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A systematic review on different aspect for mosquito management

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Abstract
Diseases including dengue, chikungunya, malaria, encephalitis, yellow fever, and many more are transmitted by mosquitoes, which are an important vector on a worldwide scale. Because there is now no effective medicine or vaccine, vector management has become the primary strategy for controlling mosquito-borne illnesses. The exponential growth of mosquito populations is a major health concern for many nations due to the transmission of diseases such as dengue fever, lyme disease, malaria, chikungunya, yellow fever, dengue, encephalitis, dengue fever, and epidemic polyarthritis. Mosquitoes can be controlled with a variety of insect repellents, including synthetic chemicals, aromatic oils, and botanicals. In comparison to their plant-based counterparts, chemical mosquito repellents are toxic, but they offer an exceptional protective profile.

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

Introduction
Worldwide, mosquitoes may be found in a wide variety of climates and geographical locations, with an estimated 3,500 species. While certain species can spread illness to humans, others are only an annoyance because of their biting habits illnesses transmitted by vectors are responsible for about 700,000 fatalities each year and over 17% of all infectious illnesses [1]. The biggest cause of vector-borne illnesses, which affect over 80% of the world's population, is mosquito-borne diseases (MBDs) [2]. Malaria, along with other mosquito-borne diseases (MBDs) including dengue, Zika, chikungunya, West Nile virus (WNV), is a huge problem for public health all over the globe. An estimated 219 million people contract malaria each year, with over 40,000 losing their lives to the disease [1] and an estimated 627,000 fatalities in 2020 [3]
An estimated 96 million individuals experience symptoms of dengue each year, and an estimated 40,000 lose their lives to the disease [1]. The global population is around 3.9 billion people. Among MBDs found in the US, WNV is by far the most frequent [4]. Across all 50 states, 21,869 cases of WNV illness were documented between 2009 and 2018 [5]. Between 2010 and 2019, the global loss of disability-adjusted life years (DALYs) was an average of 106,000 due to Zika and 44,000 to chikungunya [6]. Also, MBDs have a major impact on the economy. At least $12 billion USD is spent annually on malaria-related expenses worldwide [7]. In 2013, the projected overall cost of dengue worldwide was $8.9 billion [8].
The *Aedes aegypti* mosquito is responsible for 2.5 million cases of dengue and chikungunya annually [9]. The Anopheles mosquito is responsible for transmitting the protozoan parasites Feletti, vivax Grassi, *Plasmodium ovale* Stephens, and *Plasmodium falciparum* welch, the most common forms of malaria [10]. More urbanization, faster population expansion, less efficient mosquito control measures, and more breeding sites for the *Aedes* mosquito are the main factors contributing to the dengue fever epidemic [11].
Mosquitoes are the carriers of several harmful illnesses. *Aedes aegypti*, which causes dengue and yellow fever, Anopheles species, which transmit malaria, and *Culex quinqueflasciatus*, which causes filaria, are only a few examples of the many different kinds of mosquitoes. The dengue fever virus and its vectors may be found in almost every tropical and subtropical region on Earth. A novel formulation of a mosquito repellent chemical that is both effective and safe is necessary [12].

Precise action is required to avoid mosquito-borne infections as quickly as possible since mosquitoes are vectors for many diseases, which can be fatal [10]. It is possible to defend itself against mosquito bites in a number of ways. Wearing long sleeved shirts and slacks with socks is recommended when working outside [13]. We should also utilize bed nets, dwell in air-conditioned spaces, and present in screened areas while we are indoors [14]. You may prevent mosquito breeding by draining standing water and using insect repellents [15]. The first modern pesticides were launched for use in controlling pests in the middle of the twentieth century [40, 16]. It was thought to be the most effective insect repellent back then.

However, this is bad since it had only achieved a beginning point, and after that, it was demonstrated to be a solution that was less than perfect for the long-term control of mosquitoes [10]. Certain pesticides, such as DDT, are responsible for the entire elimination of pests, which is the most detrimental to the environment. Additionally, insects acquire resistance to the pesticide in question [17].

As the number of diseases that are spread by mosquitoes continues to climb, it is becoming increasingly vital to take measures to control mosquito populations in today's world [18]. Two of the most major causes that contribute to the rise in the number of mosquito species are the industrialization of agricultural methods and the degradation of forests. Both of these issues have come about as a result of human activities. When it comes to combating the presence of mosquitoes, the application of insect repellents is an absolute need [19].

The mechanism of action

In most cases, the biochemical or physiological processes are responsible for the repellent effect [16]. A receptor blocking mechanism, such as the lactic acid receptor blocking mechanism, provides the basis for the repellent effect that is brought about by DEET [20].

There is a certain degree of effectiveness associated with each and every product that we utilized to combat mosquitoes [16]. Mosquitoes are drawn to the lactic acid and carbon dioxide that are found in the perspiration of warm-blooded animals because these substances function as an appealing chemical. The level of carbon dioxide is recognized by the olfactory pulp, whereas the olfactory receptor of the antennae is responsible for detecting the odor associated with the host. It is through the antennae that contain the chemoreceptors that the individual is able to become aware of the odor [15]. Culex and Pipiens mosquitoes, for example, are 6.9 times more sensitive than Anopheles and *Anopheles albimanus* mosquitoes. This indicates that these mosquito species are more sensitive than the latter two. The ability to tolerate repellency is essentially a non-adaptive trait that is triggered by spontaneous mutation. A mosquito repellent that is effective has a molecular weight range that falls between 150 and 250. The vapor pressure is regarded to be the most essential characteristic when it comes to determining the effectiveness of the mosquito repellent [21].

