ISSN: **2348-5906**
CODEN: **IJMRK2**
IJMR 2015; 2(3): 200-207

Received: 20-07-2015
Accepted: 21-08-2015

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Anopheline mosquitoes and the malaria scourge

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Abstract
The high prevalence of malaria in Africa has defiled many strategies aimed at its eradication. Researchers from various fields have tried without success in this fight against mosquito and its malaria disease. Annually billions of dollars are spent in the design of programs which are aimed at combating this dreaded disease. However all this spending seems to go down the drain as malaria and its vector mosquitoes celebrate their unflinching victory. Current control measures focusing on ways of preventing the disease vis-a-vis, protect man from the vectors “anopheline mosquito” are the mainstay of malaria prevention and control. Many of these control measures are operational with each contributing in its little way. The use of Long Lasting Insecticide Treated Nets (LLITN) and Indoor Residual Sprays (IRS) are well established strategies with global recognition and currently ongoing in Africa. However, as a result of shortcomings in these major control measures, new strategies with hopes of blissful success are been sought after. Larviciding (abortion of metamorphosis) and constant and adequate environmental sanitation seems to be the next option available for use. This article therefore takes a look at the vector-anopheline mosquito, its ecology, productivity and distribution. It also considers malaria and the various control and preventive measures currently targeted at its eradication.

Keywords: Mosquito, Malaria, Larviciding, Environmental Sanitation, Bio-Insecticides

1. Introduction

Mosquitoes are vectors of disease causing agents found within almost all tropical and subtropical countries. Mosquitoes undergo complete metamorphosis, having egg, larval, pupal and adult stages. There are generally six immature stages during mosquito development; the egg stage, four larval stages referred to as 1st-4th instars and the pupal stage. Mosquito larvae are commonly referred to as “wrigglers” and pupae as “tumblers”. There are two subfamilies in the mosquito family (*Culicidae*): *Anophelinae* (*gambiae, funestus, arabiensies*) and *Culicinae* (*quinquefasciatus, pipiens, tarsalis, salinarius* etc). Most larvae in the subfamily *Culicinae* hang down just under the water surface by the siphon, whereas anopheline larvae lie horizontally just beneath the water surface supported by small notched organs of the thorax and clusters of float hairs along the abdomen [1]. Anopheline larvae have no prominent siphon. The larvae of *An. gambiae* breathe atmospheric oxygen through two ‘spiracular openings’ on the eighth segment of their abdomen and feed by moving brushlike structures on their mouthparts that create a current of water [2]. They filter out microorganisms, particulate organic matter or detritus and biofilm [3, 4]. The larvae undergo four molts (each successively larger), the last of which results in the pupal stage. The pupal stage of mosquitoes does not feed. Pupae give rise to adult mosquitoes in 2 to 4 days. The emergence process begins with splitting of the pupal skin along the back. An emerging adult must dry its wings and groom its head appendages before flying away [5]. Accordingly, this is a critical stage in the survival of mosquitoes. If there is too much wind or wave action, the emerging adult may fall over, becoming trapped on the water surface to die. This is the reason why little if any mosquito breeding occurs in open water, but occurs at the water’s edge among weeds. With optimal food and temperature, the time required for development from larva to adult can be as short as 7 days [6]. Adult mosquitoes of both sexes obtain nourishment for basic metabolism and flight by feeding on nectar [5]. In addition, females of most species need a blood meal from birds, mammals, or other vertebrates for egg development. They suck blood via specialized piercing-sucking mouthparts called probosis.

2. Ecology of Mosquitoes

Larvae and pupae of mosquitoes are always found in water. Breeding sites may be anything from water in discarded automobile tyres, tins, plastics and the axils of plants, to pools, puddles, swamps, and lakes. It is very important to note that mosquito species differ in their breeding habits, biting behavior, flight range, and so forth. Typical habitats of *An. arabiensis* and *An. gambiae* are puddles, shallow ponds, burrow-pits, brick-pits, tyre tracks, ditches, human foot and animal hoof prints which are often created by the activities of humans or domestic animals [7]. These habitats are open, containing no, little or low (grass) aquatic vegetation [8] and are often of a transient nature, as their availability corresponds to precipitation [7]. *An. gambiae* can colonize a breeding habitat within a few days after the site is created [9]. Besides temporary habitats, *An. arabiensis* is also found in market garden wells [10] and water storage tanks. A typical characteristic of breeding sites of *An. gambiae* is their shallow nature. [11] Showed that water bodies inhabited by *An.arabiensis* were on average 18.0 (95% CI ± 3.5) cm deep, by *An. gambiae* 29.4 (± 10.7) cm and by both species 9.7 (± 4.1) cm on the average. In another field study, average depths of 6.2 (±5.3 SD) and 10.6 (± 7.2) cm were recorded in dirt tracks and in ditches, respectively [7].

