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Review Article
Arthropod Invaders Pedestal Threats to Public Vigor: An Overview

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Abstract

The veterinary, medical and economic importance of arthropods across the globe and the historical status of some important arthropod borne diseases have been reviewed. Due to hasty altering thermo-climatic conditions in different parts of the world, a variety of medical and veterinary related arthropod borne diseases are expected to rise. Arthropods can infect various parts of living vertebrates, which in turn feed on the host's tissues and body fluids, often causing extensive damage if left untreated. The feeding success of arthropods is linked to the vast array of pharmacological substances in their saliva, which interfere with the host haemostasis and immune response. Reducing arthropod abundance is an imperative but elusive ambition. Some arthropods transmit pathogens that affect humans and animals worldwide. Chemical pesticides applied to territory occupied by these harmful vectors can be valuable but appear to have significant negative effects on other non-target beneficial organisms. Thus vaccination and biological control need to be explored. Natural biological control is affected by native or co-evolved natural enemies in the environment without human intervention. The purpose of this study are to synthesize the available information concerning arthropod vectors and vector-borne diseases mainly of public health significance. In conclusion a low number of investigations on various aspects of arthropod borne infections as well as incuriosity to report the cases in disease reporting system have made the arthropod borne diseases as a more or less neglected field.

Key words: Arthropods, public health significance, myiasis, flies, ticks, mosquitoes, lice

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INTRODUCTION

Arthropods are the most successful and the largest animal invertebrate group of metazoan creatures on earth with segmented bodies having six or more jointed legs[1,2]. Among all known living animals on the earth, almost 75% belong to arthropods[3], moreover, they are found ubiquitously. Arthropods range from less than 1 cm to 3.2 m like giant king crab[4]. Most familiar arthropods include butterflies, beetles, flies, fleas, ticks, mites, ants, bees, spiders, scorpions, shrimps and crabs. Regarding their importance it is stated that life on earth would end very quickly without arthropods. These invertebrates play a great role in pollination of the flora, which in turn supply food and also maintain the clearance level of air and water, furthermore, they also act as majestic recycler and decomposers, along with marvelous food source[4].

In relation to their life style small numbers of arthropods have developed the ability to parasitize a wide range of hosts including other arthropods too[1]. Some arthropods have biting habit, which can make the living awkward both for humans and animals. Arthropods are also indirectly responsible for death of many people and animals[5]. Stored food products may be damaged or contaminated by live or dead insects or their faeces, odours, webbing or cast skins[6]. Most of insects act as vectors of different pathogens. There are also a number of arthropods that cause harm through their venom[7]. Hematophagous arthropod vectors, such as mosquitoes, ticks and flies are responsible for transmitting bacteria, viruses and protozoa between vertebrate hosts, causing deadly diseases such as malaria, dengue fever and trypanosomosis[5,8]. Mortality caused by arthropods-borne diseases in human being was more than all other factor if combined combined at the beginning of 20th century. Globally, some of the important emerging vector-borne-zoonoses are simian malaria, Chagas disease and leishmanosis. Out of 1,415 human pathogen species, 868 (61%) are known to be zoonotic. Likewise of this total, 177 (13%) pathogen species are considered emerging and re-emerging. The species which are regarded as emerging or re-emerging for protozoa, the counts were 58 and 14 (25%) and for helminths, 289 and 10 (3%), respectively[9].

In the past 15 years more than 20% of gross national products in African continent was abridged by malaria alone[10]. It has been observed that malaria caused more than one million deaths, mostly children, moreover 300-500 million clinical cases of malaria are reported annually. Arthropods have played a very important role in their relationship with man and animals. Historical records from pre biblical times revealed that these creatures played havoc with living beings by causing annoyance, worries and acting as vectors of various diseases[11]. As a result of their activity, arthropods may have a variety of direct effects on their hosts[12], which include: Blood loss, myiasis, entomophobia, annoyance, social nuisance, envenomization, dermatitis, pruritus, toxic and allergic responses.

Besides causing various direct effects ecto-parasites play crucial role in scattering of deadly pathogens by acting as vectors of protozoa, bacteria, viruses and helminths. In contrast to mechanical transmission, biological transmission requires a period of time between acquisition of the pathogen and maturation of infection. The vector may then remain infective for the remainder of its life[1]. A pathogen may reside and multiply in alternative vertebrate hosts, which are immune or only mildly infected by it e.g., *Yersinia pestis*, which is responsible for bubonic plague. It is endemic in wild rodents but in domestic rats and humans it is transmitted by fleas (Xenopsylla *cheopis*). Details of individual arthropods of public health significance are discussed as under.

