American Journal of Clinical Neurology and Neurosurgery
Vol. 1, No. 3, 2015, pp. 169-174
http://www.aiscience.org/journal/ajcnn

Dissemination of Infectious Agents of Human Diseases Via Insects Vectors of Public Health Prominence

Muhammad Sarwar*

Department of Entomology, Nuclear Institute for Food & Agriculture (NIFA), Tarnab, Peshawar, Pakistan

Abstract

Knowing about the methods in which a disease is transmitted is important for implementing proper infection control measures and large scale prevention campaigns. Each disease has transmission characteristics based on the nature of the microorganisms that cause it. The purpose of this study is to present evidence showing the role of the disease-carrying arthropods in worldwide transportation. Vectors are animals that are capable of transmitting diseases such as flies, mites, fleas, ticks, rats, and dogs. The most common vectors for diseases are the insects that transfer infections like malaria, dengue fever, yellow fever, typhus and many more through saliva which comes in contact with their hosts when they are withdrawing blood. The degree of contact between the vertebrate host and vector ranges from intermittent (e.g., mosquitoes) to intimate (e.g., sucking lice). The biting behaviour of female insects may be very important in the epidemiology of disease transmission and vectors add an extra dimension to disease transmission. Since vectors are mobile, they increase the transmission range of a disease to hosts. Changes in vector behaviour can affect the transmission pattern of a disease. So, it is important to study the behaviour of the vector as well as the disease-causing microorganism in order to establish a proper method of disease prevention. In the case of malaria, insecticides are sprayed and breeding grounds for mosquitoes can be eliminated in an attempt to control the spread of malaria. Biting is not the only way by which vectors can transmit diseases, but diseases may be spread through the feces of a vector. Microorganisms could also be located on the outside surface of a vector (such as a fly) and spread through physical contact with food, a common touch surface, or a susceptible individual. Failure to implement and maintain measures to prevent human-assisted transport of insect vectors to and among the states could have catastrophic consequences for the humans. So, vector longevity is one of the most important factors in disease transmission dynamics, and implementing of vector control along with standard precautions as first-line approaches to infection prevention and control in the healthcare environment to minimize the risk of transmission of infectious agents from person to person even in high-risk situations.

Keywords

Vector, Insect Carrier, Pathogen Transmission, Vector Control, Parasites

Received: September 11, 2015 / Accepted: November 13, 2015 / Published online: January 8, 2016

1. Introduction

Vector-borne parasites have adopted insect arthropods (joint legged invertebrates) present in the environment that may influence human health directly in a number of ways. They may cause nuisance or injury directly through their bites, which usually may result in an inflammation, or in toxic effects, constituents of their bodies or their excreta may behave as antigens resulting in allergic disease, and they may act as vectors of infectious disease. Despite of numerous scientific investigations on vector-borne human infections such as malaria, filariasis, dengue and typhus, these diseases

* Corresponding author
E-mail address: mharoonsarwar92@gmail.com

continue to threaten human health. So, understanding the role of vectors in disease transmission and the most appropriate control strategies is therefore essential. The components of a transmission cycle of an arthropod borne disease are a vertebrate host which develops a level of infection with the parasite that is infectious to a vector, an arthropod host or vector that acquires the parasite from the infected host and is capable of transmission, and one or more vertebrate hosts that are susceptible to infection with the parasite after being fed upon by the vector. Frequently the host provides to the vector not only with food, in the form of blood or other tissues, but also a habitat, or place in which to live. Blood feeding by the vector typically brings parasite, vector and vertebrate host together in time and space and ultimately is responsible for the transmission of parasites from infected to susceptible vertebrate hosts. A vector usually must take at least two blood meals during its life-time to transmit a parasite, the first to acquire the infection and the second to transmit it (Tatem et al., 2006; Jones et al., 2008, Sarwar, 2014 a; 2014 b; 2014 c; 2014 d). Infections with vector-borne pathogens are a major source of emerging diseases. The ability of vectors to bridge spatial and ecologic gaps between animals and humans increases opportunities for emergence. Small adaptations of a pathogen to a vector can have profound effects on the rate of transmission to humans (Rosenberg and Beard, 2011).