Despite the dogma that *An. gambiae* is most often found in turbid water collections, various studies that examined the characteristics of larval habitat or larval population dynamics, failed to give a clear relationship between the presence of immatures and the clarity of breeding sites. It is known that dark substrates receive more eggs than light ones and moist substrates more than dry ones [12]. *An. Gambiae* was hence concluded to prefer turbid water over clear water [13]. This was supported by [11] who observed that *An. gambiae* and *An. arabiensis* were associated with habitats that were high in turbidity and that both species increased in larval densities with increasing water turbidity. In contrast, [14] found that *An. gambiae* preferred clear rainwater over natural water from forests and natural wetlands, which contained more impurities and was supported by [15] who showed a preference of *An.gambiae* to breed in rather clear water bodies. Other factors that may play an important role in habitat selection are volatile compounds that are produced by microbial populations in the breeding site [16], chlorophyll a content in the breeding site [8] or the presence of conspecific larvae or aquatic predators [17]. Some studies reported no effect of turbidity on the occurrence of *An. gambiae* [18]. However, *An. arabiensis* and *An. gambiae* are often found to share larval habitats [20]. A clear difference in requirements for the larval environment of the two species has not been observed, but is subject of discussion. Several studies suggest the requirements are similar [11], others think they differ, but were unable to show that explicitly [14].

3. Habitat productivity

Mosquito breeding site productivity, estimated in terms of the numbers and size of mosquitoes produces over time depends, not only on the initial number of eggs that are deposited, but on the growth, development rate and survival of the mosquito immatures. Larval developmental rate, survival and adult size affect the transmission of malaria. The time to develop from an egg into an adult, combined with larval survivorship, determines the numbers of emerging mosquitoes over time. The size of the emerging adults is of importance, as larger females have been found to survive longer and have a greater fecundity [20]. Smaller and virgin females on the other hand require a second or third blood meal in order to develop mature eggs, prolonging the time to their first oviposition [21]. Intermediate-sized mosquitoes were found to be more infectious to humans [21]. Besides size, various biotic and abiotic factors also affect the growth, development and survival of the immature mosquitoes and consequently affect habitat productivity [22]. Under laboratory conditions, where larvae were exposed to constant temperatures, [23] showed that larvae took 9.8 to 23.3 days to develop into adults, depending on the temperature. Another laboratory study investigated the duration between oviposition and pupation and reported a time period between 7 and 27 days [24]. In another field study, it was shown that the duration of the immature lifetime of *Anopheles gambiae* ranges from 8 to 22 days in habitats of different size [25]. Eggs hatch within one day, larvae grow into pupa within 6-19 days and the pupal stage lasts 1-2 days. A similar field study by [25] observed a shorter time range of the development from egg to adult, which was 8.4-11.5 days. Service, MW [26] observed that larvae, newly hatched from the eggs, took on average 11.8 days to develop into adults, in small ponds and pools, ditches and rice fields. The mortality observed among the immature stages of *An. gambiae* in the field is extremely high. In all, only a small fraction (2-8%) of the larvae eventually survives to the adult stage [27]. It is highly likely that many biotic and abiotic variables, interact and a combination of these factors affect the productivity of a breeding site [10]. In general it is believed that; nutrition, larval densities and water temperature are the principal contributing factors that affect growth and development of mosquito immatures [4].

4. Spatial and temporal distribution

Mosquito species differs in their distribution within the environment. Among the specie *Anopheles*, *An. gambiae* is usually the predominant species in wet environments with high humidity whereas *An. arabiensis* is more common in hotter zones with less rainfall [28]. However, both species occur sympatrically across a wide range of tropical Africa [29]. Breeding of *An.gambiae* is mostly restricted to the rainy seasons with larval and adult densities increasing rapidly and the species predominating over *An. arabiensis*, and *An. funestus* which are more dominant species during the dry periods [11, 30]. The distance between oviposition site and blood host may affect the oviposition choice [17]. Minakawa *et al.* [30] showed that immatures of *An. gambiae* would be found inbreeding sites closer to houses and further away from cowsheds and a study [31] showed that significantly more larvae of *An. arabiensis* than *An. gambiae* were collected in pools close to cattle and suggested that species distribution may be explained to a large extent by the presence of suitable hosts instead of breeding site availability.

