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Mosquito management: A review

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Abstract

This research is conducted in the University of Gujrat Pakistan. The main objectives of the research were to find best way of mosquito management, to describe different methods of mosquito control, different plants extracts that are used against mosquito and to compare either chemical or botanical control is best. In term of disease transmission and public health importance mosquito are considered as very important group of insects. Population of mosquito's increases exponentially that is huge problem for many countries because mosquito spread the filarial, encephalitis, malaria, Yellow fever, chikungunya, Japanese encephalitis, dengue, Lyme disease and epidemic poly-arthritis. Different types of mosquito repellents such as synthetic compounds, aromatic oils and herbs are used against mosquitoes. Chemical mosquito repellents have an extraordinary protection profile, but they are noxious as compare to the plant based repellents.

Keywords: Chemical repellents, synthetic repellents, plant based repellents, mosquito traps, non-chemical repellents, biological control of mosquitoes

Introduction

For many viral, bacterial and protozoans' diseases mosquitoes act as vector ^[16]. In term of disease transmission and public health importance mosquito are considered as very important group of insects. Population of mosquito's increases exponentially that is major problem for many countries because mosquito spread the different diseases such as filarial, Japanese encephalitis, Lyme disease, Yellow fever, encephalitis, malaria, chikungunya, dengue, and epidemic poly-arthritis ^[17]. In tropical and subtropical countries mosquito borne diseases are main problem ^[16].

Mosquito has approximately 3500 species and present in tropical and subtropical regions ^[11]. Major genera of mosquitoes that act as vector for various diseases are *Culex* (Japanese encephalitis, west Nile, chikungunya, *Anopheles* (filariasis, malaria) and *Aedes* (chikungunya, dengue, Yellow fever) ^[12].

Major cause for the chikungunya and dengue is *Aedes aegypti* that act as vector for the disease and affect the 2.5 million people every year ^[30]. Feletti, vivax Grassi, protozoal parasites, *Plasmodium ovale stephens* and *Plasmodium falciparum welch* are the major cause of malaria that are spread by *Anopheles* mosquito ^[10]. Most important reason for the increase of dengue fever are increased breeding places for the *Aedes* mosquitoes, less effective control of mosquito, more urbanization and enhanced growth of population ^[47].

Annually worldwide the 200 million-450 million infections are caused by the *Anopheles* mosquito that leads towards 2.7 million deaths. In more than 100 rising countries it remains endemic disease ^[22]. Virus of Japanese encephalitis occurs in the children with malnutrition and present in the areas that are linked with animal reservoirs particularly with pigs. On the other hand main cause for the encephalopathy is encephalitis ^[58]. According to the BBC world service health program the mosquito is considered as the world's most dangerous animal ^[30].

Mosquito is vector and it causes severe diseases which can lead toward death so accurate action is necessary to get away from the disease as soon as possible ^[10]. There are various methods that can be adopted to protect itself from the bite of mosquitoes. When we are working outdoor we should wear long pants inserted into socks and long-sleeved shirts ^[17]. As well as when we are in inside we should present in the areas that are screened, live in air-conditioned and can use bed nets ^[29]. Mosquito breeding can be stopped by clearing the standing water from the drains and can use repellents to kill the mosquitoes ^[35].

In the middle of the 20th century modern pesticides were firstly introduced that were used for the control of pest ^[40]. At that time it was considered the best control for the mosquitoes.

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But this is unfortunate because it had only starting achievement and after that it was evidenced to be less-than perfect solution for the long-lasting control of mosquitoes [10]. With the pesticides such as DDT complete loss of pest occur that is worst for the environment and insects also develop resistance to that pesticide [16].

Mosquito Control is somewhat of ultimate importance the existing day with increasing number of mosquito borne diseases [56]. Industrialized farming and deforestation are also two of the major issues triggering proliferation in the variety of mosquitoes. Mosquito repellents are required to combat with the mosquitoes [29].

