New York State Integrated Pest Management Program | Cornell Cooperative Extension

Geranium Oil Profile

Active Ingredient Eligible for Minimum Risk Pesticide Use

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Substance Name: Geranium oil

Active Components: Citronellol, geraniol, linalool

CAS Registry #: 8000-46-2

U.S. EPA PC Code: 597500

CA DPR Chem Code: 1887

Other Names: Oil of geranium; Oil of pelargonium geranium; oil of rose geranium; geranium absolute; geranium concrete; African geranium oil; grasse; pelargonium oil; Zradvetz oil

Other Codes: BRN: FEMA: 2508; Caswell #618B; EINECS 616-774-3; ESIS (EC): 290-140-0; MDL: MFCD00240716; Merck Index: 6841; UNII: 3K0J1S7QGC *(P. graveolens),* 5Q1I94P4WG *(G. maculatum)*

Summary: Geranium oil is an essential oil primarily derived from Pelargonium graveolens, but may be extracted from other plants in the genera Geranium and Pelargonium. The oil is a mixture of various aromatics and esters. The primary use is as a fragrance and flavoring agent, but it is also used as an insecticide, fungicide, herbicide, rodenticide and antimicrobial. In reviewing the health and safety incidents related to geranium oil, none were related to its pesticidal uses.

Pesticidal Uses: Antimicrobial, insecticide, fungicide, herbicide, rodenticide.

Formulations and Combinations: Geranium oil may be formulated with other essential oils, including cinnamon oil, citronella oil, clove oil, mint oil, pennyroyal oil, as well as various vegetable oils, including corn, cottonseed, linseed or soy oils. Citric acid is sometimes used to adjust geranium oil's pH.

Basic Manufacturers: A. Fakhry & Co.; Albert Vielle; Azelis; Biosys Plant Extracts, Inc.; Clive Teubes, Ltd.; Fridal; Guangzhou Baihua Flavours And Fragrances; Hashem Brothers; Kato Aromatica; Machalico; Silverline Chemicals; Xian Sonwu Biotech Co., Ltd.; International Flavors and Fragrances; Fermenich; Givaudan.

Safety Overview: Geranium oil was one of the 24 flower and vegetable derived essential oils reviewed for re-registration (US EPA 1993). Some products that contained geranium oil were registered as pesti-

cides by the US EPA prior to the creation of the 25(b) list. According to the Pesticide Product Label System, there have been no US EPA registered pesticides with geranium oil as an active ingredient since 1998 (US EPA 2017). The manufacturers of geranium oil did not submit data for its continued registration (US EPA 1993). The EPA subsequently determined that geranium oil met the criteria for eligibility to be exempt from registration (US EPA 1996).

Background

Geranium oil is extracted from plants of the *Pelargonium* species, principally *Pelargonium graveolens* (L.), commonly known as the rose geranium. Other sources include *P. odoratissiumum* Ait., *P. capitatum* Ait., *P. crispum* L., *P. radula* (Cav.), *Geranium maculatum* (L.) (Algerian geranium oil) and *Geranium macrorrhizum* (L.) (Bulgarian geranium oil). Geranium oil is not extracted from palmarosa (*Cymbopogon martini*), which is a major commercial source of geraniol (Khan and Abourashed 2010). Extraction is principally performed by steam distillation (Khan and Abourashed 2010). Yields typically range between 0.08 and 0.4% (Khan and Abourashed 2010; Wollmann et al. 1973). Supercritical fluid extraction (SFE) with carbon dioxide offers a more efficient and complete extraction process with greater recovery of volatile aromatics higher quality and lower energy costs than steam distillation or hexane extraction (Machado et al. 1993; Gomes, Mata, and Rodrigues 2007). Experimental results include yields of geranium oil from *Pelargonium graveolens* in excess of 2.5%, with significantly higher levels of citronellyl esters (Peterson et al. 2006). However, SFE requires specialized equipment designed to handle the high pressures needed for SFE—in excess of 30 MPa.

Egypt is the world's largest producer of geranium oil, followed by China (Market News Service 2014). True 'Bourbon' geranium oil is produced on Reunion (formerly Bourbon) Island, near the Island of Madagascar (Rose 1999). Almost all of the geranium oil from Reunion is extracted in France (Centre for the Promotion of Imports 2014). Egypt surpassed Reunion as the leading source in the 1960s, but has seen its market share slip to China in recent years (Fakhry 2004). Madagascar's production is relatively small, but commands a stable premium price over the world market (Market News Service 2014, 2011). Other countries and regions that produce geranium oil include Algeria, Morocco, Spain, France, the UK, Rwanda and the Republic of South Africa (Rose 1999; Khan and Abourashed 2010; Market News Service 2014).