5. Gonotrophic cycle

The gonotrophic period or gonotrophic cycle is defined as the time period between two ovipositions. This period includes the search for a host, the ingestion and digestion of a blood meal, the maturation of the ovaries and the search for a suitable aquatic breeding site to deposit the mature eggs. Each gonotrophic cycle lasts about 2-4 days for *An. gambiae* [32], but its length will depend on factors such as breeding site availability [33], number of previous gonotrophic cycles and temperature [34, 35]. In the field only a small percentage of females of *An. gambiae* survive for more than three or four gonotrophic cycles [36]. Although a small percentage was found to survive for over ten cycles [37].

6. Malaria burden

Fifty-five percent (55%) of the world's population was reported at risk of mosquito borne diseases in 124 countries [38]. In the first comprehensive report on the Roll Back Malaria partnership, malaria was said to be endemic in 117 countries with some 3.2 billion people living in risk areas all over the world [39]. Another report further stated that each year, there are about 350-500 million clinical cases of malaria worldwide with over 1 million death. About 59% of all clinical cases occur in Africa, 38% in Asia, and 3% in the Americas [40]. Malaria mortality is also highest in Africa with 89% of all deaths whereas 10% occurs in Asia and less than 1% in the Americas. Of all malaria cases caused by *Plasmodium falciparum*, the most deadly human malaria species, 74% are in Africa, 25% in Asia and 1% in the Americas. Anopheline mosquitoes are the vectors responsible for the transmission of the deadly malaria etiological agent "*Plasmodium*" [5]. Despite several efforts in the field of vector control, the medical and economic burden caused by vector-borne diseases including malaria continues to grow, plaguing the continent Africa with no visible remedy in sight.

7. Malaria Prevention and Control

Despite the huge investment and intensive research in the development of malaria vaccine, science is yet to record a break through. However, a number of effective preventive methods are currently utilized to combat malaria. The policies and prevention strategies used are defined by the available resources and epidemiological setting of the diseases [41]. Environmentally, to prevent these diseases, the mosquito population must be kept at a low level at all times. The most effective way to control the mosquito population is to get rid of their breeding sources [42]. As far as possible, stagnant waters should be removed permanently by good and regular housekeeping practices such as filling up ground depressions, disposing discarded containers properly and clearing choked drains and roof gutters. For those mosquito breeding habitats that cannot be removed permanently, a competent pest control operator should be engaged to look out for them within premises and treat them with insecticides to prevent breeding. Prevention of malaria encompasses a variety of measures that may protect against being bitten by the disease vector or against the development of disease in infected individuals [43]. Full coverage and access to prevention methods is the means to reducing malaria incidence and eradicating the disease. There are three primary prevention strategies that are currently being utilized by 107 malarious countries. The first is drug treatment, the second is indoor residual spraying to eradicate mosquitoes, and the third, is mosquito nets to prevent bites [44].

7.1 Drug treatment

Given the increasing incidence of resistance to previous drugs used in malaria therapy, current malaria drug treatment focuses on combination drug therapies as recommend by the World Health Organization. The synergistic effect of these drugs are employed as the resistance of the disease to conventional drug therapies, such as chloroquine, sulfadoxine pyrimethamine (SP) and amodiaquine, has increased. Artemisinin-based Combined Therapies (ACTs) are the most effective drug treatments currently. They produce a very rapid therapeutic response to malaria. Since 2001, 42 malaria-endemic countries have started using ACTs [44, 45]. Unfortunately, there seem to be an impending relapse as resistance of Plasmodium to certain Artemisinin based combined therapies emerges.

7.2 Indoor residual spraying (IRS)

IRS is a highly-effective strategy for combating malaria and may provide a lasting impact in areas of intense transmission. Unfortunately, the availability of low-risk and cost-effective insecticides is diminishing due to increasing mosquito resistance and little development of new compounds over the past 20 years. Approximately 50% of African nations currently use the IRS in malaria control [44, 45]. However, despite the use of IRS, malaria remains a major Public Health problem in Africa. To date, IRS has only been implemented in Nigeria in a limited fashion. However, according to the National Malaria Strategic Plan 2009-2013, the objective was to gradually scale up spraying to cover 20% of households nationwide (or almost seven million households) by 2013 [45].