Mosquito Repellents

The term "mosquito repellent" refers to any substance that may be applied to the skin, clothes, or other surfaces in order to prevent mosquitoes from attracting and biting on such surfaces [22].

In addition, there are mosquito repellents that are available on the market that are based on ultrasound and have high frequency noises [23].

The application of mana, vinegar, and plant oils to the skin by rubbing them on is one of the most traditional means of mosquito repellents [46, 24]. In addition, ancient people would burn bay, black cumin, oregano, and galbanum in order to reduce the number of mosquitoes in their environment. One of the oldest methods for controlling mosquitoes is the burning of plants or plant components, which results in the production of smoke [25].

Fogging is a temporary approach for reducing pests, but it is primarily required in situations where there is a threat to human health from serious insect residents and for an outside movement where these pests are unwanted [26]. Fogging is one method that may be used to manage mosquitoes. The majority of the time, thermal fogging is utilized, and each gallon contains a mixture of piperonyl butoxide at a concentration of 5% and pyrethrins at a concentration of 0.5% [15]. Furthermore, there is a method known as transdermal technology, which involves the injection of insect repellents into the bloodstream in order to protect the body from the bite of a mosquito [27].

This particular form of repellent is regarded to be the most efficient repellent that has been discovered to this day since it includes thiamine, often known as vitamin B1. The scent of thiamine, which is a fundamental mechanism for the control of mosquitoes, continues to be unpleasant to female mosquitoes [28].

Chemical Based Repellent

The uses of synthetic chemicals, aromatic oils, and botanicals are all examples of different forms of insect repellents that are employed in the fight against mosquitoes. Chemical mosquito repellents have an exceptional protective profile; nevertheless, they are toxic to the nervous system and skin, causing irritation to the eyes, edema, low blood pressure, rashes, and even more serious problems [15]. The synthetic repellent that is the most effective is called DEET, which is a poisonous substance that has the potential to create carbon monoxide and a natural odor similar to what the human body produces [29].

If you want to protect yourself from mosquitoes, IR3535 (3-[N Butyl-N-acetyl]-amino propionic acid) is the most effective repellent that lasts longer and is more efficient than DEET compared to DEET. The plant-based repellents are another source of effective alleviation that may be obtained. Essential oils have a brief duration of action, and they dissipate so quickly that they are not very effective [30].N, N-diethyl-m-toluamide, often known as DEET, and picaridin, also known as Bayrepel, KBR 3023, and Picaridin among others Permethrin for the treatment of bog myrtle in comparison to other repellents, the synthetic mosquito repellent known as N, N-diethyl-3-methyl toluamide (DEET) is the most effective and readily accessible option; nonetheless, it is not without potentially dangerous side effects. According to research, the greatest biting inhibition rate that may be achieved with the use of DEET is between 88.7 and 92.5% [31]. According to the findings of the study, however, the use of DEET is associated with a number of adverse effects, including muscular twisting, seizures, slurred speech, nausea, and rashes; impairment of motor ability; sensory disruption; loss of cognitive capacities; and harm to memory [32, 33]. It is not possible for DEET to provide a long-lasting protection against the bites of all kinds of mosquitoes, including Anopheles, which is responsible for malaria. Children, women who are breastfeeding, and women who are pregnant are not recommended to use DEET based on the recommendations.

It works in the same way as DEET does: it makes it harder, if not impossible, for insects to use their sense of smell to find humans. It is considered better than DEET since less is needed to achieve effect [35].

Hydroxyethyl isobutyl piperidine carboxylate is the common name for the chemical compound known as acaridan. Its neutral colour and odour make it an effective tool in the battle against insects. Because of its lack of smell and colour, it is used as an insecticide [35].

There are no negative effects on the eyes or skin, however it might be slightly dangerous when swallowed. In most cases, it won't irritate even the most delicate skin. Picaridin is a gentle substance that does not accumulate and goes away fast. One way to lessen its toxicity is to mix it with other compounds [36, 37].

You can't apply permethrin directly on your skin; it's only safe for use on camping gear, bed nets, shoes, and clothes [10]. Ticks and mosquitoes are both killed off by its potent effects.

You shouldn't put Permethrin-treated clothes on your skin, but they're perfectly safe for humans to use on clothes. The recommended application method is as a spray on fabric [21]. It continues to work for six hours after application. According to [35], the naturally occurring pesticide pyrethrum is the source of permethrin. When combined with DEET, it provides much greater protection. Applying Permethrin to a lightweight uniform provides 97.7 percent protection from insects. Permethrin has no major effects; however, it does irritate the skin to a moderate degree. While it poses little threat to birds or humans, it is extremely poisonous to insects [20, 38, 39].

Naturally obtained repellent

Plants are the primary source of essential oils, which are used as natural repellents. Essential oils are substances found in several odoriferous plants that are volatile [40, 41]. The concentrated hydrophobic liquid has a volatile scent and is derived from different plant sections [23]. Steam distillation, solvent extraction, hydro distillation, and other technologies are available for the extraction of essential oils. Important variables influencing essential oil composition and plant species diversity include soil and climate [42]. The process by which plants produce and store essential oils via their secretory organs, including trichomes, glandular ducts, and resin ducts [27]. Plant parts such as leaves, flowers, rhizomes, fruits, and roots are where essential oils are stored. For the purpose of keeping mosquitoes and other hemophagous insects at bay, people utilise essential oils derived from plants [54, 28].

A number of studies have shown that compounds and derivatives of essential oils can be an effective alternative to conventional mosquito control methods [43]. Because of their highly volatile properties, essential oils need to be reapplied often to keep it effective. Their efficacy is reduced since they dissipate entirely not long-lasting enough to provide full protection Essential oils derived from plants are known to have several beneficial effects [9].

