



Insect vectors of human viral diseases: Can they transmit COVID-19?

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Abstract

Many insects are naturally infected by a wide range of viruses and transmit viral diseases that cause significant morbidity and mortality to humans. Amongst insects, mosquitoes are the prominent vectors of viral diseases of which the genus *Aedes* is the most relevant species regarding disease transmission to humans. Mosquitoes mainly transmit the viruses of family Flaviviridae and the mosquito-borne *Flavivirus* diseases are the most serious and widespread. Many diseases have been caused by Flaviviruses of which Dengue viral infection and Japanese encephalitis are prominent in countries of the Asian region. Apart from the viruses of family Flaviviridae, mosquitoes also transmit viruses of families Togaviridae and Bunyaviridae, which however have caused disease outbreaks to a lesser extent than the Flaviviridae viruses. Insects other than mosquitoes transmit viral diseases to a lesser extent. Sand fly species of order Diptera transmits viruses of family Bunyaviridae, which causes Sand fly fever mainly in the countries of Europe and Africa. Insects such as cockroaches and fly species are also capable of causing viral diseases to humans, which however is by mechanical transmission, rather than the biological transmission evident in mosquitoes. Covid-19 is transmitted by a RNA virus of the family Coronaviridae, genus *Coronavirus*. There have been no reports of Covid-19 transmission by blood-sucking insects such as mosquitoes or any other such insects. However, the mechanical transmission of the virus is plausible by body parts of insects contacted with contaminated surfaces. The new coronavirus is mainly transmitted by respiratory droplets that are suspended in the air via breathing, coughing or sneezing of the infected persons. However, the virus has been detected in the feces of confirmed patients and insects in contact with or feeding on fecal surfaces may play a role in Covid-19 transmission. The coronavirus that is now threatening the world is constantly changing and subtly different from the one that first emerged in China. Everyday learning of the coronavirus and its transmission has refined our knowledge on combating it, and the role of insects in Covid-19 transmission cannot be entirely ruled out.

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1. Introduction

Insects are carriers of diseases to humans, other animals and plants. Centuries ago, they have been suggested as being possibly entailed in the spread of disease, especially with the outbreak of war (MacGregor, 1918). In 1577 Mercurialis, an Italian physician, suggested that plague, which was then ravaging Europe, was spread by flies feeding upon the diseased and dead, and later depositing fecal matter on food consumed by healthy persons (MacGregor, 1918). The connection between insects and diseases such as Yellow fever, Malaria, Anthrax, Filaria were also established a long time ago (MacGregor, 1918). The Dengue fever, whose

global incidence has grown in recent decades was named as breakbone fever at the time and was stated as an insect-borne disease of unknown origin. Sandflies and mosquitoes were named as potential vectors, but the mosquito vectors were identified as *Culex fatigans* and *Stegomyia fasciata* (MacGregor, 1918). In 1937, Cook stated of 135 species of insects as vectors of viral diseases in plants. Species of aphids (causing “curl” disease to potatoes, Bermuda Lily disease) and leafhoppers (causing “Dwarf of Rice” disease in Japan, curly top disease of sugar beet in America) were identified as some of the important plant disease vectors (Cook, 1937).

Today we are aware that insects are very common vectors of disease and transmit viral, bacterial and protozoan pathogens via their bite, or via their feces. The diseases can be asymptomatic to fatal and are commonly grouped as invasive neurological diseases, hemorrhagic fever and systemic febrile illness (Dehghani & Kassiri, 2020). Viruses transmitted by insects cause diseases that are important world-wide, and result significant morbidity and mortality in humans. However, the literature on the subject is scattered and rarely has been assembled into a single source. The present review attempts to address some key points on the subject regarding human viral diseases transmitted by insects, and the global distribution and symptoms of these diseases, virus types responsible for the diseases and species of the insect vectors are considered. Further, the possibility of insects in transmitting the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes coronavirus disease (COVID-19) is discussed.

2. Mosquitoes as vectors of human viral diseases

Amongst insects, mosquitoes are the prominent vectors of viral diseases as 3,500 species are found widely spread worldwide. These species belong to 112 genera of which four genera are repeatedly linked with disease transmission to humans in the tropics and in cooler climates: *Aedes*, *Anopheles*, *Culex*, and *Ochlerotatus*. The genus *Aedes* is the most relevant species regarding disease transmission due to their adaptability to urban life and high susceptibility to emerging and re-emerging arboviruses (Monteiro *et al.*, 2019).