Mechanism of action of repellents

Repellency usually based on the biochemical or physiological events [40]. Repellency that is caused by the DEET is based on the receptor blocking such as lactic acid receptor blocking [8].

Every product that we used against mosquitoes has different degree of efficiency. Lactic acid and carbon dioxide that is present in the sweat of warm blooded animals' acts as attractive substance for mosquitoes [40]. Level of CO₂ is detected by the olfactory pulp whereas host related odor is detected by olfactory receptor of antennae. The awareness of the scent is through antennae that contain the chemoreceptors [35].

In the body of warm blooded animals lactic acid is present that attracts the female mosquito [34]. *Aedes aegypti* is attracted toward the lactic acid that is used for behavioral studies. More indication for the role of lactic acid in host seeking originates from studies investigative mosquito physiology following a blood meal. After taking a blood meal host seeking behavior in *Aedes aegypti* ends [23]. It is suggested that after taking blood meal sensitivity for the lactic acid in neurons is dropped and after oviposition mosquito again will be normal [39]. Species of mosquitoes such as *Culex* and *Pipiens* are more sensitive that is 6.9 times more sensitive as compare to the *Anopheles* and *An. albimanus*. Tolerance of repellency is basically non-adaptive that is aroused due to the natural mutation. Molecular weight range for the effective mosquito repellent is 150-250. To check the mosquito repellent activity vapor pressure is considered as the important parameter [37].

Mosquito repellents

Anything that is used to apply to clothing, skin or other surfaces that repel the mosquito from attracting and biting on that surface is known as mosquito repellent [15]. Some mosquitoes repellent that are based on the ultrasound having high frequency sounds are also available in market [50].

Older methods of mosquito repellents include the rubbing of mana, vinegar and plant oils on the body [46]. Ancient people also used to burn the bay, black cumin, oregano and galbanum to restrict the mosquitoes. Burning of plant or plant materials produce the smoke that is oldest method to control mosquito [54].

One method for the controlling of the mosquito is fogging that is temporary method for controlling pests but is mostly essential in the situation of health dangers from severe bug inhabitants and for an outside movement where these pests are undesirable [44]. Mostly thermal fogging is used whereas each gallon contains the 5.0% piperonyl Butoxide and 0.5% pyrethrins [35]. Another technology is transdermal technology where mosquito repellents are injected into the blood stream to protect itself from the mosquito bite [24]. This type of

repellent contains the thiamine or Vitamin B1 and it is known as most effective repellent known to date. Female mosquito remains repulsive to the fragrance of Thiamine that is major mechanism for the control of mosquito [54].

A. Chemical repellents

Different types of mosquito repellents such as synthetic compounds, aromatic oils and herbs are used against mosquitoes. Chemical mosquito repellents has an extraordinary protection profile but they are noxious against the nervous system and skin as eye irritation, swelling, low blood problem, rashes and worse problem [35].

1. Synthetic repellents

Most effective synthetic repellent is DEET that is poison and has ability to make the carbon monoxide and natural odor as human body produces [14].

Longer lasting and most effective repellent is IR3535 (3-[N-Butyl-N-acetyl]-aminopropionic acid as compare to the DEET for defense against mosquitoes. Effective relief can also get from the plant-based repellents. The time of action of essential oils is short lived and it evaporates easily [20]. There examples are as follow:

- DEET (*N,N*-diethyl-*m*-toluamide)
- Icaridin known as Bayrepel, KBR 3023 and Picaridin
- Bog Myrtle
- Permethrin (Petel *et al.*, 2012)

