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I.1 INTRODUCTION

Of all the insects, mosquitoes undoubtedly cause the greatest suffering both to man and animals. Mosquito has been not only a nuisance but also a killer. They act as agents or vectors for many dreadful diseases such as Malaria, Filariasis, Dengue fever, Chikungunya, Yellow fever and Japanese Encephalitis etc. Malaria is caused by the Protozoan, Plasmodium transmitted by female Anopheles mosquito. Filariasis or Elephantiasis is caused by a parasitic Round worm, Wuchereria bancrofti carried by Culex species. Dengue fever, Yellow fever, Chikungunya are transmitted by Aedes species. Japanese Encephalitis is caused by a virus spread by various species of Culex and Aedes.

Ever in the epidemiological history of our country mosquito borne diseases have prime importance. Now there has been an unprecedented upsurge of vector borne viral diseases since 1996 (GOI 1986). In the past Kerala State was mainly endemic for Malaria and Lymphatic Filariasis. But now the state is endemic to Dengue fever, Chickengunya etc. Malaria was prevalent in the hills and foothills of the state and it is a major public health problem in our land (DHS Kerala 1978). Though it was successfully eradicated in the state in 1965, cases of Malaria are reported by around 1975(DHS Kerala 1978, ICMR Bulletin 2010). From 1984 onwards indigenous malaria cases in Kerala were found to be increasing (DHS Kerala1978). Lymphatic Filariasis is the second major public health problem and it was predominant in the coastal belt (Mariappan et al 1992). According to WHO it is a global problem and is a major social and economic scourge in the tropic and subtropics of Asia, Africa, Western Pacific and parts of America affecting over 120 million people in 80 countries more than 1.1 million people live in areas where there is a rise of infection (WHO 1998). Dengue fever is emerging as another health problem in India. In Kerala State it was totally unaffected till 1996, but 66 persons were dead in the year 2001 (DHS Kerala 2005). Today it is reported from all districts of Kerala. Dengue fever which surfaced as a new problem in the State in 1997 assumed epidemic proportion in 2003 and resulted in 2346 cases and 35 deaths. Although Dengue is reported from all districts it is comparatively higher in
Trivandrum, Kottayam, Idukki, Kannur and Kasargod except Trichur, Palakkad and Wyanad. The incidence of Dengue fever was higher in 2010 than in the previous years. In 2010 Dengue fever outbreaks occurred in Trivandrum, Kottayam, Pathanamthitta, Idukki and Kasargod (DHS Kerala 2010).

Chikungunya is another vector borne disease was not recorded before1963. But now it is an epidemic in many districts, added a new dimension to the entire scenario of vector borne diseases in Kerala (Jupp and Mc Intosh 1988). This disease was reported largely from South in 2006, middle Kerala in 2007 and Northern part in 2008. In 2009 it largely affected in Kozhikode, Malappuram, Kannur and Kasargod districts of Kerala. In 2007 the state reported 24052 suspected chikungunya infections with highest number from Kottayam district followed by Pathanamthitta districts (DHS Kerala 2007). Japanese encephalitis emerging as yet another mosquito borne disease in our land. There are no confirmed cases of JE in the state during the period from 2005 to 2009. In 2010 there were three confirmed cases. However considering various factors such as presence of a large number of amplifier hosts (Pigs, Migratory birds etc), profuse breeding of vector mosquitoes and huge influx of people especially immigrant labourers from other states, the occurrence of outbreaks or even epidemic in the state cannot be ruled out (DHS Kerala 2010). There have been major outbreaks of JE in Alappuzha during the period from 1996 to 1998. The entire Kuttanad area was severely affected by the disease during the period. Since then the incidence of JE has decreased gradually and now only a few confirmed cases are being reported from the State. It may not necessarily be due to the total absence of cases of JE but may be that cases are not properly diagnosed and confirmed.

Pathanamthitta district is having unique ecosystems that are favourable to mosquito fauna. Many regions are still not approachable due to lack of good roads communication facilities due to difficult terrain. Hence the study on mosquitoes is very scanty. The ecology and distribution of various mosquito species are important in the determination of mosquito vector abundance and related disease prevalence. Effect of natural factors such as temperature, rainfall, humidity etc has profound impact on mosquitoes. Climate has been established as an important factor in the distribution of vectors and pathogens (Pemola and Jauhari 2006). The major vector
borne diseases are usually viewed as an environmental consequence of underdevelopment, occurring in communities (Brightmer and Fantato 1998).

Pathanamthitta district is the district of the religious historical and tourist importance. Famous pilgrimage centers such as Sabarimala, Manjanikkara, Parumala, Maramon, Cherukolpuzha and Aranmula are best examples. Devotees from various parts of the world come to these places for worship, site seeing and for pilgrimage. Likewise many come as tourists in these places. It may lead to increased pollution and hence added for the generation of new mosquito species. Similarly labourers from other states such as West Bengal, Assam, Utter Pradesh, Tamil Nadu etc., immigrate to this district. Their improper dwelling, sanitation etc., create more pollution and which also added to more mosquitogenic environments.

Agriculture is the main occupation of the people. About 75% of the people are directly or indirectly engaged in this sector. The main crops raised in this district are paddy, rubber, coconut, tuber crops, banana, pepper, ginger, vegetables etc. In certain pockets cashew nuts, pineapple, sugar cane, cocoa, trees, spices are also cultivated (GOK, 2003).