Although numerous viral diseases are transmitted by mosquitoes, four have caused the most human suffering over the centuries and are continuing today. These are the viral diseases yellow fever, dengue, chikungunya and Zika fever (Powell, 2018). Dengue is associated with human epidemic diseases in urban areas and yellow fever is found in rural areas (Sarwar, 2016). Africa is clearly the ancestral home of yellow fever, chikungunya and Zika viral fever, and likely the dengue viral fever. Several species of mosquitoes, primarily in the genus *Aedes*, have been transmitting the viruses of these diseases among African primates for millennia allowing for coadaptation among viruses, mosquitoes and primates. One African primate (human) and one African *Aedes* mosquito (*Aedes aegypti*) have escaped Africa and spread around the world making it likely that when the next disease-causing virus comes out of Africa, *Aedes aegypti* will be the major vector to humans (Powell, 2018).

When considering the viral pathogens of the diseases transmitted by mosquitoes, most viruses are of the families Flaviviridae and Togaviridae (Table 1). The family Flaviviridae consists of at least 68 viruses and is divided into four genera: *Flavivirus*, *Pestivirus*, *Pegivirus* and *Hepacivirus* (Ludwig & Iacono-Connors, 1993; Salas-Benito & De Nova-Ocampo, 2015). The *Flavivirus* genus consists of 53 virus species (Huhtamo *et al.*, 2009), and is divided into four categories as mosquito-borne, tick-borne, no known vector and insect-specific viruses (Salas-Benito & De Nova-Ocampo, 2015). The mosquito-borne *Flavivirus* diseases are emerging as the cause of some of the most serious and widespread arthropod-borne viral diseases in the world and have caused large outbreaks in many countries (Table 1). Currently there are 39 defined species belonging to the mosquito-borne viruses of the genus *Flavivirus*, and are found in all continents except Antarctica. Some such as the West Nile virus have an extremely wide spread distribution, while others such as the Murray Valley encephalitis virus, Israel turkey meningoencephalomyelitis virus, Ilheus virus are restricted to endemic areas (Weissenböck *et al.*, 2010). Mosquito vectors of the genera *Aedes*, *Anopheles*, *Mansonia*, *Culex*, *Haemogogus* and *Armigeres* are responsible for transmitting Flaviviral diseases which are mainly characterized by high fever and headaches (Table 1). The genera *Aedes*, *Mansonia*, *Culex*, *Haemogogus* and *Armigeres* belongs to the subfamily Culicinae which is the largest subfamily of mosquitoes with 2500 species. *Aedes* is the largest genus comprising of about 1000 species, and *Aedes aegypti*, *Ae. albopictus*, *Ae. vittatus*, *Ae. scutellaris*, *Ae. pseudoscutellaris*, *Ae. polynesiensis*, *Ae. bromeliae*, and *Ae. africanus* are the most important vectors from a medical point of view. *Aedes aegypti* and *Ae. albopictus* are the most widespread and important vectors and transmit a wide variety of viruses belonging to three families: the Flaviviridae with the genus *Flavivirus*, Bunyaviridae comprising the genera *Bunyavirus* and *Phlebovirus* and Togaviridae comprising the genus *Alphavirus* (Das *et al.*, 2018). The Togaviridae viral diseases transmitted by mosquitoes are mostly characterized by rashes and joint pains and are more restricted in distribution. These diseases such as Chikungunya fever, Pogosta disease, Mayaro fever and Barmah Forest Virus disease are transmitted by mosquitoes of the genera *Aedes*, *Culex*, *Haemogogus*, *Anopheles*, *Mansonia*, *Psorophora* and *Sabethes* and have caused outbreaks to a lesser extent (Table 1). The family Togaviridae consists of the genus *Alphavirus* with more than 30 species which are mosquito-borne and transmitted between mosquito vectors and vertebrate hosts (Chen *et al.*, 2018).