Mosquitoes: Mosquito-borne diseases are among the world's leading causes of illness and death, moreover, despite great strides over the last 50 years, the World Health Organization (WHO) recorded more than 300 million clinical cases each year. Both natural as well as artificial circumstances result into stagnant water, which are favorable to mosquito reproduction. They need still or sluggish moving water for the completion of larval and pupal stages[13-15]. For example, *Aedes aegypti* breeds primarily in man-made water containers such as automobile tyres, metal drums, etc. or they breed in tree holes and leaf axils[16,17]. For the profusion of mosquitoes and the frequency of mosquito-borne infections three main aspects are needed i.e., warmth, rainfall and relative dampness[18].

For the effective growth of all tropical mosquito species the most favorable temperature ranges between 25-27°C[19]. Further within the mosquito vectors there is strong temperature dependence for parasite survival and development. For example, it has been seen by Oaks *et al.*[20] that the time required for the sporozoites of *Plasmodium falciparum* to get into the salivary glands is inversely proportional to the air temperature with a difference of 14 days between 30 and 10°C. The prevalence of mosquito borne infections correlate with rainfall patterns and season[20]. Low level of rainfall tends to generate less reproduction habitats and high rainfall causes washing away of the eggs[21]. Large number of the unfamiliar species having human health impacts are either relatively recently appeared (e.g., *Aedes albopictus*, *A. japonicus*, *A. koreicus* and *Ochlerotatus atropalpus*)[22] or in the last 10 years they have strongly spread (e.g., *Ambrosia artemisiifolia*)[23,24].

Simian malaria, which is caused by *Plasmodium knowlesi* is transmitted by *Anopheles laten* that feeds on monkeys. This malaria was first noticed among humans in 2004, which now poses a major threat in South East Asia region. It is usually misdiagnosed with *P. malariae*, which is a benign condition[25]. In India, simian malaria was first reported in 2013 in Andaman and Nicobar islands. It has been reported that mono infection with *P. knowlesi* contributes to 5% and co-infection with *P. falciparum* occurs in 12% drug resistant associated with *P. falciparum* infection in Andaman and Nicobar islands. Presently, one of the most important *Aedes aegypti* borne viral diseases affecting people in terms of both infection rate and death is the dengue fever. This virus belongs to the genus Flavivirus within the Flaviviridae family[21]. Across the globe it has been seen that about 2.5 billion people are at risk of this vector borne infection. Out of these more than 975 million live in urban areas in tropical and sub-tropical countries such as in Southeast Asia, the Pacific and the Americas alone[26]. Due to high infection rate this disease, it has been seen that more than 50 million new cases occur each year, resulting into hampering of the health status of children. The mortality rate is still exceeding 5% and about 500,000 hospitalizations occur for dengue haemorrhagic fever[27,28]. The annual average of dengue cases had double between 1990-1999 and 2000-2004[26]. Appearance of dengue hemorrhagic fever/dengue shock syndrome had occur due to the bite of infected *Aedes aegypti*, after hurricane due to unnecessary water lodging has also led to hyperendemicity[29]. Moreover, diptera of the genus *Aedes* spp. also have drought-resistant eggs, which are able to withstand long journeys and enter Europe associated with used tires or lucky bamboos, which are imported from Asia[22,24].

Repellents for mosquito control: Based on the different types, quantity of perspiration and rubbing of the skin and the level occurrence of mosquitoes, repellents can prove protective for one to 5 h for humans body[30]. Delicate body parts such as eyes, nostrils and lips should always be kept away from repellents, moreover, they can also damage plastics, synthetic fabrics and certain painted or varnished surfaces. Repellents used in commercial products include diethyltoluamide-containing active ingredient as N, N-diethyl-3-methylbenzamide (DEET), permethrin, citronella, Eucalyptus and other natural ingredients. The DEET is the most common and effective repellent[31]. For children's the concentration of less 15% and in adult's product a concentration of 10-35% of DEET is recommended[32]. Application of permethrin should always be done to outer parts and should not be applied to skin-clothings. Moderate protection with benefits against mosquito bites also obtained with oil of citronella, Eucalyptus and other natural ingredients[33]. All of these products are less effective than DEET. According to the United State Environmental Protection Agency (EPA), DEET is used annually by almost 40% of Americans and by about 200 million persons worldwide (www.muskol.ca/about_deet.htm).

Other methods for repelling or trapping mosquitoes: Studies have shown that reduction or elimination of biting activity and other behavior of mosquitoes are not significantly affected by any electronic or ultrasonic repeller devices[34]. Traps which use ultraviolet light as an attractant (black light bug zappers) are also not effective in reducing the biting mosquito population. However, there are modifications of this trapping concept presently being marketed that use CO_2 octenol and other chemicals to attract mosquitoes more effectively. The scented geranium plant, *Pellargonium* spp., more commonly known as the Citrosa 'Mosquito fighter' plant has not proven to be effective in repelling mosquitoes from an area. Moreover mosquito management at home level should be adopted: Water should not be allowed to stand in tin cans, plastic containers etc., clean roof gutters annually, use landscaping to eliminate standing water, use netting avoid unnecessary lighting[30,33].

