

BUG REPELLENT

What's in it?



a report by



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OVERVIEW

Bug repellents are made of both active and inert ingredients. It's common for products to list only active ingredients on labels. The rest are listed simply as "inert ingredients," which are ingredients that are not considered active repelling chemicals but are used as solvents, preservatives, fragrances, or for other purposes. Companies aren't required by federal law to list out the inert ingredients in insect repellents.

Made Safe believes in full transparency of all ingredients for all products, especially ones containing ingredients such as pesticides and insecticides. It's imperative to learn what's in a repellent product before using it.

There have been studies regarding the efficacy of some repellent chemicals individually. But researchers have yet to fully understand exactly how each chemical repels insects and how they may affect our bodies and the environment, let alone what the impact may be of the myriad ingredients in combination. Made Safe sees this as a call for total mixture testing, taking into account real world exposures and usage to more fully understand potential toxicity.

This report examines common active ingredients in conventional insect repellent and their impacts to human health and the environment, as well as more natural options.

Because our screening process doesn't allow inclusion of high risk pesticides in products, Made Safe only approves products made without these chemicals, usually focusing on those that take a natural approach to bug repellent. This may work for casual settings to diminish bites, but it cannot prevent diseases. With the rise of Zika virus and concern for other mosquito-borne diseases, we recognize there is a time and place for the use of bug repellent products that would not pass our screening process. We urge people to become informed and stay on top of advice from the Centers for Disease Control (CDC) and the World Health Organization (WHO).

Made Safe sees a need for total mixture testing, taking into account real world exposures and usage to fully understand potential toxicity of bug repellent chemicals.



WHAT IS INSECT REPELLENT?

Insect repellents are regulated as pesticides in the United States because the active ingredients in repellents *are* pesticides. According to the [EPA website](#): “People often think of the term pesticide as referring only to something that kills insects, but ‘pesticide’ is a broad term and includes products that don’t kill anything, such as insect repellents.”

In order for the EPA to allow a chemical to be used as a pesticide, it must be evaluated for harm to humans and the environment through the EPA review process.¹ However, this assessment does permit the use of pesticide chemicals that are shown to be toxic to human health or the environment. There is also growing evidence that pesticide exposure is linked to a number of diseases including asthma, cancer, Parkinson’s, Alzheimer’s, and more.² [NOTE: “Minimum Risk Pesticides” are exempted from regulation, and the essential oils Made Safe approves as botanical repellents are eligible for the [minimum risk exemption](#).]

Bug repellents are often formulated with synergistic chemicals that are designed to make the repellent work more effectively. Synergy occurs when the effect of a mixture of chemicals is greater than the sum of the effect of individual chemicals.³ Think of synergistic effects as $1 + 1 = 3$. Some of these synergistic chemicals can increase the toxicity of the formulation.⁴ For example, research shows that “children more highly exposed to pyrethroid insecticides and piperonyl butoxide (PBO), a synergist added to increase the potency of pyrethroids, are three times as likely to have a mental delay compared to children with lower levels.”⁵



Mixing sunscreen chemicals and bug spray chemicals also creates unanticipated synergistic effects. One study found that sunscreen containing oxybenzone enhanced the absorption rate of DEET through the skin.⁶

Since we don’t know how all of these chemicals work together or how that mixture might affect human health, a starting point is to avoid mixing products such as chemical sunscreen and bug sprays.

With each application, exposures to potentially harmful ingredients including active ingredients, inert ingredients, and fragrances increase. Some ingredients, like permethrin, have been found to have a half-life over 30 days, extending potential exposures.⁷ All of this can result in cumulative exposure over weeks or months of summertime use.

Bug repellents found in clip-on fans, candles, repellent stakes, yard or home foggers, and coils can release fumes that may harm health. For example, mosquito coils have been found to contain formaldehyde and other volatile chemicals. One study found that risk of lung cancer was significantly higher in frequent burners of mosquito coils than people who didn’t burn coils.⁸



INERT INGREDIENTS

Inert ingredients are everything else in the mixture excluding the active repelling chemicals, and can be all kinds of things: solvents, preservatives, anti-caking or foaming agents, fragrance, or things that protect against photodegradation.⁹

Federal law protects companies' rights to keep inert ingredients confidential because they are considered trade secrets. This can result in chemicals of concern finding their way into bug sprays without being listed on the label.

Many inert ingredients can be chemically active and are only labeled as inert because of their specific role in a product's formulation.¹⁰ While the EPA says that inert ingredients are not necessarily non-toxic,¹¹ this may be contrary to the general public's understanding of the word "inert" as non-toxic or inactive.