Today the area of cultivation except rubber and pineapple is declined considerably, which provides ample chances for mosquito breeding and rearing.

In short, the conversion of agrarian fields to non agrarian arid places, immigration of large number of people, arrival of labourers from other states etc are unique in this district which create more mosquitogenic situations in the district. Human alteration of the environment continues to expand mosquito breeding habitats. The influence of environmental conditions may make changes in mosquitoes and hence today’s vectors may not be vectors tomorrow or vice versa.

According to the World Health Report of WHO, insects flourish in conditions of heat and humidity, poverty and overcrrowing and they spread disabling diseases among almost half of the World population. Today the Mosquito is literally spreading its wings as a carrier of disease and setting in newer areas far from its original geographical boundaries. Both developing and developed countries now experience the problem due to emerging and re-emerging mosquito borne diseases and viral infections (WHO 1996). Mosquitoes are very well recognized as
vectors of protozoa, viruses and other pathogenic organisms after the discoveries made by Sir. Patric Manson (for the role of mosquitoes in the transmission of Filariasis), Sir. Ronalad Ross (in the transmission of Malaria), Major Walter Reed and Carlos John Finlay (in the transmission of Yellow Fever), (Robert 1950). In this context let us have a look on various vector borne diseases by discussing the global, Indian and Kerala situations briefly to know their impacts on human beings, especially in Pathanamthitta district.

I.2. VECTOR BORNE DISEASES: INTRODUCTION

Mosquitoes are responsible for transmitting some of the most dreadful diseases in human beings such as Malaria, Filariasis, Dengue fever, Japanese encephalitis, Chikungunya, and several other types of viral infections. In other words they act as agents or carriers of these diseases. Of all the insects that transmit diseases, the mosquito represents by far, the greatest menace. It remains mankind’s most indomitable foe, resisting costly efforts to eradicate or even control it.

I.2.1. Malaria

I.2.1.1. Introduction

All over the world Malaria is a major health problem. It is a well known oldest chronic and most wide spread fatal disease that haunted mankind for centuries, which also causes economic loss. (WHO 1998) Malaria is a mosquito borne infectious disease of human and other animals caused by Eukaryotic Protists of the genus Plasmodium. This severe disease is largely caused by *P. falciparum*, *P. vivax*, *P. ovale* and *P. malaria* transmitted by female *Anopheles* mosquitoes.

I.2.1.2. Etimology

The term Malaria originates from medieval Italian: Mala aria – “Bad air”, the disease was formerly called Auge or Marsh fever due to its association with swamp and marsh land. (Reiter 2000)

Malaria has infected humans for over fifty thousand years and Plasmodium may have been a human pathogen, close relatives of human malaria parasites remain common in Chimpanzees. Some new evidences suggest that the most virulent strain of human malaria may have originated in gorillas. (Joy et al 2003)
I.2.1.3. Malaria: Global Situation

Malaria is the most important Mosquito borne human disease. It is the most vital cause of morbidity and mortality. It is the third world’s most dreaded killer. Though Malaria is prevalent in over hundred countries across the world, it is mainly confined to tropical areas of Africa, Asia and Latin America (WHO 1994).

Coming to the history of Malaria reference to the unique periodic fever of Malaria are found throughout recorded history beginning in 2700 B.C in China (Cox 2002). Malaria may have contributed to the decline of Roman Empire and was so pervasive in Rome that it was known as the “Roman fever”. Several regions in ancient Rome were considered at risk for the disease because of the favourable conditions present for Malaria Vectors. Malaria was the most important health hazard encountered by US troops in South Pacific during world war II were about 500,000 Men were infected (Bray 2004). According to Joseph Patric Byrne, “60,000 American Soldiers died of Malaria during the African and South Pacific campaigns (Byrne 2008). Scientific studies of Malaria made their first significant advance in 1880 by Charles Louis Alphonse Laveran who observed the parasite plasmodium inside the red blood cells of people suffering from Malaria and he was awarded Nobel Prize in 1907 for Physiology of medicine (ht tp://nobelprize.org). Sir. Ronald Ross in 1898 proved the complete life cycle of Malaria parasite in Mosquitoes. He thus proved that the mosquito was the vector for Malaria in humans. For this work, Ross received the 1902 Nobel Prize in Medicine (http://nobelprize.org). The first effective treatment for Malaria came from the bark of Cinchona tree which contains Quinine which saved the life of thousands of people. World Health organization in its technical reports stated “Of the mosquito transmitted diseases Malaria is a major public health problem in tropical developing world. More than 2.4 Billion of the world populations are still at the risk. The global incidence is estimated to be 300-500 million clinical cases each year with mortality ranging from 1.1 to 2.7 million per year” (WHO 2000). The United Nations development programme (UNDP 2003) estimated 1.3 billion people of South East Asia region (SEAR) are at risk of Malaria. 30% of the populations live in areas with moderate to high risk of Malaria mainly in India, Myanmar and Thailand (Bruce-Chwatt, 1980). The World Health Organization has estimated that in 2010 there were 216 million cases of Malaria around 6,55,000 people died from the disease, Most of them were children under the age of five. The actual number of death may be
significantly higher as precise statistics are unavailable in many rural areas and many cases are undocumented (http://en.wikipedia.org/wiki/malaria).

