

Environmental Fate of Sulfometuron-Methyl

Shelley Odell
 Environmental Monitoring and Pest Management
 Department of Pesticide Regulation
 Sacramento, CA 95814-3510

This document reviewed all routes of environmental fate of sulfometuron-methyl (methyl 2-[[[[(4,6-dimethyl-2-pyrimidinyl)amino] carbonyl] amino]sulfonyl]benzoate) with an emphasis on plant uptake and plant metabolism.

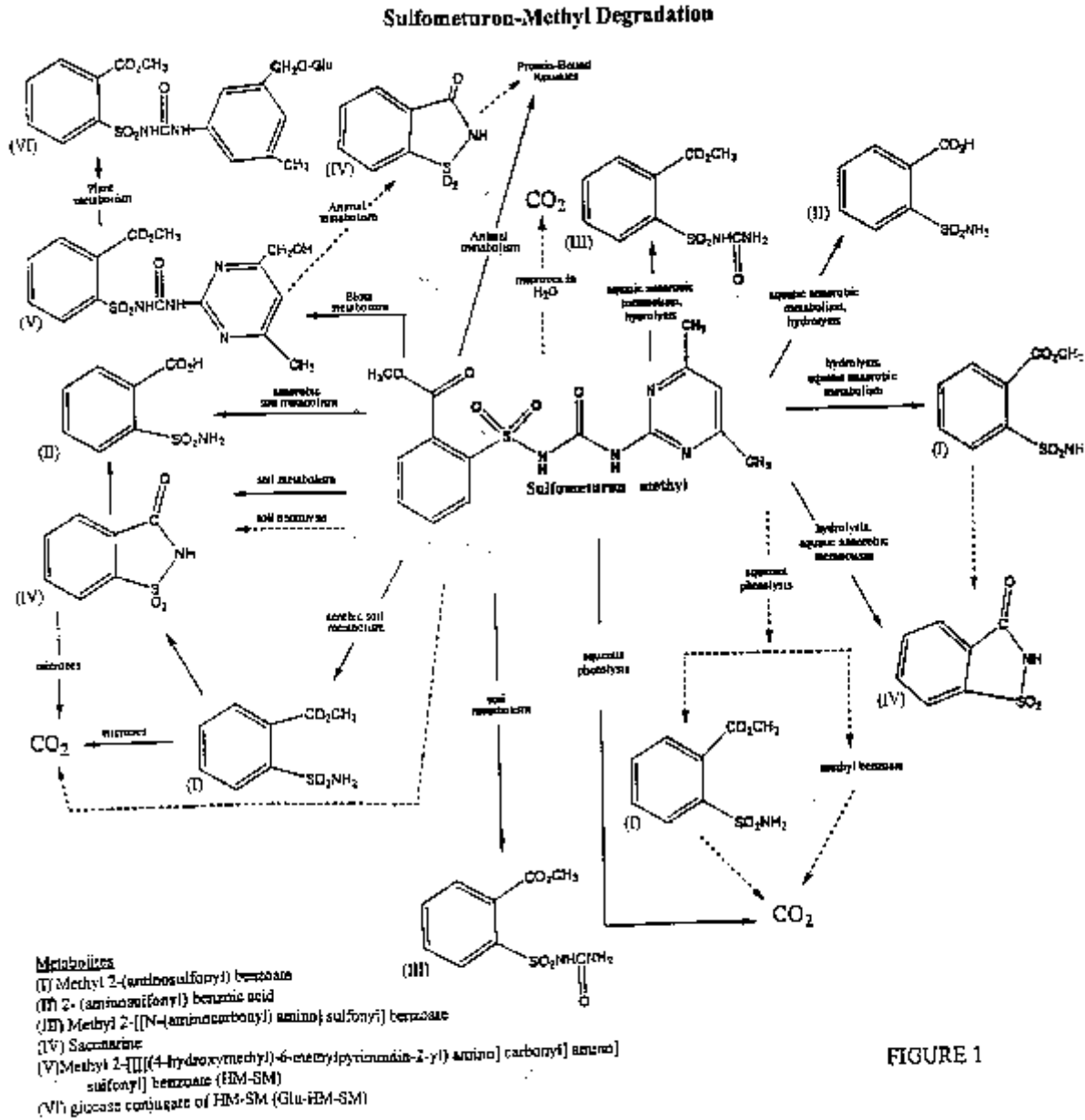


FIGURE 1

Table 1. Chemical characteristics of sulfometuron methyl

Molecular weight	364.39 g/mol
Water solubility (pH 7 at 25c)	244 ppm
Vapor pressure (at 25c)	5.5×10^{-16} mmHg
Henry's constant (pH 7 at 25c)	1.1×10^{-18} atm m ³ /mol
Hydrolysis half-life (pH 7 at 25c)	> 30 days
Aqueous photolysis half-life (pH 7.5 at 25c)	12 days
Soil photolysis half-life (at pH 6.6)	11 days
Organic carbon adsorption coefficient (K_{oc})(range of data collected for four soil types)	range of 63 to 130 cm ³ /g
Octanol-water coefficient (K_{ow}) (at pH 7)	0.35
Anaerobic soil half-life (an average of two at pH 6.5)	283 days
Aerobic soil half-life (an average of two at pH 6.4)	53 days
Field dissipation half-life (at pH 6.7)	14 days

Kollman and Segawa (1995).

Table 2. Toxicity

Bluegill Sunfish LC ₅₀ (96 hrs.)	13 ppm
<i>Daphnia magna</i> LC ₅₀ (48 hrs.)	13 ppm
Rainbow Trout LC ₅₀ (96 hrs.)	13 ppm
Bobwhite Quail 8-day LC ₅₀	>5620 ppm
Mallard Duck 8-day LC ₅₀	> 5000 ppm
Rat oral LD ₅₀	> 5000 ppm
Rabbit skin adsorption LD ₅₀	> 2000 ppm female, > 8000 ppm male
Rat inhalation 4-hour exposure LC ₅₀	> 5 ppm
Acute Oral Test - Rat (ALD) ³	> 17,000 mg/kg
Microcrustaceans LC ₅₀ ¹	> 800 ppm
Teratogenicity	not teratogenic at up to 5000 ppm in rats and 300 mg/kg in rabbits (highest levels tested)
Mutagenicity	not mutagenic
Carcinogenicity ²	not carcinogenic
Eye irritant ³	Mild irritation when tested on rabbits
Skin irritant ³	tests on rabbits and guinea pigs negative

