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In general, mosquito repellents work by interfering with the female mosquito's ability to detect the environmental cues (for example heat, CO<sub>2</sub>, and water vapor) that she uses to find a host. Repellents are applied to the skin, used to treat clothing, or released into the air.

There are a variety of synthetic and plant-derived chemicals known to repel mosquitoes. Few are considered safe enough to be applied repeatedly to the skin. The most commonly used synthetic chemical repellent is called deet (N,N-diethyl-3-methylbenzamide). Deet is used by more than 50 million Americans annually for protection from mosquito bites. It has been applied more than one billion times over the 40+ years that it has been commercially available. However, some safety concerns have arisen during this time. As of 1995, there had been 14 cases of neurotoxicity, primarily childhood encephalopathy, associated with frequent and heavy use of deet. However, in most of these cases little effort was made to eliminate possible involvement of the more common known causes of encephalopathy, such as viral infections. Because of the concerns about deet-associated neurotoxicity and dermatitis, the Environmental Protection Agency has released additional guidelines for deet use (see Fact Sheet 5.526).

In general, the length of mosquito protection provided by deet increases as the concentration of active ingredient in the product increases, with 100% products providing 8 or more hours of protection under many conditions. An exception is 3M Ultrathon, the commercial version of the product used by the US military, which is a 32% slow release formulation that provides similar protection.

There also are many repellent products containing plant derived chemicals. The most common of these is citronella, although a variety of other essential oils are used as well. In general, these products are just as repellent as deet but do not last as long. An exception may be MosquitoSafe, a new product based on geraniol, which is reported to have similar longevity to that of deet. As long as it is understood that frequent reapplication is necessary, plant-derived repellents should provide the same protection against mosquito bites as deet. Also, it should be noted that these chemicals are generally regarded as safe by the Environmental Protection Agency and therefore have undergone much less safety testing than deet.

There are many studies comparing the effectiveness of mosquito repellents. However, it is difficult to compare among studies because of the variety of methods used in comparing products. Two recent studies are summarized in Tables 1 and 2 to provide an idea of the variety of products available and of the range of efficacy of these products. It is important to keep in mind that these tests usually involve mosquito species that are vectors of virus diseases such as West Nile and that results may not apply to other important vector groups. For example, the plant-derived repellents are generally ineffective against ticks and deet is much less effective against some of the mosquito species that transmit malaria.

Deet and citronella repellents also are available as treated wristbands. However, recent tests indicate that these are ineffective (Tables 1 and 3). Repellents containing the active

ingredient permethrin may be applied to clothing, but not the skin, for long lasting protection against mosquitoes, biting flies, and ticks. Permethrin is primarily a fast-acting insecticide and has some repellent activity as well.

Repellents and adulticides (insecticides intended to kill adult mosquitoes) may also be released into the air by burning (coils and candles). Results have been mixed, with some studies indicated moderate biting suppression and others indicating no effect (for example, Table 3). Also, there are some health concerns associated with inhalation of smoke generated in this manner. The mosquito plant is supposed to release repellents into the air as well, but several studies have shown no effect or slightly increased biting rates (for example, Table 3).

#### Mosquito Control Devices

Mosquito control devices fall into one of two categories. Attract and kill devices use different combinations of ultraviolet light, CO<sub>2</sub>, and octenol to attract mosquitoes to an electrocuting grid. "Bug zappers" rely on just ultraviolet light for attraction and are ineffective in reducing mosquito biting rates and kill many harmless or beneficial insects, as well. In one study, just 0.13% of the insects killed by one of these devices were female mosquitoes. Another study estimated that up to 350 billion beneficial insects are killed annually in the United States by these devices.

Attract and kill devices become more effective as CO<sub>2</sub> and octenol attractants are added. Also, efficacy is strongly influenced by the manner in which the attractants are dispersed from the trap. The most effective of these traps has been shown to be as effective as deet in a contained environment (large outdoor tent) with a known number of mosquitoes. There is no scientific evidence, however, that they are effective in reducing mosquito biting rates outdoors (for example, Table 3, Experiment 1).

The other category of mosquito control devices are the sonic and ultrasonic repellents. Sonic repellents were first marketed in the 1970s. They purported to imitate the flight sound of a male mosquito and worked on the assumption that a mated female mosquito would avoid further contact with males. Other devices were supposed imitate the flight sounds of dragonflies. Although testimonials as to their effectiveness abound, most of these devices have been tested in the laboratory or field and have shown no repellency.

More recently ultrasonic repellents have been developed, which purport to mimic the sounds made by bats. These also have been tested in controlled experiments and found ineffective in reducing mosquito biting rates (for example, Table 3, Experiment 1).

#### Larvicides

Mosquito larvae are aquatic, and a basic mosquito management recommendation around the home or small acreage is to eliminate any standing water that might serve as a mosquito breeding site (see Fact Sheet 5.526). However, there are some potential breeding sites that can not be eliminated or periodically emptied; e. g., fish ponds, water gardens, and stock tanks. These may be treated with larvicides to eliminate mosquito larvae before they emerge from the water as adult mosquitoes.

Treatment of aquatic habitats to control insects can be risky, and much effort has been put into developing environmentally sound products for this use. These are summarized in Table 4. Some products are for use by mosquito control districts, government agencies or licensed pest control operators. However, private individuals should have access to most of these active ingredients in at least one commercial product. Also, availability of these products in retail outlets currently is quite limited. However, the

increased public interest in mosquito control due to West Nile virus should increase the number and availability of retail larvicides.

