Sulfur Dioxide

Handling

Identification of Petitioned Substance

Chemical Names:
Sulfur dioxide

Other Name:
Sulfur (IV) oxide
Sulfur superoxide
Sulfurous acid anhydride
Sulfurous anhydride

Trade Names:
Sulfurous oxide

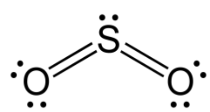
CAS Numbers:
7446-09-5

Other Codes:
EINECS 231-195-2
EPA Pesticide Chemical Code 077601
CA DPR Chemical Code 561
UN 1079

Characterization of Petitioned Substance

Composition of the Substance:

Sulfur dioxide (SO_2) is an angular molecule containing a sulfur atom and two oxygen atoms and can be produced naturally or as a result of combustion of sulfur-containing substances such as petroleum or coal. The sulfur atom has a formal charge of zero and an oxidation state of +4 and is surrounded by five electron pairs. The chemical structure of sulfur dioxide is shown below:



Source: HSDB, 2010

Properties of the Substance:

Sulfur dioxide is a colorless gas with a strong, pungent odor. It is nonflammable and very soluble in water. Sulfur dioxide is a strong reducing agent and is highly reactive.

Due to its high vapor pressure, sulfur dioxide is primarily present in the gaseous phase and can move unchanged to other natural surfaces, including water, soil, and vegetation, following release to the atmosphere (ATSDR, 1998). Because of the high water solubility of sulfur dioxide, oceans can serve as sink (ATSDR, 1998). Sulfur dioxide can be absorbed by soil if pH and moisture content are suitable (ATSDR, 1998). The physical and chemical properties of the sulfur dioxide are described in Table 1.

Specific Uses of the Substance:

Sulfur dioxide products are used to prevent spoilage and oxidation in wine. In the winemaking industry, sulfur dioxide is commonly referred to more generally as 'sulfite.' In this instance, the term 'sulfites' is used to generally refer to multiple sulfur containing compounds, including sulfur dioxide. Sulfur dioxide naturally occurs in wine and prevents microbial growth (including yeasts, bacteria, and molds) by killing microorganisms outright and preventing any remaining microorganisms from reproducing. Sulfur dioxide is classified as an anti-oxidant because it prevents oxidation, which causes the browning of fruit (Henderson, 2008). If too much sulfur dioxide is added to the wine, the yeast that has been intentionally added to the wine will be killed, thereby preventing the process of fermentation before the desired reaction end point is reached. It can also halt the malolactic fermentation (conversion of malic acid to lactic acid), which yields wine that tastes unfinished. In addition, if too much sulfur dioxide is added, the wine will have the pungent odor characteristic of sulfur (Amerine, 1979).

Table 1. Physical and chemical Properties of Sulfur Dioxide

Physical or Chemical Property:	Value:
Physical State	Gas
Appearance	Colorless
Odor	Strong odor, suffocating
Molecular Weight	64.06
Boiling Point	10° C
Melting Point	-72.7° C
Solubility	11.3 g/100 mL (water at 20° C) 0.58 g/100 mL (water at 90° C)
Vapor Pressure	300 mm Hg at 20° C
Relative Density	1.4 at -10° C (water = 1)
Specific Gravity	2.26

Source: EPA, 2007a

Sulfur dioxide is used to preserve and maintain the appearance of fruit products (e.g., dried fruits) by preventing rotting (EPA, 2007a). Rotting is prevented because of the inherently anti-microbial properties of sulfur dioxide (Henderson, 2008).