Items that deter insects, like as lemon grass, citronella oil components: oil, dill, rosemary, lavender, eucalyptus, and soybean tulsi, clove, limeone, castor, camphor, chrysanthemum, essential oils of geranium, neem, galbanum, peppermint, and cedar and basil [43, 30].

For example, cinnamon and neem oil can destroy mosquito larvae, clove, eucalyptus, rosemary, peppermint, lemon grass, and citronella oil can repel mosquitoes [27]. Cedar oil is also effective against moths and mosquitoes. One natural defence against bloodsucking mosquitoes is essential oil, which is a natural product with the highest concentration of volatile chemical components [45].

The combination of lutes and rosewood in a 1:1 (V/V) ratio at a 10% concentration is 86% effective in repelling mosquitoes. Insect repellents that are biodegradable, effective, and environmentally friendly can be developed using essential oils that have shown operative consequences [28].

A comparison was made between chemical repellent (IR3535 12.5 w/w) and eight essential oils derived from citrus plants, including *Citrus aurantium*, *Citrus hystrix*, *Citrus medica*, *Citrus aurantifolia*, Citrus reticulate blanco, *Citrus sinensis*, and *Citrofortunella microcarpa*, which were used against *Culex quinquefasciatus* (Say) and *Aedes aegypti* (Linn.) [33, 33].

In a study using eight different essential oils, the results demonstrated that *C. aurantifolia* had the most effective repellent against two mosquito species, while *C. maxima* and *C. reticulate* were the least effective. *C. sinensis* and *C. hystrix* were also ranked lower than *C. aurantium* and *C. medicavar*. sarcodactylis, respectively. On the other hand, compared to IR3535, the duration of protection against *Ae. Aegypti* and *Cx. quinquefasciatus* mosquitoes was longer for all herbal essential oils (3.0±0 minutes) [11].

The ovicidal and oviposition deterrent activities in *Cx. Quinquefasciatus*, *Aedes aegypti*, and An. Stephensi are caused by the essential oils of *Cinnamomum zeylanicum* and Zingiber officinale [35]. The ovicidal, repellent, and larvicidal actions of the Cassia fistula leaf extract are utilised to combat the *Aedes aegypti* mosquito. Mosquitoes, an invasive species, are repulsed by oil extracted from the *Coriandrum sativum* plant (Apiaceae) [46, 48].

Mosquitoes, particularly the filarial vector *Cx quinquefasciatus*, are repelled by the plants Curcuma aromatic (Zingiberaceae), *Azadirachita indica* (Meliaceae), and *Zanthoxylum alatum* (Rutaceae) [34, 38].

Extracting oil from catnip plants is a safe and potentially effective way to keep insects away. This oil contains two different forms of the nepetalactone molecule [12, 38]. Resistant to on all thirteen insect families as a result of the existence of both stereoisomers. Its E, Z-nepetalactone variant is has a lower level of repellency against American cockroaches than the Z. enepetalactone form while it's effective against mosquitoes, cockroaches, and house flies repels for six hours [48]. Tests revealed that on mosquitoes, including *Aedes* albopictus, *Cx. Catnip* oil from *Aedes quinquefasciatus* and *Aedes aegypti* is time-dependent. On a scale from six hours to two hours, sixty minutes to two for forty-five minutes each. Taken up against *Cx. catnip* oil from three species: quinquefasciatus, *Cx. annulirostris*, and *Ae. vigilax* provides greater security [49, 50].

The use of non-chemical repellents

The types of approaches that are not chemical include the mechanical and physical means to control the mosquito.

Physical Method

One week is the minimum amount of time that should pass before the water in the bird baths, pools, fountains, and rain barrels is replaced. Full-sleeved apparel is strictly required to be worn during the early morning and late evening hours. An additional very significant measure to take in order to protect oneself from the attack of mosquitoes is to screen the doors and windows [51].

I) Mosquito net

As a result of the fact that their utilisation does not result in any

adverse health effects, these nets are regarded as being more protective than coils and other repellents [52]. It is also possible to defend oneself from the onslaught of mosquitoes by sleeping under netting. Medicated nets and non-medicated nets are the two categories of nets that are distinguished from one another [29].

a) Medicated net

In order to make mosquito nets more effective, K-O pills that contain 25% deltamethrin can be used to medicate them. First, one tablet is combined with one litre of water, then the net is submerged in the mixture for ten minutes, and finally, the net is dried in a cold environment [52]. For a period of six months, this net will continue to be effective, and mosquitoes will be kept away. It has been determined by the World Health Organisation that medicated nets are more successful than liquidators or coils [54]. These nets have been accredited by the WHO.

b) Non medicated net

There is a wide range of mosquito netting available, which can be produced from a variety of materials including polyester, polyamide, and cotton. Other sizes and forms are also available. When it comes to protecting oneself from the bite of a mosquito, the type of net is very significant [10]. It is essential to purchase a net that has a mesh size that is simultaneously large enough to allow air to circulate through it and small enough to protect against the bites of mosquitoes. According to [37], mosquito nets are an effective method of naturally preventing the presence of mosquitoes.

c) Mosquito Trap

Traps for mosquitoes are utilised in order to collect and attract the female mosquitoes. These traps replicate the numerous aspects of the environment that attract mosquitoes, such as body heat and carbon dioxide that is breathed. There is no risk involved in using the majority of the traps because they are fueled by either propane or electricity [55]. Traps are equipped with impeller fans, and when a mosquito is drawn to the trap, it will attach itself to the sticky surface of the trap, causing it to become electrocuted [56].

