CHAPTER TWO

LITERATURE REVIEW

2.1 Breeding Environment of the Immature *A. aegypti*

The environment of the immature stages of the mosquito is aquatic, depending on atmospheric air for breathing and therefore typically spending much of their lives suspended from the surface film of the aquatic environment. While mosquitoes as a group, are found breeding in an almost infinite variety of sizes and types of water habitats, each species is generally associated with certain types of breeding places. In some species, however, breeding is restricted to a narrow range of habitats while others breed readily in a wide range of water types.

Moderate frequent rainfall usually increases the opportunity for prolific breeding but repeated and heavy rainfall causes severe flooding that result in a temporary flushing out of breeding places and reduction in mosquito populations.

The extent to which the breeding place is shaded or exposed to sunlight determines which species of mosquito inhabits a particular water body. Unless islands of vegetation are present to provide local breeding sites, mosquito larvae are not found in open waters of deep fresh water bodies such as lakes, ponds, rivers or reservoirs but are confined to their sheltered, shallow edges. Water is an essential component of the mosquito environment and whether it is running, standing, clean or polluted, fresh or brackish, shaded or sunlit, determines which species of mosquito breeds in it. The habitats of the immature stages and adult mosquitoes are interdependent since the adult mosquito must have access to water for egg-laying.

In recent years, considerable environmental changes have taken place in many areas as a result of creation of man-made lakes, the development of agricultural projects, deforestation, urbanization and other economic development activities involving land and water use. As a consequence, the classical breeding habits of mosquito vectors and even some aspects of their bionomics may also be changing in these areas. The most effective way to control mosquitoes is to find and eliminate their breeding sites.

2.1.1 Rainfall and Abundance of *A. aegypti*

A. aegypti is usually found in abundance during the rainy season. An epidemio-meteorotropic analytical study of Selangor by Li *et al.* (1985) examined the monthly incidence of dengue for the period of 1973 - 1982 to assess possible quantitative association with the monthly rainfall. A 120% increase in the number of dengue cases was observed when the monthly rainfall was 300mm or more (Li *et al.* 1985). This relationship suggested that rainfall might have exerted its effect on dengue infection partly through the creation of more breeding sites for dengue vectors and it is a factor worthy of careful surveillance and monitoring.

In another study carried out by Moore *et al.* (1978), a long term co-operative study of seasonal fluctuation in the population of the *A. aegypti* mosquito in Puerto Rico was described. During each month of the first 3 years of the project due to constant heavy showers, *A. aegypti* was found breeding in all 5 of the communities studied. Mosquito density was positively correlated with rainfall and the relationship is more marked in the dry, southern coastal part of the island.

To investigate seasonal abundance of dengue vectors in Manila, Philippines, Schultz (1993) stated that *A. aegypti* was the principal container breeder within the residential areas. He noted that the population of *A. aegypti* was low from February through May during the dry season and was higher from June to September during the rainy season. Schultz (1993) concluded that dengue transmission appears to be closely related to rainfall, with cases increasing about 2 months following the onset of the rainy season. Biswas *et al.* (1993) confirmed that Breteau index for *A. aegypti* showed a wide variation (25 in December, 1990 and 93 in August, 1991) and the fluctuation in density of the larval population of *A. aegypti* paralleled the fluctuation in both rainfall and humidity.

Studies on the breeding habitats and seasonal prevalence of the larval population of *A. aegypti* was carried out in 10 different locations in Dhaka city (Khan, 1980). Nine locations were found infested with larvae of either one or both *A.aegypti* and *A. albopictus* during the rainy season (May to October) . Seasonal variations in the larval population of both species followed closely the fluctuations in the rainfall with zero populations during the driest 3 months.

