

Bug Sprays & Repellants

Understanding Chemicals of Concern, Ingredients, Risks, and Safer
Alternatives

By MADEWORKS™ Intelligence

August 2026

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Executive Summary

Insect repellents can reduce exposure to mosquitoes, ticks, and other biting insects, including species capable of transmitting disease. Repellent products, however, vary in their active ingredients, supporting ingredients, intended uses, effectiveness, and human health and environmental profiles. Conventional products may contain active ingredients such as N,N-Diethyl-meta-toluamide, commonly known as DEET, and synthetic pyrethroids, including permethrin and cyfluthrin, identified as chemicals of concern based on evidence related to neurological effects, exposure, persistence, and toxicity to aquatic and terrestrial organisms.

Product labels often do not reveal the full formulation. Active pesticide ingredients must be identified, while most inert or “other” ingredients in federally registered pesticide products are not required to be disclosed. The term “inert” refers to function in the formulation and does not mean that an ingredient is harmless.⁴

Plant-based repellents can provide alternatives in some settings, but effectiveness and duration vary by ingredient and formulation. Essential oils can also irritate skin or trigger allergic reactions, and care should be taken to ensure that concentrated oils are appropriately diluted. Oil of lemon eucalyptus (OLE) and its repellent component para-menthane-3,8-diol (PMD) have stronger evidence for effectiveness than many other botanical options.^{7, 14}

Where mosquito- or tick-borne disease is a significant risk, preventing bites is an important health consideration. Consumers should consider local disease risk and follow current guidance from public health authorities and healthcare professionals.⁷

Purpose and Scope

This report provides guidance on chemicals of concern in bug repellents, plant-based alternatives, and practical bite-prevention strategies. It focuses on active ingredients used in skin-applied repellents, clothing and gear treatments, yard or household pest-control products, and the less-known ingredients that may accompany them. Pesticide registration or regulatory status does not exclusively determine whether an ingredient is the safest choice.

Understanding Bug Repellent Ingredients

Active vs. Inactive Ingredients

Insect repellents are regulated as pesticides in the United States because pesticides include substances intended to repel, rather than only kill, pests. Most skin-applied repellents must be registered with the US Environmental Protection Agency (EPA) before they enter the marketplace.^{4, 6} Certain low-hazard “minimum risk” pesticide products are exempt from this registration requirement, provided their active and inert ingredients are limited to those EPA has designated as minimum risk and the product label meets specific disclosure conditions.⁵

Active ingredients perform the pesticidal function, such as repelling or killing insects, and must be identified by name and percentage on the product label. Inert or other ingredients can include solvents, carriers, preservatives, fragrances, emulsifiers, anti-caking agents, and other substances that support the formulation. In most federally registered pesticides, these ingredients are not required to be individually named on the label. However, “inert” does not mean non-toxic or risk-free.⁴

Active Ingredients and Insecticides of Concern

The substances below are not an exhaustive list, but they represent prominent examples currently available for sale in the marketplace.

DEET

DEET, or N,N-diethyl-meta-toluamide, is one of the most effective and widely used insect repellents and is also used for protection against ticks. DEET is considered to be a chemical of concern based on human health and environmental hazard information.

Large doses of DEET have been linked to skin blisters and irritation, seizures, memory loss, headaches, joint stiffness, and shortness of breath. DEET has also been linked to neurotoxicity that may contribute to physiological or behavioral effects, including changes involving motor skills, learning, and memory.⁸

DEET is absorbed quickly through the skin. A study found that 48% of an applied dose of DEET was totally absorbed within six hours. When DEET was used with the sunscreen ingredient oxybenzone, dermal absorption was found to increase further.⁹

DEET has been shown to cross the placenta. In numerous animal studies, DEET was detected in the fetus and in newborns following maternal exposure, supporting concern about exposure during development.¹⁰

From an environmental perspective, DEET breaks down slowly in soil and has the potential to reach groundwater. It has been detected in groundwater, surface water, and drinking water, making environmental release and persistence an area of concern.

Cyfluthrin

Cyfluthrin is a synthetic pyrethroid insecticide used in household and yard pest-control products. It displays similarities to dichlorodiphenyltrichloroethane, or DDT, in its action on the nervous system and its tendency to accumulate in fatty tissues.

Cyfluthrin interferes with sodium and potassium ion channels in nerves and has been associated with loss of coordination, muscle trembling, and behavioral changes. Studies have also reported changes in blood parameters, liver function, and behavior following developmental exposure. Cyfluthrin is very highly toxic to fish and freshwater invertebrates, and bees are highly sensitive to contact exposure.¹²

Permethrin

Permethrin is a synthetic pyrethroid pesticide commonly used to treat insect-resistant clothing, mosquito netting, and outdoor gear. It is also used in some insect-control sprays and widely in agriculture. Current public-health guidance uses permethrin-treated clothing and gear as an additional bite-prevention measure. Products intended for fabric treatment should not be applied directly to skin.⁷

Permethrin acts on sodium ion channels and can produce repeated nerve impulses. At high exposure levels, effects on other ion channels can contribute to neurological toxicity, including seizures.