II) Mechanical Method

Magnetic mosquito traps and electro mosquito zappers are examples of the types of devices that fall under the mechanical method.

a) An electric zipper for mosquitoes

This gadget is effective at capturing mosquitoes because it makes use of UV light. Later, the mosquitoes are killed when they come into contact with the electric charge that is harmful to them [33].

b) Magnet for mosquitoes

Its fundamental premise is based on the imitation of the characteristics of mammals, such as the emission of heat, moisture, and carbon dioxide. The mosquito is drawn in by the device, and it suddenly passes away when it gets close enough to it. Sand flies, black flies, midges, and mosquitoes are all susceptible to being destroyed by this magnet, which, when paired with octenol, can be used to eliminate them [33].

Biological methods to control mosquitoes

Entomopathogenic fungi

The entomopathogenic fungus plays a very essential function in the management of the infectious agents that are responsible for malaria. Fungal species belonging to the genera Beauveria, Coelomomyces, Metarhizium, Culicinomyces, Entomophthora, and Lagenidium are examples of those that are utilised for this purpose [57].

For the purpose of providing protection against mosquitoes, fungal spores are utilised in the production of curtains, cotton accessories, inside house services, and outside traps [53, 47]. Fungus can be used in conjunction with DDT to efficiently combat mosquitoes that are vulnerable to insecticides as well as those that have developed resistance to insecticides. Anopheles gambiae is more vulnerable to the infection caused by fungi in comparison to other insecticides; nevertheless, the rate of fungus infection is slower in comparison to the action of the pesticide [57].

In order to determine whether or not fungi could be utilised for the purpose of microbial control of mosquito larvae, a number of different species are now being considered. There is a possibility that the larvae of mosquitoes are susceptible to the biocidal effects of certain fungi, such as those belonging to the genera *Coelomomyces*, *Lagenidium*, Metarhizium, Culicinomyces, Entomophthora, and others [58].

The manner of action of these fungi, on the other hand, has been described by researchers, and it demonstrates that the principal targets of these fungi are the cuticle and the abdomen of mosquito larvae [59]. At first, the spores of certain fungi adhere to the cuticle of the larvae of their respective mosquito species. Following this, the spore is created, and it ultimately makes its way through the cuticle to the hemocoel, which is the location where the process of growth and development takes place (2009). The larva finally dies, the saprophytic feeding process commences, and the fungi make their appearance again.

Planarians

Through its consumption of mosquito larvae, the planarian species Dugesia bengalensis has the potential to be utilised for the purpose of successfully eliminating mosquito populations. Biologically controlling the growth of mosquitoes and ensuring that their population is under control can be accomplished through the production of a large number of predators that feed on mosquitoes. It is essential to include planarians, which are helminths that live in free-living environments. Ponds and lakes, as well as those with stagnant water that contains other microorganisms [60], are good environments for the cultivation of these species. In addition to being able to survive in temperatures as low as 32 degrees Celsius, these animals are carnivorous by their very nature and reproduce asexually for reproduction.

It is possible to define the word "feeding mode" as the manner in which aquatic invertebrates obtain their food in the natural environment. If an individual is able to retain their location or existence (For example, planktonic organisms, clingers, etc.) or move (For example, swimmers, divers, etc.), we use the term habit to refer to these behaviours [60]. The larvae of mosquitoes, along with other aquatic invertebrates, have developed morphological adaptations that enable behavioural flexibility for the purpose of feeding on a variety of resources [61, 62]. Consequently, a number of studies have described several techniques of feeding, as well as alterations of the mouth parts of the larvae and their link to the various modes [63, 64].

III) Biological control of mosquitoes by beetles

A mosquito's life cycle may be broken down into four distinct stages: the egg, the larva, the pupa, and the adult. Their ability to feed on aquatic insects allowed them to contribute to the effort to control mosquitoes. This was made possible by the fact that the first three stages of the mosquito are only found in water. The majority of the insects that feed on mosquito larvae are members of the insect groups Coleoptera, Diptera, Hemiptera, and Odonata. Predators of aquatic insects are primarily found in aquatic environments. Some of these predators are generalists, meaning that they consume a wide variety of prey (Known as polyphagous). Other predators, on the other hand, have diets that are restrictive (known as oligophagous) or perhaps do not consume any prey at all (Known as monophagous), and are therefore categorised as specialist predators. There is a high probability that mosquito larvae will consume multiple creatures. These predators employ a wide range of strategies to hunt their prey, and the effectiveness of these strategies is determined by the shape of their jaws. It is possible for a few of predators belonging to the order Odonata to eat their prey by using their chewing mouthparts. The bodily fluid (Hemolymph) of their victim is sucked by predators like beetle larvae and Hemiptera, who have sucking mouth parts. The larvae and pupae of mosquitoes are preyed upon by a wide variety of aquatic insects. This includes many species of Coleoptera (Especially the Dytiscidae), Hemiptera (Especially notonectids), and Odonata [65].

Bacterial Agents

Bacillus sphaericus (Bs) and *Bacillus thuringiensis* (Bt) are two bacteria that can be utilised for the purpose of controlling malaria vectors. These bacteria are completely safe for the environment, very effective, have selective actions, and are non-toxic in their natural state [20, 30]. In addition to being simple to work with, Bacillus strains are produced locally, can be applied in a practical manner, are inexpensive, and have the capacity to spread rapidly. In comparison to *Aedes*, *Culex quinquesfasciatus*, and *Aedes arabiensis*, the effect of Bs and Bt is even more pronounced on *Aedes gambiae* [24, 39]. The creation of endotoxin proteins is caused by Bs and Bt, which causes the stomach of larvae to get damaged, which ultimately results in the larval's death [66]. Interlinking is the mechanism by which two different types of endotoxin proteins, such as Cry and Cyt1A, collaborate to accomplish their functions. The resistance to cry proteins is delayed by Cyt1A, which is responsible for the long-lasting effects of cry proteins [67].

