

# Mosquito Repellent Textiles

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## Abstract

In the present scenario, textiles are no longer perceived as an aesthetic commodity but much more is expected out of it. Hence, efforts of technologists have led to the emergence of textiles with some functional finishes applied on it to perform specific functions.

The need for such fabrics performing specific functions is ever increasing and novel developments are coming up at rapid pace. Fabrics such as water repellent fabrics, flame – retardant fabrics, anti-bacterial fabrics etc have already been developed. A new and more complicated challenge of developing a mosquito repellent fabric which should affect neither environment nor the user faces the technologists now. Since, the mosquitoes are causing many dreadful diseases in the world such as malaria, filarial, dengue etc., it becomes imperative to develop such fabrics.

Although some chemicals are available, they have been banned by WHO since they seem to have some side – effects on humans and also harmful for the environment. In this paper, we have discussed all the types of mosquito repellents that are available like DEET, PERMETHRIN, ALLETHRIN, and MALATHION; the way they can be used with their properties and the precautions that we have to take for their use.

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## 1. Introduction

Insect repellents are preparations which are used externally to repel and/or drive away insects and also ticks and mites and are intended to prevent insects, ticks and mites from becoming active on the skin. Insect repellents are intended to protect the skin from irritation by blood-sucking or biting insects and other parasites and/or pests by repelling these before they settle on the skin, so that stings or bites do not result. Accordingly, the agents act not as contact poisons, but only as repellents since they do not kill the animals but only drive them away.

Stings or bites from insects and other parasites normally lead to urtication, redness and itching and in isolated cases to mostly harmless infections. However, insects, in particular mosquitoes, can also be transmitters of parasitic and viral infections (such as, for example, malaria, yellow fever or dengue fever). In total, there are, for example, no fewer than 3000 different species of mosquito, of which about 100 can spread epidemics. Repelling or driving away these insects therefore also serves in particular as protection against such infections.

## 2. History

Even in primeval times, people were plagued by stinging or biting insects or other parasites. Accordingly, mankind's need for insect repellents is old. A method known from early history for making it unattractive or unpleasant for annoying or harmful insects to stay close to people is the lighting of fires with aromatically or pungently

smelling herbs or woods which produce lots of smoke. The treatment of skin with strongly smelling substances to repel insects has also already been known since ancient times. At around the turn of the last century, a number of natural essential oils was already being used as insect repellents, eg. anise oil, bergamot oil, birch wood tar, camphor, citronella oil, eucalyptus oil, geranium oil, pine oils, coconut oil, lavender oil, nutmeg oil, clove oil, orange blossom oil, peppermint oil, pennyroyal oil, pyrethrum, thyme oil and cinnamon oil.

In spite of an intense odor, on account of their predominantly inadequate effectiveness and their sometimes inadequate tolerability in higher concentrations, these substances have largely been replaced in modern insect repellents by synthetic substances with better effectiveness. These are primarily high-boiling liquids or low-melting or subliming crystalline substances which evaporate slowly at room temperature. Most repellent active ingredients belong to the classes of amides, alcohols, esters and ethers.

## 3. Mosquitoes

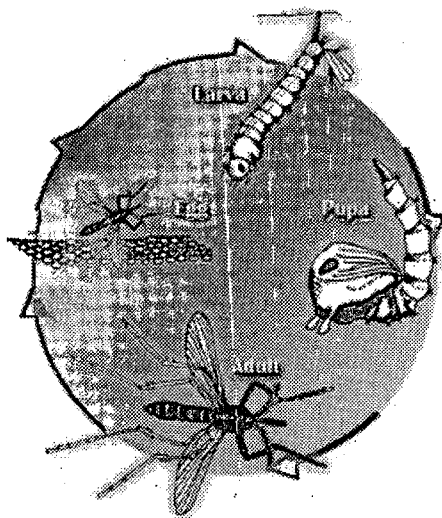
Mosquito is a member of the family Culicidae. These insects have a pair of scaled wings, a pair of halteres, a slender body, and long legs. The females of most mosquito species suck blood (hematophagy) from other animals. This blood sucking characteristic has made mosquitoes one of the most deadly vectors known to man, killing millions of people over thousands of years and continuing to kill millions per year by the spread of diseases.

Size varies but is rarely greater than 16 mm (0.6 inch). Mosquitoes weigh only about 2 to 2.5 mg (0.03 to 0.04 grain). A mosquito can travel up to 10 km in a night, and fly for 1 to 4 hours continuously at up to 1-2 km/h. Most species are nocturnal or dawn or evening feeders (crepuscular). During the heat of the day most mosquitoes land in a cool place and wait for the evenings. They may still bite if disturbed.