7.3 Mosquito nets

Mosquito nets, particularly insecticide-treated nets, are a highly recommended strategy for the prevention of malaria. Mosquito nets serve as the principal prevention strategy against malaria because they are cost-effective, efficacious, and more available than other strategies. Long-lasting insecticide nets have recently been developed and provide protection for up to five years. Most of the mosquitoes that carry the malaria parasite bite individuals during the night hence bed nets protect individuals from the mosquitoes during this time by preventing contact and thus reducing the risk of malaria. Furthermore, if treated with the insecticide, the net repels mosquitoes and shorten the life of the mosquito [44]. The use of mosquito nets has consistently shown a reduction in malaria cases and overall mortality related to malaria [45]. Twelve insecticides from four classes (organochlorines, organophosphates, carbamates and pyrethroids) have been recommended for IRS [46, 47], but only pyrethroids have been approved for treating bed nets. Since the mid-1950s, there have been numerous reports of reduced *Anopheles* susceptibility to DDT, malathion, fenithrotion, propoxur and bendiocarb, and resistance to all four classes of insecticides has been found in *Anopheles* species in different parts of Africa [48, 49]. A much more recent development is that of pyrethroid resistance with cross-resistance to DDT, first reported in *An. gambiae* from Côte d'Ivoire [50] and now widespread in West Africa. Pyrethroid-DDT cross-resistance presents a major challenge for malaria vector control in Africa because pyrethroids represent the only class of insecticides approved for treating bed nets and DDT is recommended for use in IRS [51].

8. Resistance to chemical insecticides

For a long time, most insect control strategy has been based on the use of chemical insecticides. However, with the emergence of resistance amongst most species of insect to available insecticides, man is left with no other option but to search for more reliable control strategies. Resistance to insecticides has appeared in the major insect vectors from every genus. As of 1992, the list of insecticide resistant vector species included 56 anopheline and 39 culicine mosquitoes, body lice, bedbugs, triatomids, eight species of fleas, and nine species of ticks [52]. However, insecticide resistance is now widespread and is reported in nearly two thirds of countries with ongoing malaria transmission [53]. It affects all major vector species and all classes of insecticides [53]. Insecticide resistance is the term used to describe the situation in which the vectors are no longer killed by the standard dose of insecticide (they are no longer susceptible to the insecticide) or manage to avoid coming into contact with the insecticide. The emergence of insecticide resistance in a vector population is an evolutionary phenomenon [54]. According to World Health Organisation [55], if nothing is done and insecticide resistance eventually leads to widespread failure of pyrethroids, the public health consequences would be devastating. Insecticide resistance is expected to directly and profoundly affect the reemergence of vector-borne diseases [56], and where resistance has not contributed to disease emergence, it is expected to threaten disease control [52]. The two major forms of biochemical resistance of mosquitoes (as opposed to insecticide avoidance behaviors) are target-site resistance, which occurs when the insecticide no longer binds to its target, and detoxification enzyme-based resistance, which occurs when enhanced levels or modified activities of esterases, oxidases, or glutathione S-transferases (GST) prevent the insecticide from reaching its site of action. An additional mechanism based on thermal stress response has been proposed [57], but its importance has not been assessed.

9. Phytochemicals/botanicals

One of the most effective alternative approaches under the biological control programme is to explore the floral biodiversity and enter the field of using safer insecticides of botanical origin as a simple and sustainable method of mosquito control [58]. Phytochemicals are botanicals which are naturally occurring insecticides obtained from floral resources [58]. Although often conceived as a new approach, the use of botanicals as insecticides dates back to ancient times when plants were used as repellants to ward off insects. However the discovery of synthetic insecticides such as DDT in 1939 side tracked the application of phytochemicals in mosquito control programme. Unfortunately, the extensive and repeated use of synthetic organic insecticides such as organophosphates and organ chlorines have led to disruption in natural biological control systems heading to resurgence and resistance in target species and destruction of no target beneficial fauna, in turn resulting in fostered environment and human health concern [59]. According to Remia and Logaswamy, [60] more than 2000 plant species have been known to produce secondary metabolites of value in biological pest control programs and among these, products of some 344 species have been reported with significant activity against mosquitoes. Botanical phytochemicals with mosquitocidal potential are now recognized as potent alternative insecticides to replace synthetic insecticides in mosquito control programs due to their excellent mosquitocidal properties and the chemicals derived from plants have been projected as weapons in future mosquito control program as they are shown to function as general toxicant, growth and reproductive inhibitors [61]. Unlike conventional insecticides which are based on a single active ingredient, plant derived insecticides comprise botanical blends of chemical compounds which act concertedly on both behavioural and physiological processes. Thus, there is a very little chance of pests developing resistance to such substances [62]. Identifying bio-insecticides that are efficient, as well as being suitable and adaptive to ecological conditions, is imperative for continued effective vector control management. The botanicals have widespread insecticidal properties and will obviously work as a new weapon in the arsenal of synthetic insecticides and in future may act as suitable alternative products to fight againstmosquito-bornediseases [58].