According to the U.S. Environmental Protection Agency (EPA) Registration Eligibility Document (RED) for inorganic sulfites, sulfur dioxide is registered for use as a fungicide and is typically used to treat for *Boitrytis cinerea*, which causes gray mold disease on grapes. Sulfur dioxide fumigation products are formulated as a compressed liquid that becomes a gas upon release. Compressed liquid fumigation is used in cold-storage facilities and for fumigation of vehicles used to transport post-harvest grape products. In addition, sulfur dioxide is used to sanitize equipment used in wineries, and to treat, in combination with carbon dioxide, for black widow spiders on grapes in storage settings. Another common use of sulfur dioxide is as a bleaching agent in food. In addition, sulfur dioxide is sometimes added as a warning marker and fire retardant to liquid grain fumigants (EPA, 2007a). As discussed further below, the U.S. Department of Agriculture (USDA) National Organic Program (NOP) and the Canada Food Inspection Agency both approve the use of sulfur dioxide as a rodenticide in smoke bombs that are released underground.

Sulfur dioxide is used in a wide variety of industrial applications, including the manufacture of hydrosulfites and by the petroleum industry (ATSDR, 1998). It is also used to dechlorinate wastewaters before release (EPA, 2007a). Specifically, free and combined chlorine are reduced to chloride upon reaction with sulfur dioxide. Because of its reduction properties, sulfur dioxide also acts as a bleaching agent for paper and clothing (ATSDR, 1998).

Sulfur dioxide emissions are produced by industries, vehicles, and equipment that combust sulfur-containing fossil fuels, as well as from various industrial processes (EPA, 2010). When fossil fuel combustion occurs at power plants, sulfur dioxide is released to the atmosphere (EPA, 2010). Atmospheric sulfur dioxide then reacts with water, oxygen, and other chemicals to produce acid rain (EPA, 2007b). Acid rain is defined as the mixture of wet and dry deposition from the atmosphere that contains high amounts of sulfuric and nitric acids (EPA, 2007b).

Approved Legal Uses of the Substance:

Since 2001, sulfur dioxide has been included on the National List of Allowed and Prohibited Substances (i.e., the National List) for organic crop production. Specifically, sulfur dioxide is approved for use in organic handling and is permitted only in wine labeled 'made with organic grapes,' provided that the total concentration of sulfite does not exceed 100 parts per million (ppm) (7 CFR 205.605(b)).

Sulfur dioxide is currently included on the National List as an allowed synthetic substance for use in underground smoke bombs for rodent control in organic crop production (7 CFR 205.601(g)); however, this substance is expected to be removed from the National List after its sunset date of October 21, 2012. The EPA has not registered sulfur dioxide for use as a rodenticide; however, EPA has registered rodent control smoke bombs with the active ingredients sulfur, charcoal carbon, and sodium nitrate or potassium nitrate (saltpeter).

Sulfur dioxide is considered by the U.S. Food and Drug Administration (FDA) as generally recognized as safe (GRAS) when used in accordance with good manufacturing practice, except that it is not to be 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 (21 CFR 182.3862). The FDA does not set limits on the amount of sulfur dioxide (in ppm) permitted in all other foods. However, proper labeling is required on foods containing levels of sulfur dioxide that exceed 10 ppm. Typical concentrations of sulfur dioxide found in foods are as follows:

- Less than 100 ppm: wine, dried fruits (excluding dark raisins and prunes), lemon and lime juices, molasses, and sauerkraut juice;
- Between 50 and 100 ppm: grape juice, wine vinegar, fruit topping, gravies, dried potatoes, and maraschino cherries;
- Between 10 ppm and 50 ppm: pectin, corn syrup, corn starch, fresh shrimp, sauerkraut, pickled foods, hominy, frozen potatoes, maple syrup, imported jams and jellies, and fresh mushrooms.

