Sulfurous Acid

Crops

Identification of Petitioned Substance

Chemical Names:
sulfurous acid
hydrogen sulfite

Other Names:
sulphurous acid
sulfur dioxide solution
schweflige saure
acide sulfureux
acido sulfuroso

Trade Names:
None Listed

CAS Numbers:
7782-99-2

Other Codes:
CHEBI 48854
EINECS 231-973-1
UN 1833
InChlKey LSNNMFCWUKXFEE-UHFFAOYSA-N

Summary of Petitioned Use

Following a petition submitted in 2008, the NOSB recommended the adoption of sulfurous acid, as a soil amendment in a May 6, 2009 vote (NOSB, 2009 a, b, c, d). A proposed rule was published on January 10, 2010 (Pegg, 2010). The final rule was published on July 6, 2010. Sulfurous acid was added to the National List (Electronic Code of Federal Regulations, 2013) as follows:

> § 205.601 Synthetic substances allowed for use in organic crop production, (j) as plant or soil amendments, (9) sulfurous acid (CAS #7782-99-2) for on-farm generation of substance utilizing 99% purity elemental sulfur per paragraph (j)(2) of this section.

As required by the Organic Foods Production Act, the National Organic Standards Board has the responsibility to review each substance on the National List within five years of its adoption to determine whether the substance should be renewed or removed from the National List. The NOSB has requested an updated technical evaluation report for sulfurous acid to support their decision-making.

The current listing for sulfurous acid is scheduled to sunset on 7/7/2015.

Characterization of Petitioned Substance

Composition of the Substance:

Sulfurous acid is the name given to water that has been sprayed through smoke and fumes produced by burning elemental sulfur. The composition of this fluid is complex containing a number of dissolved substances including but not limited to sulfur dioxide, hydrogen sulfide and hydrogen sulfite (bisulfite). Because sulfur dioxide forms hydrogen sulfite when dissolved in aqueous solution and hydrogen sulfite is acidic, effluent water from the sulfurous acid generator becomes acidified. Acidified irrigation water is used to adjust soil pH into the acidic range.

Source or Origin of the Substance:

The primary ingredients used in the preparation of sulfurous acid are water and elemental sulfur. Elemental sulfur was once mined and extracted from salt domes where it sometimes occurs in nearly pure form, but this method has been obsolete since the late 20th century. Today, almost all elemental sulfur is produced as a byproduct of coal, natural gas and petroleum refinement (Davis and Detro, 1992). Desulfurization of diesel fuel, gasoline, and jet fuel to meet today's air pollution standards requires the reduction of sulfur concentration from levels exceeding 500 ppm to less than 15 ppm (Song, 2003). Residual sulfur is removed from petroleum, natural gas and coal by the Claus process and refined to very high levels of purity suitable for sulfurous acid production (El-Bishtawi and Haimour, 2004; Elsner et al., 2003).

Properties of the Substance:

Sulfurous acid is produced by dissolving the fumes of burning sulfur in irrigation water. Sulfur is an odorless, tasteless, light yellow solid usually sold in blocks or pellets. It is easily crushed into a powder. Sulfur is a reactive element that given favorable circumstances combines with all other elements except gases, gold, and platinum (Georgia Gulf Sulfur Corporation, 2000). Burning sulfur emits sulfur dioxide. Sulfur dioxide dissolved in aqueous solution is called sulfurous acid. In fact, sulfurous acid is not chemically stable at temperatures above -196.15 ^{o}C. The predominate form that sulfur dioxide take in solution is as hydrogen sulfite (bisulfite, HSO_3^-—Equation 1). Hydrogen sulfite is acidic in aqueous solution (pK_a=6.97). Molten sulfur can also evolve hydrogen sulfide. The basic physical properties for sulfur are boiling point: 832 ^{o}F (445 ^{o}C); melting point: 230 to 246 ^{o}F (113 to 120 ^{o}C); vapor pressure: 4x10-6 mm Hg @ 86 of (30 ^{o}C); specific gravity (H_2O = 1): approx. 1.96 (varies); percent volatiles: negligible; Flashpoint: 405^{o}F (207.2^{o}C), Flammability Limits: Lower explosive limit: 3.3% Upper explosive limit: 46.0%, Auto-ignition Temperature: 478-511^{o}F (248-266^{o}C) and solubility: insoluble in water. Sulfur dioxide (CAS 7446-09-5), a product of burning sulfur and the active ingredient of sulfurous acid, is a toxic gas with a pungent irritating smell. Sulfur dioxide forms hydrogen sulfite when combined with water. Hydrogen sulfite is a weak acid.

