

Type	Insecticide, insect repellent, and dog and cat repellent.
Controls	As an inert ingredient it is a solvent or fragrance, as an active ingredient it repels or controls fleas, lice, mites, and ticks, and also can be used as a cat or dog repellent.
Mode of Action	Affects the sensory nerves of the peripheral nervous system, but it is not a ChE inhibitor (Reference 4).

Thurston County Review Summary:

Exposures to d-limonene occur from many sources; it is a natural ingredient in certain food, it is an additive in perfume and soap, it is in insecticides and many other products. The Food and Drug Administration has d-limonene classified as Generally Regarded as Safe (GRAS) for use in food products, soaps, and perfumes (Reference 1). This review focuses on the pesticidal uses of d-limonene as an active ingredient as well as its use as an inert ingredient in other EPA registered products.

D-Limonene is rated conditional by Thurston County's review criteria. Specific uses of products containing d-limonene can result in potential exposures that range from low to high in hazard. Potential high hazard exposures come from the use of insecticidal shampoos and dips and from specific applications of paints or stains containing d-limonene as an inert ingredient. The acute and chronic risk assessment sections detail the hazard ratings of other potential exposures to d-limonene.

MOBILITY

Property	Value	Reference	Rating
Water Solubility (mg/L)	13.8	1	Low
Soil Sorption (Kd=mL/g)	Not found		
Organic Sorption (Koc=mL/g)	1030 - 4780	2	Moderate

Mobility Summary:

D-Limonene is not very soluble in water and it adheres strongly to soil with organic matter. Because d-limonene dissipates quickly into the air and binds strongly to soil it is not expected to move off the site of application and get into surface water or ground water. The hazard for mobility is rated low.

PERSISTENCE

Property	Value	Reference	Rating
Vapor Pressure (mm Hg)	2	1	Low
Biotic or Aerobic Half-life (days)	<14 (up to 98%)	2	Moderate
Abiotic Half-life (days)	<2 hours (in air)	2	Low
Terrestrial Field Test Half-life (days)	Not found		
Hydrolysis Half-life (days)	>1,000	2	High
Anaerobic Half-life (days)	"No metabolism"	2	High
Aquatic Field Test Half-life (days)	4 hours	1	Low

Persistence Summary:

D-Limonene has a high vapor pressure so it is likely to dissipate into the air when it is applied to vegetation or to the ground. In the air, d-limonene will react with other chemicals and degrade within minutes to hours. If d-limonene gets into water it will volatilize off the surface, breakdown in sunlight, and bind to sediments. After d-limonene is introduced to the environment, it is likely to reach half of the applied concentration in less than one week. Thurston County rates the hazard of chemical persistence as low.

BIOACCUMULATION

Property	Value	Reference	Rating
Bioaccumulation Factor	Not found		
Bioconcentration Factor	246 - 262	2	Moderate
Octanol/Water Partition Coefficient	4.2	1	Moderate

Bioaccumulation Summary:

D-Limonene adheres more readily to organic solvents than to water indicating the potential to bind to fish or animal tissue. Calculated bioconcentration factors indicate that there is a moderate hazard for accumulation in fish tissue. The hazard for bioaccumulation is rated moderate.

ACUTE TOXICITY HAZARD - ECOTOXICITY

Test Subject	Value	Reference	Rating
Mammalian (LD50)	4,400 mg/kg	1	Low
Avian (LD50)	5,620 mg/kg	2	Low
Honey bee or insect (LD50)	Assumed high		
Annelida -worms (LC50)	6 ppm	2	High
Fish (LC50)	0.7 mg/l	2	High
Crustacean (LC50)	0.4 mg/l	2	High
Mollusk (LC50)	Not found		
Amphibian (LD50 or LC50)	Not found		

Acute Toxicity Testing and Ecotoxicity Summary:

Single-dose toxicity testing indicates that d-limonene is highly toxic to worms, fish, and other aquatic organisms but low in toxicity to mammals and birds. It is assumed that it is highly toxic to bees and other insects because it is an active ingredient for insecticides. Toxicity to pets and wildlife is not expected from the insecticidal use of d-limonene because it dissipates rapidly into the air and contacting treated vegetation or soil is not likely to cause a significant exposure (except to insects and possibly to worms). Risk of toxicity to non-target organisms from the use of d-limonene products is rated low.

ACUTE TOXICITY - Risk Assessment

Subject and Scenario	Dose of Concern	Exposure	Margin of Safety	Route	Reference	Rating
Adult applying RTU shampoo	1.33 mg/kg-bw/day	1.25 mg/kg-bw/day	<2	Skin absorption	1	High
Adult applying granular product by hand	1.33 mg/kg-bw/day	0.31 mg/kg-bw/day	4.3	Skin absorption	1	Moderate
Adult applying paint/stain by airless sprayer	1.33 mg/kg-bw/day	0.95 mg/kg-bw/day	1.4 (inert use)	Skin absorption	1	High
Applying RTU with pump-trigger spray	1.33 mg/kg-bw/day	0.19 mg/kg-bw/day	7	Skin absorption	1	Moderate

Acute Toxicity Risk Assessment Summary:

Risk of toxicity from short-term exposures to d-limonene were calculated for uses as an insecticide active ingredient and for uses as an inert ingredient. Because d-limonene dissipates rapidly into the air after it is applied as a liquid, there were no assessments made for post-application contact to treated surfaces. All post-application exposures to d-limonene are rated low in hazard.