Source: U.S. EPA, 2007a

The Alcohol and Tobacco Tax and Trade Bureau (TTB) allows the total amount of sulfur dioxide in wine to be 350 mg/L (27 CFR 4.22(b)(1)). The TTB also requires that a sulfite declaration appear on the labels for wine and other beverage alcohol products containing 10 or more mg/L total sulfur dioxide, regardless of whether any sulfiting agents were added to the grapes, juice or wine (27 CFR 4.32(e)) (TTB, undated). Under the authority of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), U.S. EPA provides a tolerance for sulfur dioxide residues in or on post harvest grapes (40 CFR 180.444). The tolerance is listed as 10.0 ppm when sulfur dioxide is used as a fungicide. Fumigation may occur indoors or in trailers or other transport devices. Grapes may be fumigated up to 20 times and on a seven to ten day interval. If fumigation area concentrations exceed 2.0 ppm, a NIOSH/MSHA approved respirator must be used for short exposures of limited duration. Labels on fumigation products containing sulfur dioxide must include information on the appropriate personal protective equipment (eye protection, gloves, boots, and protective clothing). When sulfur dioxide is used to treat for black widow spider, the U.S. EPA approves a concentration of up to 10,000 ppm and an exposure period of approximately thirty minutes. During the aeration phase of treatment, the approved sulfur dioxide release concentration is one below 30 ppm (EPA, 2007a).

The U.S. EPA has proposed label revisions for sulfur dioxide end-use products (fumigants) in their May, 2007 document titled the 'Reregistration Eligibility Decision- Inorganic Sulfites' (EPA, 2007a). The proposed revisions are as follows:

- When treating grapes for *Botrytis cinerea* (bunch rot/gray mold) or black widow spider in a warehouse fumigation chamber, do not release treated air into the atmosphere containing concentrations of sulfur dioxide in excess of 30 ppm (as determined by a Sensidyne or Kitagawa syringe sampler, or a Draeger handpump);

- When treating grapes in a truck, trailer or other transport vehicle, do not release treated air into the atmosphere containing concentrations of sulfur dioxide in excess of 2 ppm (as determined by a Sensidyne or Kitagawa syringe sampler, or a Draeger handpump);

- Sulfur dioxide concentration in transport vehicles must be below 2 ppm before moving over public roads or highways;

- Before moving or using sulfur dioxide fumigant products, handlers must be trained how to appropriately use respirators which conform to Occupational Safety and Health Administration (OSHA) requirements (described in 29 CFR 1910.124) and how to appropriately handle and use sulfur dioxide;

- When making gas applications or checking connections handlers must wear a National Instiute of Safety and Health (NIOSH)/Mine Safety and Health Administration (MSHA) approved full face respirator with an organic-vapor removing cartridge, in addition to sulfur dioxide impervious gloves, boots and coveralls over long-sleeved shirt and long pants;

- If a sulfur dioxide concentration of 2 ppm is exceeded at any time, all persons working in the fumigation area must wear a NIOSH/MSHA approved full face respirator with an organic-vapor removing cartridge. If sulfur dioxide concentrations of 10 ppm are exceeded, or when concentrations are unknown, an approved self-contained breathing mask (SCBA) or combination air supplied SCBA respirator must be used by all persons working in the fumigation area; and

- Sulfur dioxide aerations must not be performed concurrently from multiple chambers.

Action of the Substance:

Sulfur dioxide is commonly added to wine because it acts as a preservative. Sulfur dioxide is able to kill unfavorable microorganisms that contaminate wine. The substance acts as an antimicrobial by entering the microbe and disrupting the activity of the enzymes and proteins of the cell. Only the molecular form of sulfur dioxide is able to pass through the microbe's cell membrane, and therefore, microbial growth is controlled by the concentration of molecular sulfur dioxide (Henderson, 2008).

Wine is perishable and prone to oxidation as well as the development of aldehyde off-odors. Sulfur dioxide has become an important additive[1], particularly for white wines, for preserving freshness. Wines without any sulfur dioxide generally have a short shelf life of around six months and need to be kept in perfect storage conditions. Maintaining perfect storage conditions is typically out of the control of the wine maker, so adding preservatives has helped to ensure that consumers receive a product that is more palatable (Amerine, 1979; Henderson, 2008).