Equation 1 $$SO_2 + H_2O \rightleftharpoons HSO_3^- + H^+$$

Specific Uses of the Substance:

Sulfurous acid is useful in arid and semi-arid agricultural regions where irrigation water and soil are likely to be saline and alkaline (Allison et al., 1954; FAO, 1990). The product is used to improve water quality by instantly reducing pH. In some climates and topographies, decreased soil moisture results in accumulation of soluble salts and alkali carbonates with replacement of calcium and magnesium by sodium in the adsorbing complex of soil. Humus, an important part of this complex is also gradually reduced and replaced by alumino-silicate clay and a shallow potentially precipitated humus layer saturated with sodium (Wakman, 1936). Sulfurous acid reduces soil pH and changes mineral solubility. This results in a short term improvement of the humus layer and a better yield for some crops. In reducing alkalinity, sulfurous acid temporarily removes incrustations from roots, releases mineral plant food, disintegrates hardpan, helps to breakdown organic matter and increases nitrates (Pacific Coast Nurseryman, 1945). In contrast, a related product, elemental sulfur, is commonly used for the same purpose. Although longer lasting, it requires months or years to be effective. The addition of sulfite to water and soil by sulfurous acid provides a substrate for sulfur-bacteria that in turn provides available and organic sulfur.

Approved Legal Uses of the Substance:

The SO_2 generator developed by Harmon Systems International, LLC can be used to treat coal bed methane production (CBM) water (EPA, 2004). In 2004, US Environmental Protection Agency (EPA) concluded that it should not identify the CBM industry for effluent guidelines rulemaking.

A proposal to revoke the EPA exemption from a tolerance requirement for sulfurous acid use as a pesticide was filed on June 1, 2005 (EPA, 2005). Subsequently, sulfurous acid was removed from EPA's list of registered pesticides; its list of inert ingredients for food use pre- and post-harvest, exemptions from the requirements for a tolerance (40 CFR 180.910), and its list of chemicals not requiring a tolerance or an exemption from tolerance in food (40 CFR 180).

Sulfurous acid is currently listed by the EPA as an inert ingredient permitted for use in nonfood use pesticide products (EPA, 2011). An inert ingredient is any substance other than an "active" ingredient, which is intentionally included in a pesticide product. It is important to note, the term "inert" does not imply that the chemical is nontoxic. All inert ingredients in pesticide products, including those in an inert mixture, must be approved for use by the EPA. A tolerance or tolerance exemption is required only for those inert ingredients applied to food. Impurities are not included in the definition of inert ingredient.

Sulfur dioxide, the active ingredient of sulfurous acid, is a major contributor to air pollution attributed to burning fossil fuel. As a result, EPA includes sulfur dioxide in many documents pertaining to sulfur recovery, fossil fuel refinement and air pollution abatement. Despite the withdrawn tolerance exemption, EPA has not established a tolerance for sulfurous acid effluent produced by a sulfurous acid generator. However, a tolerance of 10 ppm has been set for the use of sulfur dioxide as a fungicide and a food preservative.

The US Food and Drug Administration finds sulfur dioxide generally recognized as safe when used in accordance with good manufacturing practice, except that it is not used in meats; in food recognized as a source of vitamin B1; on fruits or vegetables intended to be served raw to consumers or sold raw to consumers, or to be presented to consumers as fresh (FDA, 2013a). Food grade sulfurous acid may be employed to assist caramelization in food, in amounts consistent with good manufacturing practice (EPA, 2013b).

The USDA includes sulfurous acid in the National Organic Program's National List for use in crop production as a soil amendment when 99% pure elemental sulfur is used (USDA, 2010).