The acetic acid bacteria that colonise the female eggs and male reproductive systems of *A. albopictus*, *A. stephensi*, *A. gambiae*, and *A. aegypti* are found in the genus Asia. These bacteria travel via the progeny of their respective populations and are transmitted to the next generation. The life span of mosquitoes is shortened as a consequence, their immunity is diminished, and the establishment of parasites within the mosquito population is facilitated [28, 68]. For the purpose of fighting malaria, microbial agents are believed to be of great significance. These agents have the ability to either inhibit the growth of Plasmodium in the mosquito or directly mark the Anopheles vector population [43].

Larvivorous Fish (Fish)

The utilisation of predatory fish is the most time-honored approach to the management of mosquito populations. *Gambusia affinis* and other species belonging to the family Cyprinodontidae were the most commonly employed for the purpose of controlling mosquito larvae. It has been determined that the utilisation of larvivorous fish is a more effective strategy in comparison to the utilisation of chemical control [67]. They are able to be utilised due to the fact that they have a lower risk of mosquito resistance, an inexpensive production process, are safe for both humans and wildlife, and are administered in low dosages [41]. When utilising larval fish, there are two major considerations that need to be taken into account. The first is that the fish needs to be able to adjust to the environment in which it is being used. The second is the quantity of larvae that the fish consumes [50].

By utilising a mixed population of *Ctenopharyngodon idella*, *A. sinesis*, and *Cyprinus carpio*, it is possible to dramatically reduce the number of larvae that are produced by the Anopheles population. In contrast, the combination of *Cyprinus carpio*, *Catla catla*, *Cirrhinus mrigala*, and *Ctenopharyngodon idella* results in an 81% reduction in the population of the species that are responsible for malaria. The introduction of Gambusia affinis into the water results in a reduction of 98% in the number of *A. stephensi* larvae [52]. The genus *Aplocheilus*, *Colisa*, *Aphaniusdispar*, Oryziamelastigma, Chandanama, and Macropoduscupanus are the indigenous larvivorous fishes that are utilised for the purpose of controlling the malaria. *Oreochromis*, *Xenentodon*, *Carassius*, *Poecilia*, and Gambusia are some of the exotic larvivorous fishes that are utilised as a control agent for the disease known as malaria [69].

Gambusia are classified as opportunistic predators because they consume a wide variety of food, including zooplankton, algae, the young and eggs of amphibians, and aquatic insects [70]. The behaviour of these fishes is aggressive, and they are capable of engaging in competition with other species for space and food [71]. An increase in the temperature of the water, an increase in the number of phytoplankton, a decrease in the clarity of the water, and an increase in the amount of dissolved organic phosphorus are all caused by the origin of harmful ecological changes in the environment. It is vital to remove vegetation in order to increase the effectiveness of fish activities [39].

The mechanism of action of phytochemicals within the body of insects

Secondary metabolites are sometimes referred to as plant extracts, and they are responsible for protecting plants from herbivores [72]. In general, these metabolites are toxic, meaning that they are damaging to insects and have an effect on the molecules that are the targets of their actions. These molecules include biomembranes, nucleic acid, cellular components, and proteins. There are disruptions in the physiology of insects that have an effect on the neurological system, including the production of neurotransmitters, their storage, their release, and the activation of receptors [18]. Using essential oil acetylcholinesterase inhibition, thymol inhibits the GABA-gated chloride channel, rotenone inhibits the cellular respiration, and pyrethrin inhibits the potassium-sodium exchange. All of these effects are achieved through the administration of essential oil [38].

To the greatest extent possible, the suppression of the activity of acetyl cholinesterase, which is the primary enzyme responsible for the transmission of nerve impulses [57]. Therefore, when repellents are employed against insects, the

acetylcholinesterase enzyme is blocked, which ultimately blocks nerve transmission. This is due to the fact that AChE is the only mechanism that insects have for building resistance [22].

Various repellent preparations

It is possible to use repellents in the form of creams, lotions, pastes, or other preparations in order to ensure that their effects are longer long lasting. It is possible for natural repellents to be present in the following form:

In order to make lotions, the repellents are first dissolved in the alcohol, and then the mixture is thickened with either arachis oil or castor oil [73]. In order to create creams of the ointment variety, the repellent admixture is combined with a solid greasy basis, which may include petroleum jelly, lanolin, soft and hard paraffin, magnesium stearate, and acetyl alcohol.

The essential oils are what are used to make the vanishing type cream. When this kind of cream is put to the skin, it disappears because it is absorbed into the skin in a sudden manner, and water evaporates as a result of this process. Water, emulsifiers consisting of triethanolamine and triton X, and a fatty base are all components of this substance [35]. Due to the fact that vanishing cream has features that cause it to disappear, its usage is not considered to be appropriate. However, it is appropriate for products that give an irregular distribution of the repellent. Because of the benefits that it has that endure for a long time, waxy cream is believed to be the most effective [74].

Conclusion

There are numerous ethnobotanical evaluations that show plants to be effective repellent agents. In a great number of regions across the globe, plant repellents are utilised. Plant-based repellents are not hazardous to humans or domestic animals, and they can be quickly biodegraded. They also do not represent any additional risks to the environment. In contrast to manufactured substances, natural goods are superior in terms of their safety for human consumption. The application of synthetic repellents results in the development of pesticide resistance in mosquitoes, has a negative impact on creatures that are not the intended targets, and poses a risk to the environment. These plant-based repellents have garnered a lot of interest from consumers since they have a smaller impact on the environment and are more affordable. At this point in time, there is a pressing need for novel drug distribution systems that utilise plant-based active components. More research into the chemical ecology of mosquito mate seeking, swarming landmarks, and mate choice in swarming areas is necessary to develop more effective vector control techniques. Several natural items also have been studied for their potential to prevent mosquitoes, including *Zanthoxylum armatum* (Rutaceae), *Azadirachta indica* (Maliaceae), and Curcuma aromatica (Zingiberaceae) [75].

