Sodium Lauryl Sulfate

Crops

Identification of Petitioned Substance

Chemical Names:
Sodium lauryl sulfate (SLS)

Other Names:
dodecyl sodium sulfate
dodecyl sulfate
sodium dodecyl sulfate (SDS)
sodium n-dodecyl sulfate
Chemfinder (2006) lists many additional names for SLS

Trade Names:
Aquarex ME
Dupanol WAQE
CT-535 (petition)
Richonol AF
Stepanol ME
HSDB (2002a) and RTECS (2005) list over a hundred additional trade names for SLS and mixtures containing SLS

CAS Number:
151-21-3

Other Codes:
X1001083-4 (ACX number)
1315 (HSDB number)
SS110 (IMS number)
WT1050000 (RTECS number)
079011 (USEPA PC Code)

Characterization of Petitioned Substance

<u>Composition of the Substance</u>:

SLS has the chemical formula $C_{12}H_{25}NaO_4S$ or CH_3-$(CH_2)_{11}$-O-$SO_3^-Na^+$ and its structure is presented in Figure 1. SLS is a high production volume chemical (i.e., annual production and/or importation volumes above 1 million pounds in the United States). In solution, the sodium cation (Na^+) dissociates from the anionic part of the compound (lauryl or dodecyl sulfate), and this anionic compound is the active chemical.

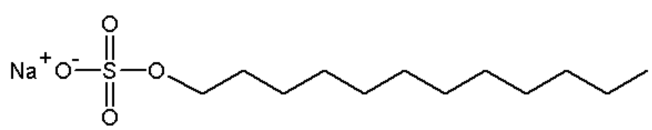

Figure 1. Chemical Structure of Sodium Lauryl Sulfate

<u>Properties of the Substance</u>:

SLS is an anionic surfactant, which is a class of chemicals used for their detergent properties. One end of the molecule is charged and therefore has an affinity for water, and the other end is nonpolar and soluble in fats/oils. SLS has a negatively charged sulfonate group as its "hydrophilic" end and a saturated 12-carbon chain for its "lipophilic" end. SLS has a faint odor of fatty substances and at room temperature, occurs as white or cream-colored crystals, flakes, or powder (Chemfinder 2006), or a clear to yellowish thick fluid. SLS is stable under ordinary conditions of use and storage but is incompatible with strong acids or strong oxidizing agents (PTCL 2005). When heated to decomposition, SLS emits toxic fumes (sulfur oxides and sodium oxides) (HSDB 2002a).

Specific Uses of the Substance:

SLS is a "soap" type of herbicide and pesticide (PAN 2005). The petitioner is requesting that SLS be included on the National List as a synthetic substance allowed for use in organic crop production as an herbicide with no restrictions. More specifically, the petitioned use would be as a non-selective herbicide to be applied (sprayed) on weeds in the proximity of crops for organic production. NOP §205.601(b)(1) allows "As herbicides, weed barriers, as applicable: (1) Herbicides, soap-based - for use in farmstead maintenance (roadways, ditches, right of ways, building perimeters) and ornamental crops" provided that use does not contribute to contamination of crops, soil, or water. NOP §205.601(e)(7) allows "Soaps, insecticidal" for use as insecticides with the same restriction described for herbicidal soaps.

In general, the major use of SLS is as a synthetic chemical surfactant[1] for emulsion[2] polymerization (HSDB 2002). Other major uses include the following: in the electroplating industry as an emulsifier; as a wetting agent and adjuvant in insecticides; as an emulsifier and penetrant in varnish and paint remover; in the formulation of injection-molded explosives; as a model surfactant and reference toxicant in aquatic and mammalian toxicological testing; as a whipping agent and surfactant in foods; and as a cleaning agent in a wide variety of personal care products, such as toothpastes, shampoos, bubble baths, shaving creams—any product that requires a thickening effect and the ability to create a lather. HPD (2004) lists household products that include SLS.

Approved Legal Uses of the Substance:

SLS is included as one of 31 "Active Ingredients Which May Be in Minimum Risk Pesticide Products" which are exempt to Section 25(b) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (EPA 2000, 2004).