Action of the Substance:

Saline and alkali soil conditions reduce the value and productivity of considerable areas of land. The problem is an ancient one, and there is much information on this subject in technical literature (Cowen, 1999). For many farms in dry climates, rain is sporadic and the only naturally available water source is alkaline or saline, moreover these farms may be using irrigation systems where the water source contains a high level of dissolved mineral salts. Without abundant fresh water, good drainage, and a source of fertilizer, these farms may eventually fail, the result of the irrigated soils becoming salinized. In salinization, soluble salts produce toxic effects in plants by increasing the salt content of the soil solution and by increasing the degree of saturation of exchange materials in soil with exchangeable sodium. The soluble salts in soils consist of variable proportions of cations: sodium, calcium, and magnesium and anions: chloride and sulfate; to a lesser extent potassium cations and bicarbonate, carbonate, and nitrate anions. The condition of saline and alkali soil is recognizable by elevated electrical conductivity, high osmotic pressure, increased pH, elevated levels of toxic soluble boron, reduced infiltration rate, reduced permeability and hydraulic conductivity, reduced moisture retention, increased soil aggregation, and crust formation (Allison et al., 1964). Sulfurous acid is effective under the described saline/alkali soil conditions acting both to reduce alkaline-earth carbonate content and pH. Where acidic conditions are desirable for crop production and available water is alkaline, hydrogen sulfite produced by dissolved sulfurous acid acidifies irrigation water which in turn contributes to maintaining soil acidity. In one study comparing the use of a sulfurous acid generator to gypsum in reclaiming saline/sodic soils for growing wheat, it was found that a sulfurous acid generator can improve wheat yield to a level comparable or greater than addition of gypsum alone (Ashraf, 2004). Sulfite oxidation to sulfate by *Thiobacillus* bacteria produces bioavailable sulfur for plants. Phytotoxicity can result from low pH, but generally this conversion proceeds faster with increasing pH and oxygen content (Barker and Pilbeam, 2010).

Combinations of the Substance:

Dissolved sulfurous acid is not toxic and does not react adversely with other chemical substances. It may be used in conjunction with other approved soil amendments when considering improvement of saline/alkali soils.

Status

Historic Use:

This application of sulfurous acid to agriculture was described in an agricultural trade journal as "A golden key to a new prosperity of Western agriculture" (Pacific Coast Nurseryman, 1945). Discovered by Del Alvos of Santa Barbara California in 1939, liquid sulfur was produced by burning sulfur and collecting sulfur dioxide in irrigation water. Production plants for sulfurous acid were built in the western United States at that time to facilitate farming. Sulfur or brimstone burning as a biocidal product dates back to prehistory. Sulfur candles have been used for many years as a treatment for various insect pests, and later, burning sulfur with moisture added was used as a room and fixture disinfectant in medical settings (Cheatham, 1866; Clark, 1871; Kenwood, 1871). The burning sulfur product was named sulfurous acid and was provided a hypothetical chemistry by members of the medical community based on the assumption that the predominant sulfur pyrolysis product was sulfur dioxide. They also proposed that sulfur dioxide in aqueous solution became sulfurous acid. Sulfur dioxide is acidic and does decrease pH in aqueous solution; however, it does not form sulfurous acid. Experimental investigations have subsequently shown that sulfurous acid is thermodynamically unstable at ambient temperature (Voegele et al., 2002).

Organic Foods Production Act, USDA Final Rule:

Sulfurous Acid is currently on the National List (§ 205.601) as a synthetic substances allowed for use in organic crop production, (j) as plant or soil amendments, (9) sulfurous acid (CAS #7782-99-2) for on-farm generation of substance utilizing 99% purity elemental sulfur per paragraph (j)(2) of this section.

International

Canada - Canadian General Standards Board Permitted Substances List –

Sulfurous acid can be used in the production Canadian Organic Products as a preservative in alcoholic beverages made from grapes or other fruit, although minimum use is recommended. No mention is made of using sulfurous acid as a soil amendment (CGSB, 2011a, b).

CODEX Alimentarius Commission, Guidelines for the Production, Processing, Labelling and Marketing of Organically Produced Foods (GL 32-1999) -
ftp://ftp.fao.org/codex/Publications/Booklets/Organics/organic_2007e.pdf

Sulfurous acid is not mentioned explicitly for use as a soil amendment in the Codex Alimentarius standard for organically produced food permitted substances list (Codex Alimentarius, 2007).

