SCREENING-LEVEL HAZARD CHARACTERIZATION
Monoterpene Hydrocarbons Category

_d_-Limonene (CASRN 5989-27-5)
_dl_-Limonene (CASRN 138-86-3)
Terpinolene (CASRN 586-62-9)
Myrcene (CASRN 123-35-3)
Dihydromyrcene (CASRN 2436-90-0)
Hydrocarbons, terpene processing by-products (CASRN 68956-56-9)
Orange peel oil, sweet (Citrus sinensis (L.) Osbeck) (CASRN 8008-57-9)
Terpenes & terpenoids, sweet orange oil (CASRN 68647-72-3)
Terpenes & terpenoids, limonene fraction (CASRN 65996-98-7)
Terpenes & terpenoids, turpentine oil, limonene fraction (CASRN 65996-99-8)

The High Production Volume (HPV) Challenge Program[1] was conceived as a voluntary initiative aimed at developing and making publicly available screening-level health and environmental effects information on chemicals manufactured in or imported into the United States in quantities greater than one million pounds per year. In the Challenge Program, producers and importers of HPV chemicals voluntarily sponsored chemicals; sponsorship entailed the identification and initial assessment of the adequacy of existing toxicity data/information, conducting new testing if adequate data did not exist, and making both new and existing data and information available to the public. Each complete data submission contains data on 18 internationally agreed to "SIDS" (Screening Information Data Set[1,2]) endpoints that are screening-level indicators of potential hazards (toxicity) for humans or the environment.

The Environmental Protection Agency's Office of Pollution Prevention and Toxics (OPPT) is evaluating the data submitted in the HPV Challenge Program on approximately 1400 sponsored chemicals by developing hazard characterizations (HCs). These HCs consist of an evaluation of the quality and completeness of the data set provided in the Challenge Program submissions. They are not intended to be definitive statements regarding the possibility of unreasonable risk of injury to health or the environment.

The evaluation is performed according to established EPA guidance[2,3] and is based primarily on hazard data provided by sponsors; however, in preparing the hazard characterization, EPA considered its own comments and public comments on the original submission as well as the sponsor's responses to comments and revisions made to the submission. In order to determine whether any new hazard information was developed since the time of the HPV submission, a search of the following databases was made from one year prior to the date of the HPV Challenge submission to the present: (ChemID to locate available data sources including Medline/PubMed, Toxline, HSDB, IRIS, NTP, ATSDR, IARC, EXTOXNET, EPA SRS, etc.), STN/CAS online databases (Registry file for locators, ChemAbs for toxicology data, RTECS, Merck, etc.) and Science Direct. OPPT's focus on these specific sources is based on their being

[1] U.S. EPA. High Production Volume (HPV) Challenge Program; http://www.epa.gov/chemrtk/index.htm.
[2] U.S. EPA. HPV Challenge Program – Information Sources; http://www.epa.gov/chemrtk/pubs/general/guidocs.htm.
[3] U.S. EPA. Risk Assessment Guidelines; http://cfpub.epa.gov/ncea/raf/rafguid.cfm.

of high quality, highly relevant to hazard characterization, and publicly available.

OPPT does not develop HCs for those HPV chemicals which have already been assessed internationally through the HPV program of the Organization for Economic Cooperation and Development (OECD) and for which Screening Initial Data Set (SIDS) Initial Assessment Reports (SIAR) and SIDS Initial Assessment Profiles (SIAP) are available. These documents are presented in an international forum that involves review and endorsement by governmental authorities around the world. OPPT is an active participant in these meetings and accepts these documents as reliable screening-level hazard assessments.

These hazard characterizations are technical documents intended to inform subsequent decisions and actions by OPPT. Accordingly, the documents are not written with the goal of informing the general public. However, they do provide a vehicle for public access to a concise assessment of the raw technical data on HPV chemicals and provide information previously not readily available to the public.

Chemical Abstract Service Registry Number (CASRN)	**123-35-3** **138-86-3** **586-62-9** **2436-90-0** **5989-27-5** **8008-57-9** **68647-72-3** **68956-56-9** **65996-98-7** **65996-99-8**
Chemical Abstract Index Name	**1, 6-Octadiene, 7-methyl-3-methylene-** **Cyclohexene, 1-methyl-4-(1-methylethenyl-** **Cyclohexene, 1-methyl-4-(1-methylethylidene-** **1, 6-Octadiene, 3,7-dimethyl-** **Cyclohexene, 1-methyl-4-(1-methylethenyl)-, (4R)-** **Oils, orange, sweet** **Terpenes and Terpenoids, sweet orange-oil** **Hydrocarbons, terpene processing by-products** **Terpenes and Terpenoids, limonene fraction** **Terpenes and Terpenoids, turpentine-oil, limonene fraction**
Structural Formula	See Section 1

Summary

Members of the monoterpene hydrocarbons category are liquids with moderate water solubility and moderate to high vapor pressure. The monoterpene hydrocarbons are expected to have moderate mobility in soil. Volatilization of the monoterpene hydrocarbons is considered high based on their Henry's Law constants. The rate of hydrolysis is considered negligible since the monoterpene hydrocarbons lack functional groups that hydrolyze under environmental conditions. The rate of atmospheric photooxidation is considered moderate to rapid. All the chemicals in the monoterpene hydrocarbons category are expected to have low persistence (P1). The bioaccumulation potentials for members of this category are expected to be low (B1) to moderate (B2).

The acute toxicity of the monoterpene hydrocarbons category members is low via the oral (rats and mice) and dermal (rabbits) routes of exposure. CASRN 5989-27-5 is an eye irritant (rabbits), skin irritant (rabbits and humans) and skin sensitizer (guinea-pigs and humans).

Repeated oral exposures in rats and mice with CASRN 123-35-3 showed hematological effects as well as splenic atrophy in rats, and histopathological changes in the liver of mice, at 1000 mg/kg-bw/day. The NOAEL was 500 mg/kg-bw/day in rats and mice. Repeated oral exposures in rats and mice with CASRN 5989-27-5 showed decreasing body weights followed by mortality at 2400 and 2000 mg/kg-bw/day, respectively. In male rats, nephropathy associated with

alpha2u-globulin formation was the primary systemic effect. The NOAEL was 1200 mg/kg/bw in rats and 1000 mg/kg-bw/day in mice. Repeated oral exposures in rats with CASRN 8008-57-9 showed clinical chemistry effects and lesions in the stomach at 1500 mg/kg-bw/day. In male rats, nephropathy associated with alpha2u-globulin formation was the primary systemic effect. The NOAEL was 600 mg/kg-bw/day. CASRN 8008-57-9 did not elicit an immune response *in vitro* up to 2500 mg/kg-bw/day.

No studies that specifically address the reproductive toxicity endpoint were available for CASRN 5989-27-5; however, the evaluation of the reproductive organs in the 13-week repeated-dose studies showed no treatment-related effects. In a modified oral developmental toxicity study in rats with CASRN 123-35-3, effects on the fertility of female off-spring were observed at 1000 mg/kg-bw/day. The NOAEL for reproductive toxicity was 500 mg/kg-bw/day. In the same study, maternal body weights were decreased and perinatal mortality, delayed postnatal development and decreased pup body weights were observed at 1000 and 500 mg/kg-bw/day, respectively. The NOAEL for maternal and developmental toxicity was 500 and 250 mg/kg-bw/day, respectively. In an oral combined reproductive/developmental toxicity study in rats with CASRN 123-35-3, no adverse effects on reproduction were observed. The NOAEL for reproductive toxicity was 500 mg/kg-bw/day. In the same study, skeletal abnormalities were observed at 500 mg/kg-bw/day and the NOAEL for developmental toxicity was 300 mg/kg-bw/day; the NOAEL for maternal toxicity was 500 mg/kg-bw/day. In an oral combined reproductive/developmental toxicity screening test with CASRN 8008-57-9 in rats, still births and pup mortality were observed at 1500 mg/kg-bw/day. The NOAEL for reproductive and developmental toxicity was 750 mg/kg-bw/day. The NOAEL for maternal toxicity was 1500 mg/kg-bw/day. Prenatal oral developmental toxicity studies with CASRN 5989-27-5 showed decreased fetal body weights and delayed ossification in rats and mice at 2869 and 2363 mg/kg-bw/day, respectively. Mortality was observed in the adult rats and mice at 2869 and 2363 mg/kg-bw/day, respectively. The NOAEL for maternal and developmental toxicity was 591 mg/kg-bw/day for both species. In rabbits, maternal body weight gain was reduced but no developmental toxicity was observed at 500 mg/kg-bw/day. The NOAEL for maternal and developmental toxicity was 250 and 1000 mg/kg-bw/day, respectively.

CASRN 5989-27-5 and CASRN 8008-57-9 did not induce gene mutations *in vitro*. CASRN 5989-27-5 and CASRN 123-35-3 did not induce chromosomal aberrations *in vitro* or *in vivo.* CASRN 5989-27-5 induced tumors in male rats via a mode of action not considered relevant to humans, and did not induce tumors in female rats and mice.

The acute hazard to fish is based on the toxicity values for CASRN 586-62-9 of 1.21 mg/L and CASRN 5989-27-5 of 0.7 mg/L. The acute hazard to aquatic invertebrates is based on the toxicity values for CASRN 586-62-9 of 1.38 mg/L and CASRN 5989-27-5 of 0.421 mg/L. The acute hazard to aquatic plants is based on the toxicity values for CASRN 586-62-9 of >3.38 mg/L and CASRN 5989-27-5 of >1.81 mg/L.

The chronic toxicity to aquatic invertebrates for CASRN 2436-90-0 remains as a data gap under the HPV Challenge Program.