Biological control: As biological control does not cause chemical pollution, it is considered as a better method for mosquito control by many people. The most commonly used predators of mosquitoes include:

- **Entomopathogenic fungi:** Coelomomyces, Culicinomyces (have direct contact with the mosquito external cuticle), Beauveria (causes slow killing), Metarhizium (affect feeding habits), Lagenidium (affect behavior and fitness conditions) and Entomophthora (elevate immune response plus production of secondary metabolites in the haemolymph)[35,36]
- **Bacterial agents:** *Bacillus thuringiensis* (suppress late instars and outgrowing pupae), *Bacillus sphaericus* and acetic acid bacteria (genus Asaia) (destroy larval stomach by endotoxin-protein production), wMelPop strain of Wolbachia (rapidly colonize the male reproductive system and female eggs of many mosquito vectors)[37,38]
- **Larvivorous fish:** *Gambusia affinis*, Cyprinodontidae, *Cyprinus carpio*, *Ctenopharyngodon idella*, *Tilapia* spp. *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala*, *Aphanius dispar*, *Aplocheilus blocki*, *Poecilia reticulata*, *Lebistes reticulates*, *Nothobrachius guentheri* and *Poecilia reticulate* (all reduce larval density)[39]

- **Microsporidian parasites:** *Vavraia culicis*, *Edhazardia aedis* (has combinatorial effects on different mosquito epidemiological traits: Decrease larval survival rates, decrease the number of adults, affect adult longevity, abort parasite development in the mosquito, affect mosquito biting rates)[40]
- **Viruses:** Densonucleosis viruses or denso viruses (DNVs) (alter the ability to house the malaria parasite, transduce certain anti-plasmodium genes or specific Anopheles toxins in mosquito cells and reduce mosquito longevity)[41]
- **Nematodes:** Different strains (*Romanomermis iyengari*) of the *Mermithidae* family (interfere in the reproductive behavior causing biological castration, reduce its populations, decrease the rates of malaria transmission)[42]
- **Protozoa:** *Nosema algerae*, *Lamborella* spp., after larvae of mosquitoes
- **Plants:** *Azolla spinnata* reduce oviposition and egg hatchability rate, algae *Caldophora* spp. and *Chara* spp. Inhibit larval development
- **Predators:** Non blood feeding mosquitoes like Toxorhynchites have been found to be voracious mosquito larvae eater
- **Genetic control:** Genetic control is directed against adult mosquitoes. Sterile-male release techniques are being studied in some countries for getting a high proportion of infertile insemination[1]

Ticks: Ticks transmit a variety of pathogens including protozoa, rickettsia, bacteria and viruses to both humans and livestock[43] and cause substantial economic damage worldwide[44-46]. Macroclimatic factors play a major role on the seasonal population dynamics of ticks and thus on tick borne diseases[47]. Lyme disease, rocky mountain spotted fever, ehrlichiosis, babesiosis, tularemia, tick paralysis, tick-borne encephalitis and mountain tick fever are some of the common diseases of humans transmitted by ticks. Lyme disease is the most common vector-borne disease of humans in the United States and Europe[48,49]. Annually 20,000-27,203 cases are reported to CDC (http://www.cdc.gov/lyme/stats/maps/interactiveMaps.html).

Mosquitoes suck blood several times but on the other hand, ticks act as blood feeders only once per stage of their life cycle. However, they can take large amount of blood meals equivalent to 10-100 times more to their own body weight[10]. The primary hosts of *Ixodes scapularis* that carries *Borrelia burgdorferi*, which causes lyme disease in humans are the white-footed mice (*Peromyscus leucopus*) and white-tailed deer (*Odocoileus virginianus*)[48]. During their life cycle, different ixodid species may use one, two or three different hosts[50-53] Rocky mountain spotted fever is most important rickettsial disease affecting about 1,000-2,000 cases per year and is characterized by headache, fever, chills, malaise, gastrointestinal symptoms, which sometimes lead to coma and at last death[42]. Regarding human monocytic ehrlichiosis case reported in 2012 were 1,128 with 1.1% fatality, primarily affecting the hosts leukocytes. Cases recorded in human granulocytic anaplasmosis were 2,389 in 2012 affecting RCBs of host[42]. Up till 1969 in USA alone more than 300 cases of babesiosis were recorded in humans. A total of 716 confirmed cases were recorded in 2012 depicting malaria like symptoms. Humans affected by tularemia (rabbit fever) in 2012 were 149 (http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6153a1.htm). Tick-borne encephalitis is a complex disease of closely related virus; it may lead to severe motor dysfunction. Tick paralysis is caused by salivary toxin of tick and it leads to acute, ascending, flaccid motor paralysis[1].