European Economic Community (EEC) Council Regulation, EC No. 834/2007 and 889/2008
http://www.organic-world.net/news-eu-regulation.html
http://eur-lex.europa.eu/LexUriServ/site/en/oj/2007/l_189/l_18920070720en00010023.pdf

Although not mentioned in the European Community Organic Standard for use as a soil amendment, sulfurous acid is permitted as a preservative and a food coloring agent of conventional foods.

Japan Agricultural Standard (JAS) for Organic Production—
http://www.ams.usda.gov/nop/NOP/TradeIssues/JAS.html

Japan permits the use of a sulfur smoking agent and a number of sulfur powder substances for use in pest and disease control (MAFF, 2012).

International Federation of Organic Agriculture Movements (IFOAM) – http://www.ifoam.org/sites/default/files/page/files/ifoam_norms_version_august_2012_with_cover_1.pdf

Sulfurous acid is not listed in Appendix 2 of the IFOAM norms, fertilizers and soil conditioners. The IFOAM Norms explicitly state that "Operators shall prevent or remedy soil or water salinization where these pose a problem" (IFOAM, 2012). Sulfurous acid is used as a remedy for salinization of soil.

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

Evaluation Question #1: Indicate which category in OFPA that the substance falls under: (A) Does the substance contain an active ingredient in any of the following categories: copper and sulfur compounds, toxins derived from bacteria; pheromones, soaps, horticultural oils, fish emulsions, treated seed, vitamins and minerals; livestock parasiticides and medicines and production aids including netting, tree wraps and seals, insect traps, sticky barriers, row covers, and equipment cleansers? (B) Is the substance a synthetic inert ingredient that is not classified by the EPA as inerts of toxicological concern (i.e., EPA List 4 inerts) (7 U.S.C. § 6517(c)(1)(B)(ii))? Is the synthetic substance an inert ingredient which is not on EPA List 4, but is exempt from a requirement of a tolerance, per 40 CFR part 180?

Sulfurous acid is a sulfur containing substance. Sulfurous acid appears on the EPA non-food inert list, and does not require a tolerance or an exemption from tolerance. According to the manufacturer, SO_2 released into the atmosphere by a sulfurous acid generator (SAG) is minimal. EPA does not regulate this emission.

Evaluation Question #2: Describe the most prevalent processes used to manufacture or formulate the petitioned substance. Further, describe any chemical change that may occur during manufacture or formulation of the petitioned substance when this substance is extracted from naturally occurring plant, animal, or mineral sources (7 U.S.C. § 6502 (21)).

Sulfurous acid is produced by burning pure sulfur in a sulfurous acid generator under closed conditions. Fumes evolved into the generator contain a complex mixture of sulfur compounds, but is largely composed of sulfur dioxide. These fumes are captured by the generator in a scrubbing process. Scrubbing dissolves the sulfur laden fumes in irrigation water pumped through the system. Influent irrigation water becomes acidified with dissolved hydrogen sulfite and is released as an effluent. There are several manufacturers of patented sulfurous acid generators (Forbush et al., 1985; Jackson, 2002; Harmon Systems International, 2013). According to them, toxic emissions from their devices are minimal.

Evaluation Question #3: Discuss whether the petitioned substance is formulated or manufactured by a chemical process, or created by naturally occurring biological processes (7 U.S.C. § 6502 (21)).

Sulfurous acid is produced by a synthetic process from elemental sulfur and irrigation water. It is produced by burning elemental sulfur. Elemental sulfur of appropriate purity as defined by the NOP (99.9% purity) is produced synthetically as a byproduct of a variety of desulfurization processes used by the oil, gas and coal industries to reduce the sulfur content of their products. Products of sulfur pyrolysis are collected by partitioning evolved fumes and gases into irrigation water to form an acidic solution that is delivered to soil. In nature, sulfurous acid is produced as a result of underwater volcanic activity and contact of rain with sulfur dioxide in the atmosphere. The latter is known as "acid rain."

Evaluation Question #4: Describe the persistence or concentration of the petitioned substance and/or its by-products in the environment (7 U.S.C. § 6518 (m) (2)).