SLS is included as one of more than 3,000 total substances that together comprise an inventory often referred to as "Everything Added to Food in the United States (EAFUS)" determined by the U.S. Food and Drug Administration (FDA) Center for Food Safety and Applied Nutrition (CFSAN). The list of substances are ingredients that may be added directly to food which FDA has either approved as food additives or listed or affirmed as "Generally Recognized As Safe" (GRAS) substances (FDA 2005). More specifically, FDA allows SLS to be used as a direct food additive (emulsifier) in or with egg whites; as a whipping agent in the preparation of marshmallows; as a surfactant in fumaric acid-acidulated dry beverage base and fruit juice drinks; and as a wetting agent in the partition of crude vegetable oils and animal fats (HSDB 2002). SLS is also an FDA-approved indirect food additive for use as a component of resinous and polymeric coatings and as a component of resinous and polymeric coatings for polyolefin films.

Action of the Substance:

No specific information was located regarding the mode of action of SLS as an herbicide. In general, the principle value of soap-based herbicides (like SLS) is in their capacity to penetrate green plant tissue and disrupt cellular structure, leading to dehydration and eventual death (Whitacre and Ware 2004). Herbicidal soaps can effectively kill plant parts with which they come in contact within hours; however, they do not affect underground portions of the plant such as roots (Lanier 1998). The most effective fatty acid[3] salts are those near the carbon chain length of lauric acid (12 carbons). Similarly, insecticidal soaps work on contact only and kill susceptible insects by washing away the protective coating on the surface of the insect and by disrupting normal membrane functions inside the insect, causing cell contents to leak and resulting in the rapid death of sprayed insects (IMP-Alaska 2005). For both soap-based herbicides and

[1] By lowering the surface tension of aqueous solutions, surfactants are often used as wetting agents by enhancing the spread of water over surfaces (NICNAS 2003).
[2] An emulsion is a mixture of two immiscible (unblendable) substances; one substance (the dispersed phase) is dispersed in the other (the continuous phase).
[3] A fatty acid is a carboxylic acid (or organic acid), often with a long aliphatic tail (long chains of carbon atoms), either saturated or unsaturated with hydrogen atoms.

insecticides, the organisms must come into direct contact with the spray droplets for the material to be effective.

Status

International

Sodium lauryl sulfate is not specifically listed for the petitioned use or other uses in the following international organic standards:

- Canadian General Standards Board
- CODEX Alimentarius Commission
- European Economic Community (EEC) Council Regulation 2092/91
- International Federation of Organic Agriculture Movements
- Japan Agricultural Standard for Organic Production

Evaluation Questions for Substances to be used in Organic Crop or Livestock Production

Evaluation Question #1: **Is the petitioned substance formulated or manufactured by a chemical process? (From 7 U.S.C. § 6502 (21))**

SLS is manufactured by a chemical process. Lauryl alcohol (1-dodecanol, $CH_3(CH_2)_{10}CH_2OH$) is the main feedstock and may be obtained by converting (reducing) coconut oil fatty acids into alcohols (HSDB 2002b). A sulfonate group is added to the lauryl alcohol by a sulfation process, in which the alcohol is mixed with a solution of sulfur trioxide (SO_3) or chlorosulfonic acid ($ClSO_3H$) (Singer and Tjeerdema 1993). After sulfation, the mixture is neutralized with a cation source, usually sodium hydroxide (NaOH), sodium carbonate (Na_2CO_3), or sodium bicarbonate ($NaHCO_3$) to form SLS (HSDB 2002a, Singer and Tjeerdema 1993). The product is then purified with one or more solvents (e.g., n-butanol, diethyl ether, ethanol) (Singer and Tjeerdema 1993).

Evaluation Question #2: Is the petitioned substance formulated or manufactured by a process that chemically changes the substance extracted from naturally occurring plant, animal, or mineral sources? (From 7 U.S.C. § 6502 (21).)

Commercial SLS may be manufactured by a process that alters naturally occurring coconut oil fatty acids (see Evaluation Question # 1). For example, "sodium coco sulfate," which has the same CAS number as SLS, is commercially available and advertised as a naturally-derived alternative because the lauryl alcohol is derived from coconut oils (ChemistryStore 2002).

Evaluation Question #3: Is the petitioned substance created by naturally occurring biological processes? (From 7 U.S.C. § 6502 (21).)