2. Routes of Transmission of Infectious Agents

This is any mechanism through which an infectious agent, such as a virus, is spread from a reservoir or source to a human being. The survival and reproduction of vertebrate parasites depend on a reliable mechanism for their movement from one host animal to another. Usually each type of infectious agent is ordinarily spread by only one or a few of the different routes. Transmission is accomplished more easily by vertebrate ecto-parasites that live on or near the surface of the host than by endo-parasites that must penetrate exterior defences and get inside their host. There are two basic channels for infectious agents to get on or inside their vertebrate hosts, direct contact, and indirect contact such as ingestion of contaminated water or food and inhalation of contaminated air. Direct contact includes physical contact with contaminated surfaces or infected individuals including mating contact, active penetration usually in water by invasive stages of parasites, and contact via infected vectors as a result of their feeding or defecation behaviour. Therefore, vectors are agents of parasite infection and represent a unique route of direct transmission (Ribeiro, 1989; Randolph et al., 1996; Randolph, 1998; Edman, 2004).

2.1. Direct Contact Transmission

It is the direct and essentially immediate transfer of infectious agents to a receptive portal of entry through which human or animal infection may take place. This type of transmission is at base, immediate and the transfer of the infectious agent is as the name implies, directly into the body. Different infectious agents may get into the body using different routes. Some routes by which infectious diseases are spread directly include personal contact, such as touching, biting, kissing or sexual intercourse. In these cases the agent enters the body through the skin, mouth, an open cut or sore or sexual organs. Infectious agents may spread by tiny droplets of spray directly into the conjunctiva or the mucus membranes of the eye, nose or mouth during sneezing, coughing, spitting, singing or talking (although usually this type of spread is limited to about within one meter distance, this is called droplet spread). When researchers talk about vectors, often they are talking about insects, which as a group of invertebrate animals carry a host of different infectious agents. However, a vector can be any living creature that transmits an infectious agent to humans. Vectors may mechanically spread the infectious agent, such as a virus or parasite. In this scenario the vector for instance a mosquito contaminates its feet or proboscis with the infectious agent or the agent passes through its gastrointestinal tract. The agent is transmitted from the vector when it bites or touches a person. In the case of an insect, the infectious agent may be injected with the insect's salivary fluid when it bites. Or the insect may regurgitate material or deposit feces on the skin, which then enter a person's body, typically through a bite wound or skin that has been broken by scratching or rubbing. In the case of some infectious agents, vectors are only capable of transmitting the disease during a certain time period. In these situations, vectors play host to the agent. The agent needs the host to develop and mature or to reproduce (multiply) or both (called cyclopropagative). Once the agent is within the vector animal, an incubation period follows during which the agent grows or reproduces or both, depending on the type of agent. Only after this phase is over the vector becomes infective. That is, only then can it transmit an agent that is capable of causing disease in the persons.

2.2. Indirect Contact Transmission

There are several types of routes of transmission mechanism of parasites and indirect transmission may happen in any of several ways:-

2.2.1. Vehicle-Borne Transmission

In this situation, a vehicle that is, an inanimate object or material called in scientific terms a fomite becomes contaminated with the infectious agent. The agent, such as a virus, may or may not have multiplied or developed in or on the vehicle. The vehicle contacts the person's body and it may be ingested (eaten or drunk), touch the skin, or be introduced internally during surgery or medical treatment. Examples of vehicles that can transmit diseases include cooking or eating utensils, bedding or clothing, toys, surgical or medical instruments (like catheters) or dressings. Water, food, drinks (like milk) and biological products like blood, serum, plasma, tissues or organs can also be vehicles. There may be any other substance serving as an intermediate means by which an infectious agent is transported and introduced into a susceptible host through a suitable way.

2.2.2. Airborne Transmission

In this type of transmission, infective agents are spread as aerosols, and usually enter a person through the respiratory tract. Aerosols are tiny particles, consisting in part or completely of the infectious agent itself, that become suspended in the air. These particles may remain suspended in the air for long periods of time, and some retain their ability to cause disease, while others degenerate due to the effects of sunlight and dryness. When a person breathes in these particles, they become infected with the agent especially in the alveoli of the lungs. Small particles of many different sizes contaminated with the infective agent may rise up from soil, clothes, bedding or floors when these are moved, cleaned or blown by wind. These dust particles may be fungal spores, infective agents themselves, tiny bits of infected feces, or tiny particles of dirt or soil that have been contaminated with the agent. Droplet nuclei can remain in the air for a long time. Droplet nuclei are usually the small residues that appear when fluid emitted from an infected host evaporates. In the case of the virus causing hanta virus pulmonary syndrome, the rodent carriers produce urine. The act of spraying the urine may create the aerosols directly, or the virus particles may rise into the air as the urine evaporates. In other situations, the droplets may occur as an unintended result of mechanical or work processes or atomization by heating, cooling, or venting systems in microbiology laboratories, autopsy rooms, slaughter houses or elsewhere. Both kinds of particles are very tiny. Larger droplets or objects that may be sprayed or blown but that immediately settle down on something rather than remaining suspended, are not considered to belong to the airborne transmission mechanism. Such sprays are considered direct transmission.

