the most infected hospital setting areas were the ICU following the Obstetric Isolation Ward, Isolation Ward, Fever Clinics, CT Examination Room, and General Ward. The most infected articles and PPE for COVID-19 management in hospital settings were hand sanitizer dispensers followed by self-service printers, desktops, doorknobs, gloves, telephones, public facilities, and from walls and floor of the hospital explained the massive healthcare facility acquired infection found in 2,055 HCW all over China by February 20, 2020.<sup>[16]</sup> Food and packaging have a significant risk of contracting viruses as, during shopping, we touch a shopping cart or basket, which comes in contact with other symptomatic and asymptomatic people. As it was observed that SARS-CoV-2 could remain on smooth, hard surfaces, including car door handles, lift buttons, and ATM surface, for up to 3 days.<sup>[14,17]</sup> WHO issued a report that there was no evidence of transmission of COVID-19 through food to date. Interestingly, consumption or contact of raw foods of animal origin and raw milk is considered possible SARS-CoV-2 transmission sources in humans. WHO advised that the virus is thermolabile, so food should be cooked properly, raw meat and milk should be handled with extra care.<sup>[18]</sup> However, no enough studies and

evidence are available. Further research is needed to explore any possible food-borne transmission, as might occurred in Wuhan, either through contact or consumption of contaminated food. In Singapore, early investigations reported SARS-CoV-2 was detectable in the shedding from the nasopharynx in 83% of patients, followed by stool in 50% of patients. However, the infectivity of the virus in feces was low.<sup>[19]</sup> Another study on three patients in Singapore obtained genetic material of SARS-CoV-2 from stool samples of infected patients who had no pneumonia or diarrhea but have upper respiratory symptoms.<sup>[20]</sup> Moreover, a study conducted in China found respiratory and gastrointestinal excretion of SARS-CoV-2 virus in most pediatric patients. The virus remained detectable well in feces even after nasopharyngeal swabs turned negative, indicating that rectal swab testing might be more useful for treatment progression monitoring and decision making to terminate quarantine after recovery.<sup>[21]</sup> In Queensland, Australia, using RT-q PCR, two times, RNA copies of SARS-CoV-2 detected within 6 days; when using wastewater epidemiology, the estimated RNA copies in wastewater were similar to infected persons residing in the catchment area.<sup>[22]</sup> Even in the Netherlands, sewage samples from seven cities and airports showed COVID-19 positive when tested using RT-PCR for nucleocapsid protein gene (N1-3) and envelope protein (E). It suggested sewage surveillance as an essential and sensitive tool for virus infection among the population.<sup>[23]</sup> Ministry of Health and Family Welfare, India's government, considered this route a lower risk for transmission for COVID-19 and acknowledged a virus in some reported studies but not considered any role of fecal-oral transmission in the present outbreak.<sup>[24]</sup> This might be a possible route of transmission of COVID-19 among humans and animals, evident by GI symptoms and viral RNA or live infectious virus presence in feces of infected cases. Routine wastewater surveillance during and after pandemic for SARS-CoV-2 may be beneficial for detecting the presence of the virus in the community and its recurrence. Further research and investigations need the hour to know the virus's capability to produce clinical infection and immune response in humans and animals to these mild infections and for utilization in disease surveillance.

### Possible aerosol transmission for better containment strategies

Aerosol transmission may be possible if prolonged exposure to elevated aerosol concentrations in closed areas. In a study, aerosol particle sized  $<5 \mu\text{m}$  were found viable and transmissible throughout the experiment's 3 h duration at room temperature  $21\text{--}23^\circ\text{C}$ .<sup>[16,25]</sup> During isolation of 13 confirmed positive cases of COVID-19 in the University of Nebraska medical center, human-to-human transmission occurred through fomite and airborne transmission.<sup>[26]</sup> A recent study conducted in a hospital in Wuhan, China, found that COVID-19 can spread in the air with high ICU contamination than in the ward. Floor, desktop, fan, window, and other objects were contaminated with an actual transmission distance of about 4 m.<sup>[21]</sup> Improper ventilation with asymptomatic carriers is also a potential source of SARS-CoV-2

through airborne particles. The virus aerosol deposited on PPE and floor surface, and subsequently, its re-suspension is a possible route of transmission.<sup>[19,27]</sup> But, WHO maintains the same rhythm and recommendation in the context of COVID-19 transmission through contact and droplets route.<sup>[28]</sup> However, this is the need of time when these recommendations must be revised on behalf of present knowledge and evidence to frame appropriate guidelines for isolation and physical distancing. However, further necessary investigations are needed to establish a final opinion. It may take time and cost lives to collect evidence, considering the possible airborne transmission of COVID-19 is the need of the hour for containment strategies.

