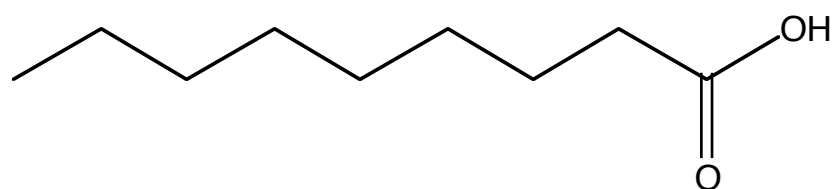


Chapter 7—Pelargonic Acid



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7.1 Introduction

Pelargonic acid, also known as nonanoic acid, is a naturally occurring fatty acid found in plants and animals.¹ When applied to growing plants in sufficient quantities, pelargonic acid rapidly desiccates green tissue by removing the waxy cuticle of the plant and disrupting the cell membrane, resulting in cell leakage, causing tissue death.² It is not translocated in treated plants and provides no residual weed control. It is only effective as a post-emergent herbicide and provides burndown of both annual and perennial broadleaf and grass weeds, as well as most mosses. It is also used as a blossom thinner for apple and pear trees and as an antimicrobial compound for use on foods.³ EPA indicates that no risks to humans or the environment are expected when pesticide products containing pelargonic acid are used according to the label directions.

The U.S. Food and Drug Administration (FDA) has approved pelargonic acid for use in food, cosmetics, shampoos and other personal care products, and in transdermal drug delivery systems. Other applications are as a developer for photographic plates, in lacquers and plastics, and in lubricants and metalworking fluids.

Pelargonic acid is a long-chain (aliphatic), nine-carbon fatty acid that belongs to a class of pesticides that include a variety of both saturated (only C-C single bonds present) and unsaturated (at least one C=C double bond present) long-chain fatty acids (C₈–C₁₈) and their potassium or ammonium salts, also known as soaps. EPA considers all soap salts with saturated fatty acids with C₈–C₁₈ chain lengths and unsaturated fatty acids with C₈–C₁₂ chain lengths to be virtually identical in regard to chemistry and toxicology.

As part of the reregistration process, US EPA conducted a risk assessment for soap salts of fatty acids in the early 1990s and published the RED in 1992.⁴ While the RED does not specifically identify the active ingredient pelargonic acid by name, EPA expressly stated that the conclusions of the RED are applicable to pelargonic acid.⁵ Fatty acid toxicity to terrestrial and aquatic animals tends to increase with chain length from six carbons to 12 carbons.⁹ For plants, pelargonic acid is the most toxic fatty acid.^{6,7,8}

Fatty acids are a significant part of a person's normal daily diet. Pelargonic acid is naturally present in fruits, vegetables, dairy products, meat, and grains at levels ranging from 0.2–400 mg/kg. It is used as an antifungal additive in low-fat cheddar cheese at levels of 10–10,000 mg/kg.^{9,3} Pelargonic acid is also produced in the musk of some birds.¹⁰

In 2003, EPA exempted pelargonic acid from food tolerances when it is applied as a component of a food contact surface sanitizing solution.¹¹ At that time, it was already exempt from food tolerances as an herbicidal residue. Pelargonic acid is designated by the US Food and Drug Administration (FDA) as a GRAS (Generally Regarded As Safe) chemical. The FDA permits use of pelargonic acid as a synthetic food flavoring agent, as an adjuvant, as a sanitizer to be used in contact with food (up to a 1% solution), or to assist in lye peeling of fruits and vegetables.¹¹

EPA registered the first pesticide products containing mostly pelargonic acid in 1992, although products with mixtures of soap salts that included pelargonic acid were registered much earlier. As of March 2008, there were six EPA-registered herbicide products containing pelargonic acid

alone or in combination with other herbicidal active ingredients.¹² Commercial and agricultural use of pelargonic acid reported through the California Pesticide Use Reporting system was 8,800 pounds in 2005; total fatty acid use was 39,000 pounds.¹³ Total California sales of pelargonic acid was 184,000 pounds in 2005,¹⁴ suggesting that non-commercial, consumer use of this pesticide accounts for most of the total use.

The Dow product Scythe was designated as a candidate herbicide for use by MMWD. The product contains 57% by weight of pelargonic acid, 3% other fatty acids (C₆–C₁₂), 30% paraffinic petroleum oil, and 10% of an unidentified emulsifier.

This chapter focuses on the human toxicity, ecotoxicity, and environmental fate of pelargonic acid, drawing primarily from the EPA RED for soap salts,⁴ a Federal Register Notice posted by EPA announcing an exemption from food tolerances for pelargonic acid,¹¹ two Federal Register Notices posted by EPA for an exemption from food tolerances for ammonium nonanoate (the ammonium salt of pelargonic acid),^{9,9} and the EPA Ecotox database¹⁵ (Terretox for the terrestrial database and AQUIRE for the aquatic database). An extensive survey of the peer-reviewed literature was conducted to find additional research results not available in these documents.

7.2 Pelargonic Acid Toxicity to Humans and Levels of Concern

Most of the data on pelargonic acid's toxicity and potential risk of adverse health effects are in unpublished studies that are not available to the public. The EPA RED for soap salts⁴ and the Federal Register notices^{5,9} only provide very brief summaries of the primary toxicology data. There are no epidemiological studies of the effects of pelargonic acid in humans, but the fact that it is a natural component of humans' daily diet suggests that the active ingredient in this pesticide is not systemically toxic at doses that are likely to occur in the diet—up to several grams per day.

The acute toxicity of pelargonic acid is very low, except for moderate, but reversible, eye irritation (Category II). Oral acute toxicity is very low (Category IV) and dermal and inhalation toxicities are ranked by U.S. EPA as Category III. Exposure to concentrated solutions of pelargonic acid causes skin and eye irritation.

Pelargonic acid is rapidly absorbed through the skin and is used in patented systems for dermal drug delivery to enhance drug uptake from skin patch delivery systems.¹⁶ Although it is a skin irritant, it is not a sensitizer and is routinely used in studies that compare and contrast non-sensitizing irritants with sensitizing irritants.¹⁷

Because of the low toxicity and the common occurrence of naturally occurring pelargonic acid in the diet, EPA did not develop an RfD. As a result, this risk assessment compares exposure estimates with a Dietary Reference Value (DRV), an estimate of the amount of pelargonic acid that might commonly be found in a human's daily diet. Amounts above the DRV are not necessarily harmful; instead, this approach is meant to flag exposures that are above naturally occurring dietary levels.

7.2.1 Levels of Concern for Humans

Because of the low toxicity and the common occurrence of naturally occurring pelargonic acid in the diet, EPA did not develop an RfD. As a result, this risk assessment compares exposure

estimates with a Dietary Reference Value (DRV), an estimate of the amount of pelargonic acid that might commonly be found in a human's daily diet.

The DRV was developed based on an estimate of the amount of pelargonic acid that might be eaten by the average human in a day. Determining the pelargonic acid intake was difficult due to the lack of data on the concentrations of this fatty acid in various types of food. Pelargonic acid is found in the flesh (130, 140, and 0.2 mg/kg for oranges, grape pulp and apples) and skin (400 mg/kg for grapes) of fruits;² in potatoes, milk and cheese (10-400 mg/kg);² in processed cheeses (10–10,000 mg/kg);³ in beef (≥ 47 mg/kg) and other meats;¹⁸ and in dry grains (0.1-90 mg/kg).¹⁹ This list of foods is not exhaustive; other foods may also contain pelargonic acid.

A daily diet was constructed to obtain an approximate estimate of daily pelargonic acid intake. Pelargonic acid concentrations were not available for a large number of foods; therefore, reasonable average pelargonic acid concentrations were estimated for each food type described below. *Note: Because data were sparse, these estimates are only approximate. Additionally, pelargonic acid concentrations vary substantially by the type and amount of food and how it is processed prior to eating.*

Fruit: Estimates of pelargonic acid concentrations were available for three fruits: apples (0.2 mg/kg), oranges (130 mg/kg), grape pulp (140 mg/kg) and grape skin (400 mg/kg).² The difference between skin concentrations and pulp concentrations was not distinguished for apples and oranges. Assuming a grape is 10% skin and 90% pulp gives a pelargonic acid concentration of 166 mg/kg for grapes. The values for apples, oranges, and grapes were averaged to give an estimate of the concentration of pelargonic acid in fruit of 100 mg/kg.

Vegetables: Potatoes are the only vegetable for which there was information about the pelargonic acid content (10-400 mg/kg).² The mid-range (210 mg/kg) concentration of pelargonic acid was used for potatoes and all vegetables.

Grains: Oats were the only grain for which the pelargonic acid concentration could be found.¹⁹ There was some mention of pelargonic acid in rice, but no quantitative information was provided. For oats, the range of possible concentrations (0.1–90 mg/kg) was found to vary by time after harvest and by type of oat (wild versus common). The concentration of pelargonic acid in the grain peaks shortly before harvest, coinciding with seed dormancy. High pelargonic acid concentrations are the plant's adaptation to avoid premature sprouting. After harvest, the pelargonic acid concentrations in the grain decline. After approximately four months, the pelargonic acid concentration in oats is 32 mg/kg; after five months, the concentration is 10 mg/kg and after six months, the concentration is 1 mg/kg. A pelargonic acid concentration of 1 mg/kg was used for all grains.

Diary: The maximum possible concentration of pelargonic acid (10,000 mg/kg) was used for processed cheeses (range of concentrations 10-10,000 mg/kg).³ The maximum concentration of 10,000 mg/kg was used in the calculation to compensate for the lack of data on other processed foods that likely also contain pelargonic acid, since the sample diet assumes that processed cheeses are the only processed foods eaten in the diet. This may be an overestimate, but without

additional data, it is a reasonable approximation. The mid-range value of possible pelargonic acid concentrations (10-400 mg/kg) for the remaining dairy products is used.²

Meat: Pelargonic acid concentrations were available only for beef (≥ 47 mg/kg). This is a minimum estimate that was measured as the emissions of pelargonic acid from charbroiling of meats.¹⁸ Additional pelargonic acid likely remained in the meat in the form of triglycerols. A value of 50 mg/kg was used for pelargonic acid concentrations in meat.

The daily dietary exposure of pelargonic acid is described by the following equation:

$$\text{DRV} = \frac{\sum_{\text{food types}} \left(\left(\frac{\text{kcal of food}}{\text{energy content of food in kcal/kg}} \right) \times \left(\frac{\text{pelargonic acid concentration in food}}{\text{mg acid/kg food}} \right) \right)}{\text{body weight of adult female (64 kg)}}.$$

Results are summarized in Table 7-1. Based on intake estimates, a Dietary Reference Value, or DRV, of 20 mg/kg was selected for pelargonic acid. This value was compared to exposure estimates to yield a Fraction of Dietary Intake, or FDI. Similar to a hazard quotient, the FDI provides a ratio of estimated exposure to a reference value. Amounts above the DRV are not necessarily harmful; instead, this approach is meant to flag exposures that may be above naturally occurring dietary exposures.