Permethrin exposure, alone or with DEET, has been linked to changes in neural cells and to effects on motor skills, learning, memory, and neural processing following early-life exposure.⁸

Permethrin is highly toxic to fish, aquatic invertebrates, and honeybees. These ecological hazards are important when considering outdoor application, runoff, and release to aquatic environments.^{11, 13}

Pyrethroids

Pyrethroids are a broad class of synthetic insecticides that includes permethrin and cyfluthrin as well as lambda-cyhalothrin, prallethrin, metofluthrin, tetramethrin, phenothrin, and allethrin compounds. They are used in products ranging from household sprays and yard treatments to mosquito-control products and other treated materials.¹³

Pyrethroids are neuroactive chemicals that alter normal nerve signaling through effects on voltage-sensitive sodium channels. Acute exposure can produce skin sensations such as burning or itching, nausea, incoordination, and, at higher exposures, more pronounced neurological effects. Potential endocrine activity and possible carcinogenicity for certain pyrethroids have been reported.^{8,}

¹³

Environmental concerns are particularly well established. The EPA has identified ecological risks for the pyrethroid class and employs mitigation strategies aimed at reducing spray drift and runoff because of risks to fish and aquatic invertebrates. Certain uses also present concerns for bees and other terrestrial invertebrates.¹³

Plant-Based Repellent Ingredients

Some plants produce compounds that can repel biting insects, and essential oils and plant extracts are used in many botanical repellent products. Their effectiveness varies widely with concentration, formulation, mosquito or tick species, temperature, perspiration, and how quickly volatile ingredients evaporate. A plant-derived ingredient should not be assumed to be non-irritating or universally effective simply because it is “natural”.¹⁴

Many essential oils are highly volatile. Carrier oils and other formulation ingredients can slow evaporation and extend the time a botanical repellent remains on the skin. Coconut and andiroba oils are carrier oils that can help slow the evaporation of volatile essential oils. Concentrated essential oils

should be appropriately diluted, and pre-formulated products can help reduce the risk of improper dilution.

OLE and PMD

Oil of lemon eucalyptus (OLE) can be obtained from the lemon eucalyptus plant, while para-menthane-3,8-diol (PMD) may be synthesized via plant material sourced from the lemon gum tree or citronella grass. The EPA regulates OLE and PMD as separate pesticide active ingredients. Both are among the EPA-registered repellent ingredients identified by the Centers for Disease Control and Prevention (CDC) as providing effective protection against insect bites.^{6, 7}

Studies have shown that eucalyptus-based repellent containing 30% PMD provides a high level of protection over at least four hours of use. The CDC distinguishes registered OLE/PMD repellents from “pure” lemon eucalyptus essential oil, which has not undergone the same caliber of safety and efficacy testing. The CDC also advises adhering to age restrictions for OLE/PMD products.⁷

Other Botanical Ingredients

Plant-Based Ingredient	Strengths	Potential Concerns
Clove oil	Has shown strong mosquito-repellent activity, including in combination with other botanical oils.	Can irritate skin; eugenol is a recognized contact allergen.
Geraniol	Has demonstrated mosquito-repellent activity	Can be plant-derived or synthetic; may irritate

	for roughly 1–3 hours in some studies.	sensitive skin and is a fragrance allergen.
Lemongrass oil	Has shown substantial mosquito repellency, although effectiveness and duration vary.	Can cause irritation or allergic reactions.
Linalool	Has demonstrated repellent activity in laboratory studies.	Can be naturally derived or synthetic; may cause skin sensitization.
Neem	Has shown repellent activity, but study results are variable.	Should be properly diluted; high concentrations can irritate skin.
Thyme oil	Has shown strong mosquito-repellent activity, with protection lasting several hours in some studies.	Can irritate skin at higher concentrations; proper dilution is important.
Citronella	Can repel mosquitoes, but protection may be short-lived because it evaporates quickly.	Can cause skin sensitization and is not a preferred alternative.

Table 1. Plant-based repellent ingredients and considerations.^{2, 14, 15}

Disease Risk and Bite Prevention

Mosquitoes and ticks can transmit illnesses including West Nile virus, dengue, malaria, Zika, chikungunya, Lyme disease, and other infections. Risk varies by geography, season, travel, activity, and local disease prevalence.⁷ When the risk of mosquito- or tick-borne disease is significant, effective bite prevention may take priority over certification considerations. MADEWORKS recognizes that there are circumstances in which protecting against a serious health risk may warrant the use of a repellent that would not otherwise meet certification requirements. Consumers should follow current guidance from the CDC, World Health Organization (WHO), local public-health agencies, and healthcare providers.⁷

Additional Ways to Reduce Bites

Physical barriers can help reduce insect exposure without relying exclusively on repellents. Wearing long sleeves, long pants, socks, and closed shoes when possible can limit exposed skin, while mosquito netting can provide additional protection for sleeping areas, strollers, camping, and porches. Reducing mosquito breeding habitat can also help by eliminating standing water in buckets, pools, gutters, and other areas where water may collect.