Sulfur dioxide prevents the browning associated with the oxidation of fresh fruits and vegetables. Sulfur dioxide stops the activity of oxidizing enzymes by removing the oxygen from the enzyme before undesirable brown pigments are formed (Grotheer et al., 2009). Sulfites act as an effective inhibitor of browning because sulfite binds to a carbonyl intermediate group and prevents subsequent polymerization, which forms browning. Sulfites act as a reducing agent that combines with ortho-quinones, which converts them back to diphenols that are considered to be colorless. This action prevents the nonenzymatic condensation of o-quinones to brown polymers associated with 'browning' in fruit (Grotheer et al., 2009).

In the case of yeast, sulfur dioxide does not actually kill yeast but rather changes the environment so that 'wild' type yeasts are unable to reproduce and over populate. The cultured wine yeast that is added to wine is more tolerant of sulfur dioxide and has the ability to reproduce, eventually out competing wild type yeasts for dissolved oxygen and fermentable sugar and nutrients. There are no nutrients left for the wild type yeasts and they die without propagating. Although some sulfur dioxide is naturally present in wine, the level of this substance dissipates over time and more must be added in order to maintain the characteristic anti-microbial properties (Henderson, 2008).

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[1] It is important to note that sulfites are also a natural byproduct of yeast metabolism during the process of fermentation. Even if a wine maker chooses not to add additional sulfur dioxide, some chemical is still present in the wine following the natural reaction of fermentation (Henderson, 2008).

Combinations of the Substance:

A combination of sulfur dioxide, water, and citric acid is used as an effective sanitizing agent in wineries and is used to clean equipment and storage areas. Citric acid makes the solution acidic. Compressed sulfur dioxide gas in EPA-registered fumigant generally is not used in combination with other substances. When used to treat for black widow spiders on grapes in storage settings, sulfur dioxide gas may be used in combination with carbon dioxide (EPA, 2007a).

Sulfur-based rodenticide smoke bombs contain sulfur, charcoal carbon, and either potassium nitrate or sodium nitrate as active ingredients. Combustion of these chemicals produces smoke containing sulfurous oxides and other chemicals (EPA, 2007a).

Status

Historic Use:

Ancient Greek and Roman winemakers burned sulfur in order to capture sulfur dioxide for use as a wine preservative (Phillips, 2006). Sulfur candles were burned to sterilize wine barrels and amphorae after it was observed that this practice kept wine vessels fresh and prevent the presence of a vinegar smell (Henderson, 2008). Ancient Greeks also are believed to have used sulfur dioxide, produced by burning sulfur, to fumigate homes (Phillips, 2006).

The high reactivity and acidic properties of sulfur dioxide make for its common use in commercial processes (ATSDR, 1998). Sulfur dioxide has been used in the paper and pulp industry as a bleaching agent (ATSDR, 1998). Other common uses of sulfur dioxide include use as a steeping agent for grain in food processing, as a catalyst or extraction solvent in the petroleum industry, as an intermediate for bleach production, and as a flotation depressant for sulfide ores in the mining industry (IARC, 1992).

OFPA, USDA Final Rule:

Sulfur dioxide is approved for use in organic handling and is permitted only in wine labeled 'made with organic grapes,' provided that the total concentration of sulfite does not exceed 100 ppm (7 CFR 205.605(b)). Beginning in 2001, sulfur dioxide was included on the National List for use in underground rodent control only (as smoke bombs) (65 FR 80637; 7 CFR 205.601(g)(1)). However, this substance is expected to be removed from the National List after its sunset date of October 21, 2012, based on a 2011 recommendation from the National Organic Standards Board (NOSB, 2011).