Use of the DRV does not account for the unknown toxicity of the inert ingredients in Scythe. With no information available on the identity of the inerts, any toxic effects from exposures to these compounds remains unknown.

7.2.2 Data Gaps

Fatty acids like pelargonic acid are a common component of the human diet, and their metabolism has been studied extensively for many years. Higher-dose effects that might result from the combined normal dietary amounts of pelargonic acid plus additional exposure from herbicidal use have not been studied. Animal studies with high doses (up to 1,000 mg/kg) of pelargonic acid indicate no toxic effects.

The identity and toxicity of the “inert” ingredient(s) used as emulsifiers in the Scythe product are unknown, with no information available because the formulation is confidential. Thirty percent of the Scythe product is paraffinic petroleum distillates. The specific petroleum-derived chemicals are not identified, so the toxicity of this part of the mixture is also unknown.

Mixtures of chemicals may behave differently than individual chemicals. Acute toxicity testing has been done on the Scythe product mixture (see Section 7.4.4), but the sub-chronic and chronic toxicity of the mixture have not been evaluated.

Table 7-1: Estimated Pelargonic Acid Concentrations in a Daily Diet

Food	Food Intake (kcal)	Energy density (kcal/g)^a	Food Intake (kg)	Estimate of Pelargonic Acid Concentration (mg/kg)	Estimated Pelargonic Acid Intake (mg)
Fruit	200	0.48 (apples) 0.47 (oranges) 0.89 (bananas) Average: 0.61	0.3	100	30
Vegetables	200	0.41 (carrots) 0.20 (chard) 0.18 (tomatoes) 0.20 (peppers) 0.40 (onions) 0.87 (potatoes) Average: 0.38	0.5	210	110
Grains	700	1.24 (pasta, cooked) 1.30 (rice, cooked) 2.60 (bread) Average: 1.7	0.4	1	0.4
Dairy	600 (total) = 300 (processed) + 300 (all other dairy)	4.03 (cheddar cheese) 2.54 (mozzarella) Average processed: 3.3 0.60 (milk, whole) 0.34 (milk, skim) 0.63 (low-fat yogurt) Average dairy: 0.54	0.1 (processed) 0.6 (all other dairy)	10,000 (processed) 210 (all other dairy)	1,000 (processed) 130 (all other dairy)
Meat	400	2.95 (hamburger patty) 2.5 (sirloin steak) 2.32 (T-bone steak) Average: 2.6	0.15	50	10
Total Adult Female (64 kg)	2,100				1,280 mg 20 mg/kg

^a Data Source: http://www.netzingers.com/cgi-bin/calorie_lookup.php.

7.3 Pelargonic Acid Toxicity to Animals and Plants and Levels of Concern

This section of the report summarizes pelargonic acid toxicity to nine taxa groups, including mammals, birds, fish, terrestrial and aquatic invertebrates, terrestrial and aquatic plants, and soil microorganisms. Pelargonic acid has been registered in the US since 1992. There are very few toxicological studies available as part of the EPA registration process or in the academic literature; however, dietary fatty acids have been extensively studied, and the metabolic pathways of common dietary fatty acids are well known.

Acute and chronic pelargonic acid toxicity to mammals is low, with no adverse effects observed in studies with laboratory animals up to doses of 1,500 mg/kg-day. Pelargonic acid is not acutely toxic to birds, slightly toxic to insects, highly toxic to soil fungal microbes and to the leaf tissue of terrestrial plants. Pelargonic acid is classified as moderately to not acutely toxic to fish and amphibians, highly to slightly toxic to aquatic invertebrates and not acutely toxic to aquatic plants. Although extensive toxicology data are not available for pelargonic acid, the fact that this active ingredient is a naturally occurring component of plants and animals suggests that exposures to this chemical are unlikely to cause adverse effects.

There is very little information on the ecotoxicity of pelargonic acid in the academic literature or in EPA's Ecotox database. To expand the database, this toxicity review also includes related chemicals like capric (decanoic) acid and other soap salts, which EPA views as toxicologically equivalent to pelargonic acid.⁵ Dietary reference values (DRVs) and toxicity reference values (TRVs) selected for the MMWD risk assessment for pelargonic acid are summarized in this section in Table 7-4 on page 7-17. Because the USFS has not evaluated this herbicide, there are no USFS TRVs available for comparison.

Only studies with LD₅₀ or LC₅₀ endpoints were available for the ecotoxicity data; thus, the TRVs were adjusted downward to be sufficiently protective. This approach uses EPA methodology for assessing effects on endangered species.²⁰ The adjustment employed was to divide the LC₅₀ by six (or 20 in the case of salmonids), based on an extensive review of existing ecotoxicological data on pesticides.²¹ The review noted that sublethal effects did not typically occur at concentrations below one-fourth to one-sixth of the LD₅₀, when taking into account the same percentages or numbers affected, test system, duration, species, and other factors. This effect is termed the "6x hypothesis." However, it should be noted that this review is almost 30 years out-of-date, and that the factor of six is meant to translate an LC₅₀ to a NOEC of the same species. The use of a single NOEC for all species in a taxa group suggests that interspecies variability may not be fully accounted for by the factor of six. Further, the factor of six appears to be too low for salmonids. As discussed in the EPA report, salmonids' olfactory ability seems to be particularly sensitive to pesticide concentrations 20 times lower than the LC₅₀.²² Thus, for fish, the LC₅₀ values are divided by 20 to obtain the TRV used in the MMWD risk assessment.

Levels of concern for pelargonic acid are also summarized in this section, with Table 7-4 on page 7-18 presenting the toxicity reference values (TRVs) selected for the MMWD risk assessment.

7.3.1 Mammals

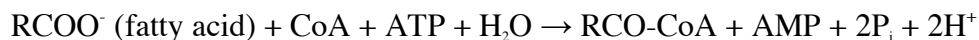
Most of the data on toxicity of pelargonic acid to mammals is from studies conducted in laboratory animals in support of EPA registration of soap salts,⁴ pelargonic acid^{2,11} and its ammonium salt,^{5,9} and decanoic acid.²⁴ Because pelargonic acid is a common part of the mammalian diet, its metabolism has been studied extensively as part of research on fat metabolism. No systemic toxicity is anticipated at doses comparable to the levels normally found in the diet, and none was found in subchronic toxicity studies up to doses of 2,000 mg/kg-day. Pelargonic acid is rapidly absorbed through the skin, and is a moderate to severe eye and skin irritant. It has low acute oral and inhalation toxicity.

Because of its low toxicity, common occurrence in the diet, and known metabolic pathway, pelargonic acid was not evaluated by EPA for carcinogenicity or chronic toxicity.

7.3.1.A Metabolism and Pharmacokinetics of Pelargonic Acid

Fatty acids are a natural component of the mammalian diet and are metabolized in the cells by oxidation to smaller molecules. These metabolites are used as an energy source and as building blocks for the structural components of cells.

Fatty acids are first activated for transport into the mitochondria through binding to the enzyme acetyl CoA; energy for the process is provided by hydrolysis of ATP to AMP and inorganic phosphate (P_i).²³



Catalyzed by carnitine acyltransferase, this fatty acid-CoA complex is transported into the mitochondria. Once inside the mitochondria, oxidation of the fatty acid occurs, with two-carbon fragments repeatedly cleaved from the original fatty acid to form multiple units of acetyl CoA. Acetyl Co-A then enters the Krebs cycle, producing the reduced electron transport coenzymes NADH and FADH, which are then used to produce ATP, the energy source for all cellular activity.

7.3.1.B Acute Toxicity of Pelargonic Acid

Pelargonic acid has very low acute toxicity, and the dermal and oral LD₅₀ in rats and rabbits is > 5,000 mg/kg.⁴ Fatty acids and their salts were found to be mild to moderately irritating to rabbit skin when small amounts were applied; in humans, pelargonic acid was found to be a moderate skin irritant. The ammonium salt of pelargonic acid causes severe eye irritation. EPA places technical pelargonic acid in category II (moderately toxic) for primary eye irritation, category IV (not acutely toxic) for acute oral toxicity, and category III (slightly toxic) for acute dermal and inhalation toxicity.¹¹

Inhalation of pelargonic acid aerosols causes respiratory irritation. No mortality resulted from dosing 10 rats at 0.46 mg/L for 4 hours, but 80% mortality was observed at 3.8 mg/L.

7.3.1.C Sub-Chronic Toxicity of Pelargonic Acid

The sub-chronic toxicity of pelargonic acid is low, and no systemic toxicity was observed in mammals at oral doses of 2,000 mg/kg-day or less.¹¹ EPA's requirement for a 90-day sub-chronic study was waived on the basis of low toxicity observed in the preliminary study and the natural occurrence of fatty acids in the human diet. Dermal doses of 500 mg/kg-day for 10 days caused severe skin irritation and swelling during the treatment, but the skin was healed two weeks after exposure ceased. No systemic effects were observed. Several sub-chronic studies for the closely related capric (decanoic) acid were also available.²⁴ Table 7-2 summarizes the available sub-chronic toxicity tests.

Table 7-2: Sub-chronic Toxicity of Pelargonic Acid to Mammals

Test animal	Study Duration (days)	Doses Tested (mg/kg-day)	Dose (endpoint) (mg/kg-day)	Observed Effects
Test animal not stated 3M, 3F at each dose ¹¹	14	Pelargonic acid. Dietary study. Doses not stated, except for highest at 1,834 (~2,000).	> 2,000 (NOAEL)	No effects observed at HDT. No adverse effects on survival, clinical signs, body weight gain, food consumption, hematology, clinical chemistry or gross pathology. Study did not report organ weights and histopathology, a deficiency in this study.
NZW rabbits ¹¹ 5M, 5F	28	Pelargonic acid. 500 (dermal) for 5 d/wk for 2 wks; 2 wk recovery period		During wk 1 & 2, slight body weight loss and decreased food consumption. One female rabbit showed ocular discharge and hypoactivity during the second week of treatment. By day 14, all rabbits showed signs of severe erythema and moderate edema. Dermal reactions consisting of moderate desquamation, moderate fissuring, eschar, exfoliation and necrosis were also observed at day 14. By day 29, all dermal reactions had reversed. No systemic effects observed at 500 mg/kg/day.
Rats ²⁵	150	Decanoic acid. 10% in diet	NA	No adverse effects noted.
Rats ²⁴	329	Decanoic acid. 2,500	> 2,500	No adverse effects noted.
Rats ²⁴	42	Decanoic acid. 4,000	> 4,000	Reduced body weight gain and increased plasma triglyceride levels.
Dogs ²⁴	102	Decanoic acid. 4,400	> 4,400	No adverse effects noted.

