Review Article

Coronavirus Disease Pandemic and Insects: A Historical Overview

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Abstract | Coronaviruses have significantly changed 21st century medicine, healthcare systems, education, and the global economy by driving the ongoing coronavirus disease (COVID-19) pandemic. COVID-19 in humans is characterized by a wide range of symptoms, from asymptomatic to mild or severe illnesses, including death. The existing literature shows the roles of insect vectors in aiding the transmission of viral pathogens and the possible roles of some insects in severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission. In this study, we briefly review the possibility of biological or mechanical transmission of SARS-CoV-2 by insects in the environment.

Keywords | Insects, Biological transmission, Mechanical transmission, COVID-19, SARS-CoV-2

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INTRODUCTION

Coronavirus disease (COVID-19) is an infectious disease caused by a virus named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which was discovered in December 2019 in Wuhan, China. It is highly contagious and has spread rapidly worldwide since 2019. It can cause respiratory symptoms such as a cold, flu, or pneumonia, as well as other symptoms when it invades other body parts. Coronaviruses, like other respiratory viruses, spread quickly via the production of droplets released from the mouth or nose when a person breathes, coughs, sneezes, or speaks. Many questions persist regarding how SARS-CoV-2 spreads and its transmission route.

Furthermore, there may be concerns regarding SARS-CoV-2 transmission from insects, such as warmer weather approaches, which could pose a further threat. Insects are among the most prevalent and successful organisms on earth and play a dominant role in transmitting many critical diseases worldwide. For decades, they have been known to be among the most important vectors for the transmission of many diseases (Sharawi, 2021). There is no doubt that insects play a vital role in the transmission of many viruses because they are involved in both the mechanical and biological transmission of viruses (Chamberlain, 1968). Globally, mosquitoes are the most prominent vectors responsible for transmitting infections to humans. They are responsible for the spread of diseases such as malaria, Zika fever, West Nile fever, Eastern equine encephalitis, chikungunya, yellow fever, and various other diseases.

Biological transmission occurs when a vector is infected and replicates the virus during its feeding cycle, after which the virus can spread to susceptible hosts through the feeding cycle (Balaraman et al., 2021). Mechanical transmission occurs when the virus is passively acquired and harbored for a short period on a vector's internal or external surfaces, and then transported from one source to another (Balaraman et al., 2021). It is estimated that viruses could remain viable on smooth surfaces in the environment for up to 72 h (Kwon et al., 2021) and for days in feces (Wu et al., 2020) and urine (Liu et al., 2021).

Viruses can remain stable for a long time, and combined with the behavior and dietary habits of insects, this allows them to spread. This study presents a brief overview of how insects in the environment can spread SARS-CoV-2 via biological and mechanical routes.

Mechanical transmission

Mechanical transmission occurs when, in addition to passive transmission, contaminated mouth parts, legs, setae, or any other part of an insect's body transmit pathogens without any developmental changes or multiplication of the pathogen within or on the surface of the insect. Therefore, the insect only serves as a medium for transferring the virus (Barclay and Esther, 2020). Cockroaches are among the most common carriers of diseases and belong to the Blattodea order. Additionally, they are one of the oldest groups of insects on the planet and have been around for about 300 million years. It is estimated that approximately 5000 species of cockroaches have been identified so far. Most of them are found in tropical or subtropical forests and are considered decomposers because they feed on dead and decaying organic matter (Appel, 1995).

Cockroaches are well adapted to living with humans because they live in shaded areas. They enter houses searching for food and shelter from the outdoors (Gondhalekar et al., 2021). Like any other insect pest, they can be classified as domestic or peridomestic, depending on where they are found. Species found mainly in indoor environments are domestic species, while those found outside buildings are known as peridomestic species. Cockroaches are not only nuisance pests but can also have serious medical implications as a result of infestation. In some cases, they come into contact with human pathogenic microorganisms on their bodies and physically or mechanically transfer them to surfaces on which food is served or handled (Pai et al., 2003).