3. Modes of Transmission of Parasites by Vector

The transmissions of parasites by vectors may be vertical or horizontal. The vertical transmission is the passage of parasites directly to subsequent life stages or generations within vector populations, while horizontal transmission describes the passage of parasites between vector and vertebrate host (Herms and James, 1995; Reisen, 2002; Frances et al., 2002; Rodríguez-Perez et al., 2006).

3.1. Vertical Transmission

There are types of vertical transmission possibly within vector populations, transstadial, transgenerational and venereal transmission.

3.1.1. Transstadial Transmission

The transstadial transmission is the sequential passage of parasites acquired during one life stage or stadium through the moult to the next stages or stadium. The transstadial transmission is essential for the survival of parasites transmitted by mites and hard ticks that feed blood once during each life stage and die after oviposition. Lyme disease spirochetes, for example, that are acquired by larval ticks must be passed transstadially to the nymphal stage before transmission to vertebrates.

3.1.2. Transgenerational Transmission

The transgenerational transmission is defined as the vertical passage of parasites by an infected parent to its offspring. Some parasites may be maintained trans-generationally for multiple generations, whereas others require horizontal transmission for amplification. The transgenerational transmission normally occurs transovarially through the ovary after the parasites infect the ovarian germinal tissue. In this situation most of the progeny are infected. Other parasites do not actually infect the ovary and although they are passed on to their progeny, transmission is not truly transovarial. This situation is usually less efficient and only a small percentage of the progeny are infected. The transgenerational transmission in vectors such as mosquitoes must also include transstadial transmission, because the immature life stages do not feed on blood.

3.1.3. Venereal Transmission

The venereal transmission is the passage of parasites between male and female vectors and is relatively rare. Venereal transmission usually is limited to transovarially infected males who infect females during insemination, which, in turn, infect their progeny during fertilization.

3.2. Horizontal Transmission

The horizontal transmission is essential for the maintenance of almost all vector-borne parasites and is accomplished by either anterior biting or posterior defecation routes. Anterior station transmission occurs when parasites are liberated from the mouthparts or salivary glands during blood feeding e.g., malaria parasites, encephalitis viruses, filarial worms. Posterior station or stercorarian transmission occurs when parasites remain within the gut and are transmitted via contaminated feces. The trypanosome that causes Chagas disease, for example, develops to the infective stage within the hindgut and is discharged onto the host skin when the triatomid vector defecates during feeding. Irritation resulting from salivary proteins introduced into the host during feeding causes the host to scratch the bite and rub the parasite into the wound. Louse-borne relapsing fever and typhus fever rickettsia also employ posterior station modes of transmission. There are four types of horizontal transmission, depending upon the role of the arthropod in the life cycle of the parasite: mechanical, multiplicative, developmental and cyclo developmental.

3.2.1. Mechanical Transmission

The mechanical transmission occurs when the parasite is transmitted among vertebrate hosts without amplification or development within the vector, usually by contaminated mouthparts. Arthropods that are associated intimately with their vertebrate hosts and feed at frequent intervals have a greater probability of transmitting parasites mechanically. The role of the arthropod is essentially an extension of contact transmission between vertebrate hosts. Eye gnats, for example, have rasping, sponging mouthparts and feed repeatedly at the mucous membranes of a variety of vertebrate hosts, malting them an effective mechanical vector of the bacteria which cause conjunctivitis or pink eye. Mechanical transmission also may be accomplished by contaminated mouthparts if the vector is interrupted while blood feeding and then immediately refeeds on a second host in an attempt to complete the blood meal.

3.2.2. Multiplicative or Propagative Transmission

The multiplicative or propagative transmission occurs when the parasite multiplies asexually within the vector and is transmitted only after a suitable incubation period is completed. In this case, the parasite does not undergo metamorphosis and the form transmitted is indistinguishable from the form ingested with the blood meal. St. Louis encephalitis virus, for example, is not transmitted until the virus replicates within and passes through the midgut, is disseminated throughout the hemocoel, and enters and replicates within the salivary glands. However, the form of the virus does not change throughout this process.