The main use of geranium oil is as a fragrance in perfumes and cosmetics, including soaps, creams and lotions. Geranium oil is used extensively as a flavoring agent in food and beverages. This review mainly concerns the naturally occurring essential oils extracted by steam distillation of *P. graveolens* unless otherwise specified.

Chemical and Physical Properties

The three major types of geranium oil (Algerian, Bourbon and Moroccan) are mainly composed of a mix of alcohols, esters, aldehydes, and ketones. Alcohol content is 60-70%, with the monoterpenoid alcohols l-citronellol and geraniol the most abundant, with lesser amounts of linalool and phenethyl alcohol (Merck 2015). These terpenoids are believed to be the main active constituents. Geranium oil's ester content is 20-30%, and is comprised mostly of geranyl and citronellyl esters. Other esters found in geranium oil include geranyl acetate, geranyl tiglate, citronellyl formate, and citronellyl acetate. The remaining com-

ponents are carotenoids and other hydrocarbons, such as formates and tiglates. A number of aromatic alcohols found in geranium oil are classified as terpenoids (Sell 2000). Aldehydes and ketones include l-isomenthone, citronellal, citral, decyl aldehyde (Khan and Abourashed 2010).

The other properties characteristics of geranium oil are reported in Table 1.

Table 1

Physical and Chemical Properties of Geranium Oil

Property	Characteristic/Value	Source
Molecular Formula:	N/A	
Molecular Weight:	N/A	
Percent Composition:	Alcohols (60-70%): Citranellol, geraniol, linalool and phenethyl alcohol. Esters (20-30%): geranyl and citronellyl esters.	(Radulović, et al. 2012)
Physical state at 25°C/1 Atm.	Liquid	(Sigma-Aldrich 2014)
Color	Colorless to light green-brown translucent oil	(Merck 2015)
Odor	Sweet, rosaceous, minty. Egyptian is less herby and woodier and more pronounced tobacco note than China/Bourbon oil.	(Azelis 2013)
Density/Specific Gravity	d^{15}_{15} = 0.894-0.905.	(Merck 2015)
Melting point	NA	
Boiling point	197°C (387°F)	(Sigma-Aldrich 2014)
Solubility	Slightly soluble in water; Soluble in 10% EtOH (30 g/100ml); Very soluble in $CHCl_3$ & Et_2O	(Merck 2015)
Vapor pressure	0.2 mm Hg @ 20° C	(Vigon International 2011)
pH	Not found	
Octonol/Water (K_{ow}) coefficient	5.79	(EPI 2012)
Viscosity	Not found	
Miscibility	Not miscible or difficult to mix.	(Azelis 2013)
Flammability	Flash point: 64°C (closed cup)	(Sigma-Aldrich 2014)
Storage stability	Normally stable under proper conditions	(Vigon International 2011)
Corrosion characteristics	Not found	
Air half life	0.238 hr	(EPI 2012)
Soil half life	720 hrs	(EPI 2012)
Water half life	360 hrs	(EPI 2012)
Persistence	402 hrs	(EPI 2012)

Human Health Information

Acute Toxicity

The acute toxicity of geranium oil is summarized in Table 2.

Table 2

Acute Toxicity of Geranium Oil

Study	Results	Source
Background	Not found	
Acute oral toxicity	>5,000 mg/kg (rat)	(Vigon 2011)
Acute dermal toxicity	2,500 mg/kg (rabbit)	(Vigon 2011)
Acute inhalation	Not found	
Acute eye irritation	Not found	
Acute dermal irritation	Moderately irritating (rabbit) Negative (mice)	(Vigon 2011)
Skin sensitization	Negative at 10%	(Vigon 2011)

Dermal toxicity tests show mixed results. A global study found that about 8.4% of 178 volunteers selected from patients with a history of sensitization in England, Ireland, Japan, Sweden, Switzerland, and the US reacted to rose geranium oil in petrolatum administered by a patch test (Larsen et al. 2001). Three out of 200 subjects (1.5%) reacted to geranium oil in a balsamic patch (Rudazki et al. 1976). Another study showed that 10% geranium oil in petrolatum produced no irritation in human subjects after 48 hours (Lis-Balchin 2002). However, contact dermatitis has been reported for fragrances and cosmetics that contain geranium oil as an ingredient (Nardelli et al. 2009), though other ingredients in the products may be responsible for the allergic reaction.