DPR data package 50294-016 (1983)

¹ Naqvi and Hawkins (1989)

² Pesticide Fact Sheet (1995)

³ DPR data package 50294-004 (1981)

General Information and Mode of Action

Sulfometuron methyl is the active ingredient in Oust®, a broad-spectrum sulfonylurea herbicide recommended for preemergence and postemergence control of annual, biennial, and perennial grasses and broad-leaf weeds. The herbicide is used for general weed control on industrial noncrop sites and for selective weed control on turf grasses on industrial sites. It is also used for selective weed control in forest site preparation and in the release of several types of pines and certain hardwoods (DuPont, 1998). Preemergence treatments control or suppress weeds through root uptake and postemergence treatments control via root and foliar uptake. Best results are seen when applications are made prior to or during early weed development, before root systems are established. Sulfometuron methyl should be applied during seasons when rainfall occurs because moisture is needed to move the herbicide to the root system. For best postemergence results, sulfometuron methyl should be applied to young, actively growing weeds. The use rate depends upon weed species, size of weed at application, and soil texture. Rates of application range from 3-5 ounces per acre as a preemergence and early postemergence treatment and 6-8 ounces per acre as a postemergence treatment on actively growing weeds. Sulfometuron methyl is quickly absorbed by foliage and roots and moves rapidly throughout the plant with initial effects ordinarily seen within 2-3 weeks following application and final effects seen after 4-6 weeks after application (Du Pont, 1988). Warm, moist conditions following application accelerate herbicidal activity while cold, dry conditions delay activity. Weeds hardened off by drought stress are less susceptible to sulfometuron methyl.