Malaria continues to remain a serious widespread and complex global health problem affecting 109 countries and putting around 3 billion people i.e., 40% of the world population at the risk of infection. The World Health Organization (WHO) estimates around 250 million Malaria episodes and over one million deaths across the globe every year (WHO 2008).

I.2.1.4. Malaria: Indian Situation

Malaria has been known in India from time immemorial and it has always been a major public health hazard. India is one of the affected countries. Millions of people die in every year due to Malaria. Most of the arid and semiarid in Western India fall in an unstable Malaria zone in the country (Srivastava and Yadav 2000). Malaria unquestionably remains the most important vector borne disease in India as far as the studies of Central Bureau of Health Education (CBHE) and the Directorate of National Malaria Eradication Programme (NMEP) are concerned. According to CBHE, after the independence, an estimate of malaria problem made in 1953, indicated an annual incidence of 75 million cases with 0.8 million deaths (CBHE 1958). According to the Directorate of National Malaria Eradication programme (NMEP) the Malaria incidence lead dropped down to 2 million cases in 1958 (NMEP 1968). In the report of Government of India (GOI 1986) stated an upsurge of Malaria occurred in 1965 and the cases rose from 1.48 lakhs in 1966 to 6.4 million in 1976.

According to Park, since 1984, irrespective of implementing nationwide control programmes, Malaria incidence remains more or less static with about 2.1 million per year (Park 2002). According to Rajagopalan and Das, in India the geo climatic peculiarities and manmade other natural habitats in urban agglomerations form the Mosquitogenic conditions conducive for the transmission of vector borne diseases (Rajagopalan and Das 1987 and Mariappan 2000).

In India 58 species of Anopheles have been reported (Das et al., 1990). Among these species only 9 species viz., An. stephensi, An. culicifacies, An. varuna, An. sundaikes, An. fluvatilis, An. annularis, An. philippinensis, An.minimus and
*An. dirus* have been known to transmit malaria. Of the nine established vectors of malaria, two species viz., *An. culicifacies* in rural and *An. stephensi* in urban area are well known vectors of malaria in our country (Mariappan et al 1992). The occurrence of urban Malaria vector *An. stephensi* was reported first time from Cochin in 1992 (Mariappan et al 1992) before which urban Malaria cases were not recognized in the state (DHS Kerala 1998). According to Service there are over 430 species of mosquitoes under the genus Anopheles out of them 70 are malaria vectors of which 40 are important malaria vectors (Service 2004).

### I.2.1.5. Malaria: Kerala Situation

Malaria has been long been identified as a major problem in Kerala. Nagam Aiya, in his book ‘The Travancore State Manual’ in 1906 stated malaria had been highly endemic in the hills and forests were primitive tribes and aborigines constituted the reservoir of infection (Nagam Aiya 1906). From here the disease spread towards other places and epidemic were occurred eg., Neyyattinkara epidemic in 1935-1936, Wayanad Epidemic in 1945-1946. In the former 50,000 human lives in the later 2000 lives abolished (Das et al 1996).

A number of scientific enquiries of Malaria Epidemiology was made by Iyyankar in Travancore (1934), Covell and Harbhagwan in Waynad (1939), Mathews in south Travancore (1939) confirmed that *Anopheles* mosquitoes are important vectors in Kerala. *An.fluviatilis, An.culcifacious, An.varuna, An. jeyporiensis var candidiensis*. Among them only *An. fluviatilis* was recognized as the principal Vector, especially in the hills and foot hills. The other three vectors had only casual roles and local importance in the transmission of Malaria.

As part of National Malaria control programme (NMCP) Malaria control activities started in December 1953 and it was intensified and continued., In 1958 indoor residual spraying of Dichloro Diphenyl Trichloroethane (DDT) took place and it was stopped in 1963 on the basis of reports of Directorate of Health services (DHS Kerala 1964). According to DHS Malaria cases reported again in 1975 (DHS Kerala 1978). From 1984 onwards indigenous malaria cases in Kerala were increasing. Though the Malaria was a rural problem in Kerala, by 1990 it began to spread in urban places. This clearly shows the availability of Anopheles vector mosquitoes in the state.
According to DHS Kerala, from 2005-2012 the total number of confirmed cases of Malaria reported was 16789 and the number of deaths was 38 (DHS Kerala 2012). In Pathanamthitta district, from 2006 to 2012 the number of Malaria cases reported was 1029 and no death was reported to have occurred (DHS Kerala 2012).

I.2.2. Dengue Fever (DF)

I.2.2.1. Introduction

Dengue fever (DF) and Dengue Hemorrhagic fever (DHF) are acute febrile diseases found in the tropics and caused by four closely related virus serotypes (DEN-1, DEN-2, DEN-3 and DEN-4) of the genus Flavivirus, family ‘Flaviviridae’ (Tyagi et al 2006). It is also known as ‘Break borne fever’, transmitted to human by Aedes aegypti and also by Aedes albopictus (Chaturvedi et al, 2006). Dengue is one of the most serious and fast emerging tropical diseases which in certain socio ecological settings exacts disease burden 465,000 DALY’s across the globe that can only be paralleled with that of Malaria (Gubler 1977). The most comprehensive method for estimating costs associated with dengue illness of all degrees of severity employs Disability Adjusted Life Years (DALY’s) (Murray, 1994). Dengue is an inconsequential disease presenting initially with flu like symptom. But it can progress to fatal DHF and Or DSS. Aedes aegypti and Aedes albopictus are the principal vector responsible for Dengue transmission the world over (Chaturvedi and Nagar, 2006).