HDT = highest dose tested.

7.3.1.D Chronic Toxicity and Carcinogenicity of Pelargonic Acid

Only a single chronic toxicity test was available for pelargonic acid, in which mice were treated dermally with 50 mg of pelargonic acid twice per day for 80 weeks.¹¹ Histopathology showed no non-neoplastic or neoplastic lesions on the skin and internal organs. EPA concluded that the

study adequately assessed the chronic toxicity and the carcinogenic potential of pelargonic acid via the dermal route.

Pelargonic acid was found to be non-mutagenic in the Ames Test (Salmonella/reverse mutation assay).¹¹ A negative result was also obtained from an *in vivo* micronucleus assay. In a mouse lymphoma forward mutation study, pelargonic acid induced a weak mutagenic response at or higher than the 50 mg/mL level. This result was observed in the presence of increasing toxicity, and may be an indication of gross chromosomal changes or cell damage and not actual mutational changes within the gene.

7.3.1.E Reproductive and Developmental Toxicity of Pelargonic Acid

Only two developmental toxicity studies were available. Pregnant rats (22) were treated with a high dose (1,500 mg/kg-day) of pelargonic acid on gestation days 6–15, inclusive.¹¹ Maternal body weight was not significantly affected during the treatment. One out of 22 animals showed signs of unspecified clinical toxicity. No significant histopathology signs were observed in the maternal animals, including no excess mortality, no reduction in body weight gains, and no decreased food consumption. No treatment-related effects were noted in the dams in terms of pregnancy rates, implantation efficiency, uterine weights and litter data. Although two instances of cleft palate, two fetuses with a small tongue, and one incidence of hydronephrosis were observed in the treatment group, these anomalies were not statistically significant relative to the control group. Additionally, EPA indicated that the doses tested in this study were far above the limit dose for toxic effects. The doses of pelargonic acid that might be anticipated from pesticidal uses of pelargonic acid are substantially lower than those tested and within range of what might reasonably be anticipated in the mammalian diet. For maternal and fetal toxicity, EPA determined the NOAEL to be 1,500 mg/kg/day.

A second developmental toxicity study with using doses of 1,000 mg/kg-day of ammonium nonanoate in rats showed no maternal or fetal effects above the limit dose of 1,000 mg/kg-day.⁵

7.3.1.F Neurotoxicity

There are no studies designed to detect potential adverse effects on the central or peripheral nervous system in mammals exposed to pelargonic acid; however, the constant presence of low levels of this compound in the diet suggests that neurological effects are unlikely.

7.3.1.G Immunotoxicity

There are no data available to assess the potential immunotoxic effects of pelargonic acid; however, it was not found to be a skin sensitizer in dermal toxicity tests, only an irritant. Systemic immune system effects seem unlikely in light of the fact that pelargonic acid is a natural component of the daily diet and no allergies have been reported.

7.3.1.H Endocrine Disruption

There are no studies specifically evaluating pelargonic acid's potential to interact or interfere with estrogen, androgen, thyroid or other endocrine systems. A European Union survey of the scientific literature on endocrine effects of pesticides does not list pelargonic acid as a chemical of concern,²⁶ nor do other sources of information on endocrine disrupting effects.²⁷ Pelargonic acid is a fatty acid that is metabolized by a well-known mechanism that produces acetyl-CoA, an

enzyme conjugate that forms the basis of the energy cycle used by many forms of life, including humans. It seems highly unlikely that molecules that are so central to supporting the metabolism of the organism would also function as endocrine-active compounds.

7.3.1.1 Levels of Concern for Mammals

Because of the low toxicity and the common occurrence of naturally occurring pelargonic acid in the diet, EPA did not select a mammalian NOAEL that suitable for use as a TRV. For the MMWD risk assessment, the rat developmental toxicity NOAEL of 1,000 mg/kg was selected as the TRV.

7.3.2 Other Terrestrial Organisms

The following section summarizes the available information on pelargonic acid toxicity to terrestrial animals other than mammals. Table 7-3 provides a summary of available toxicity information and Table 7-4 presents the DRVs/TRVs used in the risk assessment. Information about chemicals similar to pelargonic acid is included, because of the paucity of information on pelargonic acid.

Pelargonic acid is slightly toxic to birds and slightly toxic to honeybees. There are few studies on other insects, and none with typical toxicity endpoints. Several studies suggest that pelargonic acid is highly toxic to microorganisms, especially fungi.

7.3.2.A Birds

Pelargonic acid is relatively non-toxic to waterfowl and upland game birds.²⁸ Most of the toxicity information is taken from the EPA RED for soap salts. A summary of the available studies can be found in Appendix H, Table H-2.

Three avian toxicity studies were reported in the Terretox database for pelargonic acid.¹⁵ Two studies reported LC₅₀ values of 5,620 mg/kg food for bobwhites and mallards. The third study reported an LD₅₀ for a bobwhite of 2,250 mg/kg. The study duration for the three studies was not stated.

EPA's RED for soap salts⁴ provides avian toxicity information for ammonium salts of fatty acids. For a 14.65% pure active ingredient, the oral 8-day LC₅₀ was 5,000 mg/kg for bobwhites and mallards. It is not clear from the RED if this LC₅₀ refers to the active ingredient or a 14.65% pure solution. If it refers to the latter, than the actual dose would be 715 mg a.i. per kg of organism. Since the exact fatty acid was not specified, presumably it is a mix of different acids.⁴ The RED also reports LD₅₀ values of >2,000-2,250 and >2,510 for bobwhites and mallards, respectively. These studies were done with technical grade material, which is preferable to studies conducted with a low-percentage solution of the active ingredient.

The musk of the petrel *Pachyptila desolata* contains small amounts of pelargonic acid.¹⁰ Individual birds had similar mixtures of odor compounds from year to year and it was hypothesized that their individualistic musk signatures allowed them to distinguish their nesting sites from others and help find mates.¹⁰

Levels of concern for birds: An LD₅₀ of 2,000 for bobwhites was used in the MMWD risk assessment as the starting point for acute toxicity. Using the “6x hypothesis”²⁰ the LD₅₀ as divided by six because a NOAEL was unavailable. The resulting TRV is 333 mg/kg; this value is used for both chronic and acute TRVs for the MMWD assessment.

7.3.2.B Insects

There is only one study on honeybees in the Terretox database yielding an LD₅₀ of 25 µg/bee.

Very few current studies exist on the effects of pelargonic acid on non-honeybee insects, and existing studies do not report typical toxicity endpoints. Male and female blood-sucking insects *Triatoma infestans* secrete ethanoic to pelargonic acids, which repel other individuals of the same species.²⁹ The specifics of the study were not available. Another study found that pelargonic acid altered the feeding habits of the pine weevil *Hylobius abietis*.³⁰ For mosquitoes, a methyl group on the second or third carbon in the chain was essential for insecticidal activity.³¹ These branched fatty acids are produced when larvae are overcrowded.

Levels of concern for bees: For this risk assessment, the LD₅₀ of 25 µg/bee was divided by six to adjust for the fact that the endpoint was not a NOAEL. The mass of a honeybee was assumed to be 0.000093 mg. Dividing the LD₅₀ by six and by 0.000093 yields the TRV of 45 mg/kg day that was used in the MMWD assessment.

7.3.2.C Terrestrial Plants

Pelargonic acid works as an herbicide by penetrating waxy cuticle of the leaves and disrupting normal membrane permeability. Disruption of cellular physiology results in cell leakage and foliar dessication. The herbicide does not translocate, and only treated leaves are affected.

Of the fatty acids with two (C2) to ten carbons (C10), C8 and C9 (C9 is pelargonic acid) were the most herbicidal. Dilute solutions (3% pelargonic acid by volume) caused between 30-70% visual damage on the plant at application rates of 12 L pelargonic acid per hectare.⁶ The superiority of pelargonic acid to other fatty acids has been confirmed in other studies.^{7,8} Substantial visual damage (see Figure 1 in reference 7) to crabgrass occurred upon adding pelargonic acid solutions of approximately 17.5 kg/ha (the study reportedly added 26.3 mg pelargonic acid to each potted plant; assuming the soil surface area in the pot is approximately 150 cm² yields as application rate of 17.5 kg/ha).⁷ Damage to cucumber cotyledons could be seen within three hours of application.⁷

Pelargonic acid can work synergistically with other compounds to enhance herbicidal activity. The addition of succinic acid, diammonium succinate, lactic acid or glycolic acid doubled the visible damage caused by pelargonic acid treatments.³² Foliar damage to weed species (Canada thistle *Cirsium arvense*, buckhorn plantain *Plantago lanceolata*, eastern black nightshade *Solanum pycnanthum*, giant foxtail *Setaria faberi* and redroot pigweed *Amaranthus retroflexus*) ranged from 20% for 2.7 L/ha of pelargonic acid alone to 44% and 46% damage with the addition of diammonium succinate and succinic acid, respectively. Solutions were 1% of a pelargonic acid product by volume (which was 70% pelargonic acid, 20% sorbitan monolaurate, and 10% ethoxylated nonylphenol). For velvetleaf (*Abutilon theophrasti*) and common lambsquarters (*Chenopodium album*) the efficiency gains were less striking. Diammonium

succinate increased the foliar damage of 5.4 L/ha pelargonic acid formulations from 31 to 54% and 65 to 76% damage for velvetleaf and lambsquarters, respectively. Lactic acid and glycolic acid were almost identical in added potency for the two species. For velvetleaf, both lactic acid and glycolic acid increased the foliar damage of 4 L/ha pelargonic acid formulations from 34 to 57%. For lambsquarters, lactic acid and glycolic acid increased the foliar damage of 4 L/ha pelargonic acid formulations from 34 to 56 and 54% respectively.

The addition of pelargonic acid to other herbicides does not appear to enhance phytotoxicity. Adding pelargonic acid to glyphosate does not improve herbicidal activity.^{33, 34}

All of the abovementioned studies report on pelargonic acid's effects on vegetative vigor. Because the herbicide works by disrupting the waxy cuticle of plant leaves, it does not affect seed germination.

Levels of concern for terrestrial plants: There are no studies reporting the lowest pelargonic acid concentration at which foliar plant damage is observed. The lowest reported application rate was 2.7 L/ha (approximately half the anticipated MMWD application rate) on Canada thistle *Cirsium arvense*, buckhorn plantain *Plantago lanceolata*, eastern black nightshade *Solanum pycnanthum*, giant foxtail *Setaria faberi* and redroot pigweed *Amaranthus retroflexus*. Because seedling emergence will likely not be affected by pelargonic acid, no TRV was selected for this effect.