Sulfometuron methyl acts to suppress amino acid synthesis in plants by inhibiting the plant enzyme acetolactate synthase, particularly in growing tips, roots, and shoots of over 60 species (Meister & Sine, 1997; Anderson & Dulka, 1992). The herbicide is absorbed by both roots and foliage of weeds with visual effects progressing

from growth inhibition followed by a decline in plant vigor followed by reddish-purple discoloration, chlorosis, necrosis, vein discoloration and terminal bud death (Park, 1983). Seed development is usually not inhibited but root and shoot development are normally retarded or stopped (seedling may sprout and then die).

Physical/Chemical Properties

Sulfometuron methyl is an odorless, white, granular solid that is mixed with water and dispersed as a spray. In its granular form, Oust® is 75% active ingredient and 25% inert ingredients (Du Pont, 1988). Solubility in water is pH dependent and is about 10 ppm at pH 5 and 244 ppm at pH 7 both at 25EC (Budavari, 1989; & Kollman and Segawa, 1995). Stability of sulfometuron methyl is indefinite in the dry crystalline form. The compound is stable for a minimum of one month in aqueous solution at pH 7 and 25EC, but is subject to hydrolysis under weakly acidic or strongly alkaline conditions (Park, 1983).

Environmental Fate and Persistence of Sulfometuron Methyl

Environmental Fate and Persistence in Air: Sulfometuron methyl has a low vapor pressure 5.5×10^{-16} mm Hg, (Kollman and Segawa, 1995) so the solid does not readily volatilize. The herbicide also has a very low tendency to volatilize from aqueous solution as evidenced by its low Henry's Law constant, (H). The compound can be considered nonvolatile (Hoffman, 1988). As pH increases, the Henry's Law Constant of sulfometuron methyl decreases. At pH 5, H is 4.3×10^{-17} atm m³/mole; at pH 7, H is 1.1×10^{-18} atm m³/mole, and at pH 9 H is expected to be even lower (Hoffman, 1988).

Environmental Fate and Persistence in Water: Hoffman (1988) determined that the solubility of sulfometuron methyl in water was 244 ppm at pH 7, and that as pH increases more of the salt ionizes and therefore dissociates thus increasing solubility. How much of the compound is found in surface water is largely dependent on pH and temperature. Hydrolysis is the major degradation pathway for sulfometuron methyl. Methyl 2-(aminosulfonyl) benzoate is the normal hydrolysis product of sulfometuron methyl, followed by cleavage of the methyl ester and ring closure to saccharin (Harvey, 1981) (Figure 1). The compound 2-(aminosulfonyl)benzoic acid is the ring-opened derivative of saccharine which is also a predominant hydrolysis degradate (Harvey, 1981). According to Friedman and Harvey (1981), hydrolysis occurred more at lower pH values and was more rapid at 25EC than at 15EC. The hydrolysis half-life of sulfometuron methyl in water at pH 5 was 5 days to 2 weeks at 25EC and greater than 30 days at 15EC. The hydrolysis half-life at pH 7 and 25EC was also greater than 30 days.

Sulfometuron methyl degrades fairly quickly under bright, sunny conditions. The photolysis half-life in water at pH 7 and 25EC is 12 days (Kollman and Segawa 1995) with a complete decomposition of the phenyl ring of sulfometuron methyl to CO₂. In one study, Harvey *et al.* (1985) found that the half-life of sulfometuron methyl was 1-3 days under photolytic conditions simulating typical summer sunshine at noon. In the dark control, sulfometuron methyl was more stable with 83% recovered intact after 2 weeks.