The Flavor and Fragrance High Production Volume Consortia submitted a Test Plan and Robust Summaries to EPA for the Monoterpene Hydrocarbon category on May 21, 2002. EPA posted the submission on the ChemRTK HPV Challenge website on June 14, 2002, (http://www.epa.gov/oppt/chemrtk/pubs/summaries/monoterp/c13756tc.htm). EPA comments on the original submission were posted to the website November 6, 2002. Public comments were also received and posted to the website. The sponsor submitted updated/revised documents on September 27, 2006 which were posted to the ChemRTK website on November 13, 2006. The monoterpene hydrocarbons category consists of 10 substances described in Figure 1.

Category Justification

The category justification is based on structural similarity, similar molecular weights and functional groups and the expectation that inherent physicochemical, environmental and toxicological properties are predicted to be similar. Five members of the monoterpene hydrocarbon category (*d*-limonene (CASRN 5989-27-5), *dl*-limonene, (CASRN 138-86-3), terpinolene (CASRN 586-62-9), myrcene (CASRN 123-35-3) and dihydromyrcene (CASRN 2436-90-0) are monoterpene hydrocarbons. Three complex mixtures (orange peel oil, sweet (CASRN 8008-57-9), terpenes and terpenoids, sweet orange oil (CASRN 68647-72-3), and terpenes and terpenoids, limonene fraction (CASRN 65996-98-7) each contain greater than 90% monoterpene hydrocarbons, and inclusion in this category is justified by the fact that they are expected to have physicochemical, environmental and toxicological properties similar to the major components of each mixture, namely limonene and myrcene. Hydrocarbons, terpene processing by-products (CASRN 68956-56-9) and terpenes and terpenoids, turpentine oil, limonene fraction (CASRN 65996-99-8) are composed of 67-95% monoterpene hydrocarbons. The inclusion of these mixtures in this category is also reasonable.

Two proposed category members are mixtures that contain 5-10% unspecified terpene hydrocarbons and additional information regarding the unspecified substances is needed to better understand the chemical composition of these mixtures and potentially different expected toxicity.

EPA does not accept the inclusion of terpenes and terpenoids, turpentine oil limonene fraction and distillation residue (CASRN 68334-40-7) and terpenes and terpenoids, turpentine-oil residue (CASRN 68938-00-1) in this category as these mixtures are composed predominantly of non-monoterpene hydrocarbons. These chemicals will be reviewed separately and are excluded from this assessment.

d-Limonene has been evaluated by EPA under the IRIS program and the assessment can be found at the following link: http://www.epa.gov/ncea/iris/subst/0682.htm.

1 Chemical Identity

1.1 Identification and Purity

The following description is taken from the final Test Plan (2006):

The chemical category includes five simple monoterpene hydrocarbons (*d*-limonene, *dl*-limonene, terpinolene, *beta*-myrcene and dihydromyrcene) and five mixtures comprised primarily of the five terpene hydrocarbons. In plants, monoterpene hydrocarbons are produced by the isoprene pathway. They have a chemical formula of $C_{10}H_{16}$, or if partly or completely saturated, $C_{10}H_{18}$ or $C_{10}H_{20}$. Monoterpene hydrocarbons are ubiquitous in food given that they are present in varying degrees in all plants. Being volatile constituents of plants, they are also normal components of the atmosphere. They are mainly released by coniferous woodland such as pine trees, cedars, redwood and firs. To a lesser extent, they are also produced and released by deciduous plants. They are common components of traditional foods occurring in essentially all fruits and vegetables.

d-Limonene and terpinolene are monocyclic monounsaturated terpenes. *d*-Limonene is (R)-1-methyl-4-(1-methylethenyl)-cyclohexene, *dl*-limonene is an equal mixture of (R)- and (S)-1-methyl-4-(1-methylethenyl)-cyclohexene while terpinolene is 1-methyl-4-(1-methylethylidene)-cyclohexene. Myrcene is commonly recognized as *beta*-myrcene, the isomeric form that predominates in nature. *beta*-Myrcene is an acylclic monounsaturated isomer of limonene. The alpha isomer, 2-methyl-6-methylene-1,7-octadiene is not found in nature and is of no commercial importance. *beta*-Myrcene is 7-methyl-3-methylene-1,6-octadiene while dihydromyrcene is 3,7-dimethyl-1,6-octadiene. The chemical constituents of the mixtures are listed in Table 1.

Table 1. Chemical Structures of Monoterpene Hydrocarbons

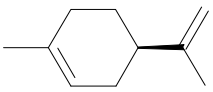
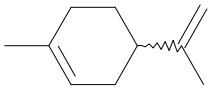
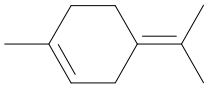
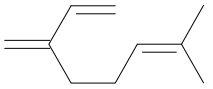
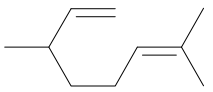
CASRN	Chemical Name	Structure
5989-27-5	*d*-Limonene	
138-86-3	*dl*-Limonene	
586-62-9	Terpinolene	
123-35-3	Myrcene	
2436-90-0	Dihydromyrcene	

Table 1. Chemical Structures of Monoterpene Hydrocarbons		
CASRN	**Chemical Name**	**Structure**
68956-56-9	Hydrocarbons, terpene processing by-products	Limonene: 22–34% Terpinolene: 22–33% Myrcene: 5–10% Limonene isomers: 18% Other terpene hydrocarbons: 10%
8008-57-9	Orange peel oil, sweet (Citrus sinensis (L.) Osbeck)	Limonene: 91–94% Myrcene: 2.0–2.1%
68647-72-3	Terpenes & terpenoids, sweet orange oil	*d*-Limonene: 91–95% Myrcene: 2.0–2.1% *alpha*-Pinene: 1–2%
65996-98-7	Terpenes and terpenoids, limonene fraction	*dl*-Limonene: 96–98% Myrcene: 1–2% Other terpene hydrocarbons: 5–10%
65996-99-8	Terpenes and terpenoids, turpentine oil, limonene fraction	*dl*-Limonene: 59–64% *beta*-Phellandrene: 14–18% *beta*-Pinene: 4–11% Other terpene hydrocarbons: 5–10%

1.2 Physical-Chemical Properties

The physical-chemical properties of the monoterpene hydrocarbons category are summarized in Table 2. Members of the monoterpene hydrocarbons category are liquids with moderate water solubility and moderate to high vapor pressure.

Table 2. Physical-Chemical Properties of Monoterpene Hydrocarbons Category[1]

Property	*d*-Limonene[2]	*dl*-Limonene[2]	Terpinolene	Myrcene	Dihydro-myrcene	Hydro-carbons, terpene processing by-products	Orange peel oil, sweet (*Citrus sinensis (L) Osbeck*)	Terpenes and Terpenoids, sweet orange-oil	Terpenes and Terpenoids, limonene fraction	Terpenes and Terpenoids, turpentine-oil limonene fraction
CASRN	5989-27-5	138-86-3	586-62-9	123-35-3	2436-90-0	68956-56-9	8008-57-9	68647-72-3	65996-98-7	65996-99-8
Molecular Weight	136	136	136	136	138	Mixtures (see Table 1 for chemical constituents)				
Physical State	Liquids									
Melting Point	**-74°C (d, measured); -97°C (dl, measured)**		0°C (estimated)	**<-10°C (measured)[3]**	-66°C (estimated)	-97 to -74°C (measured values for limonene); <-10°C (measured value for myrcene)[3]; -64°C (measured value for *alpha*-pinene)[3]; -61.5°C (measured value for *beta*-pinene)[3]				
Boiling Point	**175–179°C (measured)**		**185–186°C (measured)**	**167–172°C (measured)**	**158–168°C (measured)**	175–179°C (measured values for limonene); 185–186°C (measured values for terpinolene); 167–172°C (measured values for myrcene); 155.9°C (measured value for *alpha*-pinene)[3]; 166°C (measured value for *beta*-pinene)[3]; 171.5°C (measured value for *beta*-phellandrene)[3]				
Vapor Pressure (mm Hg)	**1.43 at 20°C (measured)**		**0.743 at 24°C (measured)[3]**	**2.01 at 25°C (measured)**	2.57 at 25°C (estimated)	1.43 at 20°C (measured value for limonene); 0.743 at 24°C (measured value for terpinolene)[3]; 2.01 at 25°C (measured value for myrcene); 4.75 at 25°C (measured value for *alpha*-pinene)[3]; 2.93 at 25°C (measured value for *beta*-pinene)[3]; 1.59 at 25°C (measured value for *beta*-phellandrene)[3]				
Dissociation Constant (pK_a)	Not applicable									

Table 2. Physical-Chemical Properties of Monoterpene Hydrocarbons Category[1]

Property	*d*-Limonene[2]	*dl*-Limonene[2]	Terpinolene	Myrcene	Dihydro-myrcene	Hydro-carbons, terpene processing by-products	Orange peel oil, sweet (*Citrus sinensis (L) Osbeck*)	Terpenes and Terpenoids, sweet orange-oil	Terpenes and Terpenoids, limonene fraction	Terpenes and Terpenoids, turpentine-oil limonene fraction
CASRN	5989-27-5	138-86-3	586-62-9	123-35-3	2436-90-0	68956-56-9	8008-57-9	68647-72-3	65996-98-7	65996-99-8
Henry's Law Constant (atm-m^3/mole)	**0.032 (measured)[3]**		**0.014 (measured)[3]**	**0.064 (measured)[3]**	0.73 (estimated)	0.032 (measured value for limonene)[3]; 0.014 (measured value for terpinolene)[3]; 0.064 (measured value for myrcene)[3]; 0.29 (measured value for *alpha*-pinene)[3]; 0.16 (estimated value for *beta*-pinene)[4]; 0.26 (estimated value for *beta*-phellandrene)[4];				
Water Solubility (mg/L)	**13.8 at 25°C (measured)**		**9.5 at 23°C (measured)**	**5.6 at 25°C (measured)**	1.87 at 25°C (estimated)	13.8 at 25°C (measured value for limonene); 9.5 at 23°C (measured value for terpinolene); 5.6 at 25°C (measured value for myrcene); 2.49 at 25°C (measured value for *alpha*-pinene)[3]; 9.2 at 25°C (estimated value for *beta*-pinene)[4]; 2.8 at 25°C (estimated value for *beta*-phellandrene)[4]				
Log K_{ow}	**4.57 (measured)[3]**		**4.47 (measured)[3]**	**4.17 (measured)[3]**	4.88 (estimated)	4.57 (measured value for limonene); 4.47 (measured value for terpinolene and sweet orange oil); 4.17 (measured value for myrcene)[3]; 4.48 (measured value for *alpha*-pinene)[3]; 4.16 (measured value for *beta*-pinene)[3]; 4.70 (estimated value for *beta*-phellandrene)[4];				