The EPA approves all inert ingredients before they can be used in products¹² and has listed around 3,000 chemicals as inert ingredients,¹³ some of which are presumably harmless (like corncobs, bread crumbs and almond shells), but some are harmful chemicals, including naphthalene (linked to cancer¹⁴), xylene (linked to depression of the nervous system¹⁵), and triethanolamine (linked to respiratory problems and liver and bladder cancer in animal studies¹⁶).¹⁷

Inert ingredients can also contain fragrance. Common harmful fragrance ingredients include phthalates (linked to reproductive and developmental harm), synthetic musks (potential endocrine disruptors that don't break down in the environment),¹⁸ and parabens (linked to breast cancer).¹⁹ Common sunscreen chemicals like oxybenzone and octinoxate that are linked to

hormone disruption^{20, 21} are also used in fragrance formulations so that that the fragrance doesn't degrade or lose its potency over its shelf-life.²²

Many common fragrance ingredients are also allergens.²³ Not everyone reacts to allergens, but people who are sensitive to them often need to know if they're in a product, and this is difficult when inert ingredients are kept secret.

CHEMICALS OF CONCERN IN INSECT REPELLENT

None of these chemicals are permitted in MADE SAFE® certified products.

Some of the common chemicals in insect repellent linked to human health and environmental concerns are DEET, cyfluthrin, permethrin, and a class of chemicals called pyrethroids. This list is not exhaustive, but a good place to start given their frequent use in insect repellents.

DEET

DEET, which is an acronym for N,N-Diethyl-meta-toluamide is one of the most effective bug repellents and also repels ticks.²⁴

DEET and Health

Although DEET is great at repelling bugs, studies link it to human health harm. Large doses of DEET have been linked to skin blisters, seizures, memory loss, headaches, stiffness in the joints and shortness of breath,²⁵ and skin irritation.²⁶ DEET is absorbed quickly through the skin: one study showed that 48% of the applied dose is totally absorbed within six hours²⁷. When mixed with some sunscreen chemicals, it was found to be absorbed even more quickly.²⁸



DEET is also linked to neurotoxicity²⁹ and has been found to inhibit cholinesterase, which is an important neurotransmitter.³⁰ In rat studies, subchronic applications of DEET, alone and when mixed with permethrin, lead to neural cell death in various parts of the brain; the collective effects of impairing these parts of the brain may lead to physiological and behavioral problems, especially with motor skills, and learning and memory dysfunction.³¹

One study also found that when DEET and permethrin were mixed together, they induced epigenetic transgenerational inheritance of disease and sperm epimutations, which means that the mixture caused disease in the offspring of exposed adults.³² This could partially be due to DEET's ability to cross the placenta: in animal studies, DEET was found in the fetus and in newborns after exposing the mother to the chemical.³³

DEET and the Environment

DEET breaks down slowly in soil and has potential to contaminate groundwater.³⁴ It has been detected in groundwater, surface water, and drinking water.³⁵

Cyfluthrin

Cyfluthrin structurally resembles DDT and has a similar mode of action. Also similarly to DDT, it accumulates in fatty tissues.³⁶

Cyfluthrin and Health

Cyfluthrin is linked to neurotoxicity, interfering with sodium and potassium ion channels in the nerves; in animal studies, this results in loss of coordination, muscle trembling, behavior changes and more.³⁷ One study showed harmful effects of cyfluthrin on blood, including decreased glucose and red blood cells³⁸. Another study found that

mice exposed to both high and low doses of cyfluthrin in the womb displayed significant behavior changes.³⁹ Normal liver function was also disrupted by cyfluthrin in studies on rats.⁴⁰

Cyfluthrin and the Environment

Cyfluthrin is harmful to aquatic invertebrates, fish, and honeybees.⁴¹

Permethrin

Permethrin is a synthetic pesticide most frequently used to treat bug resistant clothing, mosquito netting and outdoor gear, although it's also often used in bug sprays and very commonly used worldwide as a pesticide for crops.⁴²

Permethrin and Health

Similar to cyfluthrin, permethrin is a neurotoxin which acts on sodium ion channels, causing repeated nerve impulses.⁴³ When permethrin is found at high levels, it can affect the function of chloride channels, which may result in seizures.⁴⁴ One study found that permethrin and DEET, either in combination or alone, were linked to the death of neural cells in various parts of the brain which may lead to many physiological and behavioral issues, including problems with motor skills, learning and memory.⁴⁵ Another study found that newborn exposure to permethrin impaired working memory by interfering with neural processing in the frontal lobe of the brain.⁴⁶

Permethrin and the Environment

Permethrin is toxic to fish, aquatic life, and bees.⁴⁷



Pyrethroids

Pyrethroids are the most common chemical class for bug repellent chemicals.⁴⁸ This class contains over 1,000 insecticides,⁴⁹ including:

- Lambda-cyhalothrin
- Prallethrin
- Metofluthrin
- dl-allethrolone, d-trans chrysanthemate
- Tetramethrin
- Phenothrin
- d/trans allethrin

Pyrethroids and Health

Pyrethroids are lipophilic, which means they love fat cells.⁵⁰ They can easily cross the blood-brain-barrier, which is a system of capillaries that transports blood to the central nervous system⁵¹ that has the ability to prevent certain substances from passing through to protect the brain and

spinal cord. Because pyrethroids can easily pass the blood-brain barrier, they can become toxic to the central nervous system,⁵² and the WHO has said that synthetic pyrethroids are neuropoisons.⁵³ Acute reactions to pyrethroids include dermatitis and asthma-like reactions, nausea, incoordination, and burning and itching sensations. The most severe poisoning cases have been reported in infants, because their systems can't efficiently break down pyrethroids.⁵⁴ It was found that pyrethroids' neurotoxicity potential increases in rats when they are exposed early in life.⁵⁵ Many pyrethroids have been linked to endocrine disruption like estrogen in the body,⁵⁶ and some have been classified as possible carcinogens.⁵⁷

Pyrethroids and the Environment

Most of the chemicals in this class are toxic to fish and aquatic life.⁵⁸

ZIKA AND OTHER MOSQUITO-BORNE ILLNESSES

Where do you live? Knowing your area and if you are at risk for a mosquito-borne or tick-borne illness can help you make the right bug repellent choice for you and your family. Go to Consumer Reports' [Guide to Mosquito and Tick Diseases](#) for information for your area.

As of July 2016, there were more than 1600 confirmed cases of Zika virus in the United States (a condition that is associated with microcephaly, where babies are born with unusually small heads). While the vast majority of these cases were contracted from travel abroad, a growing number of cases were contracted in Florida. The CDC recommends avoiding travel abroad to countries with confirmed Zika cases and has issued warnings in Miami, FL as well. This list is changing and should be monitored as the Zika virus spreads. Note that the CDC recommends using EPA-approved insect repellents, which include DEET, IR3535, citronella, picaridin, and lemon eucalyptus oil.

Zika virus should be taken very seriously. Here is [one recent article](#) in the *New York Times* about the virus. We urge people to keep apprised of the changing information around this epidemic, the areas impacted and any changes in advice as it becomes available.

If you think you might be at risk or are experiencing [symptoms](#) of an insect-borne illness, heed the advice from the [CDC](#), [WHO](#), and your doctor.



PLANT-BASED ALTERNATIVES

Plants contain a number of secondary metabolites, which are chemical compounds that can play a number of roles in the plant including protection against predators. Some of these secondary metabolites have pharmacological and biological properties that make plant extracts effective bug repellents.⁵⁹

There are many plant based bug spray options out there. However, it is important to note that just because something is naturally-occurring doesn't mean that it's infinitely safe or non-irritating. Some effective plant repellents can also be highly irritating; some of these compounds are even flagged by the European Commission as common allergens. Knowing your own body and skin sensitivities can help you select a plant-based option that works well for your skin and your body. If you find any ingredient irritating, discontinue use.

Citronella

The safety of citronella is controversial. Some sources document citronella as having a low toxicity profile whereas others have deemed it problematic. For example, the EU Commission lists citronella as an established contact allergen.⁶⁰ Health Canada, a Canadian federal public health agency, proposed the phase-out of citronella for use in bug sprays in 2004 because of suspected carcinogenicity.⁶¹ Citronella works best as part of a skin-applied mixture; candles only reduced bites by 50%.⁶² This oil is also volatile and evaporates quickly and so must be combined with another ingredient that can slow evaporation in order for it to be effective.⁶³

Clove Oil

In a study that tested the efficacy of five oils and various combinations of those oils, clove oil was found to be one of the two most effective mosquito

repellents.⁶⁴ Clove oil is also effective when mixed with other oils. When mixed with geranium oil or thyme oil, the mixture protected against bites for up to 2.5 hours.⁶⁵ Clove can cause irritation and is listed as an established contact allergen by the European Commission.⁶⁶ One study stated that clove is considered safe at concentrations up to .5%.⁶⁷

Geraniol

Geraniol is considered one of the most effective botanical repellents, repelling malaria, filarial and yellow fever vectors for a period of 60-180 mins.⁶⁸ This chemical can be derived from some essential oils like rose oil and can also be synthesized.⁶⁹ Geraniol is one of the most common fragrance allergens found in personal care products.⁷⁰ Some people find geraniol very irritating and it is considered an allergen by the European Commission.⁷¹

A NOTE ABOUT ESSENTIAL OILS

If you plan on exploring making your own bug spray formulas using essential oils, make sure to do some research before you begin and be careful. There are plenty of amazing books, blogs, and websites dedicated to the safe use of essential oils. But because essential oils are highly concentrated, they can be highly potent too and can inflict harm on their own. Follow manufacturer guidelines and directions; using a carrier oil is important. If you think you might be sensitive to a certain essential oil, do a small patch test before you use. Also note that damaged, inflamed or otherwise irritated skin is more sensitive to the power of essential oils. In addition, some oils can cause photosensitization, an immune response triggered by sunlight resulting in burning or inflammation.