Among all the repellents the *N,N*-diethyl-3-methyl toluamide (DEET) is best synthetic mosquito repellent that can be available easily but it has harmful effects. It is considered that the use of DEET has maximum biting inhibition rate that is 88.7- 92.5% [52]. But the study showed that the use of DEET has many side effects such as muscle twisting, seizures, slurred speech, nausea, rashes; affect motor capacity, sensory disturbance, loss of learning abilities and memory damage [58, 33]. DEET does not deliver long lasting defense from the bite of all species of mosquito such as *Anopheles* that cause malaria. The use of the DEET is not suggested for the children, lactating and pregnant women [18]. Hydroxyethyl Isobutyl piperidine Carboxylate is commonly known as Icaridin. It is colourless and odourless and used against the insects [19]. It has same working principle as DEET because it can also block the olfactory receptors of the insects or it shades the insect's sense of smell and it is difficult for them to find the human. It is considered as best as compare to the DEET because it requires in less amount for action [34]. It is non-toxic for the skin and eyes; and slightly toxic for the oral route. It can be safe to use but cannot use on the broken skin. Icaridin is moderate chemical which do not accumulate and fade away easily. To make it less toxic it's better to use it with other compounds [44, 59].

Permethrin is only useable on camping gear, bed nets, shoes and clothing and cannot use on the skin [10]. It is very effective and has the ability to kill the ticks and mosquitoes. Cloths on which Permethrin is applied remain safe for humans but these products should not put on the skin. It should use in the form of spray on the cloth [21]. Its effectiveness remains for six hours. Permethrin is obtained from the pyrethrum that is naturally occurring pesticide [19]. It gives more protection when mixed with the DEET. When Permethrin is applied on the uniform that is light weight it gives 97.7% protection from mosquitoes. When Permethrin is applied it causes somewhat skin irritation whereas it has no serious effect. It is non-toxic for humans and birds while highly toxic for insects [8, 12, 7].

2. Natural repellents

Natural repellents are basically obtained from the plants and known as essential oils. Substances that are present in the different odoriferous plants and have volatile nature are known as essential oils [13, 2]. It is obtained from the various parts of plants and have volatile aroma with the form of concentrated hydrophobic liquid [50]. Essential oil can be extracted by various methods such as steam distillation, solvent extraction and hydro distillation. Soil and climatic conditions are important factors that affect the different plant species and composition of essential oils [1]. Synthesis and accumulation of the essential oils related with the secretory structure of the plants such as resin ducts, glandular ducts and trichomes [24]. Storage of the essential oils occurs in the leaves, woods, flowers, rhizomes, fruits and roots. These plant based essential oils are used for the repellency of the mosquitoes and haematophagous insects [54].

Many research efforts revealed that essential oil compounds and their derivatives are alternative controlling measure for mosquitoes [22]. Essential oils due to their volatile nature demand for frequent reapplication to maintain its potency. They evaporate completely and thereby their effectiveness is short lived and so complete protection cannot be achieved [30]. Many plant origin essential oils are recognized to have insect repulsive possessions viz. citronella oil, lemon grass oil, rosemary, dill, eucalyptus, lavender, soybean, chrysanthemum, clove, castor, tulsi, camphor, limeone, geranium, Neem, galbanum, pepper mint, cedar essential oil and basil [27, 20].

Cedar oil is used against moths and mosquitoes, Cinnamon and Neem oil kills the larvae of the mosquito, clove, eucalyptus, rosemary, lemon grass, peppermint and citronella oil repel mosquito [24].

Essential oil as natural product has maximum volatile chemical compounds and used as individual defense against blood sucking mosquito [9]. Lutes and rosewood are taken in the ratio of 1: 1 (V/V) with 10% concentration and it shows 86% repellency against the mosquito. Essential oil exhibited operative consequence are valuable for developing biodegradable, effective and eco-friendly insect repellent [54]. Eight essential oils collected from the citrus plants such as *Citrus aurantium*, *Citrus hystrix*, *Citrus medica*, *Citrus aurantifolia*, *Citrus reticulata* Blanco, *Citrus sinensis* and *Citrofortunella microcarpa* were collected and used against the *Culex quinquefasciatus* (Say) and *Aedes aegypti* (Linn.) and compared them with chemical repellent (IR3535 12.5 w/w) [33]. Thus, repellent action showed the direction of safety time and piercing rate against two mosquito species in eight essential oils as *C. aurantifolia* > *C. microcarpa* > *C. maxima* > *C. reticulata* > *C. sinensis* > *C. hystrix* > *C. aurantium* > *C. medicavar. sarcodactylis*. Meanwhile, the period of protection time against two mosquito species of all herbal essential oil was higher than IR3535 (3.0±0 minutes for *Ae. Aegypti* and *Cx. quinquefasciatus*) [47].