3.2.3. Developmental Transmission

The developmental transmission occurs when the parasite develops and metamorphoses, but does not multiply, within the vector. Microfilariae of *W. bancrofti,* for example, are ingested with the blood meal, penetrate the mosquito gut, move to the flight muscles, where they moult twice, and then move to the mouthparts, where they remain until they are deposited during blood feeding. These filarial worms do not reproduce asexually within the mosquito vector; i.e., the number of worms available for transmission is always equal to or less than the number ingested.

3.2.4. Cyclodevelopmental Transmission

The cyclodevelopmental transmission occurs when the parasite metamorphoses and reproduces asexually within the arthropod vector. In the life cycle of the malaria parasite, for example, gametocytes that are ingested with the blood meal unite within the mosquito gut and then change to an invasive form that penetrates the gut and forms an asexually reproducing stage on the outside of the gut wall. Following asexual reproduction, this stage ruptures and liberates infective forms that move to the salivary glands, from where they are transmitted during the next blood meal.

4. General Transmission of Disease Organisms

Generally, transmission of disease organisms with biological involvement between the vector and parasite can involve multiplication without change in form e.g., *Yersinia pestis* in fleas, arboviruses in ticks and mosquitoes; multiplication with change in form e.g., Plasmodium species in Anopheles; or no multiplication (usually a decrease in parasite numbers) but with change in form e.g., filarial parasites in mosquitoes and black flies. As a matter of fact, campestral in epidemiology is used to describe transmission occurring in fields and open spaces such as plague transmission among wild rodents. But is also used sometimes to include transmission in woods and forests, which strictly is sylvatic transmission. In case of so-feeding, sometimes an infection can be passed from an infected vector feeding on a host to a nearby uninfected vector. This phenomenon has been recorded in mosquitoes, ticks and mites, such as in the transmission of scrub typhus. Dead-end host that although is infected with an arbovirus or other pathogen, may be severely affected, and has a viraemia too low in titre to infect blood feeding arthropods. Examples are humans in the epidemiology of Japanese encephalitis, and horses in western equine encephalitis transmission. Most snipe flies are predatory, feeding on other insects, but a few species bite humans and they may be involved in the mechanical transmission of disease organisms. Among the Muscidae, stable flies (Stomoxys spp.), horn flies (Haematobia spp.), and several species in the genus Glossina (tsetse) deserve special mention. These flies can severely annoy, but except for the possibility of mechanical transmission, they apparently do not transmit disease-causing microbes. Hereditary transmission involves a female vector passing disease organisms to her eggs and thus to the next generation i.e., transovarial transmission that is the production by an infected vector of eggs infected with parasites (e.g., viruses, rickettsiae). When they hatch they give rise to individuals (e.g., larvae, nymphs) that are infected and are either capable of transmitting the parasites (e.g. ticks) or passing it on to later life-cycle stages that transmit the infection (e.g,. scrub typhus mites). Aside from the transmission of disease-causing microbes, blood feeding flies occurring in large populations can annoy humans and domestic animals by their feeding activities alone (Scoles et al., 2000; Scott et al., 2009).

5. Prevention and Control of Infectious Agents Transmission

Understanding modes of transmission of infectious organisms and knowing how and when to apply basic principles of infection prevention is critical to success of an infection control program. This responsibility applies to everybody working and visiting healthcare facility, including administrators, staff, students, patients, families and care takers (Cohen et al., 1991; Gratz, 1999; Beard et al., 2002).

5.1. Precautions

Standard precautions refer to those working practices that are applied to everyone, regardless of their perceived or confirmed infectious status and ensure a basic level of infection prevention and control. Standard precautions include hand hygiene before and after every episode of vector contact, use of personal protective equipment, safe use and disposal of sharp items, routine environmental cleaning, reprocessing of reusable medical equipment and instruments, respiratory hygiene aseptic non-touch technique, and waste management.

5.2. Transmission Precautions

Transmission based precautions may include on or any combination of the continued implementation of standard precautions, appropriate use of gloves, masks, respirators and protective eye wear, appropriate air handling requirements, enhanced cleaning and disinfecting of the environment and food, and an appropriate medical facilities.