Sulfurous acid contains no persistent substances of record. Hydrogen sulfite present in the solution is metabolized by sulfite reducing bacteria and plants that recycle sulfurous acid into bioavailable sulfur compounds. Water and other dissolved compounds leach into the soils. Functionally, sulfurous acid serves to condition soils by adjusting pH. Claims from manufacturers of sulfurous acid generators suggest the only effluent from their generators besides sulfurous acid is carbon dioxide. Because the generators are small, even in the case fugitive quantities of sulfurous substances production, a reportable level of pollution produced is unlikely even for the largest of applications.

Evaluation Question #5: Describe the toxicity and mode of action of the substance and of its breakdown products and any contaminants. Describe the persistence and areas of concentration in the environment of the substance and its breakdown products (7 U.S.C. § 6518 (m) (2)).

Sulfurous acid is a weak acid with pH of approximately 6.5. Its introduction to farmland reduces the pH of saline/sodic soils at pH of 8 downward toward pH 6.5. Functionally, the reduction of pH is helpful to allow the dissolution of precipitated and insoluble minerals. Sulfurous acid must not be confused with sulfuric acid, an excluded substance and a strong acid with pK_a of -3. Sulfuric acid is highly corrosive and difficult to work with. It is also used to lower irrigation water pH, but could produce a toxic effect resulting from too much acidity. Sulfurous acid does not produce notably toxic effects on fish, aquatic invertebrates and plants (EPA, 2007). Many bacteria possess sulfite reductase enabling them to metabolize sulfurous acid. At very high concentrations, sulfurous acid may be toxic to bacteria or algae. One sulfurous acid generator manufacturer claims that sulfurous acid is biocidal and is useful to control or eliminate algae as well as pathogens in irrigation water (Harmon Systems Inc., 2013).

Evaluation Question #6: Describe any environmental contamination that could result from the petitioned substance's manufacture, use, misuse, or disposal (7 U.S.C. § 6518 (m) (3)).

When properly operated, there is no expectation that the sulfurous acid generators will contaminate the environment. Based on information provided by manufacturers and users of the generators the residual pollution in the form of SO_2 released into the atmosphere is negligible (Ashraf et al., 2004).

Evaluation Question #7: Describe any known chemical interactions between the petitioned substance and other substances used in organic crop or livestock production or handling. Describe any environmental or human health effects from these chemical interactions (7 U.S.C. § 6518 (m) (1)).

The primary purpose of sulfurous acid for crop production is reducing the pH of irrigation water to alleviate the effects of specific saline/sodic soil conditions or the effects caused by saline or sodic irrigation. Sodic or alkali soils are those that have a high exchangeable-sodium-percentage; and saline soils are those having a high value for the electrical conductivity of the saturation extract. Both contain excessive concentrations of either soluble salts or exchangeable sodium, or both. For agricultural purposes, such soils are regarded as a class of problem soils that requires special remedial measures and management practices. Soluble salts produce harmful effects to plants by increasing the salt content of the soil solution and by increasing the degree of saturation of the exchange materials in the soil with exchangeable sodium. Commonly the direct source of salt content is surface water, ground water or water used for irrigation. Sulfurous acid is introduced into irrigation water. Its effectiveness is governed principally by the alkaline-earth content and the pH reading.

Evaluation Question #8: Describe any effects of the petitioned substance on biological or chemical interactions in the agro-ecosystem, including physiological effects on soil organisms (including the salt index and solubility of the soil), crops, and livestock (7 U.S.C. § 6518 (m) (5)).