Essential oil of *Zingiber officinale* and *Cinnamomum zeylanicum* causes ovicidal and oviposition deterrent activities in the *Cx. Quinquefasciatus*, *Aedes aegypti* and *An. Stephensi* [18]. Against the *Ae. aegypti* the leaf extract of the *Cassia fistula* is used that cause the ovicidal, repellent and larvicidal activities. Extracted oil from the *Coriandrum sativum* (Apiaceae) show repellency against the invasive species of mosquitoes [53, 3].

Curcuma aromatic (Zingiberaceae), *Azadirachita indica* (Meliaceae) and *Zanthoxylum alatum* (Rutaceae) also show repellency against the mosquitoes especially against the *Cx.*

quinquefasciatus that is filarial vector [34, 12].

Safe and promising insect repellent is catnip oil that is obtained from the catnip. Two stereoisomers of nepetalactone is present in this oil [12]. It has repellency against the thirteen families of the insects due to presence of the two stereoisomers. E,Z-nepetalactone form of the oil has the ability of repellency against the cockroach while Z, E-nepetalactone form has shot less repellency against American cockroaches and house flies whereas against the mosquito it has six hours of repellency [43]. Experiments suggested that against the species of mosquitoes such as *Ae. albopictus*, *Cx. quinquefasciatus* and *Ae. aegypti* catnip oil has different time of repellency such as Six hours, sixty minutes and two hundred forty minutes respectively. Against the *Cx. quinquefasciatus*, *Cx. annulirostris* and *Ae. Vigilax* catnip oil shows more protection [36, 41].

B. Non-Chemical repellents

Non chemical methods comprise the physical and mechanical methods.

1. Physical method

It is essential to change the water in the bird baths, pools, fountains and rain barrels once a week. During the dawn and dusk it is necessary to use the full sleeved clothing. Screening of doors and windows is also very important to protect itself from the mosquito attack [57].

a. Mosquito Net

These nets are considered as more protective than coils and other repellents because their use does not cause any health problem [39]. Sleeping under netting also protect from the attack of mosquitoes. There are two types of nets such as medicated nets and non-medicated nets [14].

1. Medicated Net

Mosquito nets can be made medicated by K-O tablets that contain the 25% deltamethrin. In one liter of water one tablet is mixed, net is soaked in it for ten minutes and then dried it in chilled area [38]. This net remains effective for six months and mosquito will remain away. World Health Organization approves the medicated nets and these nets are more effective than the liquidators or coils [5].

2. Non-medicated Net

Different sizes and shapes of mosquito netting is available that can be made of various materials such as polyester, polyamide and cotton. Style of net is important to protect itself from the mosquito bite [10]. It is important to buy a net that contain the mesh size large enough to pass the air and small enough to protect from the mosquito bite. Mosquito nets are an operative way to naturally prevent from mosquitoes [59].

b. Mosquito traps

Mosquito traps are used to capture and lure the female mosquitoes. These traps copy the various mosquito attractants such as body heat and exhaled carbon dioxide. Most of the traps are powered by the propane or electricity so their use is safe [42]. Traps contain impeller fan when mosquito is attracted toward the trap it will attach on the sticky surface on the trap and will electrocuted [51].