Several new viruses that threaten human health have emerged in the last few years. They include the severe acute respiratory syndrome coronavirus (SARS-CoV), Middle East respiratory syndrome related coronavirus (MERS-CoV), Nipah, Epstein-Barr, Lassa fever, Marburg, Zika, Rift Valley fever, Chikungunya, Dengue, Ross River, and SARS-CoV-2 viruses (Dehghani and Kassiri, 2019). These viruses can be transmitted to humans by insects such as cockroaches (Mayer et al., 2017). Cockroaches spend a large portion of time in sewers, drains, or sewer pipes that contain an abnormally high concentration of pathogens and sewage (Basseri et al., 2016). They also spend a lot of time feeding on garbage, thus, accessing large quantities of human pathogens (Pai et al., 2003). Furthermore, their habitual actions and dirty behavior, such as their filthy eating habits, make them perfect hosts for various pathogens (Allen, 1987). A previous study confirmed that cockroaches are carriers of deadly pathogens, and their feces also carry pathogens (Allotey et al., 2009).

Coronaviruses can survive for quite some time in the environment. This means they can be transmitted by any organism that comes into contact with or eats human feces, such as cockroaches. Unfortunately, researchers have been unable to assess the effects of direct contact between infected cockroaches and humans or animals with COVID-19 (Reuben et al., 2020). Studies have reported that cockroaches can interact with contaminated feces and transmit coronaviruses from one individual to another. One study showed that non-blood-sucking insects could potentially contaminate the mucous membranes or conjunctival tissues of healthy individuals through direct contact (Heller et al., 2020). Contrastingly, another study reported that sewage and wastewater-based epidemiology is one of the principal causes of COVID-19 in communities across the country (Randazzo et al., 2020). Sewers are a favorite place for cockroaches to live. Hence, cockroaches that feed or interact with virus-contaminated human secretory or excretory can easily spread the virus, like cockroaches that transmit viruses from contact with the body surfaces of infected persons (Dehghani and Kassiri, 2020). Similarly, in 2020, another study reported that cockroaches mechanically transmitted SARS-CoV and other Coronaviruses (Reuben et al., 2020).

Musca domestica (Diptera: Muscidae) is the most common fly in the world, usually found everywhere within or around human habitations due to its gregarious nature and synanthropic predilection. It is an indiscriminate feeder and contaminates foods it consumes with microbial agents transported from waste-contaminated breeding habitats. The microbial agents then serve as breeding habitats for these foods eaten by unknown humans, who act as reservoirs for the microbes. House flies are drawn to human and animal exudates and excrement, as well as food items. This is a potential route for acquiring and transferring pathogens because they can carry >250 pathogens, including bacteria, viruses, protozoa, helminths, and fungi (Nayduch and Burrus, 2017). Due to their ability to move easily from one contaminated environment to another, they can spread microbial agents to adjacent environments.

Many studies have shown that houseflies carry pathogens inside their alimentary canals and on their external surfaces (Onwugamba et al., 2018). Several studies have demonstrated that house flies are capable of transmitting Turkey coronavirus (Calibeo-Hayes et al., 2003), Newcastle disease (Watson et al., 2007), porcine respiratory syndrome (Pitkin et al. 2009), and porcine transmissible gastroenteritis (Gough and Jorgenson, 1983). However, it is currently unknown whether houseflies can acquire, harbor, and transmit SARS-CoV-2; hence, this

remains an open-ended question. A study performed in 2021 found that all flies exposed to SARS-CoV-2 either in medium or milk substrates could acquire the virus after 4 or 24 h, respectively (Balaraman et al., 2021). Although the virus-spiked medium control group was unexposed to the viral RNA, the virus-spiked milk group ingested more viral RNA than the virus-spiked medium control group. In another study, house flies harbored an insufficient amount of Newcastle disease virus to transmit the pathogen to humans (Watson et al., 2007).

To date, only one experimental study has examined the mechanical transmission of SARS-CoV-2. According to the study, flies could acquire the virus and retain the viral RNA and infective virus for up to 24 h after exposure. Additionally, the flies could transfer the viral RNA, but not the infective virus, to virus-free surfaces (Balaraman et al., 2021). Another study involving researchers working with flies from a hospital with active COVID-19 cases detected SARS-CoV-2 RNA in the flies (Soltani et al., 2021). According to our previous review on houseflies, non-biting flies can mechanically transmit SARS-CoV-2 to a person by transferring pathogens from their contaminated mouthparts or bodies.