Tick and ticks borne diseases control measures include managerial control, chemical control, biological control and immunological control. Due to confrontation against chemical agents, biological and immunological controls are gaining significance now-a-days. In biological control many agents have been tested and provided excellent results such as bacteria: *Bacillus thuringiensis*, *B. cereus* (both target *Argas persicus*, *Hyalomma dromedarii* and *Ornithodoros erraticus*), *Proteus mirabilis* (targets *Dermacentor andersoni*), *Cedecea lapagei* (targets *Boophilus microplus*). Fungi: *Beauveria bassiana* (targets *B. microplus*), *Metarhizium anisopliae* (targets *Rhipicephalus sanguineus*)[54]. Entomopathogenic nematodes: *Hetererhabditis indicus* (targets *Boophilus annulatus*, *Hyalomma dromedarii* and *Hyalomma excavatum*) and *Steinernema riobrave* (targets *Amblyomma americanum* and *Amblyomma cajennense*, *Rhipicephalus appendiculatus*, *R. sanguineus*)[54]. In immunological control, many vaccines have been tried to elicit an immune response against ticks such as TickGUARD (*B. microplus*), TickGARD plus (*E. coli* expressed BM86+BM91), Gavac™ (*B. microplus*)[55].

Mites: Scabies mite (*Sarcoptes scabiei*) is distributed worldwide[1]. The mite gets transmitted by contact, burrows into the skin on the webbing side of fingers, later spreading to the wrists, elbows and the rest of the body[56]. The buttocks, women's breasts and external genitalia may be involved. Effective diagnosis of mites can be made by their characteristic typical rash and the burrowing tunnel, in which mite reside can be made easily visible by first coating black ink on the skin of animal followed by its wiping[57]. The mite may spread from humans to animals and vice versa. Treatment involves

swabbing of the whole body from the neck down with 1% malathion or benzene hexachloride (crotamiton for infants)[1]. Moreover, it can be systemic (e.g., oral selamectin for *S. scabiei*) or topical (e.g., amitraz dip for *D. canis*). Treatment of infestations of rabbits by *Notoedres cati* var. *cuniculi* has been successfully carried out by systemic application ivermectin[58] as well as topical application of deltamethrin[59] in India. In Brazil soap containing tetramethylthiuram monosulfide was effectively used in the treatment of cat fur mite (*Lutzomyia radovskyi*)[60]. Parasitic dermatitis results from canine demodicosis and sarcoptic mange dogs[61-63]. In the same manner, canines infected with sarcoptic mange in and endoparasites were treated with a single subcutaneous injection of doramectin 1% (0.3 mg kg^{-1})[64]. However, the resistance has been reported for allopathic drugs for demodicosis. Homeopathic medicines have been used successfully in such cases which are refractory to allopathic drugs[65]. The use of insecticide-treated bed nets has also been proven to be effective in protecting humans against *L. longipalpis* bites[66], but this strategy is not currently used in Brazil as part of the national programme against zoonotic visceral leishmaniosis. Chiggers (larvae of red mites or harvest mites) (Trombiculidae) are an important group of ectoparasites affecting humans. Before dropping off chiggers use enzymes present in their saliva and feed on partially digested skin cells after piercing the skin near a hair follicle. They neither feed on blood nor burrow into the skin of the animal[67]. Piercing activity along with presence of enzymes cause pruritic eruption and its strength depends on the sensitivity of the host mammal and may lead to fever. Chigger bites can be controlled by using insect repellents DEET. In South Asia, India, Pakistan, Sri Lanka chiggers are the vectors for scrub typhus (*Orientia tsutsugamushi*), a rickettsial disease that can (rarely) be life-threatening. Scrub typhus is prevalent all over India, but since 2004 it has shown re-emergence in places like Himachal Pradesh, Jammu and Kashmir, Rajasthan, Andhra Pradesh, Uttarakhand, Pondicherry, Kerala, Goa, Delhi and West Bengal[42]. This disease is often missed out due to non-specific symptoms, lack of awareness and non-availability of diagnostic tools. Most of diagnoses are based on high suspicion. The chance for mortality may rise to 30% if not treated[42]. Another peculiar feature is that it is not transmitted by bite but when the larva gets accidentally landed on human skin and gets crushed.