10. Larval control

Larval control is the foundation of most mosquito control programs. Whereas adult mosquitoes are widespread in the environment, larvae must have water to develop. Control efforts therefore can be focused on aquatic habitats. Minimizing the number of adults that emerge (aborting their development) is crucial to reducing the incidence and risk of disease. The three key components of larval control are environmental management, biological control, and chemical control. Larviciding is a general term for killing immature insects by applying agents, collectively called larvicides, to control larvae and/or pupae stages of these insects [63]. This is an evolving control measure that targets the larva stage of the mosquito. Many people think that the best time to begin a mosquito control program is when the numbers of biting female mosquitoes reach an intolerable level. Contrary to this believe, the best time to begin a mosquito management program is before the adult mosquitoes emerge. Control efforts should begin immediately after the mosquito eggs have hatched, the breeding site should be inspected, and the numbers of larvae present quantified to determine whether or not the use of an insecticide is justified [40]. Mosquitoes are most efficiently and economically destroyed when they are in the larval stage and are concentrated in their breeding site. Preventing the larvae from becoming adult mosquitoes minimizes the area that would have to be treated. It also prevents the development of an annoyance or health problem and it reduces the potential environmental impacts of the adult mosquito control program [40]. Larviciding can reduce overall insecticide use in a mosquito control program by reducing or eliminating the need for ground or aerial application of insecticides to kill adult mosquitoes [41]. Nandita *et al.* [64] considered mosquitoes in the larval stage an attractive target for pesticides because they breed in water and, thus, are easy to deal with in this habitat whereas [65, 66] posited that larviciding is a preferred option in vector control because larvae occur in specific areas and can thus be more easily controlled. Treatment of mosquito breeding sites provides control before the biting adults appear and disperse from such sites.

11. Chemical larvicides

Chemical larvicides/pesticides are rarely used to control mosquito larvae. Organophosphate larvicides are used infrequently because of their potential non-target effects and label restrictions. Temephos is currently the only organophosphate registered for use as a larvicide in California [67]. This product can be safely and effectively used to treat temporary water or highly polluted water where there are few non-target organisms and/or livestock are not allowed access. The efficacy of temephos may be up to 30 days depending on the formulation [67]. In Nigeria, and most Africa nation's chemical larvicides are currently not in existence and are generally unknown and unheard of. Chemical adulticides (insecticides) rather are all that seem to be as the populace unaware of the potential threat posed by the larva burden themselves with the adult insect leaving out the larva which breeds at every nock and cranny of their environment.