### Asymptomatic cases as major challenges for mitigation of pandemic

Reproductive rate ( $R_0$ ) is the expected number of secondary cases generated by one primary point in a susceptible population. Initially,  $R_0$  estimated in Wuhan was 2.2 with a mean incubation period of 5.2, based on 425 cases. WHO estimated reproductive number is between 1.4 and 2.5 while other studies have estimated differently between 3.6 and 4.0, and between 2.24 and 3.58. The more extended incubation period, estimation of the higher reproductive number, and shorter serial interval suggested that SARS-CoV-2 has more transmission potential than MERS.<sup>[3]</sup> Another study conducted in India by ICMR using simple mathematical models of infectious disease transmission estimated the lowest reproductive rate was 1.5 if viral transmission through symptomatic cases only. The highest reproductive rate was four if 50% of asymptomatic cases found were infectious.<sup>[29]</sup> It suggested that previously estimated  $R_0$  excluded asymptomatic patients, which is a major limitation of predicting the reproductive rate and transmission of COVID-19 spread, depends on infectivity and detection of asymptomatic cases.

In a study conducted in China, a total of 24 asymptomatic, infectious cases of COVID-19 were found, and 30% of cases were younger with a median age of 14 years. These cases had no symptoms with normal CT images during hospitalization. Even these cases transmitted severe pneumonia to close contacts. Children appeared to have a mild clinical course, but they may be more asymptomatic.<sup>[30]</sup> In China, a cohort of 1,099 patients with COVID-19 from 552 hospitals, 8.9% of the SARS-CoV-2 infected patients were without signs and pneumonia symptoms before admission.<sup>[31]</sup> It is necessary to test asymptomatic COVID-19 patients and pneumonia patients to find more COVID-19 patients early and reduce the broad transmission of disease. In Yokohama, Japan, a cruise ship, the Diamond Princess hosting 3,711 people, quarantined for 2 weeks on 5 February 2020. Interestingly out of 634 COVID-19 positive cases, 328 were found asymptomatic, which is more than 50% of confirmed cases.<sup>[32]</sup> A study conducted in India indicated that asymptomatic COVID-19 patients might increase early community transmission risk to understand the impact. A mathematical model-based approach was opted in the study; in an optimistic scenario, if

half of the symptomatic carriers identified and quarantined with assumptions that asymptomatic patients would not be spreading the disease, the disease prevalence would be reduced by 62%. In contrast, in the pessimistic scenario, if asymptomatic patients are 50% as infectious as symptomatic patients, the impact of quarantine of half of the symptomatic patients would be only 2%.<sup>[29]</sup> Indicating an alarming contribution of asymptomatic cases to the local transmission, and it is required to take necessary actions by policymakers of countries to prevent community transmission.

### Environmental variations associated with COVID-19 transmission and mortality

**Temperature and humidity-** In a study, the HKU39849 strain of SARS-CoV was used to assess the relative effect of temperature and humidity on the SARS coronavirus viability and transmission potential and found higher temperature and high humidity lost viral viability rapidly. While low temperature, low humidity, and the air-conditioned environment favor virus transmission and explained low transmission of SARS-CoV in tropical countries like Indonesia, Malaysia, and Thailand and high transmission in sub-tropical areas like Hong Kong.<sup>[33]</sup> Similar results were also observed in a study performed in China (21--23 January 2020) using  $R_0$  values of COVID-19 in different China cities. They found that transmission of the virus ( $R_0$ ) reduced significantly with high temperature and high humidity, similar to influenza and SARS as previous studies. For every 1°C increase in temperature and 1% increase in humidity, it reduced  $R_0$  by 0.0225 and 0.0158 and explained the reason for Japan, Korea, and Iran had a low temperature and low humidity for facing severe outbreak in comparison to warm and humid countries like Malaysia, Thailand, and Singapore.<sup>[34]</sup> With findings of a study, 90% of COVID-19 infection spread in countries with temperatures from 3°C to 17°C and humidity from 4 to 9 g/m<sup>3</sup>. In comparison, infection in countries with absolute humidity of more than 9 g/m<sup>3</sup> contributed less than 6%. However, findings suggested that due to already widespread transmission, the effect of humidity will be seen in North America and Europe after May.<sup>[35]</sup> Another study related high impact of temperature on COVID-19 spread and commented 10% reduction in infectivity on an increase of every 1°C above 5°C if physical distancing and other measures are at the right place. It also suggested that the southern hemisphere will face increased epidemic compared to the northern hemisphere, but the northern hemisphere also needs to limit air conditioners' use.<sup>[36]</sup> A study conducted between 20 January and 29 February 2020 in Wuhan, China, found daily death was related to temperature variation and humidity. A positive association was found between the diurnal temperature range and COVID-19 deaths. Still, temperature and humidity were negatively associated with COVID-19 mortality, explained that the higher deaths might be related to low humidity in the winter season.<sup>[37]</sup> Between 20 January and 4<sup>th</sup> February 2020, there were 24,232 confirmed cases in China and 26 overseas countries were included in the study and found a significant reduction of cases by 0.86 with a 1°C rise in minimum temperature. This