SLS is not created by naturally occurring biological processes (see Evaluation Questions #1 and #2). SLS can be chemically manufactured from naturally occurring coconut oil fatty acids, but these substances are altered to produce SLS.

Evaluation Question #4: Is there environmental contamination during the petitioned substance's manufacture, use, misuse, or disposal? (From 7 U.S.C. § 6518 (m) (3).)

Specific information regarding pollutants emitted from SLS manufacturing was not found. EPA (1996) evaluated emissions from soap and detergent manufacturers and identified three potential air pollutant concerns: odor (e.g., from the sulfonic acids and salts), fine detergent particles, and volatile organic compounds (VOCs) (e.g., solvents).

When applied soils (e.g., as an herbicide), SLS is biodegradable and may adsorb to soil particles or associate with soil water. The rate of biodegradation in soils depends on the presence of air, soil characteristics, diversity and acclimation status of the bacterial cultures, temperature, and other factors.

SLS is biodegradable in surface waters, ground water, and sediments. Biodegradation in water ranged from 45 to 95 percent biodegradation within 24 hours. SLS's class of anionic surfactant—linear alkyl sulfonates—was not among the anionic surfactant classes found to be persistent in studies of sewage effluent (Cserhati et al. 2002).

Products of SLS biodegradation are carbon dioxide or saturated fatty acids. SLS's surface activity is lost in the step of its biodegradation pathway (Singer and Tjeerdema 1993).

In general, the environmental occurrence of SLS arises mainly from its presence in complex domestic and industrial wastewater effluents (Singer and Tjeerdema 1993), SLS's production and widespread use as a commercial surfactant may result in its direct release to the environment through various waste streams (HSDB 2002a).

The petitioned method of using SLS in organic crop production would involve its spray application as a non-selective herbicide on weeds adjacent and not adjacent to crops. As noted previously, to be effective, soap-based herbicides such as SLS must come into direct contact with the plant to be eradicated (IMP-Alaska 2005, Lanier 1998). According to the petition, "Since the product is a herbicide, users will take care to refrain from getting product on the crops and therefore drift to crops will be absolutely minimal." Given its biodegradability and lack of toxic byproducts, SLS is not expected to persist in the environment when applied as an herbicide if recommended application levels are not exceeded.

<u>Evaluation Question #5:</u> Is the petitioned substance harmful to the environment? (From 7 U.S.C. § 6517 (c) (1) (A) (i) and 7 U.S.C. § 6517 (c) (2) (A) (i).)

If released to air, SLS will exist solely in the particulate phase in the ambient atmosphere where it will be removed from the atmosphere by wet and dry deposition (HSDB 2002a). If released to soil, SLS is expected to have little to no mobility. Furthermore, volatilization of SLS from moist soil surfaces is not expected to be an important fate process because of its water solubility and it is a salt. SLS is not expected to volatilize from dry soil surfaces based upon its estimated vapor pressure. If released into surface water, SLS is expected to adsorb to suspended solids and sediment in water. SLS has a moderate potential for bioconcentration in aquatic organisms.

The University of Minnesota Biocatalysis/Biodegradation Database includes a detailed analysis of the microorganism-assisted biodegradation of SLS (UM 2006; Yao 2004). SLS was classified as a substance of low environmental toxicity which is readily biodegradable with low bioaccumulation by the international Organisation for Economic Co-operation and Development (OECD 1997). The Environmental Defense Fund has also classified SDS as a high production volume chemical that is "Less hazardous than most [bottom 25% chemicals in one ranking system; the Indiana Relative Chemical Hazard Score]" (EDF 2004). However, the NIOSH International Chemical Safety Card (NIOSH 1997) provides the following warning to occupational users of SLS: "Do NOT let this chemical enter the environment." It also states that SLS is toxic to aquatic organisms (see Evaluation Question # 8 below).

If applied in accordance to the petitioned use in organic crop production (see Evaluation Question # 4), it is unlikely that SLS will cause harmful environmental effects, either present in the applied spray or arising from its degradation.

<u>Evaluation Question #6:</u> Is there potential for the petitioned substance to cause detrimental chemical interaction with other substances used in organic crop or livestock production? (From 7 U.S.C. § 6518 (m) (1).)