[1]The Flavor and Fragrance High Production Volume Consortia. The Terpene Consortium. November 1, 2006. Robust Summary and Test Plan for Monoterpene Hydrocarbons Category (posted November 13, 2006). http://www.epa.gov/oppt/chemrtk/pubs/summaries/monoterp/c13756tc.htm.
[2]Optical isomers have identical physical/chemical properties.
[3]SRC. The Physical Properties Database (PHYSPROP). Syracuse, NY: Syracuse Research Corporation. Available from http://www.syrres.com/esc/physprop.htm as of December 15, 2008.
[4]USEPA. 2008. Estimation Programs Interface Suite™ for Microsoft® Windows, v3.20. U.S. Environmental Protection Agency, Washington, DC, USA. http://www.epa.gov/opptintr/exposure/pubs/episuite.htm.

2 General Information on Exposure

2.1 Production Volume and Use Pattern

The Monoterpene Category Chemicals have an aggregated production and/or import volume in the United States of 66 million to 210.5 million pounds during calendar year 2005.

- CASRN 5989-27-5 Less than 500,000 pounds
- CASRN 138-86-3 1 to 10 million pounds
- CASRN 586-62-9 1 to 10 million pounds
- CASRN 123-35-3 10 to 50 million pounds
- CASRN 2436-90-0 1 to 10 million pounds
- CASRN 68956-56-9 50 to 100 million pounds
- CASRN 8008-57-9 1 to 10 million pounds
- CASRN 68647-72-3 1 to 10 million pounds
- CASRN 65996-98-7 1 to 10 million pounds

Non-confidential information in the IUR[4] indicated that the industrial processing and uses of these chemicals include processing as intermediates and odor agents, and solvents in cleaning and degreasing. Non-confidential information in the IUR indicated that the commercial and consumer products containing these chemicals include soaps and detergents; automotive care products; rubber and plastic products; and polishes and sanitation goods. The HPV submission for the Monoterpene Hydrocarbons Category states that the chemicals are typically used as flavoring substances.[5] The Hazardous Substances Data Bank (HSDB) states that CASRN 8008-57-9 is used as a flavoring agent in soaps, cosmetics, lotions and perfumes; CASRN 5989-27-5 is used in flavorings, fragrances, cosmetics solvents, wetting agents, insecticide, insect repellant, animal repellant, and the manufacture of resins; CASRN 138-86-3 is used in flavorings, perfumes, pesticides, paint brush cleansers and preservatives, solvents, wetting and dispersing agents, air fresheners, cleaning compounds, lubricating oil additives and as monomer in resins; CASRN 586-62-9 is used in flavorings, fragrances, and as solvents in the manufacture of synthetic resins; and CASRN 123-35-3 is used in perfumes, flavorings, insect repellents, and detergents.[6]

2.2 Environmental Exposure and Fate

No quantitative information is available on environmental releases of these chemicals to the environment.

The environmental fate properties are provided in Table 3. The monoterpene hydrocarbons are expected to have moderate mobility in soil. CASRN 5989-27-5 was completely biodegraded in

[4] USEPA, 2006. Inventory Update Reporting Database. v. 1.02
[5] The Flavor and Fragrance High Production Volume Consortia and The Terpene Consortium, 2006. Revised Test Plan for Monoterpene Hydrocarbons. Accessed: 01/14/09. http://www.epa.gov/chemrtk/pubs/summaries/monoterp/c13756rt.pdf
[6] HSDB, 2008. Hazardous Substances Data Bank. CASRN 8008-57-9, 5989-27-5, 138-86-3, 586-62-9, and 123-35-3. Accessed, 01/21/09. http://toxnet.nlm.nih.gov/

8 days in a laboratory study using unacclimated soil obtained from a coniferous forest. It was also shown to be readily biodegradable using the modified MITI test (OECD 301C). CASRN 586-62-9 was shown to be readily biodegradable using a modified Sturm test (OECD 301B), although it did not pass the readily biodegradable criteria using the manometric respirometry test (OECD 301F). CASRN 80-56-8, a minor constituent of several of the mixtures contained in the monoterpene hydrocarbons category, was shown to be readily biodegradable using the modified MITI test (OECD 301C). Based on the biodegradation data of these chemicals and the structural similarity and makeup of the mixtures in the monoterpene hydrocarbons category, all of the constituents are expected to biodegrade in the environment. Volatilization of the monoterpene hydrocarbons is considered high based on their Henry's Law constants. The monoterpene hydrocarbons are not expected to hydrolyze since they lack functional groups that hydrolyze under environmental conditions. The rate of atmospheric photooxidation is considered moderate to rapid. Based on these data, all the chemicals in the monoterpene hydrocarbon category are expected to have low persistence (P1). The bioaccumulation potentials for members of this category are expected to range from low (B1) to moderate (B2).

Table 3. Environmental Fate Characteristics of Monoterpene Hydrocarbons Category[1]

Property	*d*-Limonene	*dl*-Limonene	Terpinolene	Myrcene	Dihydro-myrcene	Hydrocarbons, terpene processing by-products	Orange peel oil, sweet (*Citrus sinensis (L) Osbeck*)	Terpenes and Terpenoids, sweet orange-oil	Terpenes and Terpenoids, limonene fraction	Terpenes and Terpenoids, turpentine-oil limonene fraction
CASRN	5989-27-5	138-86-3	586-62-9	123-35-3	2436-90-0	68956-56-9	8008-57-9	68647-72-3	65996-98-7	65996-99-8
Photodegradation Half-life	0.884 hours (estimated)		0.64 hours (estimated)	0.66 hours (estimated)	1.02 hours (estimated)[2]	0.884 hours (estimated value for limonene); 0.64 hours (estimated value for terpinolene); 0.66 hours (estimated value for myrcene); 1.4 hours (estimated value for *alpha*-pinene)[2]; 2.2 hours (estimated value for *beta*-pinene)[2]; 1.5 hours (estimated value for *beta*-phellandrene)[2]				
Hydrolysis Half-life	Stable									
Biodegradation	Complete biodegradation in 8 days using unacclimated soil; 41–98% in 14 days (readily biodegradable)[3]		51–80% in 28 days (readily biodegrad-able)	82–92% in 28 days (readily biodegrad-able)[4]	82–92% in 28 days (readily biodegrad-able)[4]	41–98% in 14 days (readily biodegradable) (data for limonene); 51–80% in 28 days (readily biodegradable) (data for terpinolene); 91–95% in 28 days (readily biodegradable) (data for *alpha*-pinene)[3]				
Bioaccumulation Factor	BAF = 761(estimated)[2]		BAF = 3,506 (estimated)[2]	BAF = 739 (estimated)[2]	BAF =1,398 (estimated)[2]	BAF = 761 (estimated value for limonene)[2]; BAF = 3,506 (estimated value for terpinolene)[2]; BAF = 739 (estimated value for myrcene)[2]; BAF = 3,072 (estimated value for *alpha*-pinene)[2]; BAF = 923 (estimated value for *beta*-pinene)[2]; BAF = 976 (estimated value for *beta*-phellandrene)[2]				
Log K_{oc}	3.1 (estimated)[2]		3.1 (estimated)[2]	3.1 (estimated)[2]	3.1 (estimated)[2]	3.1 (estimated values for limonene, terpinolene, myrcene, *alpha*-pinene, *beta*-pinene, and *beta*-phellandrene)[2]				

Table 3. Environmental Fate Characteristics of Monoterpene Hydrocarbons Category[1]

Property	*d*-Limonene	*dl*-Limonene	Terpinolene	Myrcene	Dihydro-myrcene	Hydrocarbons, terpene processing by-products	Orange peel oil, sweet (*Citrus sinensis (L) Osbeck*)	Terpenes and Terpenoids, sweet orange-oil	Terpenes and Terpenoids, limonene fraction	Terpenes and Terpenoids, turpentine-oil limonene fraction
CASRN	5989-27-5	138-86-3	586-62-9	123-35-3	2436-90-0	68956-56-9	8008-57-9	68647-72-3	65996-98-7	65996-99-8
Fugacity (Level III Model)										
Air (%)	0.145		0.034	0.0606	0.226	0.034–1.73				
Water (%)	32.1		20.3	25.9	32.1	20.3–44.5				
Soil (%)	64.4		58.4	62.8	53.8	38.5–64.4				
Sediment(%)	3.38		21.2	11.2	13.9	3.38–34.3				
						(estimated values for limonene, terpinolene, myrcene, *alpha*-pinene, *beta*-pinene, and *beta*-phellandrene)[2]				
Persistence[5]	P1 (low)		P1 (low)	P1 (low)	P1(low)	P1 (low)				
Bioaccumulation[5]	B1 (low)		B2 (moderate)	B1 (low)	B2 (moderate)	B1 (low) – B2 (moderate)				

[1]The Flavor and Fragrance High Production Volume Consortia. The Terpene Consortium. November 1, 2006. Robust Summary and Test Plan for Monoterpene Hydrocarbons Category (posted November 13, 2006). http://www.epa.gov/oppt/chemrtk/pubs/summaries/monoterp/c13756tc.htm.
[2]USEPA. 2009. Estimation Programs Interface Suite™ for Microsoft® Windows, v4.0. U.S. Environmental Protection Agency, Washington, DC, USA. http://www.epa.gov/opptintr/exposure/pubs/episuite.htm.
[3]National Institute of Technology and Evaluation. 2002. Biodegradation and Bioaccumulation of the Existing Chemical Substances under the Chemical Substances Control Law. http://www.safe.nite.go.jp/english/kizon/KIZON_start_hazkizon.html.
[4]Wilson, D. and Hrutfiord, B. 1975. The fate of turpentine in aerated lagoons. Pulp Pap. Can. 76:91–93.
[5]Federal Register. 1999. Category for Persistent, Bioaccumulative, and Toxic New Chemical Substances. *Federal Register* 64, Number 213 (November 4, 1999) pp. 60194–60204.