7.3.2.D Microbes

Pelargonic acid inhibits the growth of microorganisms—especially fungi—and is used as an antifungal agent in food preservation. Often released by spores as a self-inhibitor, pelargonic acid prevents spore germination of *Rhizopus oligosporus*, a fungus that can serve as an antibiotic, inhibiting gram-positive bacteria.³⁵ Suspensions of spores and pelargonic acid at a concentration of 0.040 mg/L postponed germination; at a concentration of 0.080 mg/L, germination was prevented. Another study found that pelargonic acid occurred in *Calluna vulgaris* (Heather) heath soil at a rate of 0.76 g per 100 grams of soil, a concentration that would be toxic to fungus.³⁶ Pelargonic acid is considered to be more fungitoxic than the phytotoxic decanoic and octanoic acids.³⁷ The fungicidal properties of pelargonic acid also help protect insects from parasitic *Beauveria bassiana*.³⁸

Levels of concern for microbes: Pelargonic acid is frequently used to prevent fungal growth on foods. The TRV for microbes for the MMWD assessment is derived from the study that reported a value of 760 ppm in soil as toxic to fungi (the specific toxic endpoint is not reported).

7.3.3 Aquatic Organisms

Fatty acids such as pelargonic acid are classified as slightly toxic to fish and amphibians, and slightly to highly toxic to aquatic invertebrates, based primarily on studies reported in the EPA RED for soap salts and the Federal Register notices for pelargonic acid tolerance exemptions. Toxicity reference values derived from these toxicity studies are highly uncertain given the paucity of data.

7.3.3.A Fish

Fatty acids are classified as only slightly toxic to cold and warm water fish species. For capric acid (decanoic acid) in fresh water, the 48-hr LC₅₀ for red killifish (*Oryzias latipes*) is 20 mg/L.²⁸ Sodium caprate was less toxic than the acid to killifish with an LC₅₀ of 54 mg/L.²⁸ Toxicity studies with fathead minnows (*Pimephales promelas*) for a 96-hour exposure provided LC₅₀ values of 104 mg/L²⁸ and 21 mg/L.⁴ A study on ammonium fatty acid soap salts yielded 96-hour LC₅₀ values of 9.19, 18.06 and 91 mg/L for rainbow trout (*Oncorhynchus mykiss*), and 23, 35.35, and 105 mg/L for bluegill sunfish (*Lepomis macrochirus*).^{39,4} See Appendix H, Table H-3 for more details.

Levels of concern for fish: The 9.19 mg/L 96-hour LC₅₀ for rainbow trout was selected as the starting point for the acute and chronic TRV used in the MMWD risk assessment. This value is divided by 20 to adjust for the fact that an LC₅₀ value was used because a NOAEC was unavailable. The resulting TRV is 0.46 mg/L.

7.3.3.B Amphibians

There are two toxicity studies using the African-clawed frog (*Xenopus laevis*) for pelargonic acid and two for decanoic acid. The 96-hour LC₅₀ values are 24 and 32.7 mg/L for decanoic and pelargonic acid, respectively. Effects on development and metamorphosis were observed, with 96-hour EC₅₀ values of 7.5 and 6.5 mg/L for decanoic and pelargonic acid, respectively.³⁹ These are the only available amphibian studies. Appendix H, Table H-4 summarizes available studies.

Levels of concern for amphibians: The 6.5 mg/L 96-hour EC₅₀ for changes in development and metamorphosis for *X. laevis* was used as the starting point for both the acute and chronic TRV in the MMWD risk assessment. Because the endpoint is similar to a LOEC, the value was divided by three to obtain an approximation of a NOEC according to standard EPA practice in mammalian toxicity studies. The final TRV used in the MMWD assessment is 2.2. mg/L.

7.3.3.C Aquatic Invertebrates

Fatty acids are considered to be slightly to highly toxic to aquatic invertebrates.^{28,4} An LC₅₀ for capric acid of 20 mg/L was observed for *Hyale plumulosa*,²⁸ and a 48-hour LC₅₀ of 0.57 mg/L and 102 mg/L was found for *Daphnia*.⁴ In sediment slurries from the Danish eutrophic Lake Brabrand, the NOEC for alterations in nitrification was 0.030 mg/L.⁴⁰

Levels of concern for aquatic invertebrates: The mid-range LC₅₀ value of 20 mg/L was divided by a factor of six to adjust for the absence of a NOEC for the acute TRV. The resulting TRV used in the MMWD risk assessment is 3.3 mg/L. The chronic NOEC of 0.030 mg/L for nitrification in lake sediment is used for the chronic TRV. However, there were no chronic water scenarios available.

7.3.3.D Aquatic Plants

Toxicity to algae may be estimated by comparison with data for soaps in general. For example, an LC₅₀ range of 180-320 mg/L has been reported for *Chlorella vulgaris* exposed to.²⁸

Levels of concern for aquatic plants: The starting point for the aquatic plant TRV is the LC₅₀ of 180 mg/L for *Chlorella vulgaris*. Dividing this by six to adjust for the absence of a NOEC yields a TRV of 30 mg/L for the MMWD risk assessment.

7.3.4 Data Gaps

There are few studies on which to base a toxicity assessment for pelargonic acid. For the taxa groups that have a representative study (birds, fungi, micro-organisms, fish, amphibians and aquatic invertebrates), there are few duplicates of studies, few non-lethal studies, few studies of chronic effects, and no field studies. The fact that pelargonic acid is a common part of the diet of animals suggests that exposures on the order of those that might occur naturally in the diet are unlikely to be harmful.

The identity and toxicity of the “inert” ingredient(s) used as emulsifiers in the Scythe product are unknown, with no information available because the formulation is confidential. Thirty percent of the Scythe product is paraffinic petroleum distillates. The specific petroleum-derived chemicals are not identified, so the toxicity of this part of the mixture is also unknown.

Mixtures of chemicals may behave differently than individual chemicals. Acute toxicity testing has been done on the Scythe product mixture (see Section 7.4.4), but the sub-chronic and chronic toxicity of the mixture have not been evaluated.

Table 7-3: Summary of Pelargonic Acid Ecotoxicity Data

Taxa	Endpoint	Formulation ^a	Number of Studies	Dose (mg/kg, or mg/L for aquatic) ^b		
				Min	Median	Max
Birds	8-day ^c LD ₅₀	SS, C9	4	2,000 (SS)	2,200 ^d	2,510 (SS)
	8-day LC ₅₀	SS, C9	4	5,000 (SS)	5,310 ^e	5,620 (C9)
Honeybees	LD ₅₀ ^f	C9	1	^g	25 µg/bee	^g
Fish	2–4 day LC ₅₀ ^h	C10, SS	10	9.1 (SS)	29.2 (SS)	105 (SS)
Amphibians	4-day LC ₅₀	C9, C10	2	6.5 (C9)	ⁱ	7.5(C10)
	4-day EC ₅₀	C9, C10	2	24 (C10)	ⁱ	32.7 (C9)
Aquatic Invertebrates	2-day LC ₅₀	C9, C10, SS	4	0.57 (SS)	69 ^j	102 (SS)

^a Studies for both pelargonic acid and other related chemicals (*e.g.* decanoic acid, soap salts, etc.) are included in this table. In the Formulation column, the chemical used in the study is abbreviated as follows: C9 = pelargonic acid; C10 = decanoic acid; and SS = soap salts. When there is more than one formulation in the Formulation column, the formulation of the endpoint dose is given in parentheses in the Dose column using the same abbreviations.

^b All aquatic values are reported in mg/L. All terrestrial values (except insects) are reported in mg/kg. Insects are reported in µg/bee for honeybees.

^c Two out of four of the studies were reported as 8-day; the remaining study durations were not reported.

^d Averaged from two values 2,150 (for soap salts) and 2,250 mg/kg (for pelargonic acid).

^e Averaged from two values 5,000 (for soap salts) and 5,620 mg/kg (for pelargonic acid).

^f Exposure duration was not reported.

^g Only one value was reported.

^h Different study durations (2 versus 4 days) are grouped. See Appendix H for the specifics. Two of the 10 studies did not report exposure duration.

ⁱ No median is reported because there were only two studies.

^j Averaged from LC₅₀ values for capric and pelargonic acid: 41 and 96 mg/kg, respectively.

Table 7-4: Pelargonic Acid Reference Values Used in MMWD Risk Assessments

Taxa	Exposure Type	Selected Endpoint	Dose	Adjustments to Dose	TRV/DRV ^a Used in MMWD Risk Assessment
Humans					
	acute and chronic	Dietary intake ^a	20 mg/kg-day	None	20 mg/kg-day
Mammals					
	acute and chronic	NOAEL (rat)	1,000 mg/kg-day	None	1,000 mg/kg-day
Birds					
	acute and chronic	LD ₅₀ (bobwhite)	2,000 mg/kg-day	÷ 6 ^c	333 mg/kg-day
Insects					
	honeybees	LC ₅₀	>25 (µg/bee)	÷ 0.000093 ^d ÷ 6 ^c	> 45 mg/kg-day
Amphibians					
	acute and chronic	EC ₅₀ (African clawed frog)	6.5 mg/L	÷ 3 ^b	2.2 mg/L
Plants					
	vegetative vigor	20% leaf damage ^e	2.7 L/ha	None	2.7L/ha
	seed emergence		NA		NA
Fish					
	acute and chronic	LC ₅₀ (rainbow trout)	9.19 mg/L	÷20 ^c	0.46 mg/L
Aquatic Invertebrates					
	acute	LC ₅₀ (<i>H. plumulosa</i>)	20g/L	÷ 6 ^c	3.3 mg/L
	chronic	NOEC (denitrification in lake sediment)	0.030 mg/L	None	0.030 mg/L
Aquatic Plants					
	Algae	LC ₅₀ (<i>C. vulgaris</i>)	180g/L	÷ 6 ^c	30 mg/L

Neither USFS nor EPA have conducted a risk assessment for pelargonic acid. There are no TRVs to compare to the values in this Table. NA = no studies were available

^a Summing normal to above-average human dietary exposure to pelargonic acid over various possible foods and food preservatives yields an expected 20 mg/kg day for an adult male.

^b The LOAEL from from a developmental toxicity study was divided by three to obtain the NOAEL.

^c The factor of six (all organisms except fish) or 20 (fish) is used when there is only an LD₅₀ or LC₅₀ value available, but not a NOAEL or NOEC. The factor of six is used by the US EPA in evaluation of endangered species effects and is based on a review of literature studies in which both LD₅₀ or LC₅₀ and NOAEL or NOEC values were available for comparison. The factor of 20 is used for especially sensitive species such as salmonids. See text on page 7-8 for more discussion of this concept.

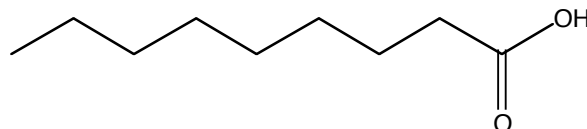
^d The LC₅₀ of 25 µg/bee was converted to a dose in mg/kg by multiplying by the conversion factor between of 0.000093 kg for the body weight of a bee.