I.2.2.2. Etymology

The origin of the word Dengue is not clear but one theory is that it is derived from the Swahili phrase “ka-dinga pepo” which describes the disease as being caused by an evil spirit. The Swahili word Dinga may possibly have its origin in the Spanish word Dengue meaning fastidious or careful, which would describe gait of a person suffering the bone pain of Dengue fever (Harper, 2001).

I.2.2.3. Dengue: Global Situation

Dengue fever is an ancient disease. It is emerging as a serious public health problem globally, with 2.5 billion people at risk and 50 million dengue infections occurring annually (Gubler kuno 1977). The relationship of countries with Dengue has long and intense. Worldwide nearly 2.5-3 billion people (40% of the global
population continue to live at constant risk of contracting infection. While 50 million cases and 22,000 deaths are estimated to regularly occur annually in 100 endemic countries worldwide, including hospitalization of nearly 500,000 cases of which 90% are children. The South East Asia region contributes 52% or 1.3 billion cases annually (ICMR Bulletin, 2006).

Dengue fever outbreaks have been documented in every continent except Antarctica (Halstead 1980). A clinical Dengue like illness was recorded in a Chinese Medical Encyclopedia in 992 with the expansion of shopping and port cities in the 18th and 19th centuries. The mosquito vector Aedes aegypti and the Dengue viruses spread to new geographic areas causing major epidemic. After World War II, rapid urbanization in South East Asia led to increase the transmission and higher endemicity (Chaturvedi and Nagar 2008). The disease had only been identified and named in 1779. The most serious global pandemic began in South East Asia in the 1950’s and by the mid 1970’s. It became frequent since the 1980’s. By the late 1990’s Dengue was second only to Malaria among most important mosquito borne diseases affecting human beings (www.dengue.in). Dengue virus was isolated in Japan in 1943 by inoculation of serum of patients in suckling mice (Kimura and Hotta, 1944). The virus was isolated from the sera of US soldiers in many parts of the world including Culcutta during 1944 (Sabin and Schlesinger, 1945). The first major epidemic of the DHF occurred in 1963-1964 (Sarkar et al, 1964, Chatterjee et al, 1965, Carey et al, 1966), it was then followed in Philippines (Rigau-perez et al, 1998). Continuing process of urbanization may cause Dengue to become a more serious problem in future, unless proper environmental control measures are enforced. Environmental degradation has severe public health consequences, since vectors and pathogens rapidly adopt to exploit new ecological niches whenever they appear.

I.2.2.4. Dengue: Indian Situation

The first epidemic of clinical dengue like illness was recorded in Madras in 1780 (Gubler, 1977). The first confirmed report of Dengue infection in India dates back to 1940s and thereafter several states began to report the disease which mostly struck in epidemic proportion often in inflicting heavy morbidity and mortality both in urban and rural environments.
DHF was occurring in the adjoining countries but it was absent in India for unknown reason as all the risk factors were present. But it started emerging in various parts of India since 1988 (Kabra et al, 1992). The first major widespread epidemic of DHF/DSS occurred in India 1996 involving areas around Delhi (Dar et al, 1999) and Lucknow (Agarwal et al, 1999) and then it spread to all over the country (Singh et al, 2000, Shah et al, 2004). Dengue virus was isolated from sera of US soldiers in many parts of the world including Culcutta during 1944 (Sabin and Schlesinger, 1945). The first virologically proved epidemic of DF occurred in India and Eastern Coast of India in 1963-64 (Sarkar et al, 1964, Chatterjee et al, 1965, Craey et al, 1966). Aedes aegypti and Ae albopictus are two well known vectors of dengue in India. Dengue has been an urban disease but now has spread to rural areas of India as well (Mehendale et al, 1991, Kumar et al, 2001, Arunachalam et al, 2004, Tewari et al, 2004).

I.2.2.5. Dengue: Kerala Situation

In Kerala cases of dengue with some deaths were reported in 1997 for the first time, Albeit detection of DEN-1, DEN-2 and DEN-4 viruses in the human sera in Kerala (Bandyopadhyay et al, 1996). Dengue antibodies had been detected in human sera from Kozhikkode, Kannur, Palakkad, Trichur, Kottayam and Trivandrum district as early as 1879 (Banerjee, 1973). Development of hyper endemicity in a short span of one decade, along with incrimination of Ae albopictus is indicative of the severity of dengue infection in Kerala which warrents a first hand review of the emerging disease under the changing climate and anthropogenic impact (ICMR Bulletin 2006).

The recent emergence of dengue fever in Kerala seems to have a definite co-relation with the climatic change and imposing anthropogenic stresses (Tyagi et al, 2003).

The Hindu, a leading daily news paper in India reported under the heading “Epidemic threat in Pathanamthitta” stated 36 cases of confirmed dengue fever (The Hindu, June 14, 2012 Page-8). This report proved that this epidemic is still a threat to the people of this district.