Lice: The relation of lice and human beings is very old as some of the Egyptian mummies were seen to be effected with lice. Moreover, phylogenetic evidence also put forward that lice-humans adaptation was about 5.6 million years ago when the ancestors of chimpanzees and humans depart from each other[68]. Three types of sucking lice are important for human health: *Pediculus humanus* var. *capitis* (head louse), *P. humanus* var. *corporis* (body louse) and *Pthirus pubis* (crab/pubic louse). Lice are very host specific, both sex are blood feeders and depart one host only to infect another host[69]. Louse typically feeds 4 times a day (die if away for more than 2 days) and molts 3 times in 10 days after hatching. In the developed world, 2-10% of children are infested with head lice[70,71]. Disease such as epidemic typhus (by body lice) is caused by *Rickettsia prowazekii*, which is a category B bioterrorism agent and an obligatory intracellular alphaproteobacteria[71]. Other disease transmitted by lice include *Borrelia recurrentis*, which causes fever with long bone shooting pains and in world war I, it affected 1,000,000 individuals. Trench fever (*Borrelia quintanas*) was also dominant in world war I.

Louse-borne relapsing fever affected 4,972 cases with 29 deaths in 1971[4]. Head lice are known to mechanically transmit *Staphylococcus auereus* and *Streptococcus pyogenes*[72]. Diagnosis is based on finding eggs or nits (eggs) in seams of clothing[73]. Coarse hairs of pubic area in adults or eye lashes in children are sometime get infested with pubic lice (crab lice)[1]. Transmission in adults is usually by sexual contact. Confirmatory diagnosis can be done by finding lice or nits in the infected area of mammal.

To decrease the chance of being infected with head lice hair should be regularly cleaned with shampoo having 1% benzene hexachloride. It should be always kept in mind that some time benzene hexachloride can be toxic, so other product such as mixture of pyrentins (0.2%) and pipronyl butoxide (2%) or copper oleate are also effective and they are less toxic too[70,73]. The permethrins are incredibly safe with only rare cases of asthma exacerbations noted in individuals with severe ragweed allergy[71]. It is effective against head louse, but in recent years the human louse has become increasingly resistant to them. Therefore, many doctors are using malathion, a common pesticide that in diluted concentration is very effective against the louse and is available over-the-counter in many countries with wider safety margin mainly in children[4].

Temperatures above 100°F or below 75°F reduced the fecundity of body lice targeting mainly its hatchability potential. Long term storage of outfits, without treatment, will help in killing all eggs, any if any young emerges it will die soon[69]. Washing clothes in hot water (60°C) also helps in killing the lice. For the effective treatment of crab louse many commercial preparations are available, which can also be

used for head or body lice. Plucking with forceps is useful for nits and lice removal from eye lashes. Some ointments having physostigmine (0.25%) or yellow mercury oxide are effective[1]. Biological control can be used and an alternate to the chemical method. Chlamydospores of fungus (*Metarhizium anisopliae*) when applied in the fleece of animals are consumed by the louse, after some time spores sprout and grow into the body of a louse resulting in its instant death. Flower extract from *Chrysanthemum cinerariaefolium* stimulates the nervous systems of lice and in the end result in its killing.

Fleas: Worldwide, more than 2,574 species of fleas parasitize mammals and birds. They belong to 16 families and 238 genera, but only a minority is synanthropic, that is they live in close association with humans[74]. The most common being the cat flea (*Ctenocephalides felis*), dog flea (*C. canis*), human flea (*Pulex irritans*) and oriental rat flea (*Xenopsylla cheopis*)[1]. Plague, caused by *Yersinia pestis* is a zoonotic disease primarily affecting rodents, but that can affect human beings. It has been the cause of three recorded pandemics[74]. Moreover, small outbreaks continue to occur throughout the world; around 2000 cases are reported annually[75]. The oriental rat flea is the primary vector of bubonic plague and murine typhus[76]. On the whole 3 forms of plague are recognized: bubonic, septicemic and pneumonic. Septicemic and pneumonic are secondary to bubonic form. Pneumonic is most dangerous form[77]. India witnessed outbreak of plague as early as 1612 in Agra. In 1994 there was an epidemic of plague in beed district of Maharashtra and Surat district of Gujarat. It was bubonic type in beed district and pneumonic type in Surat. Later outbreaks were reported in Shimla district of Himachal in 2002 and in Uttarakhand in 2004.

The three steps to effective flea management are treatment of infested pets, vacuuming and cleaning of infested premises. Since most flea problems originate from an infested cat or dog, elimination of fleas from the pets is the first and most important step. The jigger flea or chigore (*Tunga penetrans*) is a serious pest in the tropical and subtropical regions of America and Africa. Diagnosis of tungiasis is rare in North America[78]. Moreover various pathogenic bacteria have been isolated from tungiasis lesions: *Clostridium tetani*[79], *Streptococcus pyogenes*, *Pathogenic Staphylococcus aureus*, *Klebsiella aerogenes*, *Enterobacter agglomerans*, *Escherichia coli* and other Enterobacteriaceae. Both sexes feed on blood. The female flea, after insemination, burrows itself in the skin of the toes and the sole of the foot[1]. The female swells to the size of a pea, produces eggs and dies in the tissue. There is local reaction to the bite and the eggs and dead flea produce reaction[76]. The infested tissue can get infected and gangrenous. Treatments are symptomatic.