5.3. Treat of the Risks

At this stage all the information gathered from the analysis and evaluation on the risk of parasite transmissions is brought together to consider what actions should be taken. In order to make this decision, consider how the level of risk will be affected by the proposed mitigation strategies. The choice in the course of action can range from, avoiding the risk, choosing an alternate lower risk procedure or task, reducing the risk through preventative measures, existing systems and controls to adopt and guide the best way to perform the required task and minimize the risk.

5.4. Vector Control

Still, there is no universal consensus over the best method to control vectors, however, chemical control, environment modification, environment manipulation, changes to human habitats and behavior, biological control and genetic technology have potential for control of insect-borne diseases (Sarwar, 2015 a; 2015 b; 2015 c; 2015 d; 2015 e; 2015 f; 2015 g). Furthermore, as insects are vital players in transmission of certain diseases, their control is critical to success of an infection control (Sarwar, 2015 h; 2015 i; 2015 j).

6. Conclusion

The target of present guideline is to ensure students, graduates and researchers to aware of the issue of healthcare associated with parasites transmission. Understanding the chain of infection, knowing the different modes of transmission of infection in healthcare, and familiarizing of standard and transmission based precautions and their role in the prevention of transmission of infection are basic understanding of a risk management approach to infection prevention as well as control, and are able to identify potential risk for transmission of infection in the delivery of healthcare and decide what measures they should implement. The present guideline should be used in conjunction with the other guidelines for the prevention and control of infection in health care system and its key recommendations, as well as the healthcare facilities for infection control orientation program. An implementation of core strategies in the control of vectors transmission-based precautions, performing hand hygiene and putting on protective clothes before entering in the infective area, using a single-patient room, and ensuring consistent cleaning and disinfection of surfaces in close proximity to the patients and those likely to be touched by the patient and healthcare workers are imperative tools towards lessening of human parasites.

References

[1] Beard, C. R., Cordon-Rosales, C. and Durvasula, R. V. 2002. Bacterial symbionts and their potential use in control of Chagas disease transmission. Annual Review of Entomology, 4: 123-141.

[2] Cohen, D., Green, M., Block, C., Slepon, R., Ambar, R., Wasserman, S. and Levine, M.M. 1991. Reduction of transmission of shigellosis by control of houseflies (*Musca domestica*). Lancet, 337: 993-997.

[3] Edman, J. D. 2004. Arthropod Transmission of Vertebrate Parasites. In: B. F. Eldridge and J. D. Edman (eds.), Medical Entomology, Revised Edition, 151-163. Kluwer Academic Publishers.

[4] Frances, S. P., Watcharapichat, D., Phulsuksombati, D. and Tanskul, P. 2000. Transmission of *Orientia tsutsugamushi*, the aetiological agent for scrub typhus, to co-feeding mites. Parasitology, 120: 601-607.

[5] Gratz, N. G. 1999. Control of plague transmission. In: Plague Manual: Epidemiology, Distribution, Surveillance and Control. Geneva: World Health Organization. p. 97-134.

[6] Herms, W. B. and James, M. T. 1995. How arthropods cause and carry disease. In: A dictionary of epidemiology (3rd ed., J. M. Last, J. H. Abromson, et al., eds.). p. 15-26. Oxford University Press, London.

[7] Jones, K. E., Patel, N. G., Levy, M. A., Storeygard, A., Balk, D., Gittleman,, J. L. and Daszak, P. 2008. Global trends in emerging infectious diseases. Nature, 451: 990-993.

[8] Randolph, S. E. 1998. Ticks are not insects: Consequences of contrasting vector biology for transmission potential. Parasitol. Today, 14: 186-192.

[9] Randolph, S. E., Gem, L. and Nutthall, P. A. 1996. Co-feeding ticks: Epidemiological significance for tick-borne pathogen transmission. Parasitol. Today, 12: 472-479.

[10] Reisen, W. K. 2002. Epidemiology of vector-Borne Diseases. 15-27. In: Mullen, G. L. and Durden, L. A. (eds.). Medical and Veterinary Entomology, Academic Press, NY. p. 584.

[11] Ribeiro, J. M. C. 1989. Vector saliva and its role in parasite transmission. Exp. Parasitol., 69: 104-106.

[12] Rodríguez-Perez, M. A., Katholi, C.R., Hassan, H.K. and Unnasch, T.R. 2006. A large-scale entomologic assessment of *Onchocerca volvulus* transmission by pool-screen PCR in Mexico. Am. J. Trop. Med. Hyg., 74: 1026-1033.