Sulfur dioxide is the starting material for production of sulfurous acid. It is produced in the sulfurous acid generator by burning sulfur in the presence of oxygen (air). Sulfur dioxide produced in the sulfurous acid generator is absorbed into water to produce "sulfurous acid." In water, sulfur dioxide forms hydrogen sulfite. This process is the same for generating acid rain, i.e. fossil fuels containing sulfur are burned in the presence of air forming sulfur dioxide that is subsequently absorbed into rain water. The pH range for acid rain is 4.2-4.4. Acidification of lakes, rivers and streams resulting from acid rain has led to the devastation of ecological communities and has put many on the brink of destruction. Industrial nations are recognizing the environmental problems caused by acid rain and have reacted by developing processes to remove sulfur from fossil fuels. Recovered sulfur is very pure and meets the same criteria defined by the National Organic Program for sulfur used in the production of sulfurous acid. The US Environmental Protection Agency recognizes that its current models for assessment of the effects of acidification of aquatic and terrestrial ecosystems resulting from sulfur dioxide emission are inadequate and has developed a new field pilot program to address the new challenges (EPA, 2012a). However, in arid regions where soils are alkaline, rain is limited and irrigation is controlled, the acidification resulting from the introduction of sulfurous acid to the environment produces a positive effect, reducing pH to allow acid loving fruits and vegetables to be grown effectively, e.g. blueberries (Jimenez et al., 2005). Natural waters are buffered. As a result, pH is only moderately changed over an extended period of time. With controlled use, sulfurous acid does not appear to be hazard to wildlife (OECD, 2004). The 50% lethal concentration for fish and invertebrates is in the range of 50-100 mg/L dissolved sulfur dioxide. Although there is a potential for damage to the local ecosystems from improperly maintained sulfurous acid generators, this product is not considered a large generator and the process has not yet come under the scrutiny of the US Environmental Protection Agency despite recent reformation of its environmental models (EPA, 2012b). Overuse of sulfurous acid and subsequent acidification will cause the metabolism of microorganisms involved in compost and organic matter breakdown in treated streams and runoffs to be suppressed along the acidity gradient, and can lead to a decrease in humus production (Simon, et al., 2009).

<u>Evaluation Question #9:</u> Discuss and summarize findings on whether the use of the petitioned substance may be harmful to the environment (7 U.S.C. § 6517 (c) (1) (A) (i) and 7 U.S.C. § 6517 (c) (2) (A) (i)).

When exposed to water and under normal barometric pressure sulfur dioxide reaches equilibrium at less than 1 gram of sulfur dioxide per 100 grams of water. As the partial pressure of sulfur dioxide increases more of the gas can be dissolved in water. Because water flows continuously in the sulfurous acid generator, under optimized conditions sulfur dioxide does not escape into the atmosphere either from the burning or from supersaturated liquid released from the sulfurous acid generator equilibrating with the atmosphere (Rabe and Harris, 1963).

Sulfur dioxide is one of the principal components of acid rain pollution and does harm the environment (EPA, 2012b). Even so, the US Environmental Protection Agency has not provided guidance for restrictions on the use of a sulfurous acid generator in farming. Using the sulfurous acid generator as prescribed in a controlled manner provides a desirable effect upon treated water, which is to lower its pH.

<u>Evaluation Question #10:</u> Describe and summarize any reported effects upon human health from use of the petitioned substance (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)).

Sulfurous acid is an aqueous product similar to dissolved sodium dithionite which oxidizes in water to form hydrogen sulfite (HSO_3^-), sulfite (SO_3^{2-}) and hydrogen sulfate (HSO_4^-), and under strongly acidic conditions may liberate sulfur dioxide. Under anaerobic conditions (such as in the lower gastrointestinal tract), hydrogen sulfite (HSO_3^-) and thiosulfate ($S_2O_3^{2-}$) may be formed. Hydrogen sulfite (HSO_3^-) can be absorbed after ingestion. It is efficiently metabolized, and the major part rapidly excreted as sulfate into the urine. The acute oral 50% lethal dose (LD_{50}) of sodium dithionite in rats was about 2500 mg/kg body weight, with loss of muscle tone, gastro-intestinal irritation, diarrhea and dyspnea as the main clinical and pathological signs at doses near to or exceeding the LD50. Sulfurous acid is slightly irritating to the skin, and strongly irritating to the eyes of rabbits. Under acidic conditions, sulfurous acid may liberate sulfur dioxide, which is known to induce respiratory irritation in humans. Sulfurous acid is not considered to possess a significant skin sensitization potential. Hydrogen sulfite (HSO_3^-), sulfite (SO_3^{2-}) and hydrogen sulfate (HSO_4^-) are considered as substances of very low order systemic toxicity. It should be noted that sulfites, in general, reduce the thiamine content in food. These results appear to be sufficiently representative for sulfurous acid. Sulfurous acid is not expected to be carcinogenic (OECD, 2012). Sulfur dioxide is approved by the US Food and Drug administration for use as a food preservative and a food colorant (FDA, 2013a, b).