3 Human Health Hazard

A summary of health effects data submitted for SIDS endpoints is provided in table 4. The table also indicates where data for tested category members are read across (RA) to untested members of the category.

Acute Oral Toxicity

d-Limonene (CASRN 5989-27-5)
(1) Wistar rats (10/sex/dose) were administered d-Limonene in Arabic gum/water via gavage at 1500, 1900, 2500, 3300, 4300, 4400, 5200, 5600, 7300, 9400, 12,200 or 15,900 mg/kg-bw. Observation period not reported.
LD_{50} (males) = 4400 mg/kg-bw
LD_{50} (females) = 5200 mg/kg-bw

(2) Mice (10/sex/dose, strain not specified) were administered d-Limonene in Arabic gum/water via gavage at 3000, 3500, 4300, 5300, 5600, 6600, 7000, 7500, 8300, or 10,000 mg/kg-bw. Observation period not reported.
LD_{50} (males) = 5600 mg/kg-bw
LD_{50} (females) = 6600 mg/kg-bw

Terpinolene (CASRN 586-62-9)
Rats (10/dose group, strain and sex not reported) were administered terpinolene via gavage at 3.0, 3.5, 4.0 and 5.0 ml/kg-bw (corresponding to 2500, 3000, 3464 and 4300 mg/kg-bw). Observation period not reported. A dose dependent increase in the number of deaths was observed with zero deaths at 3.0 ml/kg-bw, 1 death at 3.5 ml/kg-bw, 5 deaths at 4.0 ml/kg-bw and 6 deaths at 5.0 ml/kg-bw.
LD_{50} = 3800 mg/kg-bw

Myrcene (CASRN 123-35-3)
(1) Male and female Albino Swiss mice (1/sex/dose or 3/sex/dose) were administered myrcene in corn oil via gavage at 670, 1000, 2250, 3250, 5060, 7590 or 11,390 mg/kg-bw and observed for 14 days. There were no mortalities up to 3250 mg/kg-bw. At 5060 mg/kg-bw 2/3 (males) and 3/3 (females) died, at 7590 mg/kg-bw 3/3(males) and 2/3 (females) died and both animals died at 11,390 mg/kg-bw.
LD_{50} = 5060 mg/kg-bw

(2) Wistar rats (1/sex/dose at three lower doses and 2/sex/dose at the three higher doses) were administered myrcene in corn oil via gavage at 0, 670, 1000, 1500, 2250, 3250, 5060, 7590 and 11,390 mg/kg-bw and observed for 14 days. No deaths were observed.
LD_{50} > 11,390 mg/kg-bw

***Dihydromyrcene* (*CASRN 2436-90-0*)**
Wistar rats (10 males) were administered dihydromyrcene via gavage at 5000 mg/kg-bw and observed for 14 days. One animal died.
LD_{50} (male) > 5000 mg/kg-bw

***Orange peel oil, sweet* (*Citrus sinensis* (*L.*) *Osbeck*) (*CASRN 8008-57-9*)**
Wistar rats (10 males) were administered orange peel oil, sweet via gavage at 5000 mg/kg-bw and observed for 14 days. No deaths were reported.
LD_{50} (male) > 5000 mg/kg-bw

Acute Dermal Toxicity

d-Limonene (CASRN 5989-27-5)
New Zealand White rabbits (10, sex not reported) were administered *d*-Limonene dermally at 5000 mg/kg-bw on to their clipped, abraded abdominal skin for 24 hours and observed for 7 days. There were no mortalities.
LD_{50} > 5000 mg/kg-bw

Terpinolene (CASRN 586-62-9)
Rats (4, species and sex not reported) were administered terpinolene dermally at 5 ml/kg-bw (corresponding to 4330 mg/kg-bw). There were no mortalities.
LD_{50} > 4330 mg/kg-bw

Myrcene (CASRN 123-35-3)
New Zealand White rabbits (10, sex not reported) were administered myrcene dermally at 5000 mg/kg-bw on to their clipped, abraded abdominal skin for 24 hours and observed for 7 days. There were no mortalities.
LD_{50} > 5000 mg/kg-bw

Dihydromyrcene (CASRN 2436-90-0)
New Zealand White rabbits (10 males) were administered dihydromyrcene dermally at 5000 mg/kg-bw on to their clipped, abraded abdominal skins for 24 hours and observed for 14 days. One rabbit died.
LD_{50} (male) > 5000 mg/kg-bw

***Orange peel oil, sweet* (*Citrus sinensis* (*L.*) *Osbeck*) (*CASRN 8008-57-9*)**
New Zealand White rabbits (10, sex not reported) were administered orange peel oil, sweet dermally at 5000 mg/kg-bw on to their clipped, abraded abdominal skin for 24 hours and observed for 7 days. There were no mortalities.
LD_{50} > 5000 mg/kg-bw

Repeated-Dose Toxicity

d-Limonene (CASRN 5989-27-5)
(1) In a 13-week National Toxicology Program (NTP) study, F344/N rats (10/sex/dose) were administered *d*-limonene in corn oil via gavage at 0, 150, 300, 600, 1200 and 2400 mg/kg-bw/day, 5 days/week. Mortality was seen in 9/10 females and 5/10 males at the highest dose. Male rats showed a decrease in relative and absolute body weight gain. At the three highest doses, final body weights were decreased by 6%, 12% and 23%, respectively, compared to the controls. In males, a dose dependent increase in the severity of nephropathy, characterized by

epithelial degeneration in the convoluted tubules, granular casts with tubular lumens and tubular epithelium regeneration associated with hyaline droplet formation and alpha2u-globulin formation was observed. Nephropathy associated with alpha2u-globulin formation in male rats is not considered relevant to humans (US EPA, 1991). Rough hair coats, lethargy and excessive lacrimation were observed for all animals at the two highest doses.
LOAEL = 2400 mg/kg-bw/day (based on mortality)
NOAEL = 1200 mg/kg-bw/day

(2) In a 13-week NTP study, B6C3F1 mice (10/sex/dose) were administered *d*-limonene in corn oil via gavage at 0, 125, 250, 500, 1000 and 2000 mg/kg-bw/day, 5 days/week. Mortality was observed at 2000 mg/kg-bw/day (1/10 males and 2/10 females) and 500 mg/kg-bw/day (1/10 females). In males a 10% decrease in body weight gain was observed at the two highest doses. Rough hair coats and decreased activity were observed at the two highest doses in both sexes. There were no treatment-related histopathologic lesions in either sex.
LOAEL = 2000 mg/kg-bw/day (based on mortality)
NOAEL = 1000 mg/kg-bw/day

Myrcene (CASRN 123-35-3)
(1) In a 13-week NTP study, F344/N rats (10/sex/dose) were administered *beta*-myrcene in corn oil via gavage at 0, 250, 500, 1000, 2000 or 4000 mg/kg-bw/day for 5 days/week. Right kidneys of male rats were frozen while left kidneys were processed for investigation of alpha2u-globulin. Additionally, special study groups (SSG) (10/dose/sex) were administered three doses of *beta*-myrcene daily for 23 days. The left kidneys were frozen and the right kidneys were processed and microscopically examined for the presence of hyaline droplets. At 4000 mg/kg-bw/day, all animals in the core and SSG died. At 2000 mg/kg-bw/day, mortality was 20% in the core and 40% in the SSG. The mean body weight gain decreased by >10% in males at 1000, 2000 and 4000 mg/kg- bw/day. At 2000 mg/kg-bw/day, there was a decrease in white blood cells (27% and 24%) and lymphocytes (35% and 25%) in males and females. Reticulocytes were increased in males at the 1000 and 2000 mg/kg bw/day. No treatment-related effects on clinical chemistry parameters were observed. A dose-dependent increase in absolute and relative liver and kidney weights was observed in male and female rats. A dose-dependent decrease in mean thymus weight was seen in males at and above 500 mg/kg-bw/day and at 2000 mg/kg-bw/day in females. All test groups showed evidence of renal tubular degeneration while dose levels of 1000 mg/kg-bw/day and above exhibited splenic atrophy, olfactory epithelial degeneration and chronic nasal irritation.
LOAEL = 1000 mg/kg-bw/day (based on splenic atrophy, blood effects and body weight changes)
NOAEL = 500 mg/kg-bw/day