^e Species used were: Canada thistle *Cirsium arvense*, buckhorn plantain *Plantago lanceolata*, eastern black nightshade *Solanum pycnanthum*, giant foxtail *Setaria faberi* and redroot pigweed *Amaranthus retroflexus*.

7.4 Environmental Fate of Pelargonic Acid

7.4.1 Overview

Pelargonic acid (CAS number 112-05-0) is a fatty acid herbicide, with empirical formula of $C_9H_{18}O_2$. The chemical structure is shown below. Pelargonic acid used in herbicides can be formulated as the acid or as the potassium or ammonium salt; the Scythe product selected for consideration by MMWD contains the acid form of the compound. Table 7-5 summarizes the chemical and physical properties of pelargonic acid.



Pelargonic acid is a weak organic acid, with pKa of 4.95.⁴¹ In aqueous solution, the acid is only partially dissociated to form the pelargonate anion and acid (H_3O^+). A 1% solution of Scythe herbicide (57% pelargonic acid) is acidic, with pH of 3.75.⁴²

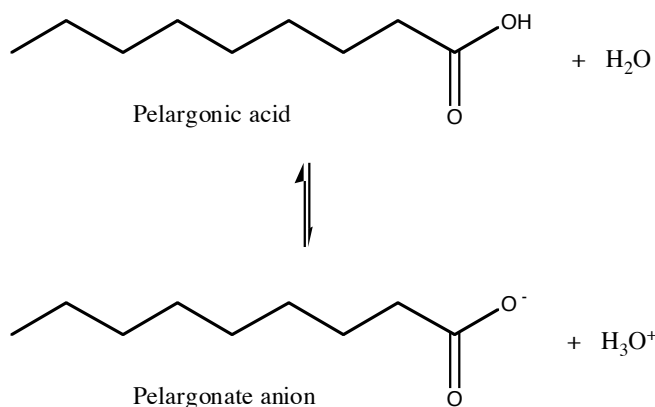


Table 7-5: Chemical and Physical Properties of Pelargonic Acid

Property	Pelargonic acid
CAS number	112-05-0
EPA PC code	217500
Molecular weight (g/mol)	158.24
Water solubility (mg/L at ~25°)	210
Half-life (days)	
Hydrolysis	Stable (sterile solution)
Anaerobic, soil	--
Aerobic, soil	1
Atmospheric	1.6
Field dissipation (soil)	--
Field dissipation (water)	--
Vapor pressure (mm Hg at ~25°C)	0.0016
K_{oc} (mL/g)	1,700
K_{ow} (20°C)	2,630
K_H (atm·m ³ /mol at ~25°C)	1.6×10^{-6}

Data sources: References 4, 9, 41, and 43.

7.4.2 Water Solubility and Soil Binding of Pelargonic Acid

Pelargonic acid is an oily liquid at room temperature and has moderate water solubility (210 mg/L at 25°C). The ammonium and potassium salts of pelargonic acid have much higher water solubility and are completely miscible in water.⁴³ The octanol-water partition coefficient, K_{ow} , for pelargonic acid is 2,630,⁴¹ indicating low solubility in water relative to organic solvents and some potential for bioaccumulation. Because the half-life of pelargonic acid is quite short and most animals rapidly metabolize the compound, bioaccumulation is unlikely to occur to a significant extent. Pelargonic acid occurs naturally in low concentrations in soil.⁴¹

The organic-carbon-adjusted soil adsorption coefficient (K_{oc}) of pelargonic acid is 1,700 mL/g,⁴¹ a value that indicates that, in a mix of soil and water, pelargonic acid preferentially binds to soil rather than remaining dissolved in water. Pelargonic acid also forms insoluble complexes with calcium and magnesium salts. As a result, pelargonic acid has low mobility in soils and binds strongly to sediments.

7.4.3 Persistence of Pelargonic Acid

Pelargonic acid is short-lived in the environment and is rapidly dissipated and degraded via several pathways. In soils, microbial activity is the primary degradation process, with an estimated aerobic soil half-life of less than one day.⁴ Ninety-seven percent of pelargonic acid applied to loam was degraded within two days.⁴⁴ Pelargonic acid does not hydrolyze in water, but will volatilize from water over time if microbial degradation or adsorption to sediments does not occur.

Pelargonic acid can be transported away from an application site or degrade in soil, water and air through a number of different chemical or biological processes. The most important processes for dissipation of pelargonic acid are microbial biodegradation, volatilization, and adsorption to soils and sediments.

7.4.3.A Microbial Degradation

Microbial transformation of pelargonic acid is the primary means of degradation in the environment. As a straight chain fatty acid, it is metabolized by beta oxidation (see Section 7.3.1.A) to form acetate, which enters the Krebs cycle and is metabolized to carbon dioxide, water and ATP. None of the metabolites are considered to have any toxicological risk.

7.4.3.B Transport by Air

Air transport of pelargonic acid away from the application site can occur through spray drift during and for a short time after an application. Spray drift can contaminate soil and surface waters, damage non-target plants, and expose humans and wildlife through inhalation and dermal exposure. Post-application volatilization drift is also a significant source of off-site transport for pelargonic acid because of its high vapor pressure (0.0016 mm Hg at 25°C).⁴¹ When dissolved in water, pelargonic acid slowly volatilizes to the air, as dictated by its low Henry's law constant of 1.6×10^{-6} atm-m³/mol.⁴¹ The modeled volatilization half-life from a river was calculated to be 29 days; volatilization from a lake was estimated to occur with a 210-day half-life.⁹ Volatilization is also expected to occur from wet soils, although microbial degradation will be the dominant

process in soils. Vapor phase pelargonic acid reacts rapidly with hydroxyl radicals in the atmosphere, with an estimated half-life of 1.6 days.⁴¹

7.4.3.C Transport by Water

Pelargonic acid adsorbs strongly to soils and is rapidly degraded by microbes, thus it is not considered to be a potential groundwater contaminant, nor is substantial surface water runoff anticipated, except through preferential flow pathways such as cracks and crevices or gravelly soils, if rain were to occur soon after an application..

7.4.3.D Uptake by Plants

Plants treated with pelargonic acid do not translocate the chemical through foliage or roots of the plant. There is no information available on the persistence of pelargonic acid residues in dead plant tissue.

7.4.3.E Field Studies on the Environmental Fate of Pelargonic Acid

No field studies are available on the environmental fate and transport of pelargonic acid.

7.4.4 Scythe Product Profile

The Scythe product has been selected as one of the herbicides to be considered by MMWD for possible use in its Vegetation Management Plan (VMP). Scythe (US EPA reg # 62719-529) contains pelargonic acid as the active ingredient (a.i.) at 57% weight percent. The product also contains other fatty acids with chain lengths from six to twelve carbon atoms (3%), and petroleum distillates (30%), with the remaining 10% percent made up with inert ingredients that act as emulsifiers.⁴² The identity of the inerts in Scythe is proprietary. The product contains 4.2 lbs/gal of pelargonic acid.⁴⁵ When applied as a foliar spray, Scythe is mixed at 3–10% by volume in aqueous solution. Probable application rates that may be used by MMWD are anticipated to be 4–10 lbs/acre.

EPA has given this product an acute hazard warning label of “Warning”, placing it in Category 2. This rating means that the product is considered to be “Moderately toxic.” Exposure to skin or eyes may cause moderate skin irritation and substantial but temporary eye irritation. It is harmful if inhaled.

7.5 Exposure Assessment and Risk Characterization for Pelargonic Acid

Assessment of risk requires knowledge of both the inherent toxicity of a chemical and the amount of exposure that is anticipated based on intended uses. Risk characterization combines the hazard and exposure data to provide a picture of risks associated with herbicide use.

This exposure analysis is divided into four categories: workers, the general public, terrestrial wildlife, and aquatic life. Only foliar applications are modeled. Expected application rates of 4.0, 8.0 and 10.0 pounds per acre were used to calculate Lower, Central and Upper exposure estimates. The Central exposure estimate provides the most likely exposure scenario and the Upper estimate represents a low-probability, worst-case event. More information about the types of exposure scenarios considered in this risk assessment is available in section 2.4. Toxicity reference values and dietary reference values for pelargonic acid used in the analysis are discussed in Section 7.2.1 (humans) and Section 7.3 (animals and other organisms).

The USFS has not yet created a worksheet for pelargonic acid or similar fatty acids; thus, a new spreadsheet was developed for the MMWD analysis. All chemical-specific parameters are from the available literature. Peak runoff was not modeled because there are no available empirical nor modeled water contamination rates. Long-term runoff was not modeled because pelargonic acid degrades rapidly in the environment and is not expected to persist into the rainy season. Bioconcentration in fish is not anticipated, since pelargonic acid is rapidly metabolized as a food source.

As with the other herbicides evaluated for the MMWD project, several additional exposure scenarios were evaluated that were not in the SERA/USFS worksheets, including drinking water exposure for birds and large mammals and all exposures for a large carnivore. Because pelargonic acid is quite volatile, a worker inhalation exposure worksheet was also added. For water contamination, scenarios for accidental spills of concentrated and diluted pelargonic acid product to a small, thermally stratified pond and Bon Tempe reservoir were evaluated.

An additional worksheet was developed to sum the dermal and ingestion exposures for wildlife to give aggregate doses. Aggregate worker exposures from multiple exposure events were also estimated. No aggregate exposures were estimated for the general public because of the low probability of multiple exposures.

Exposure scenarios were categorized qualitatively as “**Highly Probable**,” “**Probable**,” “**Possible**,” “**Improbable**” and “**Highly Improbable**.” These five categories are used throughout the exposure estimates to designate the likelihood of each scenario occurring. Common scenarios and their probabilities are summarized in Tables 2-8 through 2-11, starting on page 2-28. Assigned probabilities are based on the assumption that the application guidelines are followed.

For all of the different exposure scenarios, **Lower**, **Central** and **Upper** estimates were calculated. Upper exposure estimates were calculated by changing all parameters to values that increase estimates; Lower estimates were obtained by changing all parameters to values that decrease estimates; and Central estimates used parameter values that are perceived as most realistic. See Section 2.4 for a complete description of parameter values used in the calculations.

Exposure estimates for the humans and wildlife are presented and compared to dietary reference values (DRVs) for humans and mammals and toxicity reference values (TRVs) for other organisms to give a fraction of dietary intake (FDI) or hazard quotient (HQ) that provides an estimate of risk for different exposure scenarios. Fractions of dietary consumption above one do not necessarily indicate excessive risk, only that a normal to above-average dietary level of pelargonic acid is exceeded. Hazard quotients above one indicate that exposure exceeds the level of concern, and humans or wildlife may be at risk of adverse effects. Scenarios with $HQ > 1.0$ are flagged as potentially problematic and recommendations are made for how to avoid them. Hazard quotients between 0.1 and 1.0 suggest that there may be particularly sensitive individuals or species that may be affected. Hazard quotients below 0.1 indicate low levels of risk for the effects that have been studied and are represented by the TRVs.