According to DHS Kerala from 2006-2012 the total number of confirmed cases of Dengue was 11773 and the number of deaths was 68 (DHS Kerala State
Bulletin, 2012). In Pathanamthitta District during the period of 2006-2012 the number cases of Dengue reported was 387 and 2 deaths as occurred (DHS Kerala State Bulletin, 2012).

I.2.3. Lymphatic Filariasis (LF)

I.2.3.1. Introduction

Lymphatic Filariasis (LF) is a parasitic and infectious tropical disease caused by thread like filarial nematode worms- *Wuchereria bancrofti*, *Brugia malayi* or *Brugia timori* in the super family Filarioidea also known as “Filariae”. The mosquito vectors involved are *Culex*, *Aedes*, *Anopheles*, and *Mansonii* (Sasa, 1976). According to World Health Report of WHO, Lymphatic Filariasis (LF) is a disabling and disfiguring disease affecting mankind since antiquity.

I.2.3.2. Filariasis : Global Situation

Lymphatic Filariasis (LF) has existed as a recognizable disorder from the very beginning of recorded human history. Coming to the history of Lymphatic Filariasis is thought to have affected humans since approximately 4000 years ago (http://www.stanford.edu/class/humbio103/parasites2006/lymphaticfilariasis/discovery.com). The first clear reference to the disease occurs in ancient Greek literature, where scholars differentiated the often similar symptoms of Lymphatic Filariasis from that of Leprosy. In 1866, Themsothy Lewis, building on the work of Jean Nicolas Demarquay and Atto Henry Wucher made the connection between microfilaria and elephantiasis, establishing the course of research that would ultimately explain the disease. In 1876 Joseph Bancroft discovered the adult form of the worm. In 1877, the life cycle involving an arthropod vector was theorized by Patric Manson who proceeded to demonstrate the presence of worms in mosquitoes. In 1900 George Carmichael Low determined the actual transmission method by discovering the presence of worms in the proboscis of the mosquito vector. (http://www.stanford.edu/class/humbio103/parasites2006/lymphaticfilariasis/discovery.com).

Filarisis is a global problem and is a major social and economic scourge in the tropic and subtropics of Africa, Asia, Western Pacific and Parts of America.
affecting over 120 million people in 80 countries more than 1.1 million people live in areas where there is a rise of infection (WHO 1998, 2000).

I.2.3.3. Filariasis: Indian Situation

Ancient Indian writings describe swellings of extremities and the genitalia highly reminiscent of Filarial lesions. The Indian physician/surgeon Sushruta in his book ‘Sushruta Samhita’ by 70 AD refers a disease called ‘slipada’ (sli – elephant., pada – leg). They are cases of Lymphatic Filariasis (Rajan T V, 2000). In India the second major public health problem is Lyphatic Filariasis which had been increasing every year due to gross mismanagement of the environment. In India the predominant form of Lymphatic Filariasis is due to Wucheraria bancrofti transmitted by Culex quinquefasciatus mosquito (Menon and Rajagopalan, 1980 and Rajagopalan et al, 1977), which breeds in sewage and in unsanitary conditions. Brugian Filariasis is limited to only a few pockets in India and which is transmitted by the Mansonoides group of mosquitoes (Singh et al, 1956). For government of India in 1953 the population exposed to the risk of infection was only 25 million (Gol 1986), in comparison to 428.28 million in 1996 (Sharma and Rehman, 1998). India contributes about 40% of the total global burden of Filariasis and account for about 50% of people at risk of infection. The present Filariasis situation is alarmingly significant. In this context the World Health Organization (WHO) launched a Global Programme to Eliminate Lymphatic Filariasis (GPELF) by the year 2020 in accordance with the resolution WHA 50.29 of the 50th world health assembly (Ottesen, 2000). To achieve this global aim being a member state, India has to strengthen activities of mass drug administration, appropriate management of Filariasis patients and vector control strategies (ICMR Bulletin 2008).

Filarial causative parasites are transmitted by female mosquitoes of Culex, Anopheles, Aedes, and Mansonia species. Culex quinquefasciatus is a ubiquitous species and is abundant in tropical and subtropical countries. It is the principal vector of Bancroftian Filariasis in India (http://www.ENviscentreonbioinformatics–vectorcontrol).

There are 59 species of mosquito vectors of filariasis among them the most important vector is Cx.quinquefasciatus. It is widely distributed in tropical and sub tropical latitude (Pemola and Jauhari 2004). Increased mosquito nuisance in most
urban places is mainly because of *Cx.quinquefasciatus* (Batra *et al*., 1995). In India 98% of LF parasite is transmitted by Culex quinquefasciatus which bites only in darkness and transmit only nocturnally *W.bancrofti* is most endemic urban areas (ICMR bulletin, 2008).