This herbicide has a low octanol-water coefficient ($K_{ow} = .346$), which indicates that it is hydrophilic. As a result, the herbicide has a low tendency to sorb to sediments. Partitioning of sulfometuron methyl and its breakdown products between water and sediment is dependent on pH and organic content of the solids. Dulka and Anderson (1982) determined that partitioning of ¹⁴C-labeled materials into water was favored when pH

was high and organic matter content was low while the reverse was true for the partitioning of ¹⁴C-labeled materials into sediments. The half-life of sulfometuron methyl in sediments is 30-60 days (Buchwalter *et al.*, 1997).

Dulka and Anderson (1982) found that microorganisms had an influence on the metabolism of sulfometuron methyl breakdown products, saccharine and 2-(aminosulfonyl) benzoic acid, in anaerobic aquatic ecosystems. The final mineralization products were naturally occurring aliphatic hydrocarbons.

Environmental Fate and Persistence in Soil: Sulfometuron methyl is a polar molecule that is relatively soluble in water and has a low organic carbon soil adsorption coefficient ($K_{oc} < 100$) (Kollman & Segawa, 1995) (Table 1). These values indicate that sulfometuron methyl is potentially mobile in soil. Furthermore, mobility in soil increases with an increase in soil pH (Lym and Swenson, 1991). The hydrolysis half-life (> 30 days) and the anaerobic soil half-life (283 d) indicate that sulfometuron methyl is persistent in soil. The combination of persistence and mobility in soil suggest that sulfometuron methyl may leach through the soil profile and enter ground water. This potential to leach into ground water depends on soil conditions such as organic matter content, moisture, and soil pH. In acidic soil sulfometuron methyl has less potential for movement into ground water because the compound hydrolyzes quickly under acidic conditions. It should be noted, however, that the low application rate of 3-8 oz/acre will reduce the probability of finding it in ground water in detectable concentrations. When applied to water-saturated alkaline soil, considerable movement of sulfometuron methyl may occur because solubility increases with an increase in pH (Pesticide Fact Sheet, 1995).

A decrease in pH, increase in moisture content, and/or an increase in temperature are factors that lead to increased degradation of the compound in soil (Lym and Swenson, 1991). The major degradation products in soil are methyl 2-[[N-(aminocarbonyl) amino] sulfonyl] benzoate, methyl 2-(aminosulfonyl) benzoate, and saccharin. The latter compounds undergo further microbial degradation to CO₂ and 2-(aminosulfonyl) benzoic acid, respectively (Anderson & Dulka, 1985) (Figure 1). The initial step in the degradation of sulfometuron methyl is hydrolysis and does not require the presence of microorganisms. In order for saccharin or other hydrolysis products to degrade rapidly to CO₂ viable soil microorganisms are necessary (Anderson, 1981).

In a study conducted by Hardesty (1983), soil photolysis was determined to play a minor role in sulfometuron methyl degradation to saccharine and CO₂. Thirty-six soil samples of Keyport silt loam, Flanagan silt loam, and Fallsington sandy loam were treated with sulfometuron methyl at concentrations of either 0.2 ppm or 1.0 ppm for one month of exposure to simulated sunlight. The half-life at both concentrations for all three soil types was 1-2 weeks in both light exposed and dark samples. The relative amounts of metabolites at each concentration were also similar in both exposed and dark samples. The data show that sulfometuron methyl degrades rapidly on all three soil types under both photolytic and dark conditions equally. These similarities between exposed and dark samples in this study support the conclusion that photolysis is not the major degradation pathway for sulfometuron methyl in soil.

Environmental Fate and Persistence in Biota:

Animal: Sulfometuron methyl is a polar molecule which is relatively soluble in water (hydrophilic) rather than in fat tissue of animals. As a result, it has a low tendency to accumulate in animal tissue. While sulfometuron

methyl is rapidly absorbed through the gastrointestinal tract of animals, it is rapidly broken down and excreted. Half-lives of the compound in rats ranged from 28 - 48 hours with doses of 16mg/kg and 3000 mg/kg, respectively, and therefore did not accumulate (Extension Toxicology Network, 1996).