Flies: The house fly's (*Musca* spp.) filthy habits along with its persistence for invading homes and feeding on human food enable the house fly to spread many intestinal diseases such as dysentery and diarrhoea. They are not only the source of annoyance but also mechanical transmitters of various pathogens due to their habit of visiting decaying organic material. The pathogens are carried on the hairs of feet and body or regurgitated as salivary vomit during subsequent feeding[1]. A number of *Musca* species are associated in the spread of diseases including conjunctivitis and anthrax. They also act as intermediate hosts for some of the helminths.

There are four basic principles of pest management important in controlling house flies: sanitation, exclusion, non-chemical measures and chemical methods[1]. These are listed in order of lasting effectiveness. Regardless of advancements in chemical control, sanitation is still the best method of controlling filth flies in and around the home. Do not let garbage, manure or other decaying organic matter accumulate in the open and make sure garbage cans have sound bottoms and tight fitting lids[80]. Flies can be kept outside of homes by the use of window and door screens. Make sure screens are tight-fitting without holes. Try to make all screen doors open outward. In areas with high humidity, screens last longer when made of copper, aluminum or plastic[80,81]. A fly swatter is an economical control method for the occasional fly control[80]. Fly traps may be useful in some fly control programmes if enough traps are used, if they are placed correctly and if they are used both indoors and outdoors[82]. One trap should be placed for every 30 feet of wall inside buildings, but not placed over or within five feet of food preparation areas. Recommended placement areas outdoors include near building entrances, in alley ways, beneath trees and around animal sleeping areas and manure piles[81]. Chemical control includes the applications synthetic pyrethroid (i.e., deltamethrin, cyfluthrin, lambda-cyhalothrin, cypermethrin, sumithrin or tralomethrin) and should be applied in the form of a residual or surface spray when flies begin to appear[1]. Unfortunately, because insecticides are broken down by sunlight, the residual effect of the material will be greatly decreased and may not kill flies much beyond several days or a week[80]. Release the mist from the aerosol for a few seconds around the room and keep the room closed for 10-15 min[82]. Residual sprays providing 2-4 weeks control with 1 treatment may be applied to fly-resting surfaces. Other measures for control of adult flies include use of insecticide resin strips or various fly baits[81].

Myiasis: Myiasis, a noun derived from Greek (mya or fly) was first proposed by Hope to define diseases of humans caused by dipterous fly larvae, as opposed to those caused by insect larvae in general[83]. Myiasis is the parasitism of a vertebrate host by the larva of a dipteran fly[84]. Human cases are rare but happen especially in tropical countries[85]. Species that cause myiasis are cochliomyia (Screw worm fly), Calliphora, Oestrus, Sarcophaga and Gastrophilus, etc.[86]. Human myiasis can presented as cutaneous myiasis, anal myiasis, genito-urinary myiasis, nasopharyngeal myiasis, ocular myiasis, body cavity myiasis, wound myiasis, aural myiasis and intestinal myiasis[87]. Depending upon fly larvae myiasis has been classified in to three types including obligatory myiasis (true parasitism), facultative myiasis (oppurtunistic) and accidental myiasis (accidental ingestion of larvae)[88]. Larvae can burrow through necrotic or healthy tissue using their mandibular hooks aided by proteolytic enzymes[87]. Cutaneous myiasis may require surgical confiscation of burrowed larvae[89]. Eggs and maggots may be washed from hair, skin and wounds with soap and water[90]. Urinary myiasis usually clears itself. Purgation with anti-helminths may be necessary for gastrointestinal myiasis.

In human myiasis the flies involved are *Psychoda albipennis* (urogenital myiasis), *Telmatoscopus albipunctatus* (intestinal myiasis), *Hermetia* spp. (furuncular myiasis, intestinal myiasis), *Scenopinus* spp. (urogenital myiasis), *Eristalis tenax* (urogenital myiasis, intestinal myiasis), *Megaselia scalaris* (intestinal myiasis, urogenital myiasis, wound myiasis), *Drosophila melanogaster* (nasal myiasis, ocular myiasis), *Piophila casei* (urogenital myiasis), *Dermatobia hominis* (furuncular myiasis), *Alouattamyia baeri* (pulmonary myiasis), *Hypoderma lineatum* (migratory myiasis), *Hypoderma tarandi* (ocular myiasis), *Lucilia sericata* (wound myiasis), *D. hominis* (external ophthalmo-myiasis), *C. hominivorax* (orbital myiasis)[91].