[13] Rosenberg, R. and Beard, C. B. 2011. Vector-borne Infections. Emerg. Infect. Dis., 17 (5): 769-770.

[14] Sarwar, M. 2014 a. Defeating Malaria with Preventative Treatment of Disease and Deterrent Measures against Anopheline Vectors (Diptera: Culicidae). Journal of Pharmacology and Toxicological Studies, 2 (4): 1-6.

[15] Sarwar, M. 2014 b. Proposals for the Control of Principal Dengue Fever Virus Transmitter *Aedes aegypti* (Linnaeus) Mosquito (Diptera: Culicidae). Journal of Ecology and Environmental Sciences, 2 (2): 24-28.

[16] Sarwar, M. 2014 c. Dengue Fever as a Continuing Threat in Tropical and Subtropical Regions around the World and Strategy for Its Control and Prevention. Journal of Pharmacology and Toxicological Studies, 2 (2): 1-6.

[17] Sarwar, M. 2014 d. Proposing Solutions for the Control of Dengue Fever Virus Carrying Mosquitoes (Diptera: Culicidae) *Aedes aegypti* (Linnaeus) and *Aedes albopictus* (Skuse). Journal of Pharmacology and Toxicological Studies, 2 (1): 1-6.

[18] Sarwar, M. 2015 a. The Killer Chemicals as Controller of Agriculture Insect Pests: The Conventional Insecticides. International Journal of Chemical and Biomolecular Science, 1 (3): 141-147.

[19] Sarwar, M. 2015 b. The Killer Chemicals for Control of Agriculture Insect Pests: The Botanical Insecticides. International Journal of Chemical and Biomolecular Science, 1 (3): 123-128.

[20] Sarwar, M. 2015 c. The Dangers of Pesticides Associated with Public Health and Preventing of the Risks. International Journal of Bioinformatics and Biomedical Engineering, 1 (2): 130-136.

[21] Sarwar, M. 2015 d. Usage of Biorational Pesticides with Novel Modes of Action, Mechanism and Application in Crop Protection. International Journal of Materials Chemistry and Physics, 1 (2): 156-162.

[22] Sarwar, M. 2015 e. Commonly Available Commercial Insecticide Formulations and Their Applications in the Field. International Journal of Materials Chemistry and Physics, 1 (2): 116-123.

[23] Sarwar, M. 2015 f. Microbial Insecticides- An Ecofriendly Effective Line of Attack for Insect Pests Management. International Journal of Engineering and Advanced Research Technology, 1 (2): 4-9.

[24] Sarwar, M. 2015 g. Biopesticides: An Effective and Environmental Friendly Insect-Pests Inhibitor Line of Action. International Journal of Engineering and Advanced Research Technology, 1 (2): 10-15.

[25] Sarwar, M. 2015 h. Insect Vectors Involving in Mechanical Transmission of Human Pathogens for Serious Diseases. International Journal of Bioinformatics and Biomedical Engineering, 1 (3): 300-306.

[26] Sarwar, M. 2015 i. Insect Borne Diseases Transmitted by Some Important Vectors of Class Insecta Hurtling Public Health. International Journal of Bioinformatics and Biomedical Engineering, 1 (3): 311-317.

[27] Sarwar, M. 2015 j. Skin Disorders Inflicted Through Insect Invertebrates Along with Diagnosis and Treating of Cases. Journal of Nanoscience and Nanoengineering, 1 (4): 233-240.

[28] Scoles, G. A. Miller, J. A. and Foil, L. D. 2000. Comparison of the efficiency of biological transmission of *Anaplasma marginale* (Rickettsiales: Anaplasmataceae) by *Dermacentor andersoni* Stiles (Acari: Ixodidae) with mechanical transmission by the horse fly *Tabanus fusciostatus* Hine (Diptera: Tabanidae). Journal of Medical Entomology, 45: 109-114.

[29] Scott, C., Bestall, A., Jardine, A. and Ostfeld, R. S. 2009. Influence of hosts on the ecology of arboviral transmission: potential mechanisms influencing dengue, Murray Valley encephalitis and Ross Valley virus in Australia. Vector-Borne and Zoonotic Diseases, 9: 51-64.

[30] Tatem, A. J., Hay, S. I. and Rogers, D. J. 2006. Global traffic and disease vector dispersal. Proc. Natl. Acad. Sci. USA., 103: 6242-6247.