study again explained why the first outbreak occurred in Wuhan, as low temperature and weather have played a significant role there.<sup>[38]</sup> The virus does not replicate outside hosts but remains transmissible/infectious outside host on different surfaces depends on environmental conditions,<sup>[16,23]</sup> which is the most crucial factor of virus transmission in an epidemic of infectious disease. It is consistent with the COVID-19 pandemic, like SARS-CoV and influenza, that wake-up hopes for reduced transmission rate in the coming summer if air conditioners will be used cautiously, especially in malls, workplaces, and hospitals with better case detection, isolation, and quarantine measures.

### Pollution

Incidence of infections increases with the increase of airborne particulate matter; the same might have happened with Northern Italy. Italy's southern region followed normal human-to-human contact transmission while the Northern region experienced an increasing outbreak. This surge was observed because of the high level of PM<sub>10</sub> concentration. The PM<sub>10</sub> level in Northern Italy between 7 and 29<sup>th</sup> February was more elevated than the daily average, and findings were constant with the high transmission rate of the virus in the region because the boost process of PM10 augmented the transmission of COVID-19 in that region.<sup>[39]</sup> Nevertheless, COVID-19 spread cost lives, especially the greatest lethality in the world, served in the most polluted region of Europe, in Northern Italy (e.g., Lombardy and Emilia). Particulate matter with infective pathogen act as a carrier. Long-term exposure to air pollution produced chronic inflammation and chronic respiratory diseases, disturbed the immune system, and acted as a co-factor for COVID-19 related deaths.<sup>[40]</sup> Moreover, pre-existing conditions that increase COVID-19 related mortalities are similar to high risk because of air pollution exposure. One study conducted in the USA collected data for 3,000 counties till 4<sup>th</sup> April 2020 and covered approximately 98% of its population. They calculated the effect of county-level long-term average PM<sub>2.5</sub> on COVID-19 related death as an outcome. The result was very significant and found an increase of 15% death with every 1 microgram/m<sup>3</sup> in PM<sub>2.5</sub>. Even a small increase in this long-term exposure to PM<sub>2.5</sub> resulted in massive mortality, even 20 times higher association observed for PM<sub>2.5</sub>. All caused death, which is alarming to the concerned authorities to take appropriate actions and implement air pollution regulations during and even after this outbreak.<sup>[41]</sup> In China, an increase of 10-µg/m<sup>3</sup> in PM<sub>2.5</sub>, PM<sub>10</sub>, O<sub>3</sub>, and NO<sub>2</sub> was associated with a 2.24%, 1.76%, 4.76%, and 6.94% increase in confirmed cases.<sup>[42]</sup> Particulate matter bears many viruses responsible for rapid transmission, and underlying conditions with these airborne particles might be aided factors for disease severity, especially in higher polluted regions worldwide.<sup>[43,44]</sup> However, detailed investigations are required to explore any association in air pollution, COVID-19 transmission, and mortality, but studies suggested pollution control would be a useful measure to mitigate pandemics.

## Conclusion

The novel coronavirus is not following a similar SARS-CoV pattern and continuously raising new cases, even after global lockdown, social distancing, and increased testing. Recent shreds of evidence suggested that some factors were associated with high transmission of COVID-19. Their consideration and understanding may have a potential role for better containment strategies for COVID-19. Evidence suggested that long-term pollution control measures, limited use of air conditioners, and more physical distancing in shopping areas, malls, restaurants, and workplaces even after a period of lockdown, during a pandemic may be included to prevent further transmission along with current containment measures. Temperature and humidity also might be the contributing factor for COVID-19 transmission. Evidence also concluded that regular sewage and wastewater surveillance might help detect virus presence in the community with new recurrence. Identification of various potential hosts, routes, and associated environmental factors responsible for COVID-19 spread requires detailed epidemiological and meteorological studies to mitigate the pandemic and prevent the recurrence of a pandemic possible threat. It is time to consider the pet and wild animals as a potential intermediate host for SARS-Cov-2 and asymptomatic cases as the most significant challenge for the community. In addition to the current containment strategy, more robust asymptomatic case detection with a revised guideline of isolation and quarantine is the need of the hour.

## Key Message

### Time to consider:

- Pet and wild animals as a potential intermediate host for SARS-Cov-2.
- Asymptomatic cases as the most significant challenge.
- Pollution is a co-factor related to high mortality and transmission of the virus.
- Role of airborne transmission for containment strategies.

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## Conflicts of interest

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