Black flies: Black flies are amongst the smallest blood-sucking dipterans[92]. There are numerous species of black flies out of which the important ones are *Prosimuliim mixtum*, *Cnephia pecuarum* and *S. meridionale*[93]. They usually breed in well-aerated water bodies such as swiftly moving shallow mountain torrents[53] or sunlit, fast flowing rivers in the tropics[94]. Onchocerciasis or river blindness is caused by the helminth *Onchocerca volvulus* of the family Filariidae, whose larvae are transmitted between humans by the black flies[95]. Onchocercosis is the second leading cause of blindness in the world with 96% of the affected people living in 30 countries in sub-Saharan Africa (Yemen) with the remainder in six countries in Latin America[96]. This disease has left more than 37 million people infected and millions blind in African countries[97]. Several programmes such as the onchocercosis control programme in West Africa[98], the onchocercosis elimination programme for the Americas[99] and the african programme for onchocercosis control[100] targeted this dreadful disease.

Tsetse flies: The tsetse is a prehistoric species that originated about 100 million years ago[101]. Tsetse is derived from African word meaning 'the fly destructive of cattle'. Tsetse flies (*Glossina* spp.), which are found only in Africa transmit various protozoan parasites of the genus Trypanosoma, which cause sleeping sickness in humans and 'nagana' in domestic animals[102]. These flies appear like honey bees, 7-13 mm long, yellowish brown/black in color. They are found mainly in African countries between 15°N and 20°S latitude[102]. There are 30 species or subspecies of tsetse, classified into three groups: The fusca group (13 species), found mostly in forests, the palpalis group (5 species), found in forests and riverine vegetation and the morsitans group (5 species); found in woodland areas of Savannah regions[103]. Only Savanna and forest flies affect humans. Human sleeping sickness is caused by *Trypanosoma brucei gambiense* and *Trypanosoma brucei rhodesiense*, which threaten up to 60 million people in 36 countries of sub-Saharan Africa[104]. Uganda is the only country in which both species are present[105]. The *T. b. gambiense* is usually transmitted by tsetse of the palpalis group and occurs mostly in cultivated lands within proximity of pools of water in Western and central Africa, it is a disease adapted to humans, although other animals-especially domestic ones may be important reservoir hosts[106]. The *T. b. rhodesiense*, which is the more virulent of the two, is usually transmitted by tsetse of the morsitans group and occurs primarily in the Savannah woodlands of Eastern and central/Southern Africa[107,108], it is a disease that occurs naturally in a large number of domestic and wildlife hosts[109].

In humans, as the disease progresses, the parasite crosses the blood-brain barrier and invades the central nervous system, causing neurological problems[110]. Compared to other arthropod vectors such as mosquitoes, tsetse flies have a very low reproductive rate and a longer life expectancy[106]. The mortality and reproductive rates of tsetse flies are highly dependent upon microclimatic conditions with high survival rates in cool, moist areas[111]. Animal trypanosomosis occurs more or less throughout the area of Africa inhabited by one or more species of tsetse (an area of approximately 10 million km^2), while human sleeping sickness, which has a much higher threshold for transmission[112], occurs only in a relatively few, but very persistent, disease foci.

Sand flies: Among the most important emerging and resurging vector borne protozoan diseases, leishmanoses stand second only to malaria in terms of numbers of people affected[113]. Among >800 species of sandflies recorded, 98 are proven or suspected vectors of human leishmanoses; these include 42 *Phlebotomus* species in the old world and 56 *Lutzomyia* species in the new world[114]. Visceral leishmanosis (kala-azar), mucocutaneous leishmanosis and cutaneous leishmanosis are three diseases caused by Leishmania that spread through the bite of about 30 different species of sandflies[108].

The flight speed of phlebotomines is considerably slower than that of mosquitoes and is <1 m sce^{-1} [115]. They are unable to fly at wind speeds higher than this rate, which is the main factor limiting the range of their dispersal[114]. Studying their life cycle is complicated because the larvae, which are tiny, are very hard to find, even in areas of high disease prevalence[116]. About 88 countries are affected with leishmanosis[117]. Leishmanosis is primarily a zoonotic disease affecting mostly rodents and dogs and humans are incidental hosts. Factors such as deforestation, population migration from endemic rural areas and increased population density in areas with low sanitation have caused a resurgence of leishmanosis by increasing the contact between the vectors and the hosts[117].

Visceral leishmaniosis (VL): In the new world visceral leishmanosis is recorded as endemic in 12 countries[118]. In the past, VL has been considered a rural disease caused by *L. chagasi* in semi-arid tropical areas in which *L. longipalpis* was recognized as the sole vector[119]. The majority of the VL cases in the new world occured in Brazil. An early proposition that the cause of VL in the new world is certainly *L. infantum* was confirmed by a present continent-wide DNA microsatellite investigation of parasite populace[120].