Reference

1. World Health Organization. Vector-borne diseases.]https://www.who.int/news-room/fact-sheets/detail/vector-borne-diseases.
2. Franklinos LHV, Jones KE, Redding DW, Abubakar I. The effect of global change on mosquito-borne disease. Lancet Infect. Dis. 2019 Sept;19(9):e302–e312. https://doi.org/10.1016/S1473-3099(19) 30161-6 Epub 2019 Jun 18. PMID: 31227327.
3. World Health Organization. Malaria. [cited 2022 April o4] Available from: https://www. who.int/news-room/fact-sheets/detail/malaria.
4. Centers for Disease Control and Prevention. WestNile virus: https://www.cdc.gov/westnile/index.html.
5. McDonald E, Mathis S, Martin SW, Staples JE, Fischer M, Lindsey NP. Surveillance for West Nile virus disease-United States, 2009-2018. MMWR Surveill Summ. 2021;70(SS-1):1-15. https://doi.org/10.15585/mmwr.ss7001a1external icon.
6. Puntasecca CJ, King CH, LaBeaud AD. Measuring the global burden of chikungunya and Zika viruses: A systematic review. PLoS Negl Trop Dis. 2021;15(3):e0009055. https://doi.org/10.1371/journal pntd.0009055 PMID: 33661908
7. Center for disease control and prevention. Malaria's Impact Worldwide. https://www.cdc.gov/malaria/malaria_worldwide/impact.html.
8. Shepard DS, Undurraga EA, Halasa YA, Stanaway JD. The global economic burden of dengue: A systematic analysis. Lancet Infect Dis. 2016;16(8):935-941. https://doi.org/10.1016/S1473-3099 (16) 00146-8 PMID: 27091092.
9. Mendki MJ, Singh AP, Tikar SN, Parashar BD, Veer V, Shukla SV, *et al*. Repellent activity of N, Ndiethylphenylacetamide (DEPA) with essential oils against *Aedes aegypti*, vector of dengue and chikungunya. International Journal of Mosquito Research. 2015;2(1):17-20.
10. Gaddaguti V, Rao TV, Rao AP. Potential mosquito repellent compounds of Ocimum species against 3N7H and 3Q8I of Anopheles gambiae. Biotech. 2016;6(11):1-8.
11. Soonwera M. Efficacy of essential oils from Citrus plants against mosquito vectors *Aedes aegypti* (Linn.) and *Culex quinquefasciatus* (Say). J Agri Tech. 2015;11(2):669-681.
12. Mishra P, Kumar J, A Elphine Prabahar, Anurag Verma, Verma AK. Linalool Based Herbal Mosquito Repellant, International Journal of Mosquito Research. 2023;10(3):15-23.
13. Kamareddine L. The biological control of the malaria vector. Toxins. 2012;4(3):748-767.
14. Mandal S. Repellent activity of Eucalyptus and *Azadirachta indica* seed oil against the filarial mosquito *Culex quinquefasciatus* Say (Diptera: Culicidae) in India. Asian Pacific Journal of Tropical Biomedicine. 2011;1(8):109-112.
15. Patel EK, Gupta A, Oswal RJ. A review on: Mosquito repellent methods. IJPCBS. 2012;2(15):310-317.
16. Phasomkusolsil S, Soonwera M. Comparative mosquito repellency of essential oils against *Aedes aegypti* (Linn.), Anopheles dirus (Peyton and Harrison) and *Culex quinquefasciatus* (Say). Asian Pacific Journal of Tropical Biomedicine. 2011;1(3):113-118.
17. Kalita B, Bora S, Sharma AK. Plant essential oils as mosquito repellent-a review. International Journal of Research and Development in Pharmacy and Life Sciences. 2013;3(4):741-747.
18. Xu P, Choo YM, De La Rosa A. Leal WS. Mosquito odorant receptor for DEET and methyl jasmonate. Proceedings of the National Academy of Sciences. 2014;111(6):16592-16597.
19. Mandal S. Repellent activity of Eucalyptus and