<u>Evaluation Question #11:</u> Describe all natural (non-synthetic) substances or products which may be used in place of a petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (ii)). Provide a list of allowed substances that may be used in place of the petitioned substance (7 U.S.C. § 6518 (m) (6)).

Organic farming requires that soil conditions match conditions required for growing desired crops including favorable pH and irrigation (Cowen, 1999). Cost effectiveness is also a consideration, however; for some high value crops soil amendments are justified. A common problem in arid regions is saline/alkaline (sodic) soil or irrigation water. Saline/alkaline irrigation water can create toxic conditions or damage soil structure by disrupting the ratio of sodium ions (Na+) to magnesium (Mg++) and calcium (Ca++) ions (Christians, 1999). Sodic and saline/sodic soils restrict hydraulic properties of soil resulting from dispersion, translocation and deposition of clay platelets in conducting pores. There is considerable evidence that organic matter tends to improve saline/sodic soils. Organic matter, from crops, stems, straw, green manure, barnyard, manure and compost has shown positive effects in ameliorating saline-alkaline soils including improvement of soil structure and permeability, enhanced salt leaching and reduced surface evaporation. Organic matter also inhibits salt accumulation in the surface layers and carbon dioxide during respiration and decomposition (Mahdy, 2011). Organic matter in the form of humus improves the physical condition of soil and prevents its deterioration by promoting inorganic cation exchange; providing metabolites for micro-organisms promoting stable aggregation of particles in the soil, decreasing the bulk density of soil and increasing the ability of soil to hold moisture. However, a farmer's ability to add and maintain organic matter at optimal pH is a long term strategy that may be restricted by climate or geography (Allison et al., 1953).

A number of substances fitting the guidelines for organic production may be used with or in place of sulfurous acid to restore soil to a useful pH including aquatic plant extracts, elemental sulfur, lignin sulfonate, humic acids and liquid fish extracts (Allison et al., 1954; Zia et al., 2006; 205.601 (j)). These products are produced with an acidic pH. They can be used with or as a substitute for sulfurous acid in (1) soils containing alkaline earth carbonates, (2) soils having a pH reading greater than 7.5 but practically free of alkaline-earth carbonates, and (3) soils having a pH reading of less than 7.5 and containing no alkaline-earth carbonates acid (USDA, 1995; 2006a, b, c; 2010). Elemental sulfur is commonly used to lower soil pH and reclaim soil. It is costly and may require one to seven years for thiobacterial conversion to bioavailable sulfur (Mullen et al., 2007).

<u>Evaluation Question #12:</u> Describe any alternative practices that would make the use of the petitioned substance unnecessary (7 U.S.C. § 6518 (m) (6)).

Irrigation is the application of water to soil for the purpose of providing a favorable environment for plants. Plant growth is a function of the total soil-moisture stress. Leaching, in agriculture, is the process of dissolving and transporting soluble salts by the downward movement of water through the soil. Leaching soluble salts from the root zone is essential in irrigated soils. Without leaching, salts accumulate in direct proportion to the salt content of the irrigation water and the depth of water applied. The concentration of the salts in the soil solution results principally from the extraction of moisture from the soil by the processes of evaporation and transpiration. Salts will increase if water is removed by evaporation. Salinity can be controlled if the flow of satisfactory quality irrigation water through the soil can be controlled. Lining canals and the use of underground irrigation pipe should be considered to prevent seepage and evaporation. Through controlled leaching, the osmotic pressure of the soil solution should be maintained at the lowest feasible level; and, by a practical system of irrigation, the soil-moisture tension in the root zone should be maintained in a range that will give the greatest net return for the crop being grown. Where only irrigation water of poor quality is available or where drainage and full-scale reclamation are not economically feasible, it may be possible to carry on successfully what has been referred to as "saline agriculture." Irrigation, leaching, and tillage practices can all be directed toward salinity control. Salt-tolerant crops can be selected and chemical amendments used when necessary. Alfalfa, barley, sugar beets, and cotton are tolerant crops that can often be grown where salinity is a problem. Careful leveling of land and strategic drainage planning improves uniform water application control and tillage (Allison et al., 1954).

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