Mechanical Methods

Mechanical method contains the devices such as mosquito magnets and electro mosquito zapper.

a. Electric mosquito zipper

For trapping the mosquito this device works by using the ultraviolet light and then killing of mosquito occurs when mosquito interact with the lethal charge of electric charge [33].

b. Mosquito Magnet

Its principle based on copying of mammals properties such as giving off heat, moisture and carbon dioxide. When mosquito comes close to the device it drew in and suddenly dies. This magnet also combined with the octenol and can be used for the sand flies, black flies, midges and mosquitoes [33].

Biological control of mosquitoes

1. Entomopathogenic Fungi

For the control of malarial vector entomopathogenic fungus has very important role. Fungus species that are used for this purpose are belongs to the genera *Beauveria*, *Coelomomyces*, *Metarhizium*, *Culicinomyces*, *Entomophthora* and *Lagenidium* [48].

For protection from the mosquitoes fungal spores are used in the curtains, cotton pieces, indoor house services and outdoor traps [53]. Fungus can be used with DDT to use effectively against the insecticide susceptible and insecticide resistance mosquitoes. *Anopheles gambiae* is more susceptible to the fungus infection as compare to other insecticides but rate of fungal infection is slow as compare to the insecticide action [45].

Fungi have negative effects on the malarial transmission because it changes the fitness conditions and behavior of the vector. It also affects the survival rate of parasites with in the mosquitoes and feeding habits of the mosquitoes [6]. It has been shown that use of *Metarhizium* against the mosquitoes induces the production of the anti-malarial peptides, obstructed the communication of the malarial parasite from the vector [15]. Pathogenic fungi have their effect on the *Anopheles* at its later stage of life cycle that is considered very important. If the mosquito develops the resistance against the fungi it will be temporary because weak selection for this resistance would occur [36].

2. Bacterial Agents

For the malarial vector control *Bacillus sphaericus* (*Bs*) and *Bacillus thuringiensis* (*Bt*) can be used because these are environmentally safe, highly effective, exert selective effects and non-toxic in nature [20].

Strains of *Bacillus* are easily handled, locally manufactured, practically applied and cheap and having the ability of fast spreading. As compare to the *Aedes*, *Culex quinquesfasciatus* and *A. arabiensis* the effect of *Bs* and *Bt* is more on the *A. gambiae* [46, 6].

Bs and *Bt* cause the production of the endotoxin proteins that damages the stomach of larvae and its death occurs [32]. There two type of endotoxin proteins such as Cry and Cyt1A that work by interlinking with each other. Cyt1A delays the resistance to the Cry proteins and causes its long lasting uses [17].

Genus *Asaia* contain the acetic acid bacteria that colonize in the female eggs and male reproductive systems of the *A. albopictus*, *A. stephensi*, *A. gambiae* and *A. aegypti* that transmit in the offspring of their population. It results in the lessening the life span, reduce immunity and render the development of the parasites within the mosquitoes [28]. For combating the malaria microbial agents are considered very important; they can abandon the growth of the *Plasmodium* in the mosquito or directly mark the *Anopheles* vector [23].

Larvivorous Fish

The oldest method for the control of mosquito is the use of the predatory fish. *Gambusia affinis* and other species like family Cyprinodontidae were mostly used for the mosquito larval control. Use of larvivorous fish is considered as more effective method as compare to the chemical control [17].

They can be used because it exhibits less risk of mosquito resistance, cheap production, harmless for both wildlife and human and used at low doses [2]. When using the larvivorous fish two important factors must be taken into consideration such as fish must adapt to the environment where it is used and other one is that number of the larvae eaten by the fish [41].

Studies show that use of mixed population of *Ctenopharyngodon idella*, *A. sinensis* and *Cyprinus carpio* is significantly use to lessen the larvae of *Anopheles* population. On the other hand 81% reduction in the population of the malarial species occurs with the mixture of *Cyprinus carpio*, *Catla catla*, *Cirrhinus mrigala* and *Ctenopharyngodon idella*. Introduction of the *Gambusia affinis* into the water causes 98% reduction in the *A. stephensi* larvae [37].