#### Adulticides

Control of adult mosquitoes in a yard using insecticides can be used as a supplement to, but not as a replacement for more effective methods of mosquito suppression, notably larval management. Currently almost insecticides available for this purpose are pyrethroids.

Adult mosquito suppression can involve two common approaches. The first is an areawide spraying or fogging to kill flying mosquitoes and, presumably, some mosquitoes resting on vegetation. This is best done during peak periods of mosquito flight, often around dusk with the floodwater *Aedes*. Often a very short-lived pyrethroid insecticide is used for this purpose, such as resmethrin or natural pyrethrins. These break down very rapidly, usually within a couple of hours following application particularly in sunlight. Permethrin, a pyrethroid which has longer residual effectiveness is also used.

There are several limitations to area-wide spraying in a yard. Suppression of adult mosquitoes is usually only a few days at most since reinvasion by mosquitoes from outside the treated area can be rapid. The applications can also damage populations of desirable insects, such as pollinators and natural enemies of insect pests. Contamination of garden crops with unregistered pesticides is also a common problem.

Harborage area treatment involves insecticide application to areas where mosquitoes rest between periods of flight and biting activity. This is usually areas of dense brushy vegetation or tall grass. Insecticides with some persistence, such as permethrin or cypermethrin, are appropriate for this type of application and may kill resting mosquitoes for a week or longer. Effects will be diminished with short-lived insecticides.

Some of the insecticides found in garden centers, nurseries, and other retail outlets that may be useful for adult mosquito control.

Permethrin. Examples of currently marketed products include: Green Thumb Yard & Patio Fogger, Bonide Mosquito Beater Ready-to-Spray, ferti-lome Indoor/Outdoor Multi-Purpose Insect Spray, Safer Mosquito Patrol, Spectracide Bug Stop Multi-Purpose Insect Control Concentrate, Ortho Outdoor Insect Fogger, Raid Yard Guard, Hot Shot Fogger (with tetramethrin), Ford's InterCept Insect Control/Vegetable, Lawn, Garden Spray Concentrate, Cutter Bug Free Backyard

Pyrethrins. Examples of currently marketed products include: Quik-Kill Home Garden & Pest Spray, Ortho Insect Fogger (with permethrin), Spectracide Bug Stop Insect Killer (aerosol, also contains permethrin), ferti-lome Quik-Kill Home, Garden and Plant Insect Concentrate

Cypermethrin. Examples of currently marketed products include: Vikor Home & Patio Insect Control, Raid Concentrate Fogger

Resmethrin. An example of a product that has been recently market was: Ortho Outdoor Insect Fogger

**Summary of effectiveness of mosquito repellents reported by Fradin, M. S. and J. F. Day. 2002. Comparative efficacy of insect repellents against mosquito bites. New England Journal of Medicine 347: 13 - 18.**

<b>Product<sup>1</sup></b>	<b>Active Ingredient</b>	<b>Minutes of Complete Protection</b>	<b>Evaluation<sup>2</sup></b>
Off! Deep Woods	23.8% Deet	302	A
Sawyer Controlled Release	20% Deet	234	B
Off! Skintastic	6.7% Deet	112	C
Bite Blocker for Kids	2% Soy oil	95	D
Skin-So-Soft Bug Guard Plus	7.5% IR3535	23	E
Natrapel	10% citronella	20	E
Herbal Armor	12% citronella 2.5% peppermint oil 2% cedar oil 1% lemongrass oil 0.05% geranium oil	19	E
Green Ban for People	10% citronella 2% peppermint oil	14	E
Buzz Away	5% citronella	14	E
Skin-So-Soft Bug Guard	0.1% citronella	10	E
Skin-So-Soft Moisturizing Sun Care	0.05% citronella	3	F
Gone Original Wristband	9.5% Deet	0.3	G
Repello Wristbande	9.5% Deet	0.2	H
Gone Plus Repelling Wristband	25% citronella	0.2	H

<sup>1</sup>May or may not be available for purchase or registered for use in Colorado.

<sup>2</sup>Letters indicate groups of repellents that are statistically similar; e.g., the six repellents in category E are statistically similar to each other.

**Table 2. Summary of effectiveness of mosquito repellents reported by Consumer Reports in Buzz Off!. June 2000, pp. 14 - 17. (This article also compared products for tick repellency.)**

<b>Product<sup>1</sup></b>	<b>Active Ingredient</b>	<b>Hours of Protection</b>	<b>Evaluation<sup>2</sup></b>
3M Ultrathon	33% Deet	12 - 13	Recommended
Off! Deep Woods for Sportsmen	100% Deet	11 - 13	Recommended
Muskol Ultra 6 Hours	40% Deet	7 - 9	-
Ben's Backyard Formula	20% Deet	6 - 8	-
Bugout	15% Deet	4 - 8	-
Sawyer Controlled Release Deet Formula	20% Deet	4 - 8	-
Cutter Unscented	10% Deet	3 - 6	-
Bite Blocker Light Country Scent	2% Soy oil	1 - 4	-
Cutter Skinsations	7% Deet	<1 - 3	-
Avon-Skin So-Soft Bug Guard Plus IR3535 with Sunblock	7.5% IR3535 <sup>2</sup>	<1 - 2	-
Natrapel	10% citronella	<1 - 1	-
Avon-Skin So-Soft Bug Guard	0.1% citronella	<1	-