Both male and female mosquitoes are nectar feeders, but the female is also capable of haematophagy (drinking blood). Females do not require blood for survival, but they do need supplemental protein for the development and laying of their eggs. Prior to sucking the blood, they inject a mild painkiller, which numbs the host to the pain from the "bite" (Note: mosquitoes do not actually bite). Male mosquitoes are distinctly smaller than females, with features such as feathered antennae and having no audible sound during flight. Female mosquitoes in flight emit a distinctive high-pitched buzz, which can interrupt sleep.

### 3.1 Life Cycle

Mosquito undergoes four distinct stages: egg, pupa, larva, adult - a process that was first described by the Greek philosopher Aristotle.

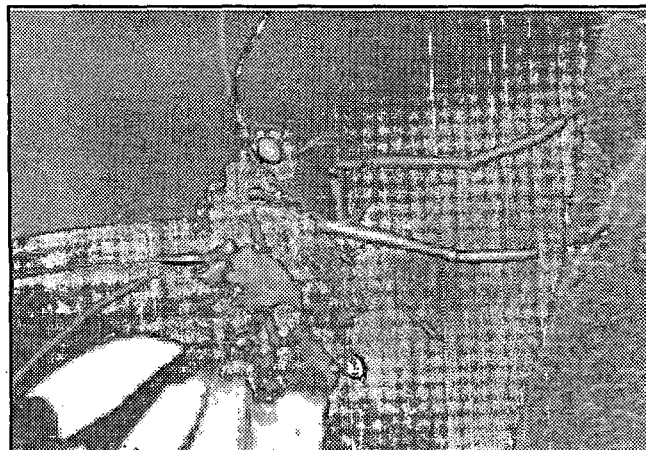


The first is the egg, which we know is laid in still water breeding grounds by adult mosquitoes. These eggs remain on the surface of the water until they hatch into larvae. In the larva stage several layers of skin are shed. This stage can range from days to weeks. The larva change into pupa and in this stage the mosquito becomes an adult over the course of a few days. Now that the mosquito is fully developed, it begins searching for food and a mate. Full of plant nectar and done with her business the female mosquito begins looking for the protein necessary for her to lay eggs and continue the life cycle. The mosquito's protein source is blood.

### 3.2 How Do They Bite?

Only female mosquitoes bite animals to get blood needed to produce eggs. Male mosquitoes do not bite, but both the male and female feed on the nectar of flowers for food. In most female mosquitoes, the mouth parts form a long proboscis (an elongated appendage from the head of an animal) for piercing the skin of mammals (or in

some cases birds or even reptiles and amphibians) to suck their blood.



Closeup image of the Cairns Birdwing, showing its large proboscis

As opposed to a syringe's typically smooth needle, the mosquito proboscis is highly serrated, which leaves a minimal number of points of contact with the skin being pierced — this reduces nerve stimulation to the point where the "bite" is typically not felt at all. The females require protein for egg development and laying, and since the normal mosquito diet consists of nectar and fruit juice, which has no protein, most females must drink blood to lay eggs. Males differ from females, with mouth parts not suitable for blood-sucking.

The female mosquitoes locate their next blood donor victims primarily through scent. They are extremely sensitive to the carbon dioxide in exhaled breath, as well as several substances found in sweat and various body odours. They are believed to be able to track potential prey for tens of meters. Some people attract more mosquitoes than others, apparently based on how they "smell" to a mosquito. Mosquitoes can also detect heat, so they can find warm-blooded mammals and birds very easily once they get close enough.

### 4. Mosquito Repellents

Repellents are substances that are mainly used to repel insects and pests rather than causing death. Several mosquito repellents are available today in the market, of which DEET is safely used by an estimated 1100 million people worldwide each year.

Repellents are a common means of personal protection against mosquitoes and are broadly classified into two categories, natural repellents and chemical repellents.

Essential oils from plant extracts that act as natural repellents are: Citronella oil, Lemongrass oil, Neem oil, castor oil, rosemary oil, cedar oil, peppermint oil, clove oil, geranium oil, and chrysanthemum.

Examples of chemical repellents include:

- DEET (N,N-diethyl-m-toluamide)
- Permethrin
- Allethrin
- Malathion

#### 4.1 Mechanism of Repellent Action

Action of repellent agent for blood-sucking insects including mosquitoes can be broadly divided into two types that are actions to repel insects by acting on the olfactory and tactile senses.