(2) In a 13-week NTP study, B6C3F1 mice (10/sex/dose) were administered *beta*-myrcene at 0, 250, 500, 1000, 2000 or 4000 mg/kg-bw/day in corn oil via gavage for 5 days/week. All animals at 4000 mg/kg bw/day died and 1/10 males and 2/10 females died at 2000 mg/kg-bw/day. At 1000 mg/kg-bw/day, group mean body weight gains were depressed for males (22.5%) and females (2.4%): mean female body weight gains were significantly depressed. For males, relative liver weights were increased at 1000 and 2000 mg/kg-bw/day, while in females a dose related increase in liver weights was observed at 500 mg/kg-bw/day and above. At 1000 mg/kg-

bw/day small hematologic changes (3-6%), decrease in red blood cells, hemoglobin and hematocrit, and increase in mean corpuscular volume and hemoglobin, were seen—these changes were more pronounced (5-43%) at 2000 mg/kg-bw/day in both sexes. No treatment-related effects on clinical chemistry parameters were observed. In females, centrilobular hypertrophy and necrosis of the liver and irritation of forestomach were observed at 2000 and 4000 mg/kg-bw/day. In males, centrilobular hypertrophy was observed at all doses and liver necrosis was observed at 1000 and 2000 mg/kg-bw/day.
LOAEL = 1000 mg/kg-bw/day (based on effects on liver, blood and body weight)
NOAEL = 500 mg/kg-bw/day

Orange peel oil, sweet (Citrus sinensis (L.) Osbeck) (CASRN 8008-57-9)
In a 28-day study, Sprague Dawley rats (10/sex/dose) were administered orange peel oil, sweet, in 1% methyl cellulose, via gavage at 0, 240, 600 or 1500 mg/kg-bw/day. No treatment-related effects were reported on survival, body weights or food consumption. Treatment-related decreases in glucose were observed in males at the high dose and in females at the mid- and high dose. Increases (significance not reported) in serum albumin and total serum protein were observed in all treated females and in the high dose males. Kidney and liver weights were increased in the treated male groups and in the high dose female groups. Treatment-related lesions were observed in the nonglandular stomach of the high dose males and females, and in the kidney of all treated males, characteristic of hyaline droplet formation and alpha2u-globulin accumulation. Nephropathy associated with alpha2u-globulin formation in male rats is not considered relevant to humans (US EPA, 1991).
LOAEL = 1500 mg/kg-bw/day (based on lesions in the stomach and clinical chemistry)
NOAEL = 600 mg/kg-bw/day

Reproductive Toxicity

d-Limonene (CASRN 5989-27-5)
There were no studies specifically designed to assess the reproductive toxicity endpoint available for *d*-limonene. Evaluation of reproductive organs in repeated-dose studies were used to address the reproductive toxicity endpoint for the purposes of the HPV Challenge Program.

Myrcene (CASRN 123-35-3)
(1) In a combined reproductive/developmental toxicity study, Wistar rats, male (15/dose) and female (45/dose) were administered *beta*-myrcene via gavage at 0, 100, 300 or 500 mg/kg-bw/day. Males were exposed to myrcene for 91 days prior to and during mating, and females were exposed for 21 days before and during mating, pregnancy and throughout lactation up to postnatal day 21. Except for a slight increase in liver and kidney weights, no other signs of toxicity were observed in either sex. No morphological changes in the liver or testes were observed. The mating and pregnancy indices were comparable to controls. No signs of maternal toxicity were observed at any dose.
NOAEL (reproductive toxicity) = 500 mg/kg-bw/day (based on no adverse effects at the highest dose tested)

(2) In a modified prenatal developmental toxicity study, pregnant Wistar rats (number not stated) were administered *beta*-myrcene via gavage at 0, 250, 500, 1000 or 1500 mg/kg-bw/day from

gestation day 15 until postnatal day 21. Reproductive capacity was assessed in the exposed offspring upon reaching maturity (120 days). At 1500 mg/kg-bw/day, mortality was observed in the dams (5/15). A decrease in body weight (significance not stated) was also observed at the two high doses. Fertility was impaired in the female offspring at 1000 and 1500 mg/kg-bw/day.
LOAEL (maternal toxicity) = 1000 mg/kg-bw/day (based on decrease in body weight)
NOAEL (maternal toxicity) = 500 mg/kg-bw/day
LOAEL (female reproductive toxicity) = 1000 mg/kg-bw/day (based on effects on fertility)
NOAEL (female reproductive toxicity) = 500 mg/kg-bw/day

Orange peel oil, sweet (Citrus sinensis (L.)Osbeck) (CASRN 8008-57-9)
In a combined reproductive/developmental toxicity screening test, female Sprague-Dawley rats (10/dose) were administered orange peel oil, sweet via gavage at 0, 375, 750 or 1500 mg/kg-bw/day for 7 days prior to and through mating, gestation, delivery and four days of lactation. Treated animals had decreased weight gains, and significantly decreased absolute and relative food consumption at 750 and 1500 mg/kg-bw/day during the seven day pre-mating period. No treatment related effects on mating performance or fertility were observed at any dose level. A significant number of stillbirths and pup deaths were observed at 1500 mg/kg-bw/day. No other treatment-related effects on offspring were observed.
LOAEL (reproductive toxicity) = 1500 mg/kg-bw/day (based on stillbirths and pup mortality)
NOAEL (reproductive toxicity) = 750 mg/kg-bw/day

Developmental Toxicity

d-Limonene (CASRN 5989-27-5)
(1) Pregnant Wistar rats (20/dose) were administered *d*-limonene via gavage at doses of 0, 591 or 2869 mg/kg-bw/day during days 9-15 of gestation. At 2869 mg/kg-bw/day, maternal mortality and decrease in maternal body weights (significance not stated) were observed. At the high dose, there was also a decrease in fetal body weights (significance not stated), a delay in ossification of fetal metacarpal bones and proximal phalanx, and decreased weights of thymus, spleen and ovaries (significance not stated).
LOAEL (maternal toxicity) = 2869 mg/kg-bw/day (based on mortality and decreased body weights)
NOAEL (maternal toxicity) = 591 mg/kg-bw/day
LOAEL (developmental toxicity) = 2869 mg/kg-bw/day (based on decreased fetal bodyweights and delayed ossification)
NOAEL (developmental toxicity) = 591 mg/kg-bw/day

(2) Pregnant Japanese White rabbits (number not stated) were administered *d*-limonene via gavage at 0, 250, 500 or 1000 mg/kg-bw/day during days 6-18 of gestation. Increased maternal mortality was observed at 1000 mg/kg-bw/day and significant decreases in maternal body weight gain and food consumption were observed at 500 and 1000 mg/kg-bw/day. No treatment related effects were observed in offspring.
LOAEL (maternal toxicity) = 500 mg/kg-bw/day (based on decreased body weight gain)
NOAEL (maternal toxicity) = 250 mg/kg-bw/day
NOAEL (developmental toxicity) = 1000 mg/kg-bw/day (based on no adverse effects at the highest dose tested)

(3) Pregnant ICR mice (number not stated) were administered *d*-limonene via gavage at 0, 591 or 2363 mg/kg-bw/day during days 7-12 of gestation. A significant decrease in maternal body weight gain was observed at 2363 mg/kg-bw/day. In the offspring, an increased incidence of fused ribs compared to that of controls, delayed ossification of some bones and decreased body weight gain were reported at the highest dose.
LOAEL (maternal toxicity) = 2363 mg/kg-bw/day (based on decreased body weight gain)
NOAEL (maternal toxicity) = 591 mg/kg-bw/day
LOAEL (developmental toxicity) = 2363 mg/kg-bw/day (based on delayed ossification, incidence of fused ribs and decreased body weight gain)
NOAEL (developmental toxicity) = 591 mg/kg-bw/day

Myrcene (CASRN 123-35-3)
(1) In a combined reproductive/developmental toxicity study, described above, Wistar rats, were administered *beta*-myrcene via gavage at 0, 100, 300 or 500 mg/kg-bw/day. No signs of maternal toxicity and no increase in externally visible malformations were observed at any dose. A slight increase (significance not stated) in the resorption rate and a higher frequency of fetal skeletal anomalies (dislocated sternum and lumbar extra ribs) were observed at 500 mg/kg-bw/day. No adverse effect on postnatal weight gain was noted. The appearance of primary coat, incisor eruption and eye opening were slightly delayed in the exposed offspring.
NOAEL (maternal toxicity) = 500 mg/kg-bw/day (based on no adverse effects at the highest dose tested)
LOAEL (developmental toxicity) = 500mg/kg-bw/day (based on skeletal abnormalities)
NOAEL (developmental toxicity) = 300mg/kg-bw/day

(2) In a modified prenatal developmental toxicity study described above, pregnant Wistar rats (number not stated) were administered *beta*-myrcene via gavage at 0, 250, 500, 1000 or 1500 mg/kg-bw/day from gestation day 15 until postnatal day 21. At 1500 mg/kg-bw/day, mortality was observed in the dams (5/15). A decrease in body weight (significance not stated) was also observed at the two high doses. At 500, 1000 and 1500 mg/kg-bw/day, there was perinatal mortality, delayed developmental landmarks and decreased pup body weights (significance not stated).
LOAEL (maternal toxicity) = 1000 mg/kg-bw/day (based on decrease in body weight)
NOAEL (maternal toxicity) = 500 mg/kg-bw/day
LOAEL (developmental toxicity) = 500 mg/kg-bw/day (based on perinatal mortality, delayed postnatal development and decreased pup body weight)
NOAEL (developmental toxicity) = 250 mg/kg-bw/day

(3) Pregnant Wistar rats (number not stated) were administered *beta*-myrcene via gavage at 0, 250, 500 or 1200 mg/kg-bw/day during days 6-15 of gestation. At 1200 mg/kg-bw/day, there was one maternal death. Decreased maternal weight gain (significance not stated) was also reported. Increased fetal skeletal malformations were reported at 1200 mg/kg-bw/day.
LOAEL (maternal toxicity) = 1200 mg/kg-bw/day (based on mortality and decreased body weight gain)
NOAEL (maternal toxicity) = 500 mg/kg-bw/day
LOAEL (developmental toxicity) = 1200 mg/kg-bw/day (based on skeletal malformations)
NOAEL (developmental toxicity) = 500 mg/kg-bw/day