No information was available to assess whether spray-applied SLS or its byproducts can react detrimentally with other substances used in livestock or organic crop production.

<u>Evaluation Question #7:</u> Are there adverse biological or chemical interactions in the agro-ecosystem by using the petitioned substance? (From 7 U.S.C. § 6518 (m) (5).)

One study cited in Cserhati et al. (2002) found that at relatively high levels (50 parts per million (ppm)), SLS inhibited the growth and nitrogen fixation of the cyanobacterium *Gloeocapsa*. SLS also has the potential to make relatively insoluble compounds more soluble in soil pore water, groundwater, and surface waters. Some concern has been expressed about how surfactants contribute to the desorption from soils and solubilization in water of relatively insoluble pollutants in soils (Jafvert and Heath 1991, Cserhati et al. 2002). These processes have the potential to make pollutants more bioavailable, which can improve biodegradation rates for these pollutants. However, the potential for aquatic organisms to come into contact with solubilized pollutants could also increase.

If the SLS is properly spray-applied to only weeds during organic crop production, it is unlikely to reach the greater agro-ecosystem in significant amounts and thus is unlikely cause adverse environmental effects. Because SLS is an NOP-approved insecticide (NOP §205.601(e)(7)) and is considered a pesticide by EPA, albeit one of minimal risk, its improper use or disposal in the agro-ecosystem could result in adverse health and/or environmental effects (see Evaluation Question #8 below).

<u>Evaluation Question #8:</u> Are there detrimental physiological effects on soil organisms, crops, or livestock by using the petitioned substance? (From 7 U.S.C. § 6518 (m) (5).)

The overall acute aquatic ecotoxicity of SLS has been characterized as slight to moderate with adverse effects ranging from non-toxic in nematodes and flatworms to moderately toxic in freshwater fish and aquatic invertebrates (e.g., molluscs, daphnids) (PAN 2005; Singer and Tjeerdema 1993). Regarding molluscs, the OECD Initial Assessment Profile for SLS (1997) reported the clam *Corbicula fluminea* to be the most sensitive environmental species to SLS. Similarly, NIOSH (1997) warns that SLS is toxic to aquatic organisms. These results indicate that SLS could have detrimental (toxic) effects on soil and aquatic organisms.

The effects of SLS to algae has been studied. At low levels, growth of some algae species was stimulated, but at higher levels, growth was inhibited (Singer and Tjeerdema 1993). However, acclimation to SLS increased the resistance of algae to growth inhibition.

As described in Evaluation Question #7, SLS inhibited nitrogen fixation of a cyanobacterium at 50 ppm. No other information available as to whether use of SLS as an herbicide in organic crop production could create unacceptable changes in soil temperature, water availability, pH levels, nutrient availability, or salt concentration.

Improper and/or excessive use of SLS could adversely affect the survival and function of soil organisms, including earthworms, , bacteria, algae, and protozoa. SLS misuse or spills could also result in the damage and even death of areas of organic crops given its non-selective herbicidal properties.

<u>Evaluation Question #9:</u> Is there a toxic or other adverse action of the petitioned substance or its breakdown products? (From 7 U.S.C. § 6518 (m) (2).)

As described in Evaluation Question #8, the overall acute aquatic ecotoxicity of SLS has been characterized as ranging from slight to moderate (PAN 2005). The National Toxicology Program (NTP) of the National Institute of Environmental Health Sciences summary for SLS studies notes that it has not conducted any standard (long-term) toxicology, carcinogenesis, reproductive, developmental, or immunology studies

(NTP 2005). However, several in vitro genetic toxicity (mutagencity) studies were conducted by NTP, all of which were negative. There is also no data on whether SLS can act as an endocrine disruptor (PAN 2005). The Australian National Industrial Chemicals Notification and Assessment Scheme (NICNAS) 2003 review of SLS toxicity for humans concluded the following "The toxicity of SLS appears to be restricted to acute toxicity and skin and eye irritation...However, these health effects are primarily based on the effects of SLS at high doses in studies in laboratory animals." RTECS (2005) summarizes laboratory animal skin and eye irritation studies and references.