3. Other insect vectors of human viral diseases

Insects other than mosquitoes transmit viral diseases to a lesser extent. In 1965, Greenberg stated that flies harbor over 100 different species of pathogenic organisms and transmits bacterial diseases and infections by parasites. According to Greenberg (1965) flies also transmit viral diseases such as poliomyelitis, coxsackie virus infection and hepatitis, a fact which has also been stated by Lindsay & Scudder (1955). However, reports of the isolation of viruses from flies are rare and their role in disease transmission are mostly circumstantial. Most viruses carried by flies are of veterinary importance such as the *Senecavirus A* whose natural hosts are pigs and cows, the porcine reproductive and respiratory syndrome virus which causes diseases to pigs, and Avian influenza virus and Newcastle disease virus that affects birds (Khamesipour *et al.*, 2018).

Dutto *et al.* (2016) reports the role of several insects in spreading the *Ebolavirus* which causes a severe disease in humans. *Periplaneta americana* (Blattaria, Blattidae), *Messor capensis* (Hymenoptera, Formicidae), Homoptera and Ephemeroptera have been identified as possible natural *Ebolavirus* reservoirs and their transmission of the virus from bats to humans needs to be established by further studies. However, it has been demonstrated that there is low potential for the mechanical transmission of *Ebolavirus* via houseflies (Haddow *et al.*, 2017). Further, houseflies are not considered as a major factor in the dissemination of poliovirus and any role played by them in disease transmission has considered to be incidental (Cirillo, 2016).

Another group of tiny flies capable of causing parasitic, bacterial and viral diseases to humans are Sandflies of order Diptera, family Psychodidae (Ayhan & Charrel, 2018). Of the 800 sand fly species distributed in the world, at least 98 are proven vectors of micro-organisms and transmit a number of viruses that cause sandfly fever, Toscana virus infection and Adria virus infection. These infections are caused by the viruses of genus *Phlebovirus*, family Bunyaviridae and are characterized by clinical symptoms such as fever, headache, malaise, photophobia, myalgia and retro-orbital pain (Ayhan & Charrel, 2018) (Table 2). The family Bunyaviridae comprises of more than 350 viruses and is divided into five genera, *Orthobunyavirus*, *Nairovirus*, *Phlebovirus*, *Hantavirus* and *Tospovirus* with additional unclassified viruses. Viruses within the *Orthobunyavirus*, *Nairovirus*, and *Phlebovirus* genera are transmitted by hematophagous arthropods, whereas *Hantaviruses* are transmitted by rodents and *Tospoviruses* by non-

hematophagous thrips. Viruses within the *Orthobunyavirus* genus are generally transmitted by mosquitoes, whereas viruses in the *Phlebovirus* genus are vectored mainly by sand flies (Horne & Vanlandingham, 2014).

Cockroaches are considered as efficient vectors of pathogens like bacteria, protozoa, fungi, eggs of pathogenic intestinal worms and viruses such as the Polio virus (Tatang *et al.*, 2017). The poliomyelitis virus has been isolated from domiciliary species of cockroaches and the successful laboratory transmissions of a number of viral infections to cockroaches indicates their capability of acting as a vector to other viral diseases such as hepatitis (Tarshis, 1962).

4. Insects and Covid-19

The coronavirus is a RNA virus of the family Coronaviridae, genus *Coronavirus* (Miller, 1999), which was first isolated in 1937 (Dehghani & Kassiri, 2020). As the largest known RNA viruses, coronaviruses are divided into four genera: alpha-coronavirus, beta-coronavirus, gamma-coronavirus and delta-coronavirus. To date, there have been six human coronaviruses (HCoVs) identified, including severe acute respiratory syndrome-CoV (SARS-CoV) and Middle East respiratory syndrome-CoV (MERS-CoV) (Wu *et al.*, 2020). New coronaviruses appear to emerge periodically in humans, mainly due to the high prevalence and wide distribution of coronaviruses, the large genetic diversity and frequent recombination of their genomes, and the increase of human-animal interface activities (Wu *et al.*, 2020). The novel coronavirus reported in late December 2019, has now created a public health emergency of international concern and brought the world to a standstill. The novel coronavirus is the seventh member of the family coronaviruses, and is a beta-coronavirus with over 70% similarity in genetic sequence to the SARS coronavirus. Bats are the most possible host of this pathogen, and snakes, minks and pangolins are also potential hosts (Wu *et al.*, 2020).