International

The Canadian organic standard permits the use of sulfurous acid (sulphurous acid) as a preservative only in alcoholic beverages labeled as organic made from grapes or other fruit. The minimum use of sulfur dioxide is recommended, however labeling wines containing sulfites as 'organic' is permitted. The maximum allowable level of sulfur dioxide in alcoholic beverages with less than five percent residual sugar is 100 ppm and 30 ppm for total sulfites and free sulfites, respectively. In alcoholic beverages with five percent or more and less than ten percent residual sugar, 150 ppm and 35 ppm, respectively, are permitted. In alcoholic beverages with ten percent or more residual sugar, 250 ppm and 45 ppm respectively, are permitted. The use of sulfites from sulfur dioxide bottled gas, as liquid sulfur dioxide, or liberated from the ignition of asbestos-free sulfur wicks is acceptable (Canadian General Standards Board, 2011). The Canadian organic standards permit labeling wines created with added sulfites as 'organic.' In contrast, organic regulations set forth in the United States by the NOP do not permit labeling wine made grapes and containing added sulfites as 'organic.' In addition, the NOP does not allow wines made with fruit other than grapes to be labeled as 'made with organic (fruit other than grapes)' (USDA, 2010).

The European Economic Community (EEC) permits the use of sulfur dioxide in fruit wines without added sugar (including cider and perry) or in mead labeled as organic. The maximum permissible level of sulfur dioxide in these products is 50 mg/L. In this context, 'fruit wine' is defined as wine made from fruits other than grapes. The maximum permissible level of sulfur dioxide in cider and perry prepared with addition of sugars or juice concentrate after fermentation is 100 mg/L (EEC 889/2008, 2008).

Sulfur dioxide is listed as an acceptable food additive in wine, cider, perry, and mead labeled as organic by the CODEX Alimentarius Commission (CODEX Alimentarius Commission, 2010; GL 32-1999). Sulfur dioxide is permitted for use in making cider and perry (14.2.2), grape wines (14.2.3) and wines made with fruit other than grapes (14.2.4). Sulfur dioxide is also acceptable for use in mead (14.2.5).

Evaluation Questions for Substances to be used in Organic Handling

<u>Evaluation Question #1:</u> 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)).

Sulfur dioxide is produced commercially from elemental sulfur, pyrites, sulfide ores of non-ferrous metals, gypsum and anhydrite, waste sulfuric acid and sulfates, hydrogen sulfide-containing waste gases, and flue gases from the combustion of sulfurous fossil fuels (IARC, 1992). The most common method of production occurs by burning sulfur, but sulfur dioxide can be produced by purifying and compressing sulfur dioxide gas from smelting operations (ATSDR, 1998). Sulfur dioxide has been produced by burning molten sulfur in a special burner with a controlled amount of air. The burner gas, free of dust and cooled, is dissolved in water in a series of two towers. In a third tower, the solution is sprayed at the top and flows down while steam is injected at the base. The gas issuing from the third tower is then cooled to remove most moisture and passed up a fourth tower against a countercurrent of sulfuric acid. The dried gas is liquefied by compression (IARC, 1992).

Below are examples of processes that result in the formation of sulfur dioxide.

1. In sulfur based smoke bombs, sulfur dioxide can be produced by burning (i.e., oxidizing) elemental sulfur:

   $$S_8 + 8\ O_2 \rightarrow 8\ SO_2$$

2. Sulfur dioxide can be produced following the combustion of hydrogen sulfide (H_2S):

   $$2\ H_2S + 3\ O_2 \rightarrow 2\ H_2O + 2\ SO_2$$

<u>Evaluation</u> <u>Question #2:</u> Is the substance synthetic? 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)).

Sulfur dioxide occurs in the environment as a product of natural processes (e.g., volcanic eruptions). However, sulfur dioxide used in industrial and commercial applications (including winemaking) is typically obtained from synthetic processes. For example, sulfur dioxide can be produced by burning molten sulfur in a fabricated burner with a controlled amount of air. The burner gas is cooled and then dissolved in water in two separate cooling towers. In a third tower, the solution is sprayed at the top and flows down while steam is injected at the base (IARC, 1992). The gas from the third tower is cooled to remove most moisture and passed up a fourth tower against a countercurrent of sulfuric acid. The dried gas is liquefied by compression so that it can be transported (IARC, 1992).