Studies on the prevalence of adult and immature *A. aegytpi* along with ecological factors were conducted in Jalore, Rajasthan (India) from 1992 to 1993 (Joshi *et al.* 1996). Presence of dengue antigen in field caught mosquitoes in the affected locality was observed mainly during the months of January to April. Water storage practices of the population due to irregular water supply was the cause for a higher vector concentration in the locality. Seasonality of occurrence of dengue fever in a particular period of the year is associated with a relatively higher vector density and presence of infected mosquitoes due to favourable temperature, relative humidity, water temperature and pH.

There is ample evidence that moderate frequent rainfall usually increases the opportunity for prolific breeding. This is due to the unwarranted creation of miscellaneous breeding sites which are excellent sources for egg-laying and supporting the growth of the immature stages of the mosquito. In Malaysia, the number of cases reported is low in the months of January to April (Ministry of Health, Malaysia 1996) which is the time period between the monsoon seasons. The following months show a gradual increase in the number of cases with the peak in July to August. This trend of seasonality is related to water collection. The start of light rainfall after the dry season in January to April and rainfall before the monsoon season increase the breeding places of *A. aegypti*, the vectors of dengue. In 1998, the number of dengue cases continued to increase during June and reached 4,813 with 13 deaths by July 1996. This is an increase of 2,363 since May and 55% above the number reported in the corresponding period in 1995 where DHF was diagnosed in 252 (5.5%) of 4561 cases. Therefore, there seems to be a positive correlation between the number of cases for dengue and the rainy season.

In an investigation carried out by Ramasamy *et al.* (1994) in Sri Lanka, mosquitoes were collected during the night (1800 to 0600 hours) at Nikamehera village in the intermediate rainfall zone of the country. Collections were made at monthly intervals in the period of October 1991 to April 1992 which was during the main rainy season due to the northeast monsoon (October to January). Vectors of dengue fever were identified in all of the collected samples.

Minimizing the potentiality of vector breeding through source reduction and water management is thought to be the simplest, cheapest and most permanent method (Yadava *et al.* 1991). For the society having varying types of habitation and varying degree of habitational facilities like planned housing, water supply and disposal, sanitation and organized anti-vector measures, the adoption of environmental management to monitor vector population is a promising proposition. Yadava *et al.* (1991) identified physical methods like drainage of excess and waste water, making water unsuitable for vector breeding and community based activities as the basic approaches for achieving this goal.

It is therefore necessary to study the breeding potential and the capacity of rainwater to support the growth and survival of these vectors from different residential areas in the Klang Valley as the data obtained would be useful to plan environmental management strategies on *A. aegypti.*

2.1.2 Breeding in River Water

For a long time, streams and rivers were overlooked as a habitat for mosquito breeding. Mosquitoes usually do not breed in running water such as rivers and streams. Larvae can be flushed out when stream volume is high and to remain in a stream requires a large amount of energy. Larvae of *A. aegypti* in streams will find vegetation along the banks with which to anchor themselves or attempt to remain away from the main flow of the stream by seeking isolated eddies. However aggressive human intervention in the environment had brought about serious consequences that had altered the stream and river flow. Streams and rivers that have been managed for power production and irrigation and the use of dams both large and small, produces large expanses of water which are suitable breeding grounds for mosquitoes that are vectors of infectious diseases (Mouchet and Carnevale (1997)).

Mosquitoes of the *Aedes sp.* actually deposit their eggs at the base of vegetation bordering streams or low lying areas subject to flooding (Potter and Knapp, 1998). Eliminating large breeding areas such as swamps or sluggishly moving streams or ditches was imperative in mosquito control. A total of 24 species of *Aedes*, *Anopheles* and *Culex* mosquitoes were collected from a river bed in the rural areas of the Northern Parana State of Brazil by Lopez and Lozovei (1995), who concluded that superficial waters with reduced gallery forest may serve as a refuge for some Culicidae.

Urban residents such as *A. aegypti* was found to breed only in clean and clear water. Therefore polluted water such as sewage systems and waste water was neglected in the surveillance of this Culicidae. Unfortunately Karch and Mouchet (1995) discovered that sewage farms and settling ponds provide suitable breeding sites for more than 10 mosquito species. Mosquito control in these areas was based on early ground treatment of breeding sites where temephos and fenotrothion were used.