The novel coronavirus is transmitted from person to person via respiratory droplets, close contact, aerosols, and possibly the faecal-oral route (Dehghani & Kassiri, 2020). There have been no reports of COVID-19 transmission by blood-sucking arthropods such as mosquitoes or any other such insects (Dehghani & Kassiri, 2020). However, viruses may be transmitted by arthropods in two ways, either biologically or mechanically. In mechanical transmission insects become contaminated with viruses during normal feeding behavior, and virus persists on their mouthparts or body until the next feed (Carn, 1996).

Table 1: Viral diseases of humans transmitted by mosquitoes.

| Disease | Family and Genus of Virus | Affected Countries | Vector | Symptoms |
|-------------------------|---|--|--|--|
| 1. Rift Valley Fever | Bunyaviridae, <i>Phlebovirus</i> (Tantely <i>et al.</i> , 2015) | Several African countries and the Arabian peninsula (Tantely <i>et al.</i> , 2015; Sang <i>et al.</i> , 2017). Outbreaks occur during periods of heavy and persistent rainfall that often leads to flooding (Sang <i>et al.</i> , 2017). | Primary vectors are species of genus <i>Aedes</i> , while secondary vectors are of the genera <i>Culex</i> , <i>Anopheles</i> , <i>Mansonia</i> (Arum <i>et al.</i> , 2015). | Hemorrhagic fever, encephalitis, mortality (Sang <i>et al.</i> , 2017). |
| 2. Zika Virus Infection | Flavaviridae, <i>Flavivirus</i> (McKenzie <i>et al.</i> , 2019) | The first large Zika Virus outbreak occurred in 2007, in Yap Island, Federated States of Micronesia (McKenzie <i>et al.</i> , 2019). Another epidemic occurred in 2015 in the countries of the Americas (Vorou, 2016). | Principal vector is <i>Aedes aegypti</i> . <i>Aedes albopictus</i> is also established as a competent vector. In Africa, Zika Virus is transmitted by many species of mosquitoes of the genus <i>Aedes</i> , <i>Ae. africanus</i> , <i>Ae. apicoergenteus</i> , <i>Ae. opok</i> , <i>Ae. dalzielli</i> , <i>Ae. fuscifer</i> , <i>Anopheles africanus</i> , <i>Anopheles coustani</i> , <i>Anopheles gambiae</i> , <i>Mansonia uniformis</i> (Vorou, 2016). <i>Aedes henselli</i> was implicated in the Yap Island outbreak (McKenzie <i>et al.</i> , 2019). | Macular or papular rash, fever, arthritis or arthralgia, non-purulent conjunctivitis, myalgia, headache, retro-orbital pain, microcephaly in fetuses born to mothers infected with the disease (Vorou, 2016). |
| 3. Yellow Fever | Flaviviridae, <i>Flavivirus</i> (Waggoner <i>et al.</i> , 2018) | Disease currently occurs in Africa and Central and South America (Barnett, 2007). Recent outbreaks in Angola, Democratic Republic of the Congo and Brazil (McGuinness <i>et al.</i> , 2017). Historically large outbreaks in Europe and North America (Barnett, 2007). | Mosquitoes of genus <i>Aedes</i> , <i>Haemogogus</i> (McGuinness <i>et al.</i> , 2017). <i>Aedes aegypti</i> is the main vector and other species are <i>Ae. africanus</i> , <i>Ae. opok</i> , <i>Ae. simpsoni</i> , <i>Ae. luteocephalus</i> , <i>Ae. taylori</i> , <i>Ae. vittatus</i> (Ngoagouni <i>et al.</i> , 2012). <i>Aedes bromeliae</i> (Agha <i>et al.</i> , 2017). | Fever, chills, headache, low back pain, myalgia, nausea, vomiting, fatigue. In severe cases high fever, bleeding diatheses, abdominal pain, renal failure, cardiovascular instability, jaundice (McGuinness <i>et al.</i> , 2017). |