The use of sulfur dioxide in organic processing and handling is limited to winemaking (7 CFR 205.605(b)). A small amount of sulfur dioxide is naturally produced by wine yeast in the process of alcoholic fermentation; however, most of the sulfur dioxide that is present in wine has been added by the manufacturer and is considered to be synthetic. During the white winemaking process, sulfur dioxide is added at most stages (such as crushing and bottling). When making red wine, a smaller amount of sulfur dioxide is added and the primary addition of this substance is following the completion of the malolactic fermentation of the wine. Sulfur dioxide is available in its pure form as a compressed gas that can be made into an aqueous solution for wine additions. Forms of sulfur dioxide added during winemaking include a pellet or direct addition into the wine as a gas from a dosing gun (Gawel, 2011).

Solid forms of sulfite are available as two common powders: potassium metabisulfite or sodium metabisulfite. Potassium metabisulfite can be used to sanitize winemaking equipment and also as a preservative in musts and wines. However, the Organic Materials Review Institute (OMRI) does not consider potassium metabisulfite as an allowed form of sulfur dioxide under the current NOP regulations (OMRI, 2011). This substance has the molecular formula of $K_2S_2O_5$ and is 57.6% available sulfur dioxide by weight (Henderson, 2008). Sodium metabisulfite should be used strictly for sanitizing equipment and should never be added to wine (Pambianchi, 2000).

Other wineries prefer to use a premixed aqueous solution of sulfur dioxide rather than potassium metabisulfite. The liquid is typically 5% to 10% sulfur dioxide by weight and can be purchased or made up at the winery by dissolving sulfur dioxide gas or potassium metabisulfite into distilled water. Then, the liquid is directly added to wine without mixing and the proper amount is measured volumetrically instead of weighed on a scale (Henderson, 2008).

Evaluation Question #3: Provide a list of non-synthetic or natural source(s) of the petitioned substance (7 CFR § 205.600 (b) (1)).

In the alcoholic fermentation process, a small amount[2] of sulfite is produced naturally as a byproduct of yeast fermentation. Fermentation is a key biochemical process used in successful wine making. The amount of sulfur dioxide released during fermentation is not sufficient and additional synthetic sulfur dioxide is added in order to make use of the preservation and antimicrobial properties of the substance (Pambianchi, 2000).
Because the amount of sulfur dioxide produced naturally during the fermentation process is not large enough to achieve the desired level of sulfur dioxide in the total product, the correct amount of sulfur dioxide is determined based on pH. Sulfur dioxide is also added before the process of alcoholic fermentation begins in order to prevent oxidative browning. Synthetic sulfur dioxide is subsequently added during the wine making process in order to reach the appropriate concentration (Henderson, 2008).

Evaluation Question #4: Specify whether the petitioned substance is categorized as generally recognized as safe (GRAS) when used according to FDA's good manufacturing practices (7 CFR § 205.600 (b)(5)). If not categorized as GRAS, describe the regulatory status. What is the technical function of the substance?

Sulfur dioxide is considered by the FDA as GRAS 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 (21 CFR 182.3862). Pectin, corn syrup, corn starch, fresh shrimp, sauerkraut, pickled foods, hominy, frozen potatoes, maple syrup, imported jams and jellies, and fresh mushrooms may contain concentrations of sulfur dioxide between 10 ppm and 50 ppm. Dried fruits (excluding dark raisins and prunes), lemon and lime juices, wine, molasses, and sauerkraut juice are allowed to contain sulfur dioxide concentrations of less than 100 ppm. Concentrations of sulfur dioxide between 50 and 100 ppm are allowed for grape juice, wine vinegar, fruit topping, gravies, dried potatoes, and maraschino cherries. Proper labeling is required on foods containing levels of sulfur dioxide that exceed 10 ppm (EPA, 2007a).

[2] Specifically, the amount of sulfur dioxide produced during this process is so small that it is often not included in graphical representations of common fermentation reactions.