Ducks have been observed to be at risk for hypothermia when exposed to detergent-polluted waters in low temperatures (e.g., 0.07 mM SDS at 0 degrees C) (Singer and Tjeerdema 1993). Surfactants such as SDS have the potential to enhance the penetration of water into the birds' feathers. This may decreases the feathers' insulating capacity, which decreases the bird's ability to maintain body temperature. However, if used properly, direct discharges to water should not occur, and aquatic organism and waterfowl exposures should be minimal.

The breakdown products of SLS are not surface active or toxic.

If SLS is properly handled by workers (NIOSH 1997) and spray-applied at minimally effective levels to cover only weeds in organic crops, it appears unlikely that SLS or its breakdown products could cause adverse health or environmental effects (see Evaluation Question # 11 below).

<u>Evaluation Question #10:</u> Is there undesirable persistence or concentration of the petitioned substance or its breakdown products in the environment? (From 7 U.S.C. § 6518 (m) (2).)

As noted previously (see Evaluation Questions # 4 and # 5), SLS has been classified as a substance of low to moderate aquatic toxicity which is readily biodegradable and has a low bioaccumulation potential. If SLS is properly spray-applied on weeds during organic crop production, it appears unlikely to reach surface waters or persist in the environment in significant concentrations.

<u>Evaluation Question #11:</u> Is there any harmful effect on human health by using the petitioned substance? (From 7 U.S.C. § 6517 (c) (1) (A) (i), 7 U.S.C. § 6517 (c) (2) (A) (i)) and 7 U.S.C. § 6518 (m) (4).)

Not if SLS is properly handled, to include use of safety goggles; rubber gloves; and proper ventilation, local exhaust, or use of breathing protection by workers during its petitioned use as an herbicide for organic crop production (NIOSH 1997). In general, occupational exposure to SLS may occur through inhalation of dust particles and dermal contact with this compound at workplaces where it is produced or used can produce irritation in the upper respiratory tract, including cough, labored breathing, headache, dry throat, or nasal congestion as a result of inhalation exposure (HSDB 2002a, NIOSH 1997). Occupational dermal exposure to SLS can result in redness, pain, or corneal (eye) damage while accidental ingestion can result in nausea, vomiting, or diarrhea. Repeated or prolonged occupational contact of SLS with skin may cause dermatitis (NIOSH 1997).

The general population may be exposed to SLS through the ingestion of food additives (thickener and emulsifier) and use of consumer products containing SLS, including detergents, shampoos, toothpaste, creams, lotions, and pharmaceutical preparations (HSDB 2002a, NICNAS 2003). In this regard, the major human health hazard associated with exposure to SLS is that it can cause irritation to the skin and eyes, the severity of which is concentration-related (EHU 2002). However, this is a common finding with most detergents and is related to their capacity to disrupt cell membranes. Indeed, in the human 4-hour patch test for irritation, SLS is often used at 20 percent concentration to serve as a positive control to identify substances or preparations that would otherwise be considered borderline irritants (NICNAS 2003).

The OECD (1997) report concluded that "…sodium dodecyl sulfate [SLS] is of no concern with respect to human health." The NICNAS (2003) report on SLS concluded the following:

> The risk to humans from SLS will depend on the amount of exposure to the chemical. The amounts of SLS used in cosmetics, and hence the potential human exposure, is significantly smaller than that used in animal

studies. Consequently, considering the human health effects associated with SLS together with data indicating potentially extensive use in both industrial and consumer areas, it appears that for consumers and workers, the human health hazards are low.

Lastly, it is important to note that there is an ongoing and persistent "Internet rumor" that SLS and sodium lauryl ether sulfate[4] are carcinogenic and extremely toxic components of many household cleaning agents, shampoo, and toothpaste (e.g., NHIC 2005). However, these claims have been refuted through governmental (EHU 2002, NICNAS 2003) and trade association (CIR 2002, reaffirming CIR 1983) reports.

Evaluation Question #12: Is there a wholly natural product which could be substituted for the petitioned substance? (From 7 U.S.C. § 6517 (c) (1) (A) (ii).)