No assessment of risks could be performed for the unidentified “inert” ingredients in the Scythe product—30% paraffinic petroleum oil, and 10% of an unidentified emulsifier—or the product mixture, and risks from exposure to these substances remain unknown. Addition of a surfactant to application mixtures is not suggested on the Scythe label, and exposures to added surfactants would not be anticipated from use of Scythe.

7.5.1 Chemical-Specific Exposure Parameters for Pelargonic Acid

Many of the parameters used to estimate exposure are constant from chemical to chemical, e.g., typical amounts of food consumed, surface area of a child, and body weight, among others. These parameters and the values used in the exposure models are discussed in Section 2.4. Other parameters, such as dermal absorption coefficients and water contamination rates, are chemical-specific and are based on experimental data and/or physical properties such as water solubility, K_{ow} , vapor pressure, K_{oc} and half-life.

Table 7-6 presents the pelargonic acid-specific parameters used in the calculations, including dermal absorption rates, half-lives, and air concentration estimates. As discussed in Section 2.4.3, USFS/SERA developed an estimate of dermal absorption rates and dermal permeability based on K_{ow} and molecular weight. This calculation was also used to estimate dermal absorption for glyphosate, triclopyr and clopyralid. For these chemicals, experimental data on dermal absorption rates were available for comparison to the estimated absorption rates. Although there are no dermal absorption data available for pelargonic acid, the calculation utilizing the K_{ow} and the molecular weight is the best available estimate and was used in the risk assessment.

The EPA-estimated half-life of pelargonic acid in soil is one day, with microbial metabolism accounting for most of the degradation. In water, half-lives of 29 days for a model river to 210 days for a model lake were estimated.⁹ None of these half-lives are ideal for calculating the half-life of pelargonic acid on vegetation. In the absence of additional experimental data and in consideration of the volatility of pelargonic acid, a Central residue half-life of 15 days was selected. The Upper and Lower estimates of one and 29 days respectively, bracket the range of possible half-lives.

Estimates of airborne concentrations of pelargonic acid at the application site due to volatilization were calculated using data from the California Air Resources Board (ARB) and Department of Pesticide Regulation (DPR) monitoring reports of pesticide applications.⁴⁶ The calculation used to estimate inhalation exposure is based on the vapor pressure of pelargonic acid and is described in detail in Section 2.4.3.A.

Table 7-6: Pelargonic Acid-Specific Exposure Parameters

Parameter	Lower Value	Central Value	Upper Value
First-order dermal absorption rate (h^{-1})	0.0062	0.025	0.11
Dermal permeability (cm/hr)	0.029	0.052	0.095
Half-life as residue on food (days)	1	15	29
Concentration in air at application site (mg/m^3)	0.00139	0.0139	0.139

Data source: References 11 and 46.

Brenton VMS listed the following techniques as potential strategies for MMWD for controlling invasive species with pelargonic acid:

- High volume foliar applications to control broom seedlings at 4.27-8.54 pounds per acre
- Spot foliar to control thistle at 4.27 pounds per acre
- Foliar applications to control annual grasses at 4.27 pound per acre

The application rates and volumes listed in Table 7-7 were used to calculate Lower, Central and Upper exposure estimates for workers, the general public, and terrestrial and aquatic wildlife.

The foliar scenarios provide an estimate of exposures from high-volume (25–50 gallons per acre) applications. The anticipated application rates of pelargonic acid would be: 4–10 lbs a.i./acre. A range of volumes from 33 to 67 gallons per acre is modeled, resulting in concentrations of 3-5% pelargonic acid (by volume). Exposure estimates for cut-stump applications are not calculated because pelargonic acid will not be used for cut-stump applications. However, workers may transport concentrated product to the site before foliar applications. Therefore, exposures for the worst-case scenario of an accidental spill of undiluted Scythe (4.2 lb a.i./gallon) were estimated for workers, the general public, terrestrial wildlife, and aquatic wildlife.

Table 7-7: Application Rate and Application Volume Model Inputs

Scenario	Parameter	Lower	Central	Upper
High-volume foliar	Application rate (lb a.e./acre)	4	8	10
	Percent a.i. (volume %)	3	3	8
	Application volume (gallons)	33	67	50

7.5.2 Application Methods for Pelargonic Acid

Because Scythe is a burndown, non-systemic herbicide, application methods that may be used on MMWD lands for pelargonic acid are limited to directed foliar sprays or ground sprays of cotyledons and seedlings not more than 12 inches in height. In directed foliar applications, the herbicide sprayer or container is carried by backpack and the herbicide is applied to selected target vegetation. Chemical contact with the arms, hands, or face is Highly Improbable because of the low height of the vegetation treated. To reduce the likelihood of significant exposure to legs, application crews should not walk through treated vegetation. Usually, a worker treats approximately 0.5 acre/hour with a plausible range of 0.25–1.0 acre/hour.

Ground sprays are usually conducted with a truck or tractor-mounted boom that applies the herbicide to a swath the width of the boom. Ground spray application methods typically treat approximately 16 acres/hour with a plausible range of 11–21 acres/hour.

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7.5.3 Water Contamination Estimates

Concentration estimates for eight accidental spill scenarios were calculated, four of the scenarios with Central, Lower and Upper values. The eight spill scenarios included three spill volumes

(one, 20 and 200 gallons) for a spill of the diluted product to a thermally stratified small pond and Bon Tempe reservoir. The 200 gallon spill of diluted product was added specifically for pelargonic acid because work crews may transport more diluted product because of the higher application rate used for pelargonic acid compared to the the three conventional herbicides. Two additional 20-gallon spill scenarios were calculated for water contamination from a spill of concentrated product to a small pond and Bon Tempe reservoir. The spills of concentrated product are designed to represent a spill that might occur on-site during mixing, since Scythe is not applied in concentrated form. See Section 2.4.2 for a detailed discussion of these scenarios. Results are shown in Table 7-8.

Throughout this document, the word “contaminated” is used to mean that any amount of a chemical residue is present. “Contaminated” does not necessarily equate to hazardous, but indicates only that the compound is present at some level.

Exposures from peak runoff and long-term runoff scenarios were not calculated because of the short degradation half-life of pelargonic acid (less than a few days). The dissipation half-life of pelargonic acid is also low as a result of its high vapor pressure, resulting in rapid volatilization and transport away from the application site with prevailing winds. Thus, it is unlikely that significant quantities of pelargonic acid would remain at an application site for a sufficient length of time that even a peak runoff scenario would cause substantial runoff into water bodies. Therefore, only concentrations from accidental spill scenarios were modeled. A 200 gallon spill of diluted product was added to the set of calculations for pelargonic acid.

Table 7-8: Calculated Pelargonic Acid Concentrations for Water Contamination Scenarios

Scenario		Concentrations (mg/L)		
		Central	Lower	Upper
Thermally-stratified pond				
Accidental spill of diluted product	1 gal	0.21	0.23	0.36
	20 gal	4.24	4.54	7.27
	200 gal	42	45	120
Accidental spill of concentrated product	20 gal	151	^a	^a
Well-mixed reservoir				
Accidental spill of diluted product	1 gal	0.000011	0.000012	0.000018
	20 gal	0.00021	0.00023	0.00037
	200 gal	0.0021	0.0023	0.0060
Accidental spill of concentrated product	20 gal	0.0077	^a	^a

^a Only a single, worst-case estimate of concentration was calculated for spills of concentrated Scythe product.

Exposures from peak runoff and long-term runoff scenarios were not calculated because of the short dissipation half-life of pelargonic acid (less than two weeks) as a result of its high vapor pressure and rapid microbial degradation. Pelargonic acid quickly volatilizes and is carried away from the application site with prevailing winds and is rapidly degraded by soil microbes. Thus, it is unlikely that significant quantities of pelargonic acid would remain at an application site long enough to be washed away in the fall/winter rainy season. Therefore, only concentrations from accidental spill scenarios were modeled.

For the three conventional herbicides, an additional calculation was developed to determine the maximum volume of herbicide that could be used in the MMWD watershed without exceeding herbicide concentrations that produce an HQ > 0.1, 0.5 and 1.0 for a child drinking water from the reservoir, assuming 5% and 100% long-term runoff of applied herbicide. This calculation was not done for pelargonic acid, since no long-term runoff is anticipated.

7.5.4 Risks to Humans

Exposure estimates were performed for both workers and members of the general public. Accidental/incidental and general handling exposures were considered for herbicide applicators for ground spray and backpack foliar applications. No exposures for pelargonic acid cut-stump applications were calculated because this type of application is not proposed for the MMWD project. Public exposure estimates were developed for the scenarios of people contacting contaminated vegetation on or near an application site, eating contaminated fruit, or drinking contaminated water. Only acute exposure scenarios were evaluated to obtain a range of exposure estimates for both worst-case and more probable scenarios.

7.5.4.A Workers

Risks from accidental and general exposure scenarios were calculated for workers. Accidental exposures include wearing contaminated gloves for one minute and one hour, direct spray onto hands, and direct spray to lower legs. General exposures for backpack spraying and ground spraying were also calculated.

The highest Central worker exposure estimate was 28 times the DRV for the Improbable event of wearing gloves contaminated by concentrated product for one hour. Dermal exposures provided the highest doses because of the high dermal permeability coefficient of pelargonic acid. Estimated exposures and hazard quotients for all worker exposure scenarios are presented in Table 7-9.

Exposure estimates from the scenarios that are the most likely to occur for workers are highlighted below:

1. **General exposure due to backpack spraying (Highly Probable).** The Central dose estimate for general backpack spraying is 0.55% of the DRV. The Upper estimate is 4% of the DRV.
2. **General exposure due to ground spraying (Highly Probable).** The Central dose estimate for general ground spraying is 0.9% of the DRV. The Upper estimate is 7.6% the DRV.
3. **Inhalation from general exposure (Highly Probable).** The Central dose estimate for inhalation due to general exposure is 0.033% of the DRV. The Upper estimate is 0.8% of the DRV.
4. **Wearing contaminated gloves for one minute (Probable).** The Upper dose estimate for wearing gloves contaminated by diluted product for one minute is 2.3% of the DRV. For the concentrated product, the dose estimate is 47% of the DRV.
5. **Wearing contaminated gloves without washing for one hour (Improbable).** The Upper dose estimate for wearing gloves contaminated with dilute product for one hour is 1.4 times the DRV. For concentrated product the same scenario yields a dose that is 28 times the DRV.