I.2.3.4. Filariasis: Kerala Situation

In Kerala the early reference for Filariasis was ‘Cochin Leg’. Because many people in Cochin town was affected by filariasis. The first important official document of the incidence of Filariasis in the Travancore state appeared in the census of 1901 (Nagam Aiya, 1906). It was affected maximum in Cherthala taluk i.e; one in every 27 of the population followed by Ampalappuzha with one in 194 persons. Among the coastal towns Alappuzha and Trivandrum were recorded as highly Filarial with endemicity rates 20.5% and 13.6% respectively (Iyengar, 1938) According to the studies of National Filariasis Control Programme (NFCP) in Alappuzha and Kozhikode revealed the endemicity rates of 21.6% and 14.94 % respectively during 1975 and 1960. Later in early 1990’s studies revealed that diminishing of Lymphatic Filariasis in certain foci of Kerala diminishing the rate of Lymphatic Filariasis (Arunachalm *et al*., 1996). Absence of Brugian type of infection and low vector density of Monsonoids species as against predominance of *Bancroftian* infection and *Culex quinquefasciatus* vectors were the trend of changes occurred over years in Kerala towards the end of 1990’s the endemicity rates had been reduced to a low level being 2.6%, 1.7 % and 1.58% respectively during 1998, 1999 and 2000 periods (NFCP Kerala, 2001).

*Bancroftian* Filariasis is mainly prevalent in urban and semi urban areas and it is transmitted by *Cx. quinquefasciatus*. Brugian Filariasis is more of rural distribution and is transmitted by *Mansonoid annulifera, Mansonia uniformis* and *Mansionia indiana* (Iyenkar, 1938 and Gok, 1961).
I.2.4. Chikungunya (CHIK)

I.2.4.1. Introduction

Chikungunya (CHIK) is a relatively rare form of viral fever caused by an alpha virus and spread by the bite of infected mosquitoes of *Aedes aegypti* species. The disease resembles Dengue fever and is characterized by severe joint pain (Arthritis) as well as fever and rash. According to Robinson, the disease was first described by Robinson following an outbreak in Makonde Plateau along the border between Tanganyika and Muzambique in 1952-53 (Robinson, 1955).

I.2.4.2. Etymology

The name Chickengunya is given by Lumsden’s initial 1955 report which is derived from Makonde word ‘Kungunyala’, meaning to dry-up or became contorted, glossed the Makonde term more specifically as “that which bends up”. Chikungunya is not considered to be fatal (Ashok et al, 2007).

I.2.4.3. Chikungunya: Global Situation

Chikungunya virus was first isolated between 1952 and 1953 from both Man and mosquitoes during the epidemic of fever in Tansania. Chikungunya virus (CHIKV) is enzootic in many countries in Asia and throughout tropical Africa. In Asia the virus is transmitted from primates to human and almost exclusively by *Aedes aegypti*. According to Pfeffer et al various *Aedes* mosquito species are responsible for human infections in Africa. (Pfeffer et al, 2002). In Asia virus strains have been isolated from Bangkok in 1960’s, India in 1964, Sri Lanka in 1969, Vietnam and Myanmar in 1975 and from Indonesia in 1982. The outbreaks have been occurred in Philippines in 1969 and in 1996 (Joselito et al, 1998) and in Malaysia in 1999. Among many of these outbreaks and epidemic the role of Aedes species mosquitoes (*Ae.aegypti* and *Ae.albopictus*) has been established by several researchers (Macasaet et al, 1969, Campos et al, 1969, Zytoom et al, 1993 and Joselito et al 1998). By the end of 1990’s chikungunya viral infection seemed to have deep rooted in African and Asian countries as the third emerging mosquito borne disease.

I.2.4.4. Chikungunya: Indian Situation

According to Jupp and McIntosh, in India the first outbreak of Chikungunya (CHIK) viral disease was recorded in 1963 in Culcutta and was followed by epidemic in different places in many states in 1964, 1965 and 1973. In the year 2000
similar outbreaks occurred in Maharashtra State. Later massive outbreaks were reported in many districts from Andra Pradesh, Karnataka and Maharashtra State (Prasanna et al, 2006). Madya Pradesh Tamilnadu, Gujarat and Kerala were the other worst affected state during 2006. Till November 2007 in India a total of 43,111 suspected cases were recorded from 14 states/union territories (GOI, 2007).

I.2.4.5. Chikungunya: Kerala Situation

In 2006, the new viral disease Chikungunya fever appeared in Kerala for the first time affecting so badly in Thiruvananthapuram and Alappuzha districts, primarily in Cherthala. In 2007 the state reported 24052 suspected Chikungunya virus (CHIK V) infections, with highest number cases from Kottayam district followed by Pathanamthitta district (DHS Kerala, 2007). All districts reported serologically confirmed cases. CHIKV cases are also transmitted by Aedes species mosquitoes namely, Aedes aegypti and Aedes albopictus, which are the established vectors of DF (Zytoom et al, 1993, WHO, 1997 and Joselito et al, 1998). Clinically it is characterized by abrupt onset of fever, chills, headache, joint pain, and swelling especially involving small joints, various types of rashes develop usually after the subsidence of fever and in the convalescent phase (Ashok et al, 2007).

During the period of 2005-2012, 1,34,932 cases of chikungunya were reported, while 2405 cases were confirmed in the state. In Pathanamthitta District 4142 cases of chikungunya are reported while 89 cases were confirmed during 2006-2012 (DHS Kerala, 2012).

I.2.5. Japanese Encephalitis (JE)

I.2.5.1. Introduction

Japanese Encephalitis (JE) is a common mosquito borne viral encephalitis found in Asia. It occurs mainly in the rural and agricultural areas.