Action of repellent on sense of smell is called transpiration repelling, and this has the effect of keeping insects away without them touching a surface processed with the repellent. The repellent molecules block insects' humidity sensory holes, which makes humans inaccessible to insects by inhibiting the function of sensing moisture, while insects usually use warm and humid convection rising from the human body as a guide for contacting humans, sensing an increase in atmospheric carbon dioxide concentrations.

Action of repellent stimulating sense of touch is called direct-contact repelling, and this drives insects off the processed surface before blood sucking even after touching the surface.

It is believed that repellent substances work on insects' peripheral nervous systems when contact is made, causing a collaterally-expressed confusional state and inhibition under sublethal doses before knockdown and lethal action.

##### 4.2.1 DEET (N,N-diethyl-m-toluamide):

**N, N-diethyl-m-toluamide**, abbreviated **DEET**, is an insect repellent chemical. It is intended to be applied to the skin or to clothing, and is primarily used to protect against insect bites. In particular, DEET protects against tick bites (which transmit Lyme disease) and mosquito bites (which transmit dengue fever, West Nile virus, Eastern Equine Encephalitis (EEE), and malaria).

DEET is believed to work by blocking insect receptors (notably those which detect carbon dioxide and lactic acid) which are used to locate hosts. DEET effectively "blinds" the insect's senses so the biting/feeding instinct is not triggered by humans or animals which produce these chemicals.

##### Salient Features

1. Slightly yellow liquid at room temperature.
2. Can be prepared from m-methylbenzoic acid and diethylamine. This can be achieved by preparing the acid chloride and subsequently reacting that with the diethylamine.
3. It can be distilled under vacuum: b.p. 111°C at 1 mm Hg.
4. Considered as a mild irritant.
5. Melting point: -45°C; boiling point: 288-292°C.
6. Some repellents are believed to offer alternatives to DEET; however, no alternative is known to work as efficiently as DEET

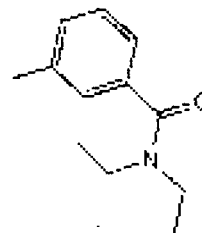
##### Concentrations

DEET is often sold and used in concentrations up to 100%. Consumer reports found a direct correlation between DEET concentration and hours of protection against insect bites. 100% DEET was found to offer up to 12 hours of protection while several lower concentration DEET formulations (20%-34%) offered 3-6 hours of protection.

##### Compositions

An insect-repelling agent contains N, N-diethyl-m-toluamide (DEET)

based on alcohol solutions as the active ingredient (repellent), and further contains an adjuvant that extends the period of effectiveness of DEET following application to human skin. It is proposed that the sole adjuvant is glycerol in an amount of more than 10 percent by weight of the insect-repelling.



N,N-diethyl-m-toluamide (DEET)

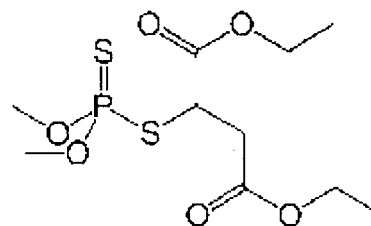
##### Disadvantages

It is safe product when used as directed but recently it has been found to cause problems with some people, particularly with very young children with females being affected more severely on average than males.

Almost all repellents including DEET are absorbed through the skin, passed through the liver and kidneys, and then expelled in the urine, (this process can take up to five days with DEET). Although these chemicals will stain fabric, the safest way to wear these repellents is to put them on your clothing so long as the clothing is NOT nylon based.

##### 4.2.2 Malathion

Malathion is an organophosphate insecticide that can cause acute and long-term neurological health problems. Malathion is an insecticide of relatively low human toxicity.

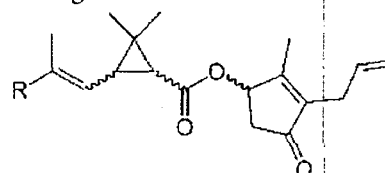


Diethyl ((dimethoxyphosphinothioyl) - thio)butanedioate

##### 4.2.3 Allethrin

Allethrin is another compound which is widely used in vaporizer repellents. Although it is considered safe; children are more susceptible to its ill-effects.

The compounds Allethrin-I and Allethrin-II have low toxicity for humans and birds, and are used in many household insecticides such as RAID as well as mosquito coils. They act by paralyzing the insect before killing it.