Orange peel oil, sweet (Citrus sinensis (L.)Osbeck) (CASRN 8008-57-9)
In a reproductive/developmental toxicity screening test described above, female Sprague-Dawley rats (10/dose) were administered orange peel oil, sweet via gavage at 0, 375, 750 or 1500 mg/kg-bw/day for 7 days prior to and through mating, gestation, delivery and four days of lactation. Treated animals had decreased weight gains, and significantly decreased absolute and relative food consumption at 750 and 1500 mg/kg-bw/day during the seven day pre-mating period. A significant number of stillbirths and pup deaths were observed at 1500 mg/kg-bw/day. No other treatment-related effects on offspring were observed.
NOAEL (maternal toxicity) = 1500 mg/kg-bw/day (based on no adverse effects at the highest dose tested)
LOAEL (developmental toxicity) = 1500 mg/kg-bw/day (based on pup mortality)
NOAEL (developmental toxicity) = 750 mg/kg-bw/day

Genetic Toxicity – Gene Mutation

In vitro

d-Limonene (CASRN 5989-27-5)
(1) In several reverse-mutation assays, *Salmonella typhimurium* strains (TA98, TA100, TA102, TA1535, TA1537 or TA1538) were exposed to *d*-limonene at concentrations up to 150 mg/plate in the presence and absence of metabolic activation. Positive controls responded appropriately. *d*-Limonene did not increase the number or revertants with or without metabolic activation.
***d*-Limonene was not mutagenic in these assays.**

(2) In two forward mutation assays, mouse lymphoma L5178Y TK+/- cells were exposed to *d*-limonene at concentrations up to 100 µg/mL in the presence and absence of metabolic activation. No increase in mutations was observed at any concentration tested, with or without activation.
***d*-Limonene was not mutagenic in these assays**

Orange peel oil, sweet (Citrus sinensis (L.) Osbeck) (CASRN 8008-57-9)
(1) In a reverse-mutation assay, *Salmonella typhimurium* strains TA98, TA100, TA1535, TA1537 or TA1538 were exposed to orange peel oil, sweet at 5000 µg/plate in the presence and absence of metabolic activation. No information on the use of positive controls and cytotoxic concentrations was provided. No evidence of mutagenic activity was reported at any concentration tested, with or without metabolic activation.
Orange peel oil, sweet (Citrus sinensis (L.) Osbeck) was not mutagenic in this assay.

(2) In a forward mutation assay, mouse lymphoma L5178Y TK+/- cells were exposed to orange peel oil at concentrations ranging from 40 to 200 µg/mL in the presence and absence of metabolic activation. Increases in mutation were observed with and without metabolic activation. Cytotoxicity (concentration not stated) was also observed.
Orange peel oil, sweet (Citrus sinensis (L.) Osbeck) was mutagenic in this assay.

Genetic Toxicity - Chromosomal Aberrations

In vitro

d-Limonene (CASRN 5989-27-5)
Chinese hamster ovary cells were exposed to *d*-limonene at concentrations of 50 – 500 µg/mL in the presence and absence of metabolic activation. A negative solvent control was used. No treatment-related increase in number of aberrant cells was observed.
***d*-Limonene did not induce chromosomal aberrations in this assay.**

Myrcene (CASRN 123-35-3)
Human lymphocytes were exposed to *beta*-myrcene dissolved in ethanol at concentrations up to 1000 µg/mL, with metabolic activation for a period of 2 hours and without metabolic activation for a period of 24 hours. No cytotoxicity was observed. No treatment-related increase in number of aberrant cells was observed.
***beta*-Myrcene did not induce chromosomal aberrations in this assay.**

Genetic Toxicity – In vivo

d-Limonene (CASRN 5989-27-5)
In a spot test assay, mouse embryos were exposed to *d*-limonene at 215 mg/kg-bw on days 10 and 11 post conception by intra-peritoneal injection. No treatment-related increase in the frequency of genetically relevant spots was observed.
***d*-Limonene did not induce spot formation in this assay.**

Myrcene (CASRN 123-35-3)
(1) In a cytogenetic bone marrow assay, male and female B6C3F1mice were administered *beta*-myrcene via gavage at 0, 1000 or 2000 mg/kg-bw/day for 90 days. There were no statistically significant increases in the frequency of micronuclei.
***beta*-Myrcene did not induce micronuclei in this assay.**

(2) In a cytogenetic bone marrow assay, Wistar rats (2 or 4/ sex) were administered beta-myrcene via gavage at 100, 500 or 1000 mg/kg-bw for 24 and 48 hours. The controls responded appropriately. The mitotic index and the frequency of chromosome aberrations were evaluated. A dose related increase in the mitotic index was observed 24-h after treatment. No significant increases in chromosomal aberrations were observed.
***beta*-Myrcene did not induce chromosomal aberrations in this assay.**

Genetic Toxicity – Other Effects

d-Limonene (CASRN 5989-27-5)
In an *in vitro* sister chromatid exchange (SCE) assay, Chinese hamster ovary cells were exposed to *d*-limonene at concentrations ranging from 16.2 to 162 µg/mL in the presence and absence of metabolic activation. There was no increase in the frequency of sister chromatid exchange with or without metabolic activation.
***d*-Limonene did not induce sister chromatid exchange in these assays.**

Myrcene (CASRN 123-35-3)
(1) In an *in vitro* SCE assay, human lymphocytes were exposed to *beta*-myrcene at concentrations up to 1000 µg/mL for a period of 24 hrs (without metabolic activation) or 2 hrs (with metabolic activation). There was no increase in the frequency of sister chromatid exchange with or without metabolic activation.
***beta*-Myrcene did not induce sister chromatid exchange in this assay.**

(2) In another *in vitro* SCE assay, Chinese hamster ovary V79 (with and without metabolic activation) and hepatic tumor cells (HTC) were exposed to *beta*-myrcene at concentrations up to 500 µg/mL, for 3 and 20 hrs, respectively. There was no increase in the frequency of sister chromatid exchange with or without metabolic activation.
***beta*-Myrcene did not induce sister chromatid exchange in this assay.**

Additional Information

Eye Irritation
d-Limonene (CASRN 5989-27-5)
d-Limonene is an eye irritant in rabbits. No study details were provided (http://www.inchem.org/documents/cicads/cicads/cicad05.htm#SectionNumber:8.2).
***d*-Limonene was an eye irritant in this study.**

Skin Irritation
d-Limonene (CASRN 5989-27-5)
(1) Rabbits were treated on the skin with *d*-limonene and the effects graded according to OECD TG 404. *d*-Limonene was a skin irritant in this test (http://www.inchem.org/documents/cicads/cicads/cicad05.htm#SectionNumber:8.2).
***d*-Limonene was a skin irritant in this study.**

(2) In a human patch test study with *d*-limonene, the sensitivity of four patch testing systems was evaluated. Skin irritation was assessed before application, immediately after application and at 1, 24, 48 and 72 hours after the removal of the patch, using a scoring system similar to OECD TG 404. There was evidence of sensory effects and urticarial responses on removal of the patches. Irritation persisted for up to 72 hours in many volunteers (www.inchem.org/documents/cicads/cicads/cicad05.htm).
***d*-Limonene was a skin irritant in this study.**

Skin Sensitization
d-Limonene (CASRN 5989-27-5)
(1) Limonene (unspecified form and unknown purity) was tested in four different sensitization assays with guinea-pigs (open epicutaneous test, maximization test, draize's test and a test with Freund's complete adjuvant). It was sensitizing in all assays except Draize's test (www.inchem.org/documents/cicads/cicads/cicad05.htm).
***d*-Limonene was a skin sensitizer in this study.**

(2) In a study in mice, *d*-limonene did not induce skin sensitization. No study details were provided (www.inchem.org/documents/cicads/cicads/cicad05.htm).

***d*-Limonene was not a skin sensitizer in this study.**

(3) In the human patch test described in skin irritation section above, the sensitivity of four patch testing systems (Finn Chamber, Hill Top patch, Van der Bend chamber and Webril patch) was evaluated in human volunteers. Perfume grade *d*-limonene reacted strongly in all types of patches within 10 to 15 minutes of exposure (www.inchem.org/documents/cicads/cicads/cicad05.htm).
***d*-Limonene was a skin sensitizer in this study.**

(4) In a Kligman Maximization test, human volunteers (25) were exposed to *d*-limonene on a skin site pre-treated for 24 hours with 5% aqueous sodium laurel sulfate (SLS). The test-substance exposure lasted 48 hours under occlusion. The induction phase with five exposures was 15 days. Following a 10-day rest period, a new skin site was washed with 10% SLS for 1 hour after which there was a challenge with an 8% solution of the test substance. A sensitization reaction with *d*-limonene was not observed in this assay (www.inchem.org/documents/cicads/cicads/cicad05.htm).
***d*-Limonene was not a skin sensitizer in this study.**

Carcinogenicity

d-Limonene (CASRN 5989-27-5)
(1) In a two-year NTP study, F344/N rats (50/sex/dose) were administered *d*-limonene via gavage at 0, 75 or 175 mg/kg-bw/day) (males) and 300 or 600 mg/kg-bw/day (females) daily for 5 day/week, for 103 weeks. Survival of male control rats, and female rats in the high dose group, was significantly reduced at 81 and 39 weeks, respectively. In male rats, the kidney was the target organ. The nonneoplastic lesions included exacerbation of the age-related nephropathy, linear deposits of mineral in the renal medulla and papilla, and focal hyperplasia of the transitional epithelium overlying the renal papilla, which is characteristic of the hyaline droplet nephropathy associated with $alpha_{2\mu}$-globulin formation. Increased incidences of tubular cell adenomas and adenocarcinomas of the kidney occurred in dosed male rats. However, the kidney tumors in male rats associated with $alpha_{2\mu}$-globulin formation are not considered relevant to humans (US EPA, 1991). There was no evidence of carcinogenicity in female rats.
***d*-Limonene did not induce tumors of relevance to humans in this study.**