Lemongrass

Lemongrass oil can also be listed as cymbopogon citratus or schoenanthus oil. One study found that lemongrass oil was 74% and 95% effective against two species of mosquitoes, respectively, for up to 2.5 hours.⁷² In laboratory studies, the oil was 78.8% effective against one species of mosquito for 12 entire hours, but another study found it 100% effective for only 30 minutes.⁷³ This oil has been established as a contact allergen in humans by the European Commission.⁷⁴ Some people might find using this oil to be irritating or to cause allergic reactions.

Lemon Eucalyptus

Oil of lemon eucalyptus can be naturally derived through hydro-distillation, or it can be synthetically produced and listed as p-menthane-3,8-diol or PMD, which is the synthesized version. The EPA has approved PMD as an effective insect repellent.⁷⁵ One study found that a eucalyptus-based repellent containing 30% PMD gave 96.89% protection for 4 hours, where DEET gave 84.81% protection.⁷⁶ The CDC advocates for the use of PMD.⁷⁷

Linalool

This chemical can be derived from lavender or synthesized. Some people can experience allergic reactions to linalool. It is a skin sensitizer.⁷⁸

Neem

Efficacy studies of neem have yielded variable results. According to one source, several field studies have shown neem to be an effective repellent.⁷⁹ It is important that neem is diluted properly as it can cause irritation if used in very high concentrations⁸⁰.

Thyme

One study that tested the efficacy of five oils independently and in various combinations found thyme oil to be one of the most effective mosquito repellents, providing 1.5 to 3.5 hours of protection and repelling malaria, filarial and yellow fever vectors for a period of 60-180 mins.^{81, 82} One study stated that thyme is considered safe at concentrations up to 2%.⁸³ Thyme can be slightly irritating to the skin, but has a very low toxicity profile.⁸⁴

CARRIER OILS

Choosing a carrier oil is important with plant-based repellents. Many essential oils are very volatile, which means that they can evaporate quickly, therefore decreasing the longevity of repellency. However, carrier oils can decrease the rate at which an essential oil evaporates, helping the finished product to repel mosquitos longer.

The oil is not enough of a repellent on its own, but laboratory testing showed that it provided better protection than Vaseline, another oil that is sometimes used in homemade bug spray formulations.⁸⁵ Coconut and andiroba oils both contain unsaturated fatty acids and natural emulsifiers that help volatile essential oils to evaporate much more slowly.⁸⁶

One efficacy study concluded that soybean oil is not considered an effective bug repellent on its own. Human hands treated with soybean oil attracted just as many mosquitoes as those without any bug repellent at all.⁸⁷



ALTERNATIVE WAYS TO HELP KEEP BUGS AT BAY

A good place to start is to minimize your exposure to mosquitos.

Time of day: Mosquitos are typically the worst at dusk and dawn in the United States.

Use mosquito netting: Netting works great for camping, strollers, baby carriers, and on the porch!

Keep the yard clear of place where mosquitoes like to breed, which can help reduce the need for yard foggers. Mosquitos like to breed in open water so cover anything that's not in use: buckets, pools, unused flower pots, etc. The rain gutters, if not in good repair and flowing properly, can also provide a breeding ground for mosquitoes.

Cover up: Cover exposed skin with long sleeves, pants and socks.

Read labels: At Made Safe, we avoid insecticides, pesticides and chemicals linked to human health harm. However we recognize that there is a time and place for the use of such ingredients and urge people to become informed and stay on top of advice from the CDC and WHO.

MADE SAFE CERTIFIED PRODUCTS

MADE SAFE screens products for chemicals that are known to be harmful to human health and the environment. We only approve products that pass our rigorous testing protocol, and we don't permit high risk pesticides. This means that any approved products are taking a natural approach to bug repellent, which may work for casual settings to diminish bites but cannot prevent diseases.

[Kosmatology Bug Repellent Balm](#)

[MamaEarth Natural Mosquito Repellent, Natural Mosquito Repellent Gel, After Bite Roll On, Anti Mosquito Body Roll On, Anti Mosquito Fabric Roll On](#)

[Oilogic Bug Bites & Itches Essential Oil Roll-On](#)

**MADE SAFE does not test for efficacy. We examine ingredients for human health and environmental harm. Please see below for efficacy studies on plant-based repellent ingredients.*

This report was released August 2016.

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END NOTES

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