| Disease | Family and Genus of Virus | Affected Countries | Vector | Symptoms |
|------------------------------|---|---|---|---|
| 4. West Nile Virus Infection | Flaviviridae, <i>Flavivirus</i> (Petersen <i>et al.</i> , 2013) | Western United States, North America (Colpitts <i>et al.</i> , 2012). Africa, the Middle East, Southern Europe, Western Russia, South-Western Asia, Australia (Petersen <i>et al.</i> , 2013). | Mosquitoes of genus <i>Culex</i> are the primary vectors: <i>Culex tarsalis</i> , <i>C. quinquefasciatus</i> , <i>C. stigmatosoma</i> , <i>C. thriambus</i> , <i>C. pipiens</i> , <i>C. nigripalpus</i> (Colpitts <i>et al.</i> , 2012). <i>Culex tritaeniorhynchus</i> , <i>C. antennatus</i> , <i>C. univittatus</i> , <i>C. theileri</i> , <i>C. neavei</i> . Certain species of genus <i>Aedes</i> have also been reported in transmitting the disease: <i>Aedes caballus</i> , <i>Ae. circumluteolus</i> , <i>Ae. albocephalus</i> (Sule <i>et al.</i> , 2018). <i>Anopheles</i> species (Johnston & Conly, 2000). | Fever, headache, neck stiffness, vomiting, chills, confusion, ataxia (Johnston & Conly, 2000). In severe cases neuroinvasive disease, including encephalitis (Colpitts <i>et al.</i> , 2012). |
| 5. Japanese encephalitis | Flaviviridae, <i>Flavivirus</i> (Solomon <i>et al.</i> , 2003) | Eastern and Southern Asia (Ghosh & Basu, 2009). | Transmitted principally by <i>Culex tritaeniorhynchus</i> (Solomon <i>et al.</i> , 2003; Chen <i>et al.</i> , 2019). Two species of <i>Culex</i> spp., one <i>Anopheles</i> sp., one <i>Aedes</i> sp., one <i>Armigeres</i> sp. (Chen <i>et al.</i> , 2019). | The disease mostly affects children. The nervous system is affected causing nonspecific fibrile illness, diarrhea and rigor, reduced levels of consciousness, seizures, headaches, photophobia, vomiting (Ghosh & Basu, 2009). |
| 6. Dengue virus infections | Flaviviridae, <i>Flavivirus</i> (Back & Lundkvist, 2013) | Epidemics have occurred in many countries. The first epidemic occurred in 1954 in Southeast Asia. Epidemics in America: Cuba (1977-78, 1997), Venezuela (1989), Latin American countries. Africa (Malavige <i>et al.</i> , 2004). | Species of genus <i>Aedes</i> : <i>Aedes aegypti</i> is the primary vector, but <i>Ae. albopictus</i> and <i>Ae. polynesiensis</i> may also act as vectors (Malavige <i>et al.</i> , 2004). | The dengue virus may cause dengue fever or dengue hemorrhagic fever. Dengue fever is characterized by headache, retro-orbital pain, myalgia/arthralgia, maculopapular rash, petechiae. Dengue hemorrhagic fever results in mucosal bleeding, hematemesis, easy bruising and bleeding at venipuncture sites (Singhi <i>et al.</i> , 2007). |