Cutaneous leishmaniosis (CL): Prior to the 1960s, CL was primarily restricted to forested areas[121]. In Mexico the condition of CL is widely recognized as 'ulcera de los chicleros' and is also nominated as 'guerrilla's sore'[121]. For the establishment of Lutzomyia vectors in Venezuela and Columbia deforestation and the replacement of primary forest by monocultures, such as coffee farming had played a crucial role[122,123]. Urbanization has greatly contributed to the emergence and increase of CL in the new world[124]. The disease has been spreading in urban cities in Brazil[124].

Phlebotomus papatasi is also known to be a vector of other human pathogens, such as *Bartonella bacillisformis* (Carrion's disease), which has two clinically distinct phases: An acute or haematic phase, known as 'Oroya fever' and an eruptive or tissue phase, known as 'Peruvian wart' or 'Verruga peruana'[125]. Any infected person can experience either one or both phases, which can occured once or more than once during a lifetime. As a consequence death of up to 40% untreated patients occur, on the same time mortality reached approximately 90% when opportunistic illness with *Salmonella* spp. had take place[126].

Throughout various armed forces operations such as the Napoleonic wars febrile disease conditions caused by sand flies occurred namely sand fly fever, which is also recognized as Phlebotomus fever, papatasi fever or three-day fever[127]. During World War II (WWII), German troops based in the Mediterranean area suffered from sandfly fever. Naples virus which was first isolated from a febrile patient in Italy in 1944[128]. Additional recoveries have been made in Egypt, India, Iran, Pakistan, Serbia and the former Soviet Union[129]. The prototype strain of Sicilian virus was isolated from humans in 1943. Other isolates were subsequently obtained in Egypt, India, Iran, Pakistan and Afghanistan. No mortality has been recorded in thousands of clinically observed cases[127]. Summer meningitis caused by Toscana virus. Toscana virus was first isolated from *P. perniciosus* and *P. perfiliewi* collected in Italy in 1971. The first evidence for the human pathogenicity and neurotropism of Toscana virus was reported more than 10 years after the discovery of the virus[127]. Three vesiculoviruses, Vesicular Stomatitis Virus (VSV)-Alagoas, VSV-Indiana and VSV-New Jersey, cause vesicular stomatitis disease in humans and domestic livestock. Incapability of naturally infected mammal to turn out a constant high-titer viraemia and the ability for transovarial spreading in arthropod hosts are the common features to these three VSVs[130].

In India Chandipura virus encephalitis was recorded from Chandipura village in Maharashtra in 1965[131]. In the Eastern part of state of Gujarat 2nd epidemic with a fatality rate of >75% was reported in 2004[131,132]. In Eastern and Northern India i.e., Bihar, Jharkhand, Uttar Pradesh and West Bengal kala-azar is endemic[133]. Among all these states, 90% of all cases occur in Bihar alone[134]. In these states from time to time epidemics have been reported[135]. Moreover, sporadic cases were recorded from non-endemic areas such as Delhi, Maharashtra, Meghalaya and Karnataka[136] and also from sub-Himalayan (Kumaon) region of Northern India[137]. In many parts of the world like in Asia, Africa and Mediterranean old world cutaneous leishmaniasis is endemic. Pathak *et al.*[138] described a case in an 18 months old male child, who had lesions on lips, nose and chin from India. Impression smears of the lesions revealed *L. tropica* amastigotes. Interestingly, on the same time a dog in close proximity had similar lesions on its legs and nostrils.

CONCLUSION

In addition to affect the human beings and animals directly some of the arthropods act as vector of dreadful diseases like yellow fever, dengue, kala-azar, encephalitis, cerebral malaria, Chagas disease, sleeping sickness etc. The socio-economic burden associated with vector-borne tropical diseases is a serious impediment to development in many tropical countries and most of these diseases are a major cause of poverty. It is estimated that malaria alone has reduced the gross national product of the African continent by more than 20% over the past 15 years. Despite advances in other methods of vector control, the farmers are largely dependent on chemical control. However, sole reliance on chemicals is in some jeopardy because of food safety, environmental concerns, insecticide resistance and a lack of commercial interest in the development of new compounds. New classes of insecticides with novel modes of action are required, since they are less likely to be effected by existing resistance mechanisms. However, the prospect of accessing new public health insecticides with the ideal vector control characteristics in the near future appears limited. The cost of developing a novel insecticide for vector control was estimated at an average of US $ 230 million/compound, which may be manifold more today. Scientists are working on non-chemical methods of vector control like exploitation of natural resistance, vaccine induced resistance and biological control. With the advent of recombinant DNA technology not only the creation of new generation of bio-pesticides is possible but also the control of insect vectors. It is now possible to modify a genome and create a transgenic vector with an objective of debilitating the vectors by way of reduced reproductive potential or vector competence and increased vector susceptibility to existing measures.

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