12. Microbial insecticides

Microbial insecticides are formulated to deliver a natural toxin to the intended target organisms. Bacteria are single-celled parasitic or saprophytic microorganisms that exhibit both plant and animal properties and range from harmless and beneficial to intensely virulent and lethal. *Bacillus thuringiensis* (*Bt*), is the most widely used agricultural microbial pesticide in the world, and the majority of microbial pesticides registered with the Environmental Protection Agency (EPA) are based on *Bt* [63]. The *Bt* serovar *kurstaki* (*Btk*) is the most commonly registered microbial pesticide, and this variety has activity against Lepidoptera (butterflies and moths) larvae [63]. It was originally isolated from natural Lepidopteran die-offs in Germany and Japan. Activity of *Bt* against species of mosquitoes were reported [68]. *Bt* products have been available since the 1950s. In the 1960s and 1970s, the World Health Organization (WHO) encouraged and subsidized scientific discovery and utilization of naturally occurring microbes. As a result of those early studies and a whole body of subsequent work, two lines of mosquito control products have been developed: crystalline toxins of two closely related gram-positive, aerobic bacteria - *Bacillus thuringiensis israelensis* (*Bti*) and *Bacillus sphaericus* (*Bs*). Mosquito control agents based on *Bt*are the second most widely registered group of microbial pesticides. Highly successful *Bti* products have expanded the role of microbial agents into the public health arena [67]. However, the use of these microbial insecticides has not received the necessary popularity in tropical and third world countries were the plague of mosquito and its corresponding diseases seem to be concentrated. The use of *Bt* insecticides although proved to be effective also presents a problem given the non selective mode of its action and hence a threat to ecologist, agriculturist, environmentalist and the world at large. Besides the use of Bacterial products in the fight against mosquitoes, a much recent bio-insecticide is the application of entomopathogenic fungi. Entomopathogenic fungi are a group of fungi that kill an insect by attacking and infecting its insect host [69]. Their main route of entrance is through integument and it may also infect the insect by ingestion method or through the wounds or trachea [70]. These fungi have a distinct advantage over the biological control agents mentioned above, in that they do not need to be ingested to infect and kill the insects - infection takes place through physical contact of the infective propagules (conidia) with the insect cuticle. As such, the contamination method is similar to conventional indoor residual spraying with insecticides [71]. Many entomopathogenic fungi have proven to be pathogenic to mosquitoes [72], and some of them have also been found active against the African malaria vectors [71]. The most important entomopathogens that have been commercially produced are *Beauveria bassiana*, *Metarhizium anisopliae* and *Isaria fumosorosea*. These are classified into different phylums including Oomucota, Ascomycota, Chytridiomycota and Zygomocata [73]. Entomopathogenic fungi are a major component of integrated pest management technique as biological control agents against insect pests and other arthropods and an integral part of mycoinsecticides in horticulture, forestry and agriculture [74, 75] While successful mosquito vector control in Africa is currently based on controlling adult mosquitoes, the vast majority of mosquitocidal fungi is aquatic and may only be used to control the aquatic stages of the insects which consist of an egg stage, four larval stages and a pupae stage. Larval control has a convincing history of malaria eradication and recent studies have also shown this approach to be highly effective [76-81]. However, recent progress has been made in using anamorphic entomopathogenic fungi (Deuteromycetes) for controlling adult African mosquitoes [82, 72, 83-85]. In line with the search for eco-friendly and highly effective alternatives, entomopathogenic fungi might be an option worth the try. It is generally accepted that the use of these insect-pathogenic fungi, such as *Metarhizium anisopliae*, as a myco-insecticide is not harmful to the environment [86, 87], nor to humans. This was illustrated by the fact that in 2003, an *M. anisopliae* isolate (strain F52) was granted registration by the U.S. Environmental Protection Agency to be used against insect pests.

13. Conclusion

As scientist and researchers continue to battle for a lasting solution that will forever bring to rest this onslaught of malaria, humanity is left with no other option but to protect its self from the vector mosquito. Prevention and protection from these insects remains the most veritable means to maintaining a malaria free nation or at least reducing its scourge to the barest minimum. However, all of these physical prevention methods require the availability of health infrastructure and education campaigns to effectively implement strategies and educate populations on the need for malaria control. Current malaria vector control, using either insecticide-treated nets (ITNs) or indoor residual spraying (IRS) relies on the continued susceptibility of *Anopheles* mosquitoes to a limited number of insecticides. Long-lasting insecticidal nets (LLINs) and indoor residual spraying (IRS) are the mainstay of malaria vector control programme because they are highly effective, have a relatively low cost, and their manufacture and distribution can be rapidly scaled up. Unfortunately, with the current trend of resistance to insecticide exhibited by these insect vectors, their continuous disruption of ecological/biological balance and the toxicity of most of these products, researchers obviously are beginning to refocus their attention on other strategies which do not rely on the use of insecticides. Interventions such as environmental management, use of bio-insecticides/larvicides can be useful but only under certain conditions, depending on the target vector and the local situation [67]. With the current spate of drug resistance and the unavailability of vaccines, vector control remains a critical facet of malaria control today and is expected to continue to be so. Vector control remains the single largest category of spending for malaria control by donors. Proper sanitation and environmental management which includes the clearing of bushes within residential areas and destruction of breeding sites such as water logged drainages, containers and ponds should be encouraged and scaled up as a means of reducing malaria scourge. Sanitary inspectors should be commissioned and sent to rural neighborhoods to educate and when necessary prosecute environmental defaulters.

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