Mosquito activity patterns vary by species and location. Many species are more active around dawn or dusk, while others may bite during the day or at night, so local conditions should guide prevention strategies. Permethrin products intended for fabric treatment should be used only on clothing, mosquito nets, or outdoor gear and should not be applied directly to skin.

When both sunscreen and insect repellent are needed, experts generally recommend applying sunscreen first and insect repellent afterward. Using separate products can make reapplication easier to manage, since sunscreen often needs to be reapplied more frequently than insect repellent.

Selection and Use Considerations

Topic	What to Look For	What to Avoid
Ingredient disclosure	Clearly listed active ingredients and, when possible, full ingredient disclosure.	Assuming all ingredients are disclosed or that “inert” means harmless.
Chemical profile	MADE SAFE Certified products or lower-hazard alternatives appropriate for the specific use conditions.	DEET, permethrin, cyfluthrin, and other pyrethroids when effective alternatives are available.
Disease risk	A repellent proven effective for the insect, setting, and level of disease risk.	Relying on an untested botanical product when strong protection is needed.
Botanical products	Properly formulated and diluted products that avoid known allergens.	Applying concentrated essential oils directly to skin or assuming “natural” means non-irritating.
Permethrin	Use only on clothing and gear as directed.	Applying fabric-treatment products directly to skin.

Topic	What to Look For	What to Avoid
Outdoor prevention	Screens, netting, protective clothing, and removal of standing water.	Unnecessary use of foggers, sprays, or coils that can increase exposure and environmental release.

Table 2. Bug repellent selection and use considerations

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We are building a bridge to a safer, more sustainable future for all. Using the MADE Ecosystem Approach, MADEWORKS Intelligence generates insights that support better product development and advance systemic change. By bringing together science, industry leadership, and informed consumer choice, we help turn meaningful information into action, transforming the marketplace for a healthier world.

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References

1. US Environmental Protection Agency. "What is an Insect Repellent?" Updated July 6, 2026. <https://www.epa.gov/insect-repellents/what-insect-repellent>
2. US Environmental Protection Agency. "Conditions for Minimum Risk Pesticides." <https://www.epa.gov/minimum-risk-pesticides/conditions-minimum-risk-pesticides>
3. US Environmental Protection Agency. "Skin-Applied Repellent Ingredients." Updated January 23, 2026. <https://www.epa.gov/insect-repellents/skin-applied-repellent-ingredients>
4. Centers for Disease Control and Prevention. "Mosquitoes, Ticks, and Other Arthropods." CDC Yellow Book: Health Information for International Travel, 2026 edition. April 23, 2025. <https://www.cdc.gov/yellow-book/hcp/environmental-hazards-risks/mosquitoes-ticks-and-other-arthropods.html>
5. Agency for Toxic Substances and Disease Registry. Toxicological Profile for DEET (N,N-Diethyl-meta-Toluamide). 2017. <https://www.atsdr.cdc.gov/ToxProfiles/tp185.pdf>
6. Kasichayanula S, House JD, Wang T, Gu X. "Percutaneous characterization of the insect repellent DEET and the sunscreen oxybenzone from topical skin application." Toxicology and Applied Pharmacology. 2007;223(2):187–194. doi:10.1016/j.taap.2007.05.016. <https://doi.org/10.1016/j.taap.2007.05.016>
7. McGready R, Hamilton KA, Simpson JA, et al. "Safety of the insect repellent N,N-diethyl-M-toluamide (DEET) in pregnancy." American Journal of Tropical Medicine

- and Hygiene. 2001;65(4):285–289. doi:10.4269/ajtmh.2001.65.285.
<https://doi.org/10.4269/ajtmh.2001.65.285>
8. National Pesticide Information Center. “Permethrin Technical Fact Sheet.” Oregon State University and U.S. Environmental Protection Agency.
<https://npic.orst.edu/factsheets/archive/Permtech.html>
 9. National Pesticide Information Center. “Cyfluthrin General Fact Sheet.” May 2018.
<https://npic.orst.edu/factsheets/cyfluthringen.html>
 10. US Environmental Protection Agency. “Registration Review of Pyrethrins and Pyrethroids.” Updated 2026.
<https://www.epa.gov/ingredients-used-pesticide-products/registration-review-pyrethrins-and-pyrethroids>
 11. Maia MF, Moore SJ. “Plant-based insect repellents: a review of their efficacy, development and testing.” Malaria Journal. 2011;10(Suppl 1):S11. doi:10.1186/1475-2875-10-S1-S11.
<https://doi.org/10.1186/1475-2875-10-S1-S11>
 12. Health Canada Pest Management Regulatory Agency. Regulatory Directive DIR2017-02: Essential Oil-based Personal Insect Repellents. 2017.
<https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/policies-guidelines/regulatory-directive/2017/02-regulatory-directive-essential-oil-based-personal-insect-repellents-dir-2017-02.html>