Koeppel and Mucha (1991) found that sulfometuron methyl was rapidly metabolized and excreted by goats, a representative ruminant animal. The majority of dosed ¹⁴C-labeled sulfometuron methyl, 94-99%, was excreted in urine and feces. Less than 1% was excreted in milk. Major residues in urine and feces consisted of both sulfometuron methyl and (hydroxymethyl)-pyrimidine sulfometuron methyl (HM-SM) (Figure 1). The major metabolite in milk was also HM-SM. Less than 10% (<0.01 ppm) of total ¹⁴C labeled residues in milk was the parent herbicide, indicating that sulfometuron methyl accumulation in milk was below detectable limits of 0.03ppm. In the same study, accumulation of ¹⁴C-labeled residues in meat and fat were also below detectable limits.

Harvey *et al.* (1985) measured the octanol-water partition coefficient (K_{ow}) of sulfometuron methyl as 0.31. This value is indicative of a compound with low bioaccumulation potential (Karickhoff and Brown, 1979). This low bioaccumulation potential was evident when the compound was tested by Harvey *et al.* (1985) in a dynamic bioaccumulation experiment using Bluegill sunfish. The study reported low accumulation of sulfometuron methyl in Bluegill Sunfish. Sulfometuron methyl was tested at an exposure level of 1.0 ppm for 28 days. The results showed low accumulation in the liver of <0.01 ppm, 0.53 ppm, and 1.6 ppm at day 1, 3, and 7 respectively. In muscle tissue the highest level reported was 0.07 ppm. Peak accumulation of the compound in both liver and muscle occurred at day 10 (1.4ppm) and lessened thereafter. Toxicity to Bluegill Sunfish, Channel Catfish, and Rainbow Trout occurs at 13 ppm. The results of the study showed that the levels of

sulfometuron methyl in Bluegill fish were well below the level for toxicity after exposure to the compound for 28 days and therefore does not bioaccumulate. Because it does not bioaccumulate, the compound is only slightly toxic to Bluegill and other freshwater fish.

The compound is practically nontoxic to the water flea, *Daphnia magna*. The LC₅₀ for the water flea is 125 ppm for technical material and greater than 1,000 ppm for dispersible granules (Extension Toxicology Network, 1996).

Sulfometuron methyl has low acute oral toxicity. The LD₅₀ of sulfometuron methyl in rats is greater than 5,000 ppm (Kollman and Segawa, 1995) with one study resulting in an LD₅₀ of greater than 17,000 ppm (Toxicology Data, 1981). Acute inhalation LC₅₀ in rats is greater than 5 ppm in air for a four hour period, indicating that sulfometuron methyl is slightly toxic by this route (Technical Data Sheet, 1983).

Acute dermal toxicity is also low. The LD₅₀ values for exposure through skin range from over 2,000 mg/kg in female rabbits to over 8,000 mg/kg in male rabbits (Kollman and Segawa, 1995).

Plant: Some grasses are tolerant to sulfometuron methyl. Bermuda grass readily metabolizes sulfometuron methyl, and is resistant to the compound's phytotoxic effects. Anderson and Swain (1992) conducted an experiment to explore the metabolism of sulfometuron methyl in wheat and investigate the tolerance of wheat to the herbicide. Guard wheat seedlings metabolized sulfometuron methyl to the more polar components of methyl 2-[[[(4-(hydroxymethyl) 6-methyl (pyrimidin-2-yl) amino) carbonyl] amino] sulfonyl] benzoate (HM-SM) and its carbohydrate conjugate (Glu-HM-MM)

(Figure 1). When compared to a sulfonylurea herbicide analog, metsulfuron methyl, there was a much slower rate of primary metabolism of parent compound as well as a much slower conjugation of HM-MM. This reduced ability to conjugate HM-MM is said to be the primary reason for tolerance to sulfometuron methyl in wheat tissue.