Azadirachta indica seed oil against the filarial mosquito *Culex quinquefasciatus* Say (Diptera: Culicidae) in India. Asian Pacific Journal of Tropical Biomedicine. 2011;1(8):109-112.
20. Ditzen M, Pellegrino M, Vosshall LB. Insect odorant receptors are molecular targets of the insect repellent DEET. Science. 2008;319(43):1838-1842.
21. Khoobdel M, Shayeghi M, Ladonni H, Rassi Y, Vatandoost H, Alipour HK. The efficacy of permethrintreated military uniforms as a personal protection against *Culex pipiens* (Diptera: Culicidae) and its environmental consequences. International Journal of Environmental Science & Technology. 2005;2(3):161-167.
22. Iturbe-Ormaetxe I, Walker T, LO'Neill S. Wolbachia and the biological control of mosquito-borne disease. EMBO reports. 2011;12(13):508-518.
23. Sukumar K, Perich MJ, Boobar LR. Botanical derivatives in mosquito control: A review. Journal of the American Mosquito Control Association. 1991;7(2):210-237.
24. Singh B, Singh PR, Mohanty MK. Toxicity of a plant-based mosquito repellent/killer. Interdisciplinary toxicology. 2012;5(1):184-191.
25. Uniyal A, Tikar SN, Singh R, Vinay S, Shukla OPA, Sukumaran, *et al*. Synergistic effect of effective oils against *Aedes aegypti* female mosquito, vector of dengue and chikungunya. International Journal of Mosquito Research. 2015;2(4):29-35
26. Ramar M, Ignacimuthu S, Gabriel P. Mosquito Knock Down and Adultcidal Activities of Essential Oils by Vaporizer, Impregnated Filter Paper and Aerosol Methods. International Journal of Mosquito Research. 2014;1(9):26-32.
27. Kongkaew C, Sakunrag I, Chaiyakunapruk N, Tawatsin A. Effectiveness of citronella preparations in preventing mosquito bites: systematic review of controlled laboratory experimental studies. Tropical Medicine & International Health. 2011;16(12):802-810.
28. Uniyal A, Tikar SN, Singh R, Vinay S, Shukla OPA, Sukumaran, *et al*. Synergistic effect of effective oils against *Aedes aegypti* female mosquito, vector of dengue and chikungunya. International Journal of Mosquito Research. 2015;2(4):29-35.
29. Impoinvil DE, Ahmad S, Troyo A, Keating J, Githeko AK, Mbogo CM, *et al*. Comparison of mosquito control programs in seven urban sites in Africa, the Middle East, and the Americas. Health Policy. 2007;83(45):196-212.
30. Kayedi MH, Haghdoost AA, Salehnia A, Khamisabadi K. Evaluation of repellency effect of essential oils of Saturejak huzestanica (Carvacrol), Myrtus communis (Myrtle), *Lavendula officinalis* and *Salvia sclarea* using standard WHO repellency tests. Journal of arthropodborne diseases. 2014;8(11):60-68.
31. Syed Z, Leal WS. Mosquitoes smell and avoid the insect repellent DEET. Proceedings of the National Academy of Sciences. 2008;105(20):13598-13603.
32. Yoon JK, Kim KC, Cho Y, Gwon YD, Cho HS, Heo Y, *et al*. Comparison of repellency effect of mosquito repellents for DEET, citronella, and fennel oil. Journal of parasitology research. 2015;2015:1-6.
33. Onyett H. Preventing mosquito and tick bites: A Canadian update. Paediatrics & child health. 2014;19(4):329-333.
34. Pal M, Kumar A, Tewari KS. Chemical composition and mosquito repellent activity of the essential oil of Plectranthusincanus link. Factauniversitatis-series: Physics, Chemistry and Technology. 2011;9(2):57-64.
35. Katritzky AR, Wang Z, Slavov S, Tsikolia M, Dobchev D, Akhmedov NG, *et al*. Synthesis and bioassay of improved mosquito repellents predicted from chemical structure. Proceedings of the National Academy of Sciences, 2008;105(13):7359-7364.
36. Ramar M, Ignacimuthu S, Gabriel P. Mosquito Knock Down and Adultcidal Activities of Essential Oils by Vaporizer, Impregnated Filter Paper and Aerosol Methods. International Journal of Mosquito Research. 2014;1(9):26-32.
37. Zhu JJ, Berkebile DR, Dunlap CA, Zhang A, Boxler D, Tangtrakulwanich K, *et al*. Nepetalactones from essential oil of Nepetacataria represent a stable fly feeding and oviposition repellent. Medical and veterinary entomology. 2012;26:131-138.
38. Ghosh A, Chowdhury N, Chandra G. Plant extracts as potential mosquito larvicides. Indian J Med Res. 2012;135(23):581-598.
39. Chandra G, Bhattacharjee I, Chatterjee SN, Ghosh A. Mosquito control by larvivorous fish. Indian Journal of Medical Research. 2008;127(32):13-27.
40. Hewitt S, Rowland M. Control of zoophilic malaria vectors by applying pyrethroid insecticides to cattle. Tropical medicine & international health. 1999;4(7):481-486.
41. Al-Akel AS, Suliman EM. Biological control agent for mosquito larvae: Review on the killifish, *Aphanius dispar* dispar (Rüppel, 1829). African Journal of Biotechnology. 2011;10(2):8683-8688.
42. Adeniran OI, Fabiyi E. A cream formulation of an effective mosquito repellent: A topical product from lemongrass oil (*Cymbopogon Citratus*) Stapf. J Nat Prod Plant Resour. 2012;2(4):322-327.
43. Koech PK, Mwangi RW. Synergistic repellent activity of plant essential oils against *Aedes aegypti* on rabbit Skin. International Journal of Mosquito Research. 2014;1(14):55-59.
44. Kumar S, Wahab N, Warikoo R. Bio-efficacy of Mentha piperita essential oil against dengue fever mosquito *Aedes aegypti* L. Asian Pacific Journal of tropical biomedicine. 2011;1(2):85-88.
45. Fayemiwo KA, Adeleke MA, Okoro OP, Awojide SH, Awoniyi IO. Larvicidal efficacies and chemical composition of essential oils of *Pinus Sylvestris* vestris and Syzygium aromaticum against mosquitoes. Asian Pacific journal of tropical biomedicine. 2014;4(12):30-34.
46. Ansari MA, Mittal PK, Razdan RK, Sreehari U. Larvicidal and mosquito repellent activities of Pine (*Pinus longifolia*, Family: Pinaceae) oil. Journal of vector borne diseases. 2005;42(5):95.
47. Tawatsin A, Asavadachanukorn P, Thavara U, Wongsinkongman P, Bansidhi J, Boonruad T, *et al*. Repellency of essential oils extracted from plants in Thailand against four mosquito vectors (Diptera: Culicidae) and oviposition deterrent effects against *Aedes aegypti* (Diptera: Culicidae). Southeast Asian J trop med public health. 2006;37(4):915-937.
48. Rajkumar S, Jebanesan A. Prevention of Dengue fever through plant based mosquito repellent *Clausena dentata* (Willd.) M. Roem (Family: Rutaceae) essential oil against