I.2.5.2. Japanese Encephalitis: Global Situation

According to Miler and Carey et al JE virus activity had been detected in many areas of east and south East Asia including Taiwan, Philippines, Indonesia, Korea, China, Siberia, Thailand and Malaysia (Miler 1960 and Carey et al 1969). According to Uno, during 1970’s it has been spread widely in South East Asia, without breaks in Thailand, Indonesia, Vietnam, India, Myanmar and Sri Lanka. An
estimated 43,000 cases of JE occur globally each year with 11,000 deaths and nearly 9,000 causing disability. About three quarters of the cases occur in the western in the Pacific countries and reminder in South East Asia especially India (WHO, 1996). The involvement of mosquitoes like Culex tritaeniorhynchus and Culex pipiens in the transmission of JE virus had been claimed. (Hammon et al, 1949) in Tokyo.

I.2.5.3. Japanese Encephalitis: Indian Situation

Japanese encephalitis (JE) is the second emerging mosquito borne viral disease in India. The disease has epidemic potential and high case fatality in addition to it causes neurological sequelae. Japanese Encephalities (JE) is prevalent in India since mid 1950’s. JE was clinically diagnosed for the first time in 1955 at Vellore, erstwhile North Arcot district of Tamilnadu. The first major outbreak of JE occurred in 1973 in two districts (Burdwan, Bankura) of West Bengal with seven hundred cases and three hundred casualties followed by another outbreak in 1976. Since then the number of outbreaks have been reported from the state of Bihar, Utter Pradesh, Assam, Manipur, Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu, Haryana, Kerala, West Bengal, Orissa and Union Territories of Goa and Pondicherry. The earliest serological evidence of JE virus activity was identified in India in 1952 (Smithburn et al, 1954). The disease has been recognized in India in 1956 (Carey et al, 1969.) The disease was recorded in India predominantly from rural areas but reports were there from sub urban areas also. Reported incident has generally been higher in males than in females. But sub clinical infections have occurred equally in both sexes. Large number of sub clinical infections occurs each year during the transmission season. Diagnoses can be made at primary health centre level based on clinical symptoms only. Therefore, there is a need to develop simple tests for use at the peripheral level both for diagnosis and for epidemiological surveys (Chaudhuri et al 1987). Outbreaks of JE have occurred in different part of India from time to time closely associated with monsoon and agricultural practices. The earliest notable outbreaks of JE have occurred in Nagpore during 1954-1955, North Arcot Madras in 1955 and in Agra, UP in 1958 (CBHE, 1981). Until early 1970, the disease was reported only from Southern part of India. Outbreaks of JE have become almost a routine affair after the first major outbreak was reported from Bunkura district in West Bengal during July – October 1973 causing large scale morbidity and mortality (ICMR Bulletin, 1980). The largest
of the reported outbreak of JE in India between 1973-99 was from Uttar Pradesh in 1988 when 4485 cases with 1413 deaths were occurred (GOI, 1999). *Culex* (*Cx*) species of mosquito especially *Culex vishnui* and *Culex tritaeniorhynchus* were considered to be the principal vectors of JE in West Bengal (Chakravarty *et al*, 1975). Other species included were *Cx. gelidus, Mansonia annulifera* and *Mansonia uniformis*. Out of 27 proven and suspected vectors of JE, *Cx. tritaeniorhynchus* and *Cx. vishnui* are the most important vectors of JE in India. *Cx. epidesmus, An. hyrcanus, An. subpictus, An. barbirostris* and *Mansonioisds annulifera* are also known as vectors of JE in India. JE virus also has been isolated from *Cx. whitmorei, Cx. pseudovishnui, and Cx. gelidus, Cx. bitaeniorhynchus*, and *Cx. fuscocephala*. Most of the region of Gujarat is free from JE but it is prevalent in north-eastern and southern part of India.

**I.2.5.4. Japanese Encephalitis: Kerala Situation**

Japanese Encephalitis and Dengue fever were reported from Kerala in mid 1990’s. Kerala which was so far free from JE, experienced the first outbreak in 1996 and since then sporadic cases were being reported. During 1996 the first affected district was Alappuzha followed by Kottayam and Pathanamthitta. There were 28 death reported out of the suspected JE cases during the year (DHS Kerala, 1997). According to DHS Kerala, 7 southern districts in Kerala were affected with JE and out of 99 cases reported 16 were death cases (DHS Kerala, 1997). Though the year 1998 was rather a silent year of JE, during 3 subsequent years there were respectively 214, 164 and 125 cases and 4, 2 and 5 deaths reported (DHS Kerala 2001). Again after 2 years gap, JE cases appeared in the years 2004, 2005 and 2006 with reported deaths(DHS Kerala 2006), there by showing the persistence of virus activity in the state. The Vector mosquitoes attributed to JE transmission belong to *Culex vishnui, Culex species, Mansonioisds and certain Anopheles species*. Four isolations made from a small number of wild caught Mansonia species mosquitoes during the outbreak of JE in Kerala in 1996 (Dhanda *et al*, 1997). According to Gaganana, a detailed study needs to be conducted on the vectoral potential of Mansonia species for JE transmission in Kerala (Gaganana, 1998).
In Kerala JE during 2005-2012, 161 cases were reported and 31 deaths occurred. In Pathanamthitta district there was no JE cases reported during 2005-2012 (DHS Kerala, 2012).