6. **Accidental spill to the hands that is left unwashed for one hour (Improbable).** The Central dose estimate for a spill of diluted product on workers' hands and leaving it for one hour is 0.17% of the DRV. The Upper estimate is 1.2 % of the DRV. The Central dose estimate for a spill of concentrated product on workers' hands and leaving it for one hour is 6.1% of the DRV. The Upper estimate is 24% of the DRV.
7. **Accidental spill to the lower legs that is left unwashed for one hour (Improbable).** The Central dose estimate for a spill of diluted product to workers' lower legs for one hour is 0.42 % of the DRV. The Upper estimate is 2.9 % of the DRV. The Central dose estimate for a spill of concentrated product on workers' lower legs and leaving it for one hour is 15% of the DRV. The Upper estimate is 60% of the DRV.

If accidental worker exposures occur, the dose from that scenario must be added to the general exposure to obtain an aggregate dose. For example, if a worker sprays vegetation with a backpack sprayer for seven hours, inhales the chemical and also wears a contaminated glove for one hour, the combined Central exposure estimate is $0.0055 + 0.00033 + 1.4 = 1.4$ mg/kg-day. In this case, wearing contaminated gloves for one hour yields an exposure that is 250 times the general exposure estimate and 4,000 times larger than the inhalation exposure. In this case, the spill exposure estimates are much higher than the general exposure for pelargonic acid, thus general exposure does not contribute significantly to the aggregate exposure. However, multiple spills and continued wearing of contaminated gloves would add up high aggregate exposures. Confidence in these assessments is low, as dermal absorption and general exposure data for pelargonic acid are not available.

These exposure estimates do not include splashes into the eyes, as there are no quantitative, systemic exposure estimates for this scenario. Scythe is a moderate eye irritant,⁴² but little systemic absorption would be expected from such an event.

Confidence in these assessments is only moderate, as dermal absorption data for pelargonic acid are not available.

Table 7-9: Estimated Pelargonic Acid Exposures and Fraction of Dietary Intake for Workers

Scenario	Calculated Dose (mg/kg)			DRV ^a (mg/kg-day)	Fraction of Dietary Intake (FDI) ^a		
	Central	Lower	Upper		Central	Lower	Upper
Foliar Worker Accidental/Incidental Exposures (dose in mg/kg-event)							
Contaminated gloves, 1 min	0.15	0.086	0.45	20	0.0075	0.0043	0.023
Contaminated gloves, 1 h	8.77	5.18	27	20	0.44	0.26	1.4
Spill on hands, 1 h	0.034	0.0089	0.23	20	0.0017	0.00045	0.012
Spill on lower legs, 1 h	0.083	0.022	0.57	20	0.0042	0.0011	0.029
Worker Accidental/Incidental Exposures with Concentrated (no dilution) Product (dose in mg/kg-event)							
Contaminated gloves, 1 min	5.22	2.88	9.46	20	0.26	0.14	0.47
Contaminated gloves, 1 h	313	173	568	20	16	8.7	28
Spill on hands, 1 h	1.21	0.30	4.8	20	0.061	0.015	0.24
Spill on lower legs, 1 h	2.98	0.73	12	20	0.15	0.037	0.60
Foliar Worker General Exposures (mg/kg-day)							
General exposure, backpack spraying	0.11	0.0018	0.80	20	0.0055	0.000090	0.040
General exposure, ground spraying	0.18	0.0026	1.51	20	0.009	0.00013	0.076
Inhalation	0.0065	0.00026	0.16	20	0.00033	0.000013	0.0080

DRV = Dietary Reference Value. FDI = Fraction of Dietary Intake. FDIs greater than one are shaded.

^a See Section 7.2.1 for a discussion of the DRV and FDIs.

7.5.4.B General Public

Acute and chronic pelargonic acid exposure scenarios for the general public were evaluated for direct spray onto a person, contact with contaminated vegetation, and consumption of contaminated fruit and water. No runoff or fish consumption scenarios were evaluated because pelargonic acid will not persist until the rainy season and it does not bioaccumulate. Exposure estimates for the general public are lower than for workers, and no exposures exceed the DRV, an amount of pelargonic acid ingested in a typical daily diet, see Table 7-10 below.

No exposure scenarios are considered to be Probable or Possible for pelargonic acid. It is still useful to consider the scenarios which yield the highest exposures, regardless of their probability, to evaluate the potential need for additional precautions to protect the public. For pelargonic acid, only two scenarios result in Central FDIs above 0.1; both are Highly Improbable.

1. **Direct spray of a child over its entire body (Highly Improbable).** The Upper and Central dose estimates for a child sprayed with pelargonic acid over its entire body are 43% and 6.4% of the DRV.
2. **A child drinking from a thermally stratified, small pond (Highly Improbable).** The Upper and Central dose estimates for a 20-gallon spill of diluted and concentrated pelargonic acid to a pond are 0.41% and 85% of the DRV, respectively.
3. **A woman consuming contaminated berries (Improbable).** The Upper and Central acute dose estimates for a woman eating berries that have been sprayed with pelargonic acid are 1.7% and 0.13% of the DRV. The Upper and Central chronic dose estimates are 0.7% and 0.03% of the DRV.

4. **A woman brushing against contaminated vegetation (Improbable).** The Upper dose estimate for a woman brushing against contaminated vegetation is 6.0% of the DRV. The Central estimate is 2.3% of the DRV.

The likelihood of exposures from brushing against contaminated vegetation can be reduced to Improbable by trimming or mowing vegetation prior to treatment.

Water Consumption Scenarios: Only the Highly Improbable scenario in which a child drinks from a thermally stratified pond contaminated with concentrated product resulted in Central HQs greater than 1.0 (20-gallon spill, HQ=4.4 times the RfD). A spill of 200 gallons of diluted Scythe product results in a smaller Central HQ of 1.3 times the RfD.

Concentrations of pelargonic acid from spills into a reservoir like Bon Tempe were lower than those for spills into a small pond by a factor of 20,000, and HQs are substantially less than one—0.033% of the DRV for the Upper exposure estimate for child drinking out of Bon Tempe reservoir after a 20-gallon spill of concentrated product. Adherence to the MMWD application guidelines would make a high-volume spill of concentrated product into a reservoir Highly Improbable, and with a plan in place to notify water treatment plants if such a spill were to occur, we conclude that it is Highly Improbable that drinking water quality in MMWD reservoirs will be compromised by spills of pelargonic acid into the reservoirs.

Contamination by long-term runoff will not occur with pelargonic acid because it degrades rapidly in the environment and is not expected to persist into the rainy season.

Table 7-10: Estimated Pelargonic Acid Exposures and Fraction of Dietary Intake for the General Public

Scenario	Receptor	Calculated Dose (mg/kg-event)			DRV ^a (mg/kg-day)	Fraction of Dietary Intake (FDI) ^a		
		Central	Lower	Upper		Central	Lower	Upper
Acute exposure estimates for diluted pelargonic acid product (foliar treatment)								
Direct spray of child, whole body	Child	1.28	0.34	8.69	20	0.064	0.017	0.43
Direct spray of woman, feet, lower legs	Adult female	0.13	0.034	0.87	20	0.0065	0.0017	0.044
Vegetation contact, shorts and T-shirt	Adult female	0.46	0.066	1.19	20	0.023	0.0033	0.060
Contaminated fruit consumption	Adult female	0.025	0.012	0.34	20	0.0013	0.0006	0.017
Water consumption (pond) after : 1 gal spill	Child	0.016	0.010	0.041	20	0.00080	0.00050	0.0021
20 gal spill	Child	0.32	0.21	0.82	20	0.016	0.011	0.041
20 gal spill of concentrated product	Child	11	6.9	17	20	0.57	0.35	0.85
Water consumption (reservoir) after : 1 gal spill	Child	8.08x10 ⁻⁷	5.28x10 ⁻⁷	2.08x10 ⁻⁶	20	4.04x10 ⁻⁸	2.64x10 ⁻⁸	1.04x10 ⁻⁸
20 gal spill	Child	1.62x10 ⁻⁵	1.06x10 ⁻⁵	4.15x10 ⁻⁵	20	8.1x10 ⁻⁷	5.3x10 ⁻⁷	2.08x10 ⁻⁶
20 gal spill of concentrated product	Child	0.00058	0.00035	0.00087	20	0.000029	0.000018	0.000043
Chronic exposure estimates for diluted pelargonic acid product (foliar treatment)								
Fruit consumption	Adult female	0.0059	0.00020	0.14	20	0.00030	0.000040	0.0070

DRV = Dietary Reference Value. Fraction of Dietary Intakes greater than one are shaded.

^aSee Section 7.2.1 for a discussion of the DRV and FDIs.

7.5.5 Risks to Wildlife

The wildlife risk assessment is divided into two parts, terrestrial and aquatic. Of the scenarios that could be evaluated, aquatic wildlife are at greater risk as a result of pelargonic acid exposure than terrestrial wildlife because of the higher toxicity of pelargonic acid to aquatic life. However, the aquatic wildlife scenarios evaluated below are either Improbable or Highly Improbable. Long-term runoff is also unlikely given the high volatility and short half-life of pelargonic acid that indicate that most of the chemical will degrade or volatilize before a runoff event.

Most of the dermal exposure scenarios for terrestrial wildlife produced to exposure estimates that exceeded 10% of the TRVs. Eating contaminated insects and vegetation also exceeded 10% of the TRV. High exposure estimates are largely a result of the high application rate of pelargonic acid because pelargonic acid tends to have high terrestrial TRVs. Hazard quotients exceeded one for most of the pond scenarios.

7.5.5.A Terrestrial Wildlife

Only a subset of the wildlife scenarios described in Chapter 2 were evaluated for pelargonic acid. Tables 7-11, 7-12, and 7-13 provide the acute, chronic, and aggregate pelargonic acid exposure estimates and hazard quotients for terrestrial wildlife. See Section 2.4.5 for a discussion of the methods used to estimate wildlife exposures and 7.2 for a summary of pelargonic acid toxicity studies and TRVs.

With the exception of the drinking water scenarios, all wildlife exposures were considered Possible or Probable for pelargonic acid. For the applications proposed by the MMWD, it is possible that TRVs for honeybees near the application site may be exceeded. These exposure estimates may be overestimates for herbivores because the invasive vegetation being sprayed is typically not the preferred diet of native species.

1. **A large mammal eating contaminated vegetation, acute (Possible).** The Central acute exposure estimates for grass-eating herbivores is 14% of the TRV. The upper estimate is 49% of the TRV.
2. **A large bird eating contaminated vegetation, acute (Possible).** The Central acute exposure estimate for an herbivorous bird is 65% of the TRV. The Upper estimate is 2.3 times the TRV.
3. **A small mammal eating contaminated insects (Probable).** The Central acute dose estimate for a small mammal eating contaminated insects is 19% the TRV. The Upper dose estimate is 69% times the TRV.
4. **A small bird eating contaminated insects (Probable).** The Central dose estimate for a small bird eating contaminated insects is 90% of the TRV. The Upper estimate is 3.4 times the TRV.
5. **Consumption of contaminated prey by carnivorous mammals or birds, acute (Possible).** Central estimates of exposure for all carnivorous mammals and birds are less than 8% of the TRVs, and the Upper estimates are less than 10% of the TRVs.
6. **A large mammal eating contaminated vegetation on-site, chronic (Possible).** The Central chronic exposure estimate for grass-eating herbivores is 1% of the TRV. The

Upper chronic exposure estimate for a grass-eating herbivore eating on-site is 20% of the TRV.