Biological transmission

The most important type of transmission of diseases by vectors is biological or passive transmission (Ismail et al., 2020). During this transmission, pathogens must undergo biological development to complete their life cycle in the vector's body. Several recent studies have examined blood-sucking insects as SARS-CoV-2 vectors (Fortuna et al., 2021); many studies have investigated mosquitoes' potential for biological transmission (Huang et al., 2020). One study detected SARS-CoV-2 in mosquitoes <24 h after virus exposure, but no biological transmission occurred (Balaraman et al., 2021). Another study examined the susceptibility of three mosquito species to the virus in 2020 by intrathoracic SARS-CoV-2 inoculation (Huang et al., 2020). No virus was found in 277 mosquitoes collected and further analyzed after inoculation. *Culex pipiens* could spread SARS-CoV-2 mechanically, while *Aedes albopictus* could not spread the virus mechanically. However, both *Culex pipiens* and *Aedes albopictus* were ineffective biological vectors (Fortuna et al., 2021). Nevertheless, the World Health Organization declared at the outset of the epidemic that mosquitoes could not transmit SARS-CoV-2 (WHO, 2020). According to experimental studies, SARS-CoV-2 cannot replicate in Aedes mosquito cells in vitro, and this was subsequently confirmed (Xia et al., 2020).

To date, no information is available on the vector competency of *Culex pipiens* for SARS-CoV-2, the virus that transmits West Nile and Usutu (Riccardo et al., 2020). Similar to mosquitoes transmission of many viruses, this presumption may be based on observations and facts gained from other Coronaviruses that have been observed and extrapolated. SARS-CoV and MERS-CoV are closely related to SARS-CoV-2; however, neither produces blood levels considered high enough to infect mosquitoes. Unlike insect-borne viruses like dengue and yellow fever, for example. There was no trace of SARS-CoV-2 in the peripheral blood of infected people or monkeys. The epithelial cells in a mosquito's midgut have to take up a sufficient viral load to make it a biological vector; then, the virus must disseminate to infect the salivary glands. Mosquitoes can only transmit viruses if they get past the midgut infection and escape barriers. Mosquitoes not susceptible to viruses bypass these barriers by inoculating the virus directly into a hemocoel. To date, there has not been a strain from this family of viruses isolated from mosquitoes. Only one study has reported on the coronavirus epidemic and mosquitoes (Fauver et al., 2017). A study in 2020 reported that mosquitoes could be used for surveillance (Huang et al., 2020). The study fed MERS-CoV to *Anopheles gambiae* mosquitoes, which had residual viral RNA, probably in their midguts, even after they had been fed the MERS virus.

Similarly, positive polymerase chain reaction detection of *Bacillus anthracis*, *Trypanosoma brucei gambiense*, and Zika virus was observed, none of which were infective or transmitted by *Anopheles gambiae*. Furthermore, RNA levels were equal to or below the input level, indicating that the organism did not replicate. The study's results showed that SARS-CoV-2 does not replicate in *Aedes* cells *in vitro* or field strains as biological control because it cannot replicate in insects that feed on blood, such as mosquitoes (Xia et al., 2020). Furthermore, even if the virus runs in their blood, the mosquito cannot be a disease vector if feeding on a native.

CONCLUSION

In December 2019, a virus named SARS-CoV-2 was discovered in Wuhan, China. It causes COVID-19, a rapidly spreading disease that is highly contagious and has rapidly spread worldwide. Insects are among the world's most prevalent and successful organisms. Hence, for decades, they have been considered important in the mechanical and biological transmission of many critical diseases and can have devastating consequences. Our review and many research papers have reported that cockroaches and houseflies can transfer SARS-CoV-2 mechanically from one part of their body to another, such as their legs, wings, and mouth. SARS-CoV-2 has shown difficulties replicating in blood-sucking insects during biological transmission. This suggests potential mechanical transmission by insects that come into contact with humans. Finally, we recommend fighting insects that transmit the Coronavirus through mechanical transmission

with various control methods, the most important of which is chemical and biological control to reduce the spread of the virus.

NOVELTY STATEMENT

Our novelty exploring the possibility of mechanical transmission of SARS-CoV-2 by insects that can come into contact with humans.

Conflict of interest

The author has declared no conflict of interest.

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