Sub-chronic Toxicity

No studies regarding geranium oil's sub-chronic toxicity when used as a pesticide were found. Geranium oil has known neurological effects, and is patented for the diagnosis and treatment of neuropathic pain (Frome 1993). Screening on rat models showed that geranium oil inhibits enzymatic activity and the metabolism of fats and simple sugars, offering a potential strategy for the management of obesity (Afifi et al. 2014).

Geranium oil has been shown to have a relaxing effect when inhaled by human subjects (Morris et al. 1995). However, inhalation of high doses of geraniol showed symptoms of depression in rats (Jenner et al. 1964; Lapczynski et al. 2008). An allergen declaration is required for cosmetic products that contain geranium oil and are imported into the European Union (Centre for the Promotion of Imports 2014).

Chronic Toxicity

Table 3

Chronic Toxicity of Geranium Oil

Study	Results	Source
Chronic toxicity	Not found	
Carcinogenicity	Negative (71% geranyl acetate; 29% citronellyl acetate)	(HSDB 2015)
Combined chronic toxicity & carcinogenicity	Not found	

Chronic toxicity of geranium oil is reported in Table 3. As with other antimicrobials, mutation tests on bacterial models require special consideration. Geranium oil derived from *Pelargonium capitatum* tested negative for mutagenicity in *Salmonella typharium* (Ames test) at the highest ineffective dose for acute toxicity to the organism (Guerrini et al. 2011). In other words, geranium oil killed the test organisms before any mutations could be observed.

Geranium oil is not identified as a carcinogen by the International Agency for Research on Cancer (IARC 2014). It is not on the California Proposition 65 list of known carcinogens (Cal-EPA OEHHA 2016)and does not appear on the Toxics Release Inventory (TRI) Basis of OSHA Carcinogens (US EPA 2015a).

Human Health Incidents

No human health related pesticide incidents were reported for geranium oil in the US between April 1, 1996 and March 30, 2016 (NPIC 2016).

Environmental Effects Information

Effects on Non-target Organisms

No studies of the effects of geranium oil on non-target organisms were found.

Environmental Fate, Ecological Exposure, and Environmental Expression

No studies were found on geranium oil's environmental fate, ecological exposure, environmental expression, or other environmental impacts.

Environmental Incidents

Three environmental incidents involving geranium oil as an active ingredient in a pesticide were reported between April 1, 1996 and March 30, 2016 (NPIC 2016). Two involved domestic animals. Of these, one was in conjunction with fipronil as well as with cedarwood oil and two other unspecified active ingredients in addition to geranium oil.

Efficacy

Insect Repellent and Insecticidal activity

Efficacy of geranium oil as a mosquito repellent varies by target species. Geranium oil (50%) combined with clove oil (50%) prevented biting by the mosquito *Anopheles albimanus* for an average of 135 minutes—over four times as long as DEET (Barnard 1999). The same geranium oil/clove oil mix used against another mosquito species, *Aedes aegypti,* prevented biting for an average of 210 minutes but was half as effective as DEET (Barnard 1999). Terminix® ALLCLEAR® Sidekick, a blend of 21% geranium oil, along with the other active ingredients cinnamon oil, lemongrass oil, eugenol, and peppermint reduced *Aedes albopictus* attacks by over 95% and *Culex pipiens* attacks by over 92% (Revay et al. 2013). The article did not identify whether the formulation was either EPA registered or exempt. Geranium oil also was shown to cause an 82.5% mortality at a dose of 0.1 mg/mL as a larvicide against the *Aedes aegypti* mosquito (Seo et al. 2012).

Tests involving the sweet potato whitefly (*Bemisia tabaci*) showed that geranium oil could be an effective repellent on greenhouse cucumbers at levels a low as 12ppm, but that higher doses at 125ppm and above resulted in phytotoxicity (Yarahmadi et al. 2013).

Human head lice (*Pediculum humanis capitis*) toxicity tests showed an LD_{50} of 2.21 µg for geranium oil extracted from *Geranium maculatum.* This was over four times to more than ten times more toxic than any of its four active constituents, citronellol, geraniol, citronellyl formate and linalool—indicating a synergistic effect of the various terpenoids (Gallardo et al. 2012). The oxidated components of geranium oil showed significant knock-down efficacy with human head lice, with citronellol and geraniol effectively reducing populations of permethrin-resistant head lice by 60% (Gonzalez-Audino et al. 2011).