7. **A large bird eating contaminated vegetation on site, chronic (Possible).** The Central chronic exposure estimate for a large herbivorous bird eating on-site is 4.5% of the TRV. The Upper estimate is 94% of the TRV.

Of the Improbable scenarios, all Upper estimates for accidental spray of insects and small mammals resulted in HQs exceeding 0.1. The Central exposure estimates exceeded 0.1 for scenarios that assume 100% dermal absorption.

Aggregate exposure estimates are the sum of dermal and food exposures. Water consumption was not included in aggregate exposure estimates because it is Highly Improbable that both an acute spill and dermal exposure would occur on the same day and long-term runoff will not occur for pelargonic acid because it dissipates before the rainy season. USFS/SERA did not calculate aggregate exposures; this calculation was added for the MMWD assessment for insectivorous and herbivorous small mammals because of their vulnerability to direct sprays and eating contaminated food in a single day. The results are presented in Table 7-13. The highest aggregate exposure produced a hazard quotient nearly equal to the TRV for the Upper exposure estimate for insectivorous small mammals. The contribution from contaminated food and direct spray was roughly equal but varied by species.

7.5.5.B Terrestrial Plants

For terrestrial plants, unintended direct spray will result in an exposure equivalent to the application rate. Most plants that are sprayed directly with pelargonic acid at or near the recommended range of application rates will be damaged. Buffer zones of 25 feet are probably sufficient to protect most plants because high application rates are necessary to achieve the herbicidal effects of pelargonic acid. Less than 2% of the chemical is expected to drift more than 25 feet. Pelargonic acid affects only plant foliage and will not have any residual herbicidal effects at the site.

Table 7-11: Estimated Acute Pelargonic Acid Exposures and Hazard Quotients for Terrestrial Wildlife

Scenario	Receptor	mg/kg-day or mg/kg/event			TRV (mg/kg)	Hazard Quotient (HQ)		
		Central	Lower	Upper		Central	Lower	Upper
Direct Spray								
First-order absorption	Small mammal	89	13	223	1,000	0.089	0.013	0.22
100% absorption of direct spray to 50% of body	Small mammal	194	97	242	1,000	0.19	0.097	0.24
100% absorption of direct spray to 50% of body	Honeybee	1282	641	1603	45	28	14	36
Consumption of contaminated fruit and vegetation								
Fruit	Small mammal	2.6	1.3	5.0	1,000	0.0026	0.0013	0.0050
Grass	Large mammal	138	69	486	1,000	0.14	0.069	0.49
Grass	Large bird	215	108	760	333	0.65	0.32	2.3
Consumption of contaminated water								
20 gal spill of diluted product into pond	Small mammal	0.62	0.66	1.1	1,000	0.00062	0.00066	0.0011
	Large mammal	0.27	0.29	0.47	1,000	0.00027	0.00029	0.00047
	Small bird	1.1	1.2	2.0	333	0.0033	0.0036	0.0060
	Large bird	0.16	0.17	0.27	333	0.00048	0.00051	0.00081
20 gal spill of diluted product into reservoir	Small mammal	0.000031	0.000034	0.000054	1,000	3.1x10 ⁻⁸	3.4x10 ⁻⁸	5.4x10 ⁻⁷
	Large mammal	0.000014	0.000015	0.000024	1,000	1.4x10 ⁻⁸	1.5x10 ⁻⁸	2.4x10 ⁻⁸
	Small bird	0.000058	0.000062	0.000099	333	1.74x10 ⁻⁷	1.86x10 ⁻⁷	2.97x10 ⁻⁷
	Large bird	8.02x10 ⁻⁶	8.59 x10 ⁻⁶	0.000014	333	2.41x10 ⁻⁸	2.58x10 ⁻⁸	4.20x10 ⁻⁸
20 gal spill of concentrated product into pond	Small mammal	22	a	a	1,000	0.022	a	a
	Large mammal	9.8	a	a	1,000	0.0098	a	a
	Small bird	41	a	a	333	0.12	a	a
	Large bird	5.7	a	a	333	0.017	a	a
20 gal spill concentrated product into reservoir	Small mammal	0.0011	a	a	1,000	1.1x10 ⁻⁶	a	a
	Large mammal	0.00050	a	a	1,000	5.0x10 ⁻⁷	a	a
	Small bird	0.0021	a	a	333	6.3x10 ⁻⁶	a	a
	Large bird	0.00029	a	a	333	8.71x10 ⁻⁷	a	a
Consumption of contaminated insects								
	Small mammal	185	93	694	1,000	0.19	0.093	0.69
	Small bird	301	150	1,128	333	0.90	0.45	3.4
Consumption of contaminated small mammals								
	Carnivorous large mammal	9.0	4.5	11	1,000	0.0090	0.0045	0.011
	Carnivorous small mammal	17	8.4	21	1,000	0.017	0.0084	0.021
	Carnivorous bird	26	13	32	333	0.078	0.039	0.097

TRV = Toxicity Reference Value. Hazard Quotients greater than 0.1 are shaded. Hazard Quotients greater than one are bolded.

^a Only a single, worst-case estimate of concentration was calculated for spills of concentrated Seythe product.

Table 7-12: Estimated Chronic Pelargonic Acid Exposures and Hazard Quotients for Terrestrial Wildlife

Scenario	Receptor	mg/kg-day or mg/kg-event			TRV (mg/kg)	Hazard Quotient (HQ)		
		Central	Lower	Upper		Central	Lower	Upper
Consumption of contaminated fruit and vegetation								
On-site, fruit	Small mammal	0.063	0.0011	0.41	1,000	0.000063	1.1x10 ⁻⁶	0.00041
Off-site, fruit		0.00063	6.14x10 ⁻⁶	0.0076	1,000	6.3x10 ⁻⁷	6.14x10 ⁻⁹	7.6x10 ⁻⁶
On-site, vegetation	Large mammal	9.8	0.11	200	1,000	0.0098	0.00011	0.20
Off-site, vegetation		0.33	0.0064	3.7	1,000	0.00033	6.4x10 ⁻⁶	0.0037
On-site, vegetation	Large bird	15	0.17	312	333	0.045	0.00051	0.94
Off-site, vegetation		0.52	0.010	5.8	333	0.0016	0.000030	0.017

TRV = Toxicity Reference Value. Hazard Quotients greater than 0.1 are shaded. Hazard Quotients greater than one are bolded.

Table 7-13: Pelargonic Acid Aggregate Exposures and Hazard Quotients for Terrestrial Wildlife

Animal	Scenario	Exposure Estimates (mg/kg)		
		Central	Lower	Upper
Herbivorous small mammal eating fruit (TRV = 1,000 mg/kg)				
	Direct spray, first order absorption	89	13	223
	Eating fruit	2.6	1.3	5.0
	<i>Sum</i>	92	15	228
	<i>HQ</i>	0.092	0.015	0.23
Insectivorous small mammal (TRV = 1,000 mg/kg)				
	Direct spray, first order absorption	89	13	223
	Eating insects	185	93	694
	<i>Sum</i>	274	106	917
	<i>HQ</i>	0.27	0.11	0.92

TRV = Toxicity Reference Value. Hazard Quotients greater than one are shaded. The values that are being summed are from Table 7-12.

7.5.5.C Aquatic Wildlife Exposures and Risk Assessment

The calculated water concentrations of pelargonic acid for aquatic life are the same as those used in the human and terrestrial exposure estimates for drinking water (see Table 7-8). Exposure estimates are compared to TRVs for fish, amphibians, aquatic invertebrates and algae, the only taxa for which toxicity information was readily available. No runoff scenarios were evaluated because of the short half-life of pelargonic acid at the application site. Results are shown in Table 7-14.

TRVs for aquatic wildlife are considerably lower than TRVs for terrestrial wildlife. Hazard quotients exceeded one for most of the pond scenarios.

Table 7-14: Estimated Pelargonic Acid Hazard Quotients for Aquatic Wildlife

Receptor	Scenario	Hazard Quotients			TRV (mg/L)
		Central	Lower	Upper	
Fish					
Spill of diluted product into pond:	1 gal	0.46	0.5	0.78	0.46
	20 gal	9.22	9.9	16	0.46
Spill of concentrated product into a pond:	20 gal	328	^a	^a	0.46
Spill of diluted product into reservoir:	1 gal	0.000024	0.000026	0.000039	0.46
	20 gal	0.00046	0.0005	0.00080	0.46
Spill of concentrated product into reservoir:	20 gal	0.017	^a	^a	0.46
Amphibians					
Spill of diluted product into pond:	1 gal	0.095	0.10	0.16	2.2
	20 gal	1.93	2.06	3.30	2.2
Spill of concentrated product into a pond:	20 gal	69	^a	^a	2.2
Spill of diluted product into reservoir:	1 gal	5.0x10 ⁻⁶	5.45x10 ⁻⁶	8.18 x10 ⁻⁶	2.2
	20 gal	0.000096	0.00011	0.00017	2.2
Spill of concentrated product into reservoir:	20 gal	0.0035	^a	^a	2.2
Aquatic Invertebrates					
Spill of diluted product into pond:	1 gal	0.064	0.070	0.11	3.3
	20 gal	1.3	1.38	2.2	3.3
Spill of concentrated product into a pond:	20 gal	46	^a	^a	3.3
Spill of diluted product into reservoir:	1 gal	3.3x10 ⁻⁶	3.6 x10 ⁻⁶	5.5x10 ⁻⁶	3.3
	20 gal	0.000064	0.000070	0.00011	3.3
Spill of concentrated product into reservoir:	20 gal	0.0023	^a	^a	3.3
Aquatic Plants					
Spill of diluted product into pond:	1 gal	0.0070	0.0077	0.012	30
	20 gal	0.14	0.15	0.24	30
Spill of concentrated product into a pond:	20 gal	5.0	^a	^a	30
Spill of diluted product into reservoir:	1 gal	3.7x10 ⁻⁷	4.0x10 ⁻⁷	6.0x10 ⁻⁶	30
	20 gal	7.0x10 ⁻⁶	7.67x10 ⁻⁶	0.000013	30
Spill of concentrated product into reservoir:	20 gal	0.00026	^a	^a	30

TRV = Toxicity Reference Value. Hazard Quotients greater than 0.1 are shaded. Hazard Quotients greater than one are bolded.

^a Only one exposure estimate was evaluated, using the highest possible pelargonic acid concentration.

References for Chapter 7

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