Several rivers flow right through the heart of the Klang Valley in Malaysia. Sungai Keroh and Sungai Damansara pass through residential areas and Sungai Gombak passes through the city centre. Due to rapid industrialization and lack of civic-consciousness, these rivers have been abused and clogged up with waste disposal causing its flow to be hindered. It would be interesting to conduct a study on the survival rates of *A. aegypti* in these rivers as it could pose a threat to the residents in its vicinity.

2.1.3 Breeding In Stagnant Waters

Since mosquitoes need water to complete their life-cycle, the source of a mosquito problem can be just about anywhere that water can collect. Farm ponds and lakes are usually not breeding grounds for mosquitoes if they contain fish and are free of weeds, algae or floating debris where mosquito larvae can hide. Human activities may create mosquito breeding sites or increase production of mosquitoes in natural bodies of water. Road building and maintenance usually impede the drainage of runoff from rainfall, creating breeding sites. Clogged drainage ditches along roads can become productive mosquito breeding sites. Logging and construction activities leave tyre ruts in the soil. These depressions are ideal breeding sites for "floodwater" mosquito species. Around the housing estates, objects such as bird baths, discarded tyres, plant pots and other such objects collect rainwater causing mosquitoes to breed.

Barrera *et al.* (1993) tested the hypothesis that deficient supply of piped water was causing a high prevalence of water storage containers, which in turn become important aquatic habitats of *A. aegypti* in a small town in Venezuela. The House (71.2%) and Breteau indices (229) of mosquitoes were considerably elevated. Prevalent positive containers were metal drums, small disposable containers (bottles, tins etc.), tyres, house plants (flowers in vases and plants in pots with earth) and tanks. Most people reported frequent interruptions in the supply of piped water and considered it to be unreliable. The frequency of interruptions in the supply of water was positively correlated with the House and Containers indices, and with the number of positive containers, water storage devices and positive water-storage devices per house. This could be interpreted that due to inadequate piped water supply, the need to store water was inevitable. It was in these water-storage containers that *A. aegypti* was found to breed and proliferate.

Khan (1980) conducted a study on the outdoor breeding habitats and seasonal prevalence of larval populations of *A. aegypti* and *A. albopictus* in 10 different locations of Dacca city. Nine locations were found to breed larvae of either one or both species during the rainy season (May to October) of the year. A total of 1,898 containers/sites were surveyed, out of which 86 (4.53%) bred either one or both species. *A. aegypti* larvae were present in only four kinds of artificial containers. Earthen pot was the most numerous breeding habitat (24.3%, 461) and contributed to the highest number of infested container (45.3%, 39).

In a survey conducted in Chungho city, Taiwan, during the period of August 12 to September 13, 1996, on the breeding of *Aedes* mosquitoes in various containers, most villages (41 in the total of 93) were found to breed *A. albopictus* Skuse. The most common breeding containers found were less than 5cm in water depth and less than 100cm^2 in freshwater area. The numbers of the vector breeding in containers reduced when the water depth and size of the container increased. The common breeding containers in villages were flower vases (30%) and water buckets (18%). In the mountains, water buckets (34%) and kitchen tools (11%) were common. In parks, water buckets (29%) and tyres (15%) were commonly found. In cemeteries, the common breeding containers were flower vases (57%) and earthenware pots (17%). The average (2.05 containers per man-hour) of positive water containers in the mountains was significantly higher than that in parks (0.62). This supported the notion that *A. aegypti* had the potential to breed in almost any kind of container that could hold water.