Geranium oil has shown itself to be limited in its efficacy for repelling storage insects and protecting stored grains and dry beans. In experiments conducted on rice weevil (*Sitophilus oryzae*) in wheat (*Triticum aestivum*), geranium oil only moderately increased insect mortality and did not significantly decrease weevil populations or result in a higher amount of healthy stored grain (Singh et al. 1989). Geranium oil had no repellent activity and was not significantly different from the no treatment control in protecting stored common beans (*Phaseolus vulgaris*) from the bean bruchid (*Acanthoscelides obtectus*) (Stamopoulos 1991).

Commercial traps with known stink bug pheromone attractants were used to test the potential repellency of essential oils to the brown marmorated stink bug (*Halyomorpha halys*). Geranium oil repelled between 65-80% of the insects when the trap was treated with geranium oil (Zhang et al. 2014). The same study noted that clove oil, lemongrass oil, spearmint oil, and ylang-ylang oil were all more effective repellents, and wintergreen oil and pennyroyal oil were in the same range of repellency as geranium oil.

Geranium oil also serves as an attractant for some insects. One study showed that geranium oil was one of five out of 41 essential oils screened that were shown as significantly more attractive for Japanese beetles (*Popillia japonica*) than an unbaited trap (Youssef et al. 2009).

Tests of 53 essential oils on the two-spotted spider mite (*Tetranychus urtica*) showed geranium oil to be one of the most effective treatments. At a concentration of 19×10^{-3} l/ml of active ingredient, geranium oil resulted in 100% mortality (Choi et al. 2004).

Antimicrobial and Fungicidal activity

Geranium oil distilled from various *Pelargonium* species, cultivars, and hybrids grown in England and South Africa were used in laboratory inhibition studies of 25 species of microorganisms, including Gram-negative and –positive bacteria, as well as fungi. Activity of the different oils varied widely by target organism species as well as by geranium species and variety (Lis-Balchin et al. 1996). Antibacterial activity by geranium variety ranged between five and 19 target species inhibited. The most sensitive were *Alcagenes faecalis, Bacillus subtilis, Brevibacterium linens, Bracothrix thermosphacta, Clostridium sporogenes, Flavobacterium suaveolens,* and *Staphylococcus aureus.* Antifungal activity against *Aspergillus niger* by geranium cultivar was a minimum of 3% and a maximum of 96%. Efficacy was correlated with terpenoid content. The cultivar responsible for 96% control was Pagoda. The monoterpenes citronellol and geraniol were considered the most effective antimicrobial constituents of geranium oil.

Oil extracted from *Graveolens sanguineum* and *Graveolens robertianum* were tested on 14 strains of 11 species of microorganisms, including *Escherichia coli, Salmonella enteritidis*, and *Staphylococcus aureus*, as

well as five different fungal species. *G. robertianum* showed strong antimicrobial activity against *E. coli* and *Aspergillus fumigatus* (Radulović et al. 2012).

Common beans (*Phaseolus vulgaris*) treated with geranium oil had the lowest infection rate of the root rot and wilt fungi *Rhizoctonia solani* and *Fusarium oxysporum* f. sp. *Phaseoli* and highest yield when compared with essential oils from three other plants—lemon, rosa and mint—as well as with the synthetic fungicide Topsin-M (thiophanate ethyl). Treatment at a concentration of 2% geranium oil achieved 100% inhibition of *R. solani* and 4% geranium oil achieved 100% inhibition of *F. oxysporum* (El-Mougy et al. 2007).

Geranium oil and its component geraniol were shown to be effective at reducing infections of *Candida albicans*—the fungus associated with vaginal yeast infections—in mice (Maruyama et al. 2008). Clinically isolated *C. albicans* grown out on plates were also shown to be susceptible to geranium oil and its constituents, with 99.9% of the inoculum killed off within 15 minutes (Zore et al. 2011).

Standards & Regulations

EPA Requirements

Geranium oil does not have a tolerance established in 40 CFR 180, nor does it have an exemption from a food tolerance in that section. As such, any residues on food would be illegal and the EPA does not have enough information to issue exemption for its use on food crops (US EPA 2015b).

FDA Requirements

Geranium oils, including generic, East Indian and rose forms are all considered Generally Recognized As Safe (GRAS) by the FDA [21 CFR 182.20] for their use as a food additive, essential oils, solvent-free oleoresins, and natural extractives (including distillates).

Other Regulatory Requirements

Non-synthetic sources are allowed under the USDA's National Organic Program (NOP) [7 CFR 205.105].

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