The mode of action and the effects sulfometuron methyl has on the metabolism and physiology of the unicellular green alga *Chlorella emersonii* were studied by Landstein *et al* (1985). The alga was found to be very sensitive to sulfometuron methyl toxicity. The increase in protein, DNA, and chlorophyll that are typical of healthy cell reproduction were halted rapidly after exposure to the compound. Sulfometuron methyl inhibits acetohydroxy acid synthase (AHAS), the first common enzyme in branched chain amino acid formation in bacteria, fungi, and plants. AHAS is the target for the herbicide. The toxicity may be due to the accumulation of a toxic metabolite (α -ketobutyrate), when AHAS is inhibited (La Rossa, *et al*, 1987). Despite significant recovery of AHAS activity in *Chlorella emersonii* and other higher plants within several hours, and the consequent decline in aKB levels, protein synthesis, growth, and cell division do not recover from sulfometuron methyl toxicity (Landstein, *et al*, 1995).

Sulfometuron Methyl under Actual Field Conditions

Truby, *et al*. (1998) conducted a study on the degradation and mobility of sulfometuron methyl in soil under field conditions in Missouri, Illinois, Texas, and California. The study was carried out on bare soil at 4 sites typical of locations where the herbicide is used. Oust® was applied once to the soil at each site at the maximum labeled rate of 630g, active ingredient / ha (9 oz. a.i./acre). Soil samples were collected before treatment and again 14, 30, 60 days post application and then every 30 days up to 360 days after treatment

(DAT). Soil cores were taken at each site to a depth of 90cm and further divided into 15cm sections for analysis. The following results pertain to the 0-15cm soil depth sections because movement below this depth was insignificant.

Analysis of the samples showed that sulfometuron methyl degraded rapidly at all sites. Soil pH at the sites ranged from 6.3-7.9 with total moisture content of the soil ranging from 15-23 % . Recorded total rainfall at Greenville, MS, Rochelle, IL, and Uvalde, TX was approximately 7.8", 10.5", and 11.4", respectively. The Madera, CA site was irrigated with approximately 6.6" of water (rainfall for the area was less than 1.0" over the course of the study). At the MS, IL, and TX sites sulfometuron methyl appeared to degrade to below quantifiable limits (<10 ppb) by DAT 61 with the soil half-life ranging from 12-15 days. The Madera, CA site was the exception with sulfometuron methyl degradate residues appearing to degrade below quantifiable limits after DAT 120 at a half-life of 25 days. This is probably attributable to this site being quite a bit drier than the other test sites.

In this study sulfometuron methyl was determined to be relatively immobile in soil (confined to the upper 15cm of soil) at all test sites. Soil degradates were also determined to be immobile at all sites throughout the study. Sulfometuron methyl levels were below 10 ppm beyond 90 DAT at all test sites. The low application rate may be a factor of the low levels of sulfometuron methyl and degradates found in soil below a depth of 15cm.

It was concluded that sulfometuron methyl degraded rapidly under field conditions at all four test sites. These data are consistent with results of other soil dissipation studies discussed previously in this report. The Trubey, *et al.* (1998) study showed that the parent compound and its degradates were immobile in field plots.

Although laboratory studies suggest that sulfometuron methyl is potentially mobile in sandy or loamy soils, when the compound was applied to soil under field conditions it and its degradates were found to be immobile.

Summary

Sulfometuron methyl is a polar, hydrophilic compound. Solubility increases as pH increases. As more of the compound dissociates in water more is available to hydrolyze, which is the major degradation pathway.

Sulfometuron methyl is relatively non-persistent in soil because it does not adsorb. The compound is potentially mobile in soil but the low application rate mitigates finding measurable amounts in soil and/or ground water.

Because sulfometuron methyl is a polar molecule it has a low tendency to bioaccumulate in animal tissue. The compound is quickly metabolized and excreted from an organism. Aquatic toxicity to fish is also low. No observable effects were seen in fish exposed for 96 hours at 13 ppm sulfometuron methyl in the environment.

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