In another survey designed to identify the different containers used by *A. aegypti,* the most common water-filled containers positive for the larvae or pupae of *A. aegypti* were outdoor drums, water storage tanks and buckets, laundry tubs, discarded tyres, and small miscellaneous containers such as drink bottles and cans (Focks and Chadee, 1997). The average standing crop per container of *A. aegypti* pupae was 9.5 and ranged 12-fold, the most and least productive being the flower pot (>30) and the small indoor vase (<3), respectively. In terms of production by type of container, four of the 11 types, outdoor drums, tubs, buckets, and small containers, accounted for >90% of all *A. aegypti* pupae. The remaining seven types were responsible for <10%. If target source reduction programs were directed by how important various container types were in the production of *A. aegypti* environmental sanitation efforts designed to actually eliminate the ubiquitous small receptacles and tyres would reduce mosquito densities by 43%. The provision of an adequate water supply system precluding the need for water storage in drums and buckets would have the potential to eliminate an additional 38%. Combined, these two measures have the potential to reduce the sources responsible for >80% of *A. aegypti* production in the country.

Tun Lin *et al.* (1995) conducted a study on the ecology of *A. aegypti* as a key to surveillance in Townsville, Charters Towers and Mingela/Ravenswood, Queensland, Australia. The *A. aegytpi* population in Townsville was totally associated with garden receptacles, discarded household items, and trash but one well and one rainwater tank were responsible for 28% of all immature forms recorded in the 1,349 premises inspected. At Charters Towers, Mingela and Ravenswood, rainwater tanks supported 60-63% of the immature forms. Control programs could be more efficient if efforts were concentrated on these sites of key vector productivity.

A study on the breeding habitats of *A. aegypti* and the water storage habits of the inhabitants in four crowded districts of urban Jakarta showed that immature mosquitoes were found in or near houses in containers of relatively clean water used for drinking and bathing purposes (Nelson *et al.*, 1976). An average of 185 containers were found per 100 houses, of which 60 were positive for *Aedes* immatures, resulting in a Container Index of 32%. The mean potential water storage capacity per house was 173 liters of which only 92 liters of water was actually being stored at any one time. Water jars were the most common containers found, but *bak mandi* (oblong concrete reservoirs) held more water per container. A mean of 0.93 pupae per house was found, pupal production indoors being ten times more than outdoors. Indoor water jars produced more pupae per house than all other containers combined. The infestation rate of covered containers was significantly higher than that of uncovered containers, perhaps because loose-fitting lids allowed entrance of gravid females to the attractive darkened interior of the container.

The breeding of *A. aegypti* in the urban housing of Sibu, Sarawak (Malaysia)was surveyed in 12 urban housing areas and 29 vacant lands in Sibu town proper (Seng and Jute, 1994). *A. aegypti* larvae were present in 10 localities and 4 vacant lands. The proportion of containers positive with *A. aegypti* in the area outside the house compound and near the house fencing were 3.2 times higher than the outdoor compound. The indoor/outdoor breeding ratio for *A. aegypti* was 1.6:1. The most preferred breeding habitats outdoor were plastic cups and used tyres while indoor habitats were ant traps and flower vases. In the vacant lands, the average number of larvae per containers were significantly higher than in houses and over 51% of the containers inspected were positive. This was due to the easy accessibility for the female adult *A. aegypti* to stagnated water for oviposition. This larval survey provided essential information in the study of vector epidemiology in DF and DHF transmission.

In a study on septic tank mosquitoes in Abia State University, south-eastern Nigeria, conducted between November 1988 to April 1989, six mosquito species were detected : *Culex quinquefasciatus C. cinereus, C. horidus, C. tigripes, Aedes vittatus* and *A. aegypti* (Nwoke *et al.*, 1993). These mosquitoes were found breeding in ammonia rich waters of latrines and septic tanks. The fact that these mosquito vectors are able to breed in highly polluted waters of septic tanks during the harsh dry months when most surface water bodies are dry is epidemiologically important. The breeding of these mosquito vectors of human disease around human dwellings indicate an intense man-vector contact creating a high level risk to the crowded urban population. However, in Accra and Tema, (Ghana) Chimery (1995) found that extensive water pollution and loss of natural adult resting places caused reduced intradomiciliary breeding of *A. aegypti* and therefore causing low yellow fever incidence.