(2) In a NTP study, B6C3F1 mice (50/sex/dose) were administered *d*-limonene via gavage at 0, 250 or 500 mg/kg-bw/day (males) and 0, 500 or 1000 mg/kg-bw/day (females), respectively. There was no evidence of carcinogenicity in either sex.
***d*-Limonene did not induce tumors in this study.**

Immunotoxicity

Orange peel oil, sweet (Citrus sinensis (L.) Osbeck) (CASRN 8008-57-9)
In a plaque-forming cell assay, female B6C3F1 mice were administered orange peel oil via at gavage 0, 625, 1250 or 2500 mg/kg bw daily for 5 days to determine effects on humoral and cell-mediated immune responses. A host resistance assay (Listeria monocytogenes bacterial challenge) was used to assess cell-mediated immunity while the antibody plaque forming cell

response to sheep erythrocytes was used to measure humoral immunity. Body weights, lymphoid organ weights and spleen cellularity were also evaluated. In the absence of modulation of the PFC response, these effects were not considered as indicators of immunotoxicity. Orange oil had no effects on cell-mediated or humoral immune response at any dose level tested.
NOAEL = 2500 mg/kg-bw/day (based on no effects at the highest dose tested)

Conclusion: The acute toxicity of the monoterpene hydrocarbons category members is low via the oral (rats and mice) and dermal (rabbits) routes of exposure. CASRN 5989-27-5 is an eye irritant (rabbits), skin irritant (rabbits and humans) and skin sensitizer (guinea-pigs and humans). Repeated oral exposures in rats and mice with CASRN 123-35-3 showed hematological effects as well as splenic atrophy in rats, and histopathological changes in the liver of mice, at 1000 mg/kg-bw/day. The NOAEL was 500 mg/kg-bw/day in rats and mice. Repeated oral exposures in rats and mice with CASRN 5989-27-5 showed decreasing body weights followed by mortality at 2400 and 2000 mg/kg-bw/day, respectively. In male rats, nephropathy associated with alpha2u-globulin formation was the primary systemic effect. The NOAEL was 1200 mg/kg/bw in rats and 1000 mg/kg-bw/day in mice. Repeated oral exposures in rats with CASRN 8008-57-9 showed clinical chemistry effects and lesions in the stomach at 1500 mg/kg-bw/day. In male rats, nephropathy associated with alpha2u-globulin formation was the primary systemic effect. The NOAEL was 600 mg/kg-bw/day. CASRN 8008-57-9 did not elicit an immune response *in vitro* up to 2500 mg/kg-bw/day. No studies that specifically address the reproductive toxicity endpoint were available for CASRN 5989-27-5; however, the evaluation of the reproductive organs in the 13-week repeated-dose studies showed no treatment-related effects. In a modified oral developmental toxicity study in rats with CASRN 123-35-3, effects on the fertility of female off-spring were observed at 1000 mg/kg-bw/day. The NOAEL for reproductive toxicity was 500 mg/kg-bw/day. In the same study, maternal body weights were decreased and perinatal mortality, delayed postnatal development and decreased pup body weights were observed at 1000 and 500 mg/kg-bw/day, respectively. The NOAEL for maternal and developmental toxicity was 500 and 250 mg/kg-bw/day, respectively. In an oral combined reproductive/developmental toxicity study in rats with CASRN 123-35-3, no adverse effects on reproduction were observed. The NOAEL for reproductive toxicity was 500 mg/kg-bw/day. In the same study, skeletal abnormalities were observed at 500 mg/kg-bw/day and the NOAEL for developmental toxicity was 300 mg/kg-bw/day; the NOAEL for maternal toxicity was 500 mg/kg-bw/day. In an oral combined reproductive/developmental toxicity screening test with CASRN 8008-57-9 in rats, still births and pup mortality were observed at 1500 mg/kg-bw/day. The NOAEL for reproductive and developmental toxicity was 750 mg/kg-bw/day. The NOAEL for maternal toxicity was 1500 mg/kg-bw/day. Prenatal oral developmental toxicity studies with CASRN 5989-27-5 showed decreased fetal body weights and delayed ossification in rats and mice at 2869 and 2363 mg/kg-bw/day, respectively. Mortality was observed in the adult rats and mice at 2869 and 2363 mg/kg-bw/day, respectively. The NOAEL for maternal and developmental toxicity was 591 mg/kg-bw/day for both species. In rabbits, maternal body weight gain was reduced but no developmental toxicity was observed at 500 mg/kg-bw/day. The NOAEL for maternal and developmental toxicity was 250 and 1000 mg/kg-bw/day, respectively. CASRN 5989-27-5 and CASRN 8008-57-9 did not induce gene mutations *in vitro*. CASRN 5989-27-5 and CASRN 123-35-3 did not induce chromosomal aberrations *in vitro* or *in vivo.*

CASRN 5989-27-5 induced tumors in male rats via a mode of action not considered relevant to humans, and did not induce tumors in female rats and mice.

Table 4: Summary of Human Health Data

Endpoints	*d*-Limonene (CASRN 5989-27-5)	*dl*-Limonene (CASRN 138-86-3)	Terpinolene (CASRN 586-62-9)	Myrcene (CASRN 123-35-3)	Dihydromyrcene (CASRN 2436-90-0)	Hydrocarbons, terpene processing by-products (CASRN 68956-56-9)	Orange peel oil, sweet (Citrus sinensis (L.) Osbeck) (CASRN 8008-57-9)	Terpenes and terpenoids, sweet orange oil (CASRN 68647-72-3)	Terpenes and terpenoids, limonene fraction (CASRN 65996-98-7)	Terpenes and terpenoids, turpentine oil, limonene fraction (CASRN 65996-98-7)
Acute Oral toxicity LD_{50} (mg/kg-bw)	**4400 (m)** **5200 (f)**	No Data 4400 (m) 5200 (f) (RA)	**3800**	**5060**	**> 5000(m)**	No Data 4400 (m) 5200 (f) (RA)	**> 5000(m)**	No Data >5000 (RA)	No Data 4400 (m) 5200 (f) (RA)	No Data 4400 (m) 5200 (f) (RA)
Acute Dermal toxicity LD_{50} (mg/kg-bw)	**> 5000**	No Data > 5000 (RA)	**> 4330**	**> 5000**	**> 5000**	No Data > 5000 (RA)	**> 5000**	No Data >5000 (RA)	No Data > 5000 (RA)	No Data > 5000 (RA)
Oral Repeated - Dose Toxicity NOAEL/ LOAEL (mg/kg-bw/day)	**NOAEL = 1200** **LOAEL = 2400** **NOAEL = 1000** **LOAEL = 2000**	No Data NOAEL = 1200 LOAEL = 2400 (RA) NOAEL = 1000 LOAEL = 2000 (RA)	No Data NOAEL = 1200 LOAEL = 2400 (RA) NOAEL = 1000 LOAEL = 2000 (RA)	**NOAEL = 500** **LOAEL = 1000**	No Data NOAEL = 500 LOAEL = 1000	No Data NOAEL = 1200 LOAEL = 2400 (RA) NOAEL = 1000 LOAEL = 2000 (RA)	**NOAEL = 600** **LOAEL = 1500**	No Data NOAEL = 600 LOAEL = 1500 (RA)	No Data NOAEL = 1200 LOAEL = 2400 (RA) NOAEL = 1000 LOAEL = 2000 (RA)	No Data NOAEL = 1200 LOAEL = 2400 (RA) NOAEL = 1000 LOAEL = 2000 (RA)
Reproductive Toxicity NOAEL/ LOAEL (mg/kg-bw/day)	No effects were seen following evaluation of reproductive organs in 13-week oral repeated-dose toxicity studies in rats and mice.	No Data No effects were seen following evaluation of reproductive organs in 13-week oral repeated-dose toxicity studies in rats and mice. (RA)		**NOAEL = 500** **(hdt)** **NOAEL(f) = 500** **LOAEL(f) = 1000**	No Data NOAEL = 500 (RA) No Data NOAEL(f) = 500 LOAEL(f) = 1000 (RA)	No Data No effects were seen following evaluation of reproductive organs in 13-week oral repeated-dose toxicity studies in rats and mice. (RA)	**NOAEL = 750** **LOAEL = 1500**	No Data NOAEL = 750 LOAEL = 1500 (RA)	No Data No effects were seen following evaluation of reproductive organs in 13-week oral repeated-dose toxicity studies in rats and mice. (RA)	