Aedes aegypti L. (Diptera: Culicidae) mosquito. Eur Rev Med Pharmacol Sci. 2010;14(6):231-234.
49. Pattanayak B, Dhal NK. Plants having mosquito repellent activity: An ethnobotanical survey. International Journal of Research and Development in Pharmacy and Life Sciences. 2000;4(3):1760-1765.
50. Polsomboon S, Grieco JP, Achee NL, Chauhan KR, Tanasinchayakul S, Pothikasikorn J, *et al*. Behavioral responses of catnip (Nepetacataria) by two species of mosquitoes, *Aedes aegypti* and *Anopheles harrisoni*, in Thailand. Journal of the American Mosquito Control Association. 2008;24(5):513-519.
51. Yang HM, Ferreira CP. Assessing the effects of vector control on dengue transmission. Applied Mathematics and Computation. 2008;198(12):401-413.
52. Peterson CJ. Insect repellents of natural origin: catnip and Osage Orange; c2001.
53. Peterson CJ, Coats JR. Catnip Essential Oil and Its Nepetalactone Isomers as Repellents for Mosquitoes. Recent Developments in Invertebrate Repellents. 2011;1090(5):59-65.
54. Atieli FK, Munga SO, Ofulla AV, Vulule JM. The effect of repeated washing of long-lasting insecticide-treated nets (LLINs) on the feeding success and survival rates of Anopheles gambiae. Malaria journal. 2010;9(3):1-9.
55. Raja ASM, Kawlekar S, Saxena S, Arputharaj A, Patil PG. Mosquito protective textiles: A review. International Journal of Mosquito Research. 2015;2(7):49-53.
56. Sumithra V, Janakiraman A, Altaff K. Bio-control of mosquito larvae through the black molly, poecilias phenops. International Journal of Pure and Applied Zoology. 2014;2(5):270-274.
57. Sritabutra D, Soonwera M. Repellent activity of herbal essential oils against *Aedes aegypti* (Linn.) and *Culex quinquefasciatus* (Say.). Asian Pacific Journal of Tropical Disease. 2013;3(1):271-276.
58. Scholte EJ, Knols BG, Samson RA, Takken W. Entomopathogenic fungi for mosquito control: A review. Journal of Insect Science. 2004;4(7):1-19.
59. Butt TM, Greenfield BP, Greig C, Maffeis TG, Taylor JW, Piasecka J, *et al*. Metarhizium anisopliae pathogenesis of mosquito larvae: A verdict of accidental death. PloS one; c2013.
60. Merritt RW, Cummins KW. Eds. An Introduction to the Aquatic Insects of North America. Dubuque, IA: Kendall/Hunt 2nd ed.; c1984. p. 722
61. Laird M. The Natural History of Larval Mosquito Habitats. London: Academic, 1988, 555.
62. Wallace JB, Merritt RW. Filter-feeding ecology of aquatic insects. Annu. Rev. Entomol. 1980;25(1):103-32.
63. Hogarth AM. British Mosquitoes and How to Eliminate Them. London: Hutchinson, 1928, 127.
64. Dahl C, Widahl LE, Nilsson C. Functional analysis of the suspension feeding system in mosquitoes (Culicidae: Diptera). Ann. Entomol. Soc. Am. 1988;81(1):105-27.
65. Verma M, Mishra P, Shakya S, Verma AK. Potential biological agents for control of mosquitoes, International Journal of Mosquito Research 2023;10(5):19-27.
66. Ogoma SB, Moore SJ, Maia MF. A systematic review of mosquito coils and passive emanators: defining recommendations for spatial repellency testing methodologies. Parasites & vectors, 2012;5(5):1-10.
67. Kamareddine L. The biological control of the malaria vector. Toxins. 2012;4(3):748-767.
68. Maia MF, Moore SJ. Plant-based insect repellents: A review of their efficacy, development and testing. Malaria Journal, 2011;10(3):1-14.
69. Kumar R, Hwang JS. Larvicidal efficiency of aquatic predators: A perspective for mosquito biocontrol. Zoological studies-taipei. 2006; 45(4):.447-460.
70. Koren G, Matsui D, Bailey B. DEET-based insect repellents: safety implications for children and pregnant and lactating women. Canadian Medical Association Journal. 2003;169(20):209-212.
71. Stanczyk NM, Behrens RH, Chen-Hussey V, Stewart SA, Logan JG. Mosquito repellents for travellers. BMJ. 2015;350:99.
72. Aremu OI, Femi-Oyewo MN, Popoola KOK. Repellent Action of Neem (*Azadirachta indica*) Seed Oil Cream against Anopheles Gambiae Mosquitoes. African Research Review. 2009;3(6):12-22.
73. Wany A, Jha S, Nigam V, Pandey D. Chemical analysis and therapeutic uses of citronella oil from Cymbopogon winterianus: A short review. Int. J Adv. Res. 2013;1(6):504-521.
74. Mnzava AP, Knox TB, Temu EA, Trett A, Fornadel C, Hemingway J, *et al*. Implementation of the global plan for insecticide resistance management in malaria vectors: progress, challenges and the way forward. Malaria journal. 2015;14(9):1-9.
75. Mishra P, *et al*. Mosquito repellents derived from plants, International Journal of Mosquito Research. 2023;10(2):37-44.