Transient water sources such as flooded areas, snowpools and ditches are used as breeding grounds for mosquito species whose eggs can stand desiccation such as *A. aegypti*. Their life-cycles require alternating wet and dry periods. Transient waters usually show water quality changes which result in various mosquito species using the same pool over a period of time. Baruah and Das (1996) discovered the breeding of *A. albopictus* in cemented drains, small ponds and ditches in Tezpur, Asam. In Singapore, Goh (1997) reported 1,172 construction sites were found to be breeding *Aedes* and the authorities issued stop-work orders to 236 sites that had been caught repeatedly. There was a rise in dengue cases in the first four months of 1998 to 1786 cases and it was mainly caused by ditches in the construction sites. These localities had a large number of potential mosquito breeding areas, housed construction workers and were located close to densely populated residential areas.

In Malaysia, Chang *et al.* (1997) found that there was an increase in dengue vectors in deforested lands. Surveys were conducted in an area undergoing oil palm development in north Sarawak. Major habitat perturbation during the forest clearing transition shifted the major mosquito faunal equilibrium in terms of species composition, relative density and occurrence. This study highlighted two contrasting effects : reduction of malaria vectors but concomitant increase of dengue vectors.

2.2 Water Parameters Affecting the Survival and Abundance of *A. aegypti*

As water plays an important role in the immature stages of *A. aegypti*, it is important that water conditions and its impact on the survival of this mosquito be thoroughly studied. The parameters that need further attention are like temperature, pH, water quality and heavy metal content and correlations that exist between these parameters and the breeding and survival of *A. aegypti*.

Jetten and Focks (1997) studied the potential changes in the distribution of dengue transmission under climate warming. They found that temperature influences adult survival, the lengths of the gonotrophic cycle and the extrinsic incubation of the virus in the vector and the vector size. The current warming projection of the International Council of Scientific Unions and the Intergovernmental Panel on Climate Change of 2°C by the end of the next century can be expected to result in a potential increase in the latitudinal and altitudinal range of dengue as the potential duration of the transmission season will also increase in temperate locations as well.

Reiter (1988) found that the El Nino phenomenon had hastened the spread of dengue fever by changing weather patterns in Southeast Asia. Rains were delayed in this region due to the El Nino. *A. aegypti* which flourishes during the rainy season, was found breeding in water-filled plastic bags and cans in dry weather. The El Nino weather disruption further intensified global warming causing higher altitude environments to become more favourable. *A. aegypti* that was previously limited globally to altitudes no higher than 1000m are now found in Colombia at elevations above 2000m.

The behavior of juvenile *A. aegypti* was evaluated in 200- L drums (Tun Lin *et al.*, 1994) that were developed to improve surveillance. All stages except the first instar was most numerous in the top 1/3 of the drum. Water temperature was the only significant variable affecting the vertical distribution of the third instar larvae. Light intensity and pH were non significant factors. Rust in the water influenced the distribution of the larvae to the surface layer. Therefore, it could be concluded that *A. aegypti* larvae were most likely to be found in the surface of shallow waters compared to deep waters due to their need for sunlight and air to breathe.

In an interesting study by Paradise and Dunson (1997) the effects of pH and sulphate and changing levels of chemicals found in precipitation in central Pennsylvania (H^+ and SO_4^{2-}) on *Aedes* species were discussed. Emergence and survival of mosquitoes were lower at lower pH. It appears that the Aedes mosquito are affected by ionic changes in simulated tree stemflow that can be caused by rainfall precipitation.

Rayms-Keller *et al.*(1998) have shown that embryos immersed in 32 ppm Cu^{2+} or 5 ppm Cd^{2+} did not hatch, but hatching resumed when heavy metals were removed. The 50% lethal concentration of third-instar larvae was 3.1, 16.5, and 33 ppm for Hg^{2+}, Cd^{2+} and Cu^{2+} respectively. In this context *A. aegypti* was used as a model system for investigating the molecular biological effects of heavy metals in aquatic insects (Keller *et al.*, 1998).