Table 4: Summary of Human Health Data

Endpoints	*d*-Limonene (CASRN 5989-27-5)	*dl*-Limonene (CASRN 138-86-3)	Terpinolene (CASRN 586-62-9)	Myrcene (CASRN 123-35-3)	Dihydromyrcene (CASRN 2436-90-0)	Hydrocarbons, terpene processing by-products (CASRN 68956-56-9)	Orange peel oil, sweet (Citrus sinensis (L.) Osbeck) (CASRN 8008-57-9)	Terpenes and terpenoids, sweet orange oil (CASRN 68647-72-3)	Terpenes and terpenoids, limonene fraction (CASRN 65996-98-7)	Terpenes and terpenoids, turpentine oil, limonene fraction (CASRN 65996-98-7)
Developmental Toxicity NOAEL/ LOAEL (mg/kg-bw/day)										
Maternal Toxicity	**(rat, mice) NOAEL = 591 LOAEL = 2869**	No Data (rat, mice) NOAEL = 591 LOAEL = 2869	No Data (rat, mice) NOAEL = 591 LOAEL = 2869	**(rat) NOAEL = 500 LOAEL = 1000**	No Data (rat) NOAEL = 500 LOAEL = 1000	No Data (rat, mice) NOAEL = 591 LOAEL = 2869	**NOAEL = 1500 (hdt)**	No Data NOAEL = 1500 (RA)	No Data (rat, mice) NOAEL = 591 LOAEL = 2869	No Data (rat, mice) NOAEL = 591 LOAEL = 2869
Developmental Toxicity	**NOAEL = 591 LOAEL = 2869**	NOAEL = 591 LOAEL = 2869 (RA)	NOAEL = 591 LOAEL = 2869 (RA)	**NOAEL = 250 LOAEL =500**	NOAEL = 250 LOAEL =500 (RA)	NOAEL = 591 LOAEL = 2869 (RA)	**NOAEL = 750 LOAEL =1500**	No Data NOAEL = 750 LOAEL = 1500 (RA)	NOAEL = 591 LOAEL = 2869 (RA)	NOAEL = 591 LOAEL = 2869 (RA)
Maternal Toxicity	**(rabbit) NOAEL = 250 LOAEL = 500**	No Data (rabbit) NOAEL = 250 LOAEL = 500	No Data (rabbit) NOAEL = 250 LOAEL = 500	**(rat) NOAEL = 500 LOAEL = 1200**	No Data (rat) NOAEL = 500 LOAEL = 1200	No Data (rabbit) NOAEL = 250 LOAEL = 500			No Data (rabbit) NOAEL = 250 LOAEL = 500	No Data (rabbit) NOAEL = 250 LOAEL = 500
Developmental Toxicity	**NOAEL =1000 (hdt)**	NOAEL =1000 (RA)	NOAEL =1000 (RA)	**NOAEL = 500 LOAEL = 1200**	NOAEL = 500 LOAEL = 1200 (RA)	NOAEL =1000 (RA)			NOAEL =1000 (RA)	NOAEL =1000 (RA)

Table 4: Summary of Human Health Data

Endpoints	*d*-Limonene (CASRN 5989-27-5)	*dl*-Limonene (CASRN 138-86-3)	Terpinolene (CASRN 586-62-9)	Myrcene (CASRN 123-35-3)	Dihydromyrcene (CASRN 2436-90-0)	Hydrocarbons, terpene processing by-products (CASRN 68956-56-9)	Orange peel oil, sweet (Citrus sinensis (L.) Osbeck) (CASRN 8008-57-9)	Terpenes and terpenoids, sweet orange oil (CASRN 68647-72-3)	Terpenes and terpenoids, limonene fraction (CASRN 65996-98-7)	Terpenes and terpenoids, turpentine oil, limonene fraction (CASRN 65996-98-7)
Maternal Toxicity **Developmental Toxicity**				**NOAEL = 500 (hdt)** **NOAEL = 300** **LOAEL = 500**	No Data NOAEL = 500 NOAEL = 300 LOAEL = 500 (RA)				No Data NOAEL = 500 NOAEL = 300 LOAEL = 500 (RA)	No Data NOAEL = 500 NOAEL = 300 LOAEL = 500 (RA)
Genetic Toxicicty – Gene Mutation *In Vitro*	**Negative**	No Data Negative (RA)	No Data Negative (RA)	No Data Negative (RA)	No Data Negative (RA)	No Data Negative (RA)	**Negative**	No Data Negative (RA)	No Data Negative (RA)	No Data Negative (RA)
Genetic Toxicity – Chromosomal Aberrations *In vitro*	**Negative**	No Data Negative (RA)	No Data Negative (RA)	**Negative**	No Data Negative (RA)	No Data Negative (RA)	No Data Negative (RA)	No Data Negative (RA)	No Data Negative (RA)	No Data Negative (RA)
Genetic Toxicicty – Gene Mutation *In Vivo*	**Negative**	**_	**_	**Negative**	**_	**_	**_	**_	**_	**_
Genetic Toxicity – Other effects Sister chromatid exchange	**Negative**	**_	**_	**Negative**	**_	**_	**_	**_	**_	**_
Eye irritant	**Positive**	**_	**_	**_	**_	**_	**_	**_	**_	**_
Skin irritant	**Positive**	**_	**_	**_	**_	**_	**_	**_	**_	**_
Skin sensitizer	**Positive**	**_	**_	**_	**_	**_	**_	**_	**_	**_
Carcinogenicity	**Negative**	**_	**_	**_	**_	**_	**_	**_	**_	**_

Measured data in bold text; (RA) = read across; NE = not established; (m) = male; (f) = female; hdt = highest dose tested; **_ - endpoint not addressed for this chemical

4 Hazards to the Environment

A summary of aquatic toxicity data submitted for SIDS endpoints is provided in Table 5. The table also indicates where data for tested category members are read across (RA) to untested members of the category.

Acute Toxicity to Fish

d-Limonene (CASRN 5989-27-5)
Fathead minnows (*Pimephales promelas*) were exposed to *d*-limonene at measured concentrations (<0.05, 0.25, 0.56, 0.96, 1.38, and 1.89 mg/L) under flow-through conditions for 96 hours (Geiger et al., 1990).
96-h LC_{50} = 0.7 mg/L

Terpinolene (CASRN 586-62-9)
Fathead minnows (*Pimephales promelas*) were exposed to terpinolene at measured concentrations (<0.03, 0.27, 0.65, 0.90, 1.36, and 1.67 mg/L) under flow-through conditions for 96 hours (Geiger et al., 1990).
96-h LC_{50} = 1.21 mg/L

Acute Toxicity to Aquatic Invertebrates

d-Limonene (CASRN 5989-27-5)
Daphnia magna were exposed to *d*-limonene at measured concentrations (<50, 287, 619, 932, 1190, and 1630 mg/L) under flow through conditions for 48 hours.
48-h EC_{50} = 0.421 mg/L

Terpinolene (CASRN 586-62-9)
Daphnia magna were exposed to terpinolene at measured concentrations (<30, 910, 1960, and 2930 mg/L) under flow through conditions for 48 hours.
48-h EC_{50} = 1.38 mg/L

Toxicity to Aquatic Plants

d-Limonene (CASRN 5989-27-5)
Green algae (*Selenastrum capricornutum*) were exposed to *d*-limonene under static conditions for 96 hours.
48-h EC_{50} > 1.81 mg/L

Terpinolene (CASRN 586-62-9)
Green algae (*Selenastrum capricornutum*) were exposed to terpinolene under static conditions for 96 hours.
48-h EC_{50} > 3.38 mg/L

Chronic Toxicity to Aquatic Invertebrates

Dihydromyrcene (CASRN 2436-90-0)
Given the log K_{ow} range of 4.8 to 5.3 for this category, EPA recommended the chronic daphnia 21- day test for the most hydrophobic chemical, dihydromyrcene.

Data Gap

Conclusion: The acute hazard to fish is based on the toxicity values for CASRN 586-62-9 of 1.21 mg/L and CASRN 5989-27-5 of 0.7 mg/L. The acute hazard to aquatic invertebrates is based on the toxicity values for CASRN 586-62-9 of 1.38 mg/L and CASRN 5989-27-5 of 0.421 mg/L. The acute hazard to aquatic plants is based on the toxicity values for CASRN 586-62-9 of >3.38 mg/L and CASRN 5989-27-5 of >1.81 mg/L.

The chronic toxicity to aquatic invertebrates for CASRN 2436-90-0 remains as a data gap under the HPV Challenge Program.

Table 5. Summary of Environmental Effects – Aquatic Toxicity Data

Endpoints	*d*-Limonene (CASRN 5989-27-5)	*dl*-Limonene (CASRN 138-86-3)	Terpinolene (CASRN 586-62-9)	Myrcene (CASRN 123-35-3)	Dihydromyrcene (CASRN 2436-90-0)	Hydrocarbons, terpene processing by-products (CASRN 68956-56-9)	Orange peel oil, sweet (Citrus sinensis (L.) Osbeck) (CASRN 8008-57-9)	Terpenes and terpenoids, sweet orange oil (CASRN 68647-72-3)	Terpenes and terpenoids, limonene fraction (CASRN 65996-98-7)	Terpenes and terpenoids, turpentine oil, limonene fraction (CASRN 65996-99-8)
Fish 96-h LC_{50} (mg/L)	**0.7**	No Data 0.7 (RA)	**1.21**	No Data 0.7 (RA)	No Data 0.7 (RA)	No Data 0.7 (RA)	No Data 0.7 (RA)	No Data 0.7 (RA)	No Data 0.7 (RA)	No Data 0.7 (RA)
Aquatic Invertebrates 48-h EC_{50} (mg/L)	**0.421**	No Data 0.421 (RA)	**1.38**	No Data 0.421 (RA)	No Data 0.421 (RA)	No Data 0.421 (RA)	No Data 0.421 (RA)	No Data 0.421 (RA)	No Data 0.421 (RA)	No Data 0.421 (RA)
Aquatic Plants 96-h EC_{50} (mg/L)	**>1.81**	No Data >1.81 (RA)	**>3.38**	No Data >1.81 (RA)	No Data >1.81 (RA)	No Data >1.81 (RA)	No Data >1.81 (RA)	No Data >1.81 (RA)	No Data >1.81 (RA)	No Data >1.81 (RA)
Aquatic Invertebrates 21-day EC_{50} (mg/L)	Data Gap									

Measured data (i.e. derived from testing) are in bold; (e) = estimated data (i.e., derived from modeling); (RA) = read across

5 References

Geiger, D.L., L.T. Brooke, and D.J. Call. (1990) Acute Toxicities of Organic Chemicals to Fathead Minnows (*Pimephales promelas*), Volume 5. Ctr.for Lake Superior Environ.Stud., Univ.of Wisconsin-Superior, Superior, WI :332 p.

US EPA (1991) Alpha2u-Globulin: Association with Chemically Induced Renal Toxicity and Neoplasia in the Rat, EPA/625/3-91/019F.