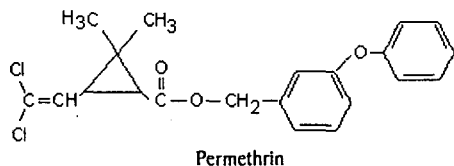


Allethrin I (R = -CH<sub>3</sub>)

Allethrin II (R = -COOCH<sub>3</sub>)

#### 4.2.4 Permethrin (synthetic analogue of pyrethrum):

Permethrin is a common synthetic chemical, widely used as an insecticide and acaricide and as an insect repellent. It belongs to the family of synthetic chemicals called pyrethroids and functions as a neurotoxin, affecting neuron membranes by prolonging sodium channel activation.



#### Mechanism of Action

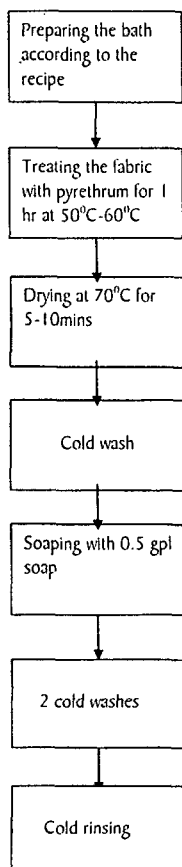
- Pyrethroids work by quickly paralyzing the nervous system of insects.
- Permethrin kills insects when it contacts them or when they eat it. They have repellent effect also.
- It is effective against all the stages of insect growth, especially larvae.

#### 5. Finishing of Fabrics

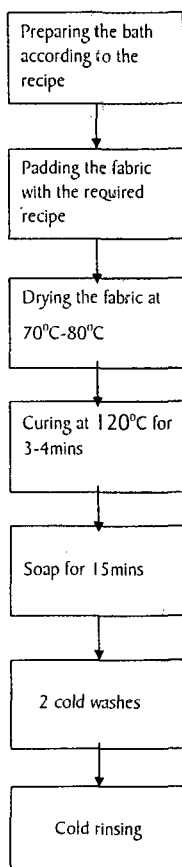
There are two methods by which the finish can be applied on to the fabrics. They are:

- Exhaust method
- Padding method

##### Process flow chart for finishing: Exhaust method:



##### Padding method:



Both the methods were found to be effective to large extent in particular the exhaustive method was highly successful for both nylon and cotton and less complicated than padding technique. Nylon was finished only by exhaustive method as it was too difficult to maintain the parameters for padding technique.

The only drawback encountered in this finish is that there is a slight yellowing problem associated with it. This result in tonal changes when this finish is applied to color goods and the bleached fabrics becomes slightly pale. Both cotton and nylon fabrics treated with Pyrethrum, posses good wash fastness properties (finish remains even after 5-10 washes).

#### 6.1 How to use it?

It should be applied to clothing, or to other fabrics (tent walls, mosquito nets, etc.). It is not intended for direct application to the skin. When treating a garment with Permethrin spray, spray the cloth outdoors and allow it to dry before wearing.

#### 6.2 Is there a need for it to be reapplied frequently to keep working?

No. One of the best things about Permethrin is its length of effectiveness per application. When applied to clothing by aerosol or trigger spray, Permethrin provides protection lasting up to two weeks or two washings, whichever comes first. Clothing soaked in Permethrin solution is effective for up to 4 months per application on stored garments.

#### 6.3 Does it damage clothes?

No. Permethrin is colorless, odorless, and non-staining. It should not change the feel or look of the clothing to which it is applied.

#### 6.4 Is it toxic?

Since Permethrin is not intended for direct use on the skin, there are very few concerns about toxicity. Any Permethrin that might inadvertently get on the skin, however, is very poorly absorbed (less than 2% of the applied dose). Permethrin is rapidly inactivated by skin and liver esterases, and its metabolites are then readily excreted by the kidneys. There is no evidence that Permethrin accumulates in human tissues. Although occupational exposure to large amounts of Permethrin has been associated with transient symptoms of itching, burning, or numbness, these symptoms have not been reported in consumers applying the products to clothing. Studies have not shown Permethrin to be a human teratogen, mutagen, or carcinogen.

#### 6.5 Are pets affected by it?

Permethrin should not be sprayed around ponds or any other areas where fish are found, since the chemical is toxic to fish. Permethrin has not been shown to be toxic to birds. Although there are Permethrin sprays specifically sold for use on dogs, these products should never be used on cats. Because of their grooming habits and slow metabolism of Permethrin, cats are much more susceptible to toxicity from Permethrin. Again, once the Permethrin has dried on any fabric, toxicity should no longer be of any concern.