| Disease | Family and Genus of Virus | Affected Countries | Vector | Symptoms |
|---|--|---|--|---|
| 7. Chikungunya Fever | Togaviridae, <i>Alphavirus</i> (Deeba <i>et al.</i> , 2016). | Has caused outbreaks in the countries of the Indian ocean region, Africa and America (Deeba <i>et al.</i> , 2016). | Transmitted by mosquitoes of the genus <i>Aedes</i> . <i>Aedes aegypti</i> is the most important vector and has extensive worldwide distribution. <i>Aedes albopictus</i> is reported from Southeast Asia, several European countries and some Asian countries; it is poorly distributed in the African continent (Monteiro <i>et al.</i> , 2019). | High fever, rashes, nausea, arthralgia and myalgia (Deeba <i>et al.</i> , 2016). |
| 8. Pogosta Disease (Finland), Ockelbo Disease (Sweden), Karelian Fever (Russia) | Togaviridae, <i>Alphavirus</i> (Sindbis virus) (Kurkela <i>et al.</i> , 2004). | Finland, Sweden, Russia (Kurkela <i>et al.</i> , 2004). Europe, Africa, Asia, Australia (Laine <i>et al.</i> , 2004). | Mosquitoes of genus <i>Culex</i> and <i>Culiseta</i> (Kurkela <i>et al.</i> , 2004). | Arthritis, maculopapular rash, low fever, fatigue, muscle pain (Kurkela <i>et al.</i> , 2004). The main clinical symptoms are related to joints, and are swelling and tenderness of the ankle, knee, wrist or fingers, especially the metacarpophalangeal joints (Turunen <i>et al.</i> , 1998). |
| 9. Mayaro Fever/ The Jungle Flu | Togaviridae, <i>Alphavirus</i> (Izurieta <i>et al.</i> , 2018). | Central and South America, Caribbean (Izurieta <i>et al.</i> , 2018). | <i>Haemagogus janthinomys</i> , <i>Aedes aegypti</i> , <i>Aedes scapularis</i> , <i>Anopheles quadrimaculatus</i> (Izurieta <i>et al.</i> 2018). Mosquitoes of genus <i>Culex</i> , <i>Mansonia</i> , <i>Psorophora</i> , <i>Sabethes</i> and <i>Aedes albopictus</i> (Acosta-Ampudia <i>et al.</i> , 2018). | Fever, chills, persistent arthralgia, retro-orbital pain, maculopapular rash, itching, dizziness and rarely lymphadenopathy (Izurieta <i>et al.</i> , 2018). As the most common symptoms a triad is described as abrupt fever, arthralgia/ arthritis, maculopapular rash often related to bleeding (Acosta-Ampudia <i>et al.</i> , 2018). |
| 10. Barmah Forest Virus Disease | Togaviridae, <i>Alphavirus</i> (Caly <i>et al.</i> , 2019). | Australia (Ehlkes <i>et al.</i> , 2012). Papua New Guinea (Caly <i>et al.</i> , 2019). | <i>Aedes vigilax</i> , <i>Ae. procax</i> , <i>Ae. camptorhynchus</i> , <i>Ae. notoscriptus</i> , <i>Verrallina funerea</i> , | Rash, fever, arthralgia, myalgia, lethargy (Ehlkes <i>et al.</i> , 2012). |

| Disease | Family and Genus of Virus | Affected Countries | Vector | Symptoms |
|--------------------------------|---|--|--|--|
| 11. Ross River Virus Infection | Togaviridae, <i>Alphavirus</i> (Harley <i>et al.</i> , 2001). | Australia, Papua New Guinea, Fiji, New Caledonia, Samoa, the Cook Islands (Harley <i>et al.</i> , 2001). | <i>Culex annulirostris</i> , <i>Coquillettidia linealis</i> (Ehlkes <i>et al.</i> , 2012). <i>Aedes vigilax</i> , <i>Ae. camptorhynchus</i> , <i>Culex annulirostris</i> (Harley <i>et al.</i> , 2001). | Joint manifestations ranging from tenderness, extreme redness, swelling and with effusions. Ankles, fingers, wrists and knees are the joints most commonly affected. Rashes may appear mainly on the limbs and trunk, but may also occur on the palms, soles, digits, face and scalp. Fever, arthralgia, myalgia, splenomegaly, hematuria, glomerulonephritis (Harley <i>et al.</i> , 2001). |

Table 2: Insect vectors of human viral diseases (with the exception of mosquitoes).