Indigenous larvivorous fishes that are used as control for the malaria are genus *Aplocheilus*, *Colisa*, *Aphaniusdispar*, *Oryziamelastigma*, *Chandanama*, and *Macropoduscupanus*. Exotic larvivorous fishes that are used as control agent for the malaria are *Oreochromis*, *Xenentodon*, *Carassius*, *Poecilia* and *Gambusia* [26].

Using of the larvivorous fish has some disadvantages such as when *Gambusia* introduced exotically it has negative impact on the environment. *Gambusia* feed on different food such as zooplankton, algae, young ones and eggs of the amphibians and aquatic insects so it is known as opportunistic predator [25]. These fishes have aggressive behavior and can fight with other species for space and food [49]. Origin of dangerous ecological changes in the environment causes to increased temperature of water, enhanced phytoplankton, lessen the water clarity and increased the dissolved organic phosphorus. For enhanced activity of fish removal of vegetation is necessary [6].

Mode of action of phytochemicals in insect body

Plant extracts are generally known as the secondary metabolites that protect them from the herbivores [4]. These metabolites are generally toxic that are harmful for the insects and effect on the target molecules that are bio membranes, nucleic acid, cellular components and proteins. Insect physiology is disturbed that affect the nervous system such as synthesis of neurotransmitter, storage, release and activation of receptors [56]. With the help of essential oil acetylcholinesterase inhibition, thymol inhibits the GABA gated chloride channel, rotenone inhibits the cellular respiration and pyrethrin inhibits the potassium-sodium exchange [11].

Most important inhibition of the activity of acetyl cholinesterase that is main enzyme for the transmission of nerve impulse [48]. So when repellents are used against the insect acetylcholinesterase enzyme is inhibited that block the nerve transmission because AChE is the only resistance mechanism for insect [15].

Repellent preparations

To ensure more lasting impacts repellents can be used in the form of the creams, lotions, pastes or other preparations. In the following form the natural repellents can be present:

Lotions are made by dissolving the repellents in the alcohol and thickened with arachis oil or castor oil^[55]. Ointment type creams are made by mixing the repellent admixture and some solid greasy base such as petroleum jelly, lanolin, soft and hard paraffin, magnesium stearate and acetyl alcohol^[10]. Vanishing type cream is made by the essential oils. This type of cream when applied on the skin gets disappeared because it is absorbed in the skin abruptly and evaporation of water occurs. It contains water, emulsifier such as triethanolamine and triton X and greasy base^[19].

The use of vanishing cream is not considered as suitable due to its disappearing properties and they are suitable to give irregular distribution of the repellent. Waxy cream is considered as most effective due to its long lasting effects^[31].

Conclusion

In many ethno botanical evaluation plants acts as repellent agents. In numerous part of the world plant repellents are used. Plant based repellents do not pose dangers of toxicity to the domestic animals and humans and can be easily biodegraded. As compare to the synthetic compounds natural products are safer for human use. Use of synthetic repellents causes the insecticide resistance in mosquitoes, harmful effect on non-target organisms and has threat for the environment. Due to the less impact on environment and low budget plant based repellents attracted great attention of people. Innovative drug distribution systems of plant based active constituents are need of the time. Modern technologies in standardization and isolation of herbal drugs motivation are necessary. Mosquito repellent devices such as nets of different types are also necessary for trapping of mosquitoes. On the other hand biological control of the mosquitoes with the help of bacterial agents and larvivorous fish is also taking in consideration. Essential oils due to their instability act for a less time. Also multiple creams with essential oil core may be a smooth distribution system. Such topically applicable formulations will be suitable for people to put on and terminate. Essential oils plentiful in nature and separately from its flavor and medicinal value, its use in repelling mosquito can be considered as sustainable and biocompatible delivery device as green alternative.

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