#### 6.6 Is it approved for children?

Permethrin-treated fabrics should be safe for children of any age.

Once the Permethrin has dried on the clothing, it is bound so tightly to the fibers that any potential for absorption through the skin is negligible.

### 6.7 Are there any environment threats?

Studies have shown that Permethrin is environmentally safe. Permethrin is degraded by sunlight, which limits its persistence in the environment. Its half-life is less than 30 days in soil, and the chemical is readily metabolized by soil microorganisms. Once dried on fabric, Permethrin is so tightly bound to the fibers themselves, that "leaching" into the environment is essentially not possible.

### 6.8 What is the difference between DEET and Permethrin?

DEET and Permethrin complement one another, but they are not interchangeable. DEET works to repel biting insects, by blocking the receptors on an insect's antennae which help it home in on its host. Permethrin is not an insect repellent. It works as a contact insecticide, stunning or killing insects that come in contact with it.

### 6.9 Use of DEET and Permethrin together

When maximum protection against insect bites is needed or desired, the ideal solution is to use a combination of DEET on exposed skin, and wear Permethrin-treated clothing. An extended-duration DEET insect repellent and Permethrin-treated clothing is the standard personal protection system used by the U.S. military deployed in areas of the world where insect-borne disease is a real threat. One field study showed that the use of both of these products provided **99.9% protection** against mosquito bites, in an environment where unprotected persons received an average of 1,188 bites per hour!

## 7. Few more ways to make fabric mosquito/ insect repellent

### 7.1 Garment incorporating functional electrical circuit

Disclosed is a breathable heater element for a garment or for the lining of a garment such as an outdoor jacket, e.g. a waterproof jacket. The heater element is formed from porous metallised fabric such a nickel plated woven polyester fabric by photochemical etching of a suitable track pattern onto the metallised fabric. The formed heater element is then laminated into a lining. The material of the lining may be impregnated with microencapsulated functional chemicals such as fragrances, perfumes, antimicrobials or insect repellents. The microcapsules release their contents on activation due to heat generated by the heater element. Functional chemicals are incorporated into the laminated structure or the garment.

### 7.2 Insect barrier garment

The textile of the garments has a base fabric and a cover fabric separated by a spacer layer. The base fabric is open to facilitate breathability. The cover fabric is sufficiently closed to inhibit insects, spiders, or other small animals from passing through the cover fabric, and sufficiently open so as not to inhibit the breathability of the textile. The spacer layer separates the base fabric from the cover fabric with sufficient distance to inhibit insects, spiders, or other small animals from probing through the textile to reach the wearer.



Representative Image of Insect Barrier Garment

The fabric uses no chemical insect repellents that would eventually wash off or smell. The fabric is very light weight, and has an open construction that breathes, allowing the wearer to remain cool. These latter features of breathability and light weight are very important because mosquitoes and most other stinging or biting insects live in hot humid environments.

### 7.3 Nets

A mosquito net offers protection against mosquitos, flies, and other insects, and thus against diseases such as malaria. Its fine, see-through, mesh construction stops many insects from biting and disturbing the person using the net. The mesh is fine enough to exclude these insects, but it does not completely impede the flow of air.

For effectiveness, it is important that the netting not have holes or gaps large enough to allow insects to enter. Because insects can bite through the net, the net must not rest directly on the skin. Mosquito nets treated with insecticides — known as insecticide treated nets (ITNs) — were developed in the 1980s for malaria prevention. These nets, impregnated with a pyrethroid insecticide like deltamethrin or Permethrin, kill and repel mosquitos. Unfortunately, standard ITNs must be replaced or re-treated with insecticide after six washes and, therefore, are not seen as a convenient, effective long-term solution to the malaria problem. ITN presently available in two forms: one requires regular treatment of insecticides and the other is long-lasting insecticides treated nets (LLIN).

For protection against mosquitos, the U.S. Centers for disease control recommend DEET, icaridin, or oil of lemon eucalyptus for skin, and Permethrin for clothing, gear, or bed nets.

## 8. Conclusion

There are many more natural and herbal products which can impart the repellent action in textiles. All that needs to be explored keeping in mind the toxic effect of those products while developing mosquito repellent fabrics. There are many more natural products which can impart this finish but their longevity is less which is the main requirement for textiles. So products should also be selected keeping this in mind. One such product which can be studied in future is catnip leaves which have tremendous potential of emerging as a safe natural repellent.