| Disease | Family and Genus of Virus | Affected Countries | Vector | Symptoms |
|-------------------------|---|--|--|--|
| Sand fly Fever | Bunyaviridae, <i>Phlebovirus</i> (Brett-Major & Claborn, 2009). | Southern Europe (Brett-Major & Claborn, 2009). In 1937, a massive outbreak occurred in Athens, Greece. Several outbreaks in the Middle East, the Mediterranean and North Africa (Ayhan & Charrel, 2018). | Sandflies (Diptera, Psychodidae) (Brett-Major & Claborn, 2009). <i>Phlebotomus papatasi</i> (Ayhan & Charrel, 2018). | Headache, photophobia, retro-orbital pain, anorexia, myalgia, low back pain (Brett-Major & Claborn, 2009). |
| Toscana Virus Infection | Bunyaviridae, <i>Phlebovirus</i> (Howell <i>et al.</i> , 2015). | European Mediterranean countries from Spain to Turkey, the North African countries of Tunisia and Morocco (Howell <i>et al.</i> , 2015). | <i>Phlebotomus perniciosus</i> , <i>P. perfiliewi</i> (Howell <i>et al.</i> , 2015). <i>Phlebotomus longicuspis</i> , <i>P. sergenti</i> , <i>P. neglectus</i> , <i>Sergentomyia minuta</i> (Ayhan & Charrel, 2018). | Headache, fever, nausea vomiting, myalgia (Howell <i>et al.</i> , 2015). Meningitis, encephalitis (Ayhan & Charrel, 2018). |
| Adria Virus Infection | Bunyaviridae, <i>Phlebovirus</i> (Anagnostou <i>et al.</i> 2011). | Greece (Anagnostou <i>et al.</i> 2011). | <i>Phlebotomus</i> species (Anagnostou <i>et al.</i> , 2011) | Febrile seizure, perioral cyanosis, masseter muscle spasm, generalized tonic convulsions of the body and extremities, involuntary loss of urine (Anagnostou <i>et al.</i> , 2011). |

Insects such as cockroaches and houseflies, which are major mechanical vectors of pathogens, can transmit diseases by contact with contaminated surfaces and studies have associated insects such as beetles and domestic insects as mechanical carriers of pathogens (Dehghani & Kassiri, 2020). SARS-coronavirus, MERS-coronavirus and influenza virus can survive on surfaces for extended periods, sometimes upto months, depending on the strain variation, titre, surface type, suspending medium, mode of deposition, temperature and relative humidity of the environment (Otter *et al.*, 2016). COVID-19 virus mainly occurs in respiratory samples of infected persons but have been reported in feces samples in a limited number of cases (Dehghani & Kassiri, 2020). According to Eslami & Jalili (2020), SARS-CoV-2 excretion by stool has been confirmed in some patients. Nath and Gupta (2020) reveals that the virus can be found in a person's stool and can remain viable for days in favourable atmospheric conditions. Therefore, any organism in contact with or feeding on human feces may play a role in COVID-19 transmission, and thus the role of insects such as houseflies and cockroaches becomes important. These insects are capable of transmitting more than 100 pathogens through their legs, body hair, mouthparts, feces and vomit which may occur on human food waste, sputum, nasal secretions, fresh and dried blood and stool (Dehghani & Kassiri, 2020).

Currently insects are known to transmit viruses of families Flaviviridae, Togaviridae and Bunyaviridae, and insect transmission of viruses of family Coronaviridae has not been documented. Further, when considering the deadly pandemics recorded in history, pandemics caused by viruses are few and when viruses are the pathogens, transmission is usually air-borne. Smallpox that has now been eradicated from the world was caused by the variola virus and transmitted by the air-borne respiratory route (MacIntyre *et al.*, 2020).

Therefore, the biological transmission of COVID-19 by insects may not be a possible route for the disease to spread. However, the mechanical transmission of the virus by insects other than mosquitoes cannot be entirely ruled out. The new coronavirus was detected in the feces of confirmed patients in Wuhan, Shenzhen and the United States, indicating that the virus can exist and replicate in the digestive tract. However, it is not certain that eating virus-contaminated food causes infection and transmission (Wu *et al.*, 2020). The mode of infection transmission has profound implications for effective containment of diseases by public health interventions. Therefore, it is important that the methods of COVID-19 transmission be further examined and understood.

5. Conclusions

Insects are important vectors of human viral diseases. Amongst insects, mosquitoes are the prominent vectors causing biological transmission of diseases, and sandflies, houseflies and cockroaches can cause mechanical transmission. COVID-19 is a deadly infectious disease caused by the most recently discovered coronavirus. It is an ongoing pandemic spread by air when people are physically close. However, it may also be transmitted via contaminated surfaces, although this has not been conclusively demonstrated. Therefore, insects in contact with or feeding on contaminated surfaces may play a role in COVID-19 transmission. At the moment the link is theoretical and under possible investigation. However, in the past insects and pandemics seem to be inextricably linked in a negative manner in the minds of people and thus their role in COVID-19 transmission is compelled for attention.

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