Sulfur dioxide is also regulated by the TTB. TTB regulation requires a sulfite declaration to be present on the labels for wine and other alcoholic beverages that contain 10 or greater mg/L total sulfur dioxide, regardless of the addition of additional sulfiting agents to the grapes, juice, or wine (27 CFR 4.32(e)). The total amount of sulfur dioxide permitted in wine by the TTB is 350 mg/L (27 CFR 4.22(b)(1)) (TTB, undated)

In food processing and handling, the technical function of sulfur dioxide is as a preservative (FAO, 1995).

<u>Evaluation Question #5:</u> Describe whether the primary function/purpose of the petitioned substance is a preservative. If so, provide a detailed description of its mechanism as a preservative (7 CFR § 205.600 (b)(4)).

As previously described under 'Action of the Substance,' sulfur dioxide is primarily used as a food preservative. Sulfur dioxide acts as both an antioxidant and an antimicrobial. Sulfites are used as antioxidants to prevent discoloration of light-colored fruits and vegetables, such as dried apples and dehydrated potatoes. Sulfites are an effective inhibitor of browning because they are capable of binding to carbonyl intermediate groups, which prevents the polymerization associated with browning. They are also used in wine-making because they inhibit bacterial growth but do not interfere with the desired development of some yeast strains, including *Saccharomyces* needed for alcoholic fermentation. This property is important in winemaking because some wild-type strains of yeast produce off-flavors and negatively affect the flavor of the wine (Henderson, 2008). In general, sulfur dioxide acts as an effective preservative by preventing rotting.

Preservatives must be highly reactive molecules. While the use of sulfur dioxide in winemaking continues, the general use of sulfur dioxide as a preservative in other foods is decreasing because of the associated antinutritional effects, such as the destruction of thiamin.[3] There is also a small subset of the population who are allergic to products containing sulfur dioxide (Grotheer et al., 2009).

<u>Evaluation Question #6:</u> Describe whether the petitioned substance will be used primarily to recreate or improve flavors, colors, textures, or nutritive values lost in processing (except when required by law) and how the substance recreates or improves any of these food/feed characteristics (7 CFR § 205.600 (b)(4)).

Sulfur dioxide is not used to recreate or improve flavors, colors, textures or nutritive values lost in processing. It is primarily used as a preservative in food handling and processing (FAO, 1995).

<u>Evaluation Question #7</u>*:* Describe any effect or potential effect on the nutritional quality of the food or feed when the petitioned substance is used (7 CFR § 205.600 (b)(3)).

As previously discussed in 'Action of the Substance' and Evaluation Question #5, sulfur dioxide is a highly reactive molecule and can affect the nutritional quality of food. Specifically sulfur dioxide can deplete levels of B vitamin that are already present in certain foods. Sulfite ions act as an electron donor and react with a thiamin molecule which destroys vitamin activity.

The use of sulfur dioxide in food has an effect on nutritional quality and has been regulated by the FDA and the agency has prohibited the use of sulfites in foods that are valuable sources of B vitamin. These foods include meats and products created with enriched flour (Whitney et al., 2008)

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[3] Sulfites are banned in foods that are a significant source of thiamin (e.g., meat products, enriched flour). Because sulfites are electron donors, they attack thiamin molecules thereby ending existing vitamin activity (Whitney et al., 2008).

Evaluation Question #8: List any reported residues of heavy metals or other contaminants in excess of FDA tolerances that are present or have been reported in the petitioned substance (7 CFR § 205.600 (b)(5)).

No reports of residues of heavy metals or other contaminants present in sulfur dioxide used in handling have been identified.

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

Sulfur dioxide is listed as a toxic substance under Section 313 of the Emergency Planning and Community Right to Know Act (EPCRA) under Title III of the Super-fund Amendments and Reauthorization Act (SARA). Disposal of wastes containing sulfur dioxide is controlled by a number of federal regulations. However, releases of sulfur dioxide to the environment from large processing facilities are not required to be reported to the Toxics Release Inventory (ATSDR, 1998).

