d-limonene (limonene)

Review Date: 12/02/2011
CAS #: 5989-27-5

Type	Contact herbicide
Controls	Grasses and broadleaf weeds.
Mode of Action	Dessicant

Thurston County Review Summary:

Exposures to d-limonene occur from many sources; food, perfume, soap, insecticides, repellants, herbicides, and many other products. The Food and Drug Administration has d-limonene classified as "Generally Regarded as Safe" 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 because potential exposures to adult applicators of herbicidal products are rated moderate in hazard. These potential exposures can come from applying products containing d-limonene either as an active ingredient or an inert ingredient.

MOBILITY

Property	Value	Reference	Value Rating
Water Solubility (mg/L)	13.8	1	Low
Soil Sorption (Kd=mL/g)	Not found		
Organic Sorption (Koc=mL/g)	1030 - 4780	3	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	Value Rating
Vapor Pressure (mm Hg)	2	1	Low
Biotic or Aerobic Half-life (days)	<14 (up to 98%)	3	Moderate
Abiotic Half-life (days)	<2 hours (in air)	3	Low
Terrestrial Field Test Half-life (days)	Not found		
Hydrolysis Half-life (days)	>1,000	3	High
Anaerobic Half-life (days)	"No metabolism"	3	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	Value Rating
Bioaccumulation Factor	Not found		
Bioconcentration Factor	246 - 262	3	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 WILDLIFE TOXICITY VALUES and Risk Assessment

Test Subject	Value	Reference	Value Rating
Mammalian (LD50)	4,400 mg/kg	1	Low
Avian (LD50)	5,620 mg/kg	3	Low
Honey bee or insect (LD50)	Assumed high		
Annelida -worms (LC50)	6 ppm	3	High
Fish (LC50)	0.7 mg/l	3	High
Crustacean (LC50)	0.4 mg/l	3	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 herbicidal 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 worms). Risk of toxicity to non-target organisms from the use of d-limone products is rated low.

ACUTE HUMAN TOXICITY - Risk Assessment

Subject and Scenario	Route	Dose of Concern	Exposure	Margin of Safety	Reference	Value Rating
Applying RTU with pump-trigger (active) spray	Skin absorption	1.33 mg/kg-bw/day	0.19 mg/kg-bw/day	7	1	Moderate
Adult mixing & applying concentrated product	Skin absorption	1.33 mg/kg-bw/day	0. 055 mg/kg-bw/day	24	1	Low
Applying RTU with pump-trigger spray (inert)	Skin absorption	1.33 mg/kg-bw/day	0.17 mg/kg-bw	7.7	1	Moderate
Post-application exposures are rated low in hazard						

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. The EPA did not perform risk assessments specific to herbicidal uses of d-limonene, but the exposure assessments for the insecticidal products are detailed enough to compare the application methods and product concentrations to rate the potential herbicidal exposures. The dose of concern was calculated for short-term exposures with the use of the Lowest Observeable Adverse Effect Level from toxicity testing (400 mg/kg for increased liver enzymes and liver weights in test animals) combined with a safety factor of 300. The short-term dose of concern for use in risk assessment is 1.33 mg/kg.

Because d-limonene dissipates rapidly into the air after it is applied as a liquid, there were no assessments made for post-application skin contact to treated surfaces. All short-term post-application exposures to d-limonene are rated low in hazard.

Potential risk from short-term exposures to applicators of d-limonene insecticides was calculated by the EPA for five different application scenarios; applying Ready-To-Use shampoos, Ready-To-Use dips, hand applying granular products, applying Ready-To-Use products with pump-trigger spray, and mixing and applying emulsifiable concentrates with a watering can. Thurston County believes that the exposure assessments for applying the Ready-To-Use products with a pump-trigger spray and mixing and applying the concentrated products are applicable for rating risk from herbicidal applications. The EPA assessments assumed the applicators did not wear gloves (although gloves are recommended on many of the product labels).

Potential exposures from mixing and applying the emulsifiable concentrates to a 1,000 square foot area were rated low in hazard (less than 10% of the dose of concern). Exposures from applying 16 ounces of Ready-To-Use product with pump-trigger spray were rated moderate in hazard (between 10% and 50% of the dose of concern). The EPA also evaluated risk assessments for residential users of products containing d-limonene as an inert ingredient. Ther review included products that are; emulsifiable concentrates, pressurized liquids (aerosols), Ready-To-Use liquids, and soluble concentrates. All of the exposure scenarios were rated low in hazard except those involving the application of paint products and for the use of a pump-trigger applicator to spray one gallon of product to turf or garden areas - which are rated moderate in hazard.

CHRONIC HUMAN TOXICITY HAZARDS

Property	Value	Adverse Effect	Reference	Rating
Carcinogenicity	IARC Group 3	"Not classifiable"	1	Low
Mutagenicity	- -	"No evidence"	1 and 3	Low
Neurotoxicity - (NOAEL)	1,000 mg/kg (LOAEL)	Decreased motor activity	3	Check risk
Endocrine Disruption	Not listed	- -	4	Low
Developmental Toxicity (NOAEL)	250 mg/kg/day	Maternal + developmental toxicity	1	Check risk
Reproductive Toxicity (NOAEL)	Not provided	"No evidene without maternal effects"	1	Low
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 carcinogeniticity). 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 observeable adverse effect. The first observeable adverse effect in long-term toxicity testing was liver toxicity (relative liver weight compared to body weight).

CHRONIC HUMAN TOXICITY - Risk Assessment

Subject and Scenario	Route	Dose of Concern	Exposure	Margin of Safety	Reference	Value Rating
Long-term exposures to d-limonene not performed						
Long-term exposures to d-limonene not performed						
Long-term post application exposures not evaluated						
Long-term post application exposures not evaluated						

Chronic Toxicity Risk Assessment Summary:

Long-term exposures to d-limonene are not expected from herbicidal uses and there were no long-term exposure assessments evaluated by the EPA that reflected potential exposures from herbicidal uses.

Metabolites and Degradation Products:

Metabolites of d-limonene include perillic acid and d-limonene-8,9-diol (and its glucuronide) Reference 3.

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 3).

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

1. USEPA. Special Review and Reregistration Division Office of Pesticide Programs. "Exposure and Risk Assessment on Lower Risk Pesticide Chemicals D-Limonene."
2. USEPA. Office of Prevention, Pesticides, and Toxic Substances. Reregistration Eligibility Decision (RED) - Limonene. EPA 738-R-94-034. September 1994.
3. International Programme on Chemical Safety. Concise International Chemical Assessment Document No. 5. Limonene. www.inchem.org
4. Scorecard - The Pollution Information site. Health Effects (Accessed 12/29/2010) http://www.scorecard.org/health-effects/