Potential risk from exposures to residential applicators from d-limonene insecticides was calculated by the EPA for five different application scenarios; applying Ready-To-Use shampoos, Ready-To-Use dips, hand applying granulars, applying Ready-To-Use products with pump-trigger spray, and mixing and applying emulsifiable concentrates with a watering can. The assessments assumed there were no gloves worn (although gloves are recommended on many of the product labels). Thurston County rates the risk to applicators of the shampoo and dip products to be high in hazard (calculated exposures were more than half of the dose of concern). Potential exposures from mixing and applying the emulsifiable concentrates were rated low in hazard (less than 10% of the dose of concern). Exposures from applying granular products and applying Ready-To-Use products with pump-trigger spray were rated moderate in hazard (between 10% and 50% of the dose of concern).

Risk assessments for residential users of products containing d-limonene as an inert ingredient included products that are; emulsifiable concentrates, pressurized liquids (aerosols), Ready-To-Use liquids, and soluble concentrates. Of the 21 potential exposures evaluated, all exposures were rated low in hazard except 4 of the 9 uses of the Ready-To-Use products. Potential exposures to a person using an airless sprayer for 15 gallons of outdoor paints/stains are rated high in hazard, spraying only 5 gallons in one day is rated moderate in hazard. Using a paintbrush to apply one-gallon of paint/stain containing d-limonene can result in an exposure that is rated moderate in hazard. Using a pump-trigger applicator to spray one gallon of product to turf or garden areas can also result in an exposure that is rated moderate in hazard.

CHRONIC TOXICITY HAZARDS

Property	Value	Adverse Effect	Reference	Rating
Carcinogenicity	IARC Group 3	"Not classifiable"	1	Low
Mutagenicity	--	"No evidence"	1 and 2	Low
Neurotoxicity - (NOAEL)	1,000 mg/kg (LOAEL)	Decreased motor activity	2	Check risk
Endocrine Disruption	Not listed	--	3	Low
Developmental Toxicity (NOAEL)	250 mg/kg/day	Maternal + developmental toxicity	1	Check risk
Reproductive Toxicity (NOAEL)	Not provided	"No evidence without maternal effects"	1	
Chronic Toxicity (NOAEL)	150 mg/kg-bw/day	Liver weight changes	1	Check risk

Chronic Toxicity Hazard Summary:

D-Limonene is classified by the International Agency for Research on Cancer in Group 3 (not classifiable as to human carcinogenicity). It is not considered a chemical mutagen and there was no evidence of reproductive or developmental toxicity without maternal toxicity. Neurotoxicity was only observed at the highest dose tested which was much higher than the dose that caused the first observable adverse effect. The first observable adverse effect in long-term toxicity testing was liver toxicity (relative liver weight compared to body weight).

CHRONIC TOXICITY - Risk Assessment

Subject and Scenario	Dose of Concern	Exposure	Margin of Safety	Route	Reference	Rating
Adult ongoing use of general cleaner	1.3 mg/kg-bw/day	0.75 mg/kg/day	2	Inhalation	1	Moderate
Adult using aerosol can 60 times/year	1.3 mg/kg-bw/day	0.0032 mg/kg/day	414	Inhalation	1	Low
Long-term post application exposures not evaluated						
Long-term post application exposures not evaluated						

Chronic Toxicity Risk Assessment Summary:

Long-term exposure assessments included the on-going use of general cleaners containing d-limonene as an inert ingredient and the use of aerosol cans containing d-limonene (spraying entire 16 oz. can 60 times a year). Risk assessments for general cleaners calculated potential exposures that reach half of the EPA's dose of concern. Although these potential exposures are calculated to be very conservative, they are rated moderate in hazard by Thurston County. Exposures from on-going use of aerosol cans were calculated to be at least 400 times less than the dose of concern and are rated low in hazard.

General cleaners containing d-limonene may be registered by the EPA for microbial disinfection. Typically, Thurston County would not review cleaning products for a pesticide review - however, since the data was available it is addressed here. Long-term use of general cleaners containing d-limonene as an inert ingredient can result in exposures that are rated moderate in hazard. Risk of toxicity from long-term exposures to d-limonene from all other pesticidal uses are rated low in hazard.

Metabolites and Degradation Products:

Metabolites of d-limonene include perillic acid and d-limonene-8,9-diol (and its glucuronide) Reference 2.

Comments:

D-Limonene is considered an eye and skin irritant and may cause skin sensitization when it is oxidized in the air (References 1 and 2).

D-Limonene has not been found to have a common mode of toxicity with any other chemical nor does it produce a toxic metabolite that is produced by any other chemical compound (Reference 1).

References

- USEPA. Office of Pesticide Programs. Exposure and Risk Assessment on Lower Risk Pesticide Chemicals. D-Limonene.
- International Programme on Chemical Safety. Concise International Chemical Assessment Document No. 5. Limonene. www.inchem.org
- Scorecard - The Pollution Information site. Health Effects (Accessed 12/29/2010) <http://www.scorecard.org/health-effects/>
- Ware, G.W. and Whitacre, D.M. University of Minnesota. The Pesticide Book, 6th ed. (2004), Published by Meister Pro Information Resources.