I.2.6. Conclusion

The factors related to climate and geography are suitable in Kerala for Mosquito breeding. The incidence of mosquito borne diseases in Kerala was found to be fluctuating since 1990’s not only in terms of number of cases and deaths, but also in the number of newly emerging and re-emerging diseases. Various mosquito transmitted diseases seemed to be widely distributed in almost all the 14 districts of Kerala state.

According to Panicker various factors like developmental activities human interference climatic changes and availability of parasitic load in the community and socio-cultural practices have contributed to increased mosquito menace and prevalence of mosquito borne diseases (Panicker1986).

Recently mosquito borne diseases have become a very serious public health issue in Kerala which required emergency actions and which have raised several questions regarding the vector capacities of mosquitoes and transmission of new viral infections in different regions of the affected districts. These situations require adequate information on the profile of mosquito species, their distribution and taxonomy. It was in this background that the present study namely “A study of medically important mosquito vectors in Pathanamthitta district of Kerala, India” was undertaken. The study was carried out to know the distribution, prevalence, species and varieties, diversity and seasonal fluctuations of mosquitoes in terms of established vectors of different mosquitoes transmitted diseases prevalent in the district Pathanamthitta, Kerala. The information acquired through the research work would help researchers and the like to proceed further in controlling mosquitoes.

I.3. Objectives of the Study

The important objectives of the present study are as follows

1. To study the medically important mosquito fauna of Pathanamthitta District of Kerala, India.
2. To identify the predominant mosquito species of the study area.
3. To study the potential of mosquito vectors in transmitting the diseases.
4. To know the environmental factors which monitor the population density of these species.
5. To formulate appropriate control measures of these mosquitoes in the study area.

I.4. Literature Review

Mosquitoes – the tiny insects have received special attention of Entomologists, Health workers and Sanitarians all over the world and hence generated enormous volumes of literatures.

Mosquitoes occur all over the world except Antarctica (Service, 2004). Mosquitoes are characterized by a slender elongated body covered with scales and possess of piercing and sucking mouth parts, belonging to the Phylum Arthropoda, Class Insecta, Order Diptera, Sub Order Nematocera family Culcidae and sub families Anophelinae, Culicinae and Toxorhynchitinae. Worldwide, there are over 3200 species of mosquitoes under 37 genera. The sub family Anophelinae consists of 3 genera, viz. Anopheles, Bironella and Chagasis, Culicina, 33 genera and Toxorhynchitinae only 1 genera.

Knowledge of mosquitoes in India dates back to the Second Century Susruta in his famous work ‘Susruta Samhita’, described twelve kinds of life destroying insects including mosquitoes and classified them into five groups namely Samudrah, Parimandala, Hastimashaka, Krishna and Parvatiya on the basis of ecological, morphological and causative characters. Nagam Aiya in the Travancore State Manual, while describing fauna of Travancore State about Dipteran Order which include mosquitoes. He explained culicidae family which include 4 species of Anophales, the elephant mosquito toxorhynchites, 5 species from genus culex, etc (Nagam Aiya 1906).

The publication of “The Monograph of Indian Anopheline and Culicine by Christopher (1933) and Barraud’s Fauna of British India (1934) marked a landmark in the history of mosquito studies in the subcontinent but the work accomplished between 1900 – 1934. Mosquito Taxonomy in India remained in slackwaters for a long time (Qutubuddin 1960).
Most of the mosquito faunistic studies in India were done in relation to the geographic location. Studies done in North east region of India by Nagpal and Sharma (1986), in Mizoram by Dutta *et al* (2003), in Western Ghats in Tamilnadu by Tiwari *et al* (1987), etc are a few examples. The above mentioned studies provided information on the distribution of mosquito species in different regions or states. The Regional Medical Research Centre, ICMR conducted many mosquito surveys and studied vector bionomics (Dutta *et al* 1992).

During the outbreak of vector borne diseases in different states of India a number of investigations were taken place. Entomological investigations during the outbreaks at dengue fever in certain villages in Maharashtra State by Ilkal Dhanda *et al* (1991), dengue vector prevalence and virus infection in rural area in South India by Tiwari *et al* (2004) etc are two examples among them.

In Kerala, mosquito faunastic studies were made by a few investigators. Iyengar in Thiruvananthapuram Taluk in (1938), Menon (1940), Rajendran *et al* (1992), Rajendran (1996), Dilip Kumar (2006), Sudharmini (2009) in Thiruvananthapuram and Kottayam districts.

In connection with the outbreak of mosquito borne diseases, a number of investigations were made by the experts. Studies on the occurrence of Aedes aegypti, the vector of dengue in Cochin City, Kerala, India by Arunachalam *et al* (1994) Potential of rubber plantations as breading source for Aedes Albopictus in Kerala, India by Sumodan (2003). A study on Chikungunya outbreak during 2007 in Kerala, South India by Kannan *et al* (2009), are a few example. I.C.M.R also did many studies in this regard to control mosquito vectors (ICMR Bulletin, 2002 and 2008).

A proper study on mosquito fauna in the study area viz. Pathanamthitta District would help in finding the distribution pattern of different mosquito species including the disease vectors indifferent seasons as well as in different ecological conditions. It would help to control mosquitoes and vectors by the proper implementation of control strategies.
It was in this background this research work –‘A study of Medically Important Mosquito vectors in Pathanamthitta District, Kerala, India’ undertaken and which was the first faunistic study in this district.