Corn gluten meal is a natural byproduct of processing corn to make corn starch and corn syrup. It is generally sold as a golden yellow meal or as light brown granules. Corn gluten prevents sprouting seeds of weeds from developing normal roots (i.e., acts a pre-emergent herbicide) (Christians 2006, Cox 2005, Sullivan 2003). Although it does not directly kill the seedlings, it makes them susceptible to dehydration if the soil gets, or is allowed to dry. Corn meal gluten, like SLS, is on the "25(b)" list of "Active Ingredients Which May Be in Minimum Risk Pesticide Products" (EPA 2000). Vinegar (acetic acid) is also considered to be a natural herbicide if applied in sufficient concentrations (5-20%) and is included on the List 4A Minimal Risk Inerts (Sullivan 2003). Several other substances included List 4A Minimal Risk Inerts (e.g., citric acid, safflower oil, sodium chloride) and on the most recent 25(b) list (e.g., clove oil, thyme oil) and can also be considered wholly natural products.

Evaluation Question #13: Are there other already allowed substances that could be substituted for the petitioned substance? (From 7 U.S.C. § 6518 (m) (6).)

Careful application of manure as a fertilizer, as currently allowed under NOP §205.203, to crop rows helps to ensure that crops, not weeds, get fertilized. Although use of manure from hoofed livestock (e.g., sheep, cattle, horses) may contain weed seed that has passed intact through their digestive systems, use of composted manure (NOP §205.203(c)(1)) contains far fewer weed seeds than does raw manure because the heat generated during the composting process kills them (Sullivan 2003).

NOP §205.601(b)(1) allows for use of soap-based herbicides allows "…for use in farmstead maintenance (roadways, ditches, right of ways, building perimeters) and ornamental crops" in organic crop production. Commercially available soap-based herbicides are manufactured from fatty acids, but "While herbicidal soaps do not really fall into the category of 'natural,' they are acceptable to many people as a substitute for synthetic herbicides" (Christians 1999).

In addition to the wholly natural products (see response to Evaluation Question #12) included on the List 4A Minimal Risk Inerts, NOP §205.601(m) allows the use of other List 4A substances (EPA 2000 for complete list) "…as an active pesticide ingredient in accordance with any limitations on the use of such substances."

Evaluation Question #14: Are there alternative practices that would make the use of the petitioned substance unnecessary? (From 7 U.S.C. § 6518 (m) (6).)

Sullivan (2003) provides a review of weed management practices, many of which can be used in the absence of herbicides—including SLS and those allowed for use in organic crop production. Crop rotations act to limit the buildup of weed populations and prevent major weed species shifts; weeds tend to prosper in crops that have similar growth requirements as the weeds. Certain cereal "cover" crops (e.g., rye,

[4] Sodium lauryl sulfate can be converted by ethoxylation to sodium lauryl ether sulfate (SLES; $CH_3(CH_2)10CH_2(OCH_2CH2)nOSO_3Na$; where n is the number of ethoxyl groups), which is also called sodium laureth sulfate or SLS. Because SLS and SLES are similar compounds and are commonly used (usually one or the other; rarely both at the same time) as a cleaning or foaming agent in many household products such as shampoo and toothpaste, they are often mistaken for each other.

barely, wheat) can be used to suppress other plants that attempt to grow around them through a natural mechanism called allelopathy. This refers to the natural ability of a plant to chemically inhibit the growth of other surrounding plants; however, this effect can be significantly diminished or lost when the soil is disturbed (tilled). Other crops can be used to smother weeds by growing faster and out-competing them. For example, in northern states, oats are commonly planted as a "nurse crop" for alfalfa, clover, and related mixtures. All of these practices are allowed under NOP §205.203(b), which states that "The producer must manage crop nutrients and soil fertility through rotations, cover crops, and the application of plant and animal materials [see response to Evaluation Question #14]." Intercropping (i.e., growing two or more crops together, such as soybeans and green wheat) can also be used as an effective weed control strategy as growing different plant types together enhances weed control by increasing shade and increasing crop competition with weeds because of tighter crop spacing (Sullivan 2003). Appropriate soil- and crop-specific tillage and cultivation practices are the most traditional means of weed management in agriculture and NOP §205.203(a) requires that "The producer must select and implement tillage and cultivation practices that maintain or improve the physical, chemical, and biological condition of soil and minimize soil erosion."

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