When used at the levels required for effective winemaking (i.e., an amount that does not produce unwanted flavors or odors and the permissible limit of up to 100 ppm), synthetic sulfur dioxide is not expected to have any adverse effects on the environment or biodiversity (USDA, 1995). No information countering this conclusion has been identified.

Evaluation Question #10: 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)).

In the general population, health effects have not been observed in humans following ingestion of foods containing sulfur dioxide. However, health effects have been reported in some specific subpopulations (Grotheer et al., 2009).

Following consumption of foods containing sulfur dioxide, health effects have been reported in individuals who have been born without the enzyme sulfite oxidase. Sulfite ions are absorbed into the blood stream and quickly oxidized to sulfate ion by sulfite oxidase. The sulfate is then quickly excreted in the urine. This process makes even large quantities of sulfite non-toxic in most individuals. Those born without this enzyme could suffer an allergic reaction if they consume wine containing sulfur dioxide. It is estimated that anywhere between .4 and 1 percent of the general population is sensitive to sulfites and a person who is sensitive to sulfite may have effects that range from moderate to life-threatening ones (HSDB, 2010; Grotheer et al., 2009). Sulfites are strongly associated with asthma attacks. However, this allergy is different than most food allergies because different people have different thresholds of the amount of sulfites needed to cause an asthma attack. Occasionally, sulfite allergies can cause symptoms such as angioedema (redness and swelling), hives, or anaphylaxis. Those who suffer from anaphylaxis after consuming sulfites should be aware that all wine contains a small amount of natural sulfite and should not drink any volume of wine. Asthma attacks are common in most people who suffer from sulfite allergies (Cleveland Clinic, 2010).

After eating foods or drinking wine preserved with sulfur dioxide or other sulfites, highly sensitive asthmatic individuals can develop bronchospasm. Sulfites appear to primarily affect asthmatics and children more than adults. It is estimated that approximately 10% of American adult asthmatics are sensitive to sulfites and only a small amount of the substance can trigger a reaction (Cleveland Clinic, 2010). Because of the health effects observed in sensitive populations, the FDA requires proper labeling on foods containing levels of sulfur dioxide that exceed 10 ppm (U.S. EPA, 2007a). The FDA requires that sulfur dioxide not be used on foods that are consumed frequently and generally in large quantities, such as 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 (21 CFR 182.3766).

Additional restrictions on the concentration of sulfur dioxide permitted by the FDA in foods are discussed in the section titled 'Approved Legal Uses.'

IARC considers sulfur dioxide, sulfites, bisulfites and metabisulfites as Group 3 substances because they are not classifiable as to their carcinogenicity to humans (HSDB, 2010).

Evaluation Information #11: Provide a list of organic agricultural products that could be alternatives for the petitioned substance (7 CFR § 205.600 (b)(1)).

Although both scientists and industry professionals have sought to identify an alternative for the use of sulfur dioxide in wine making, presently no organic agricultural products have been identified that act as a satisfactorily effective agent for preventing microbial spoilage and oxidation in wine.

Researchers in the European Union have been working to develop a process that would eliminate the need for adding sulfur dioxide to wine by instead using high pressure treatment to reduce the microorganisms present in wine. When chitosane, a polysaccharide obtained from the deacetylation of chitin, is added to wine following high pressure treatment, the substance's antioxidant properties have been observed to inhibit white wine browning. The research group also focused on the use of sesquiterpenoids (antioxidant grape skin compounds) as a substitute for sulfur dioxide (European Commission, 2008; Eureka, 2010). However, high pressure treatment has not proven to be effective in reducing microbial populations in all types of wines (e.g. Barbara must) (Delfini and Formica, 2001).

References:

Amerine, M.A., and Joslyn, M.A., 1970. Table wines: the technology of their production, Volume 2. University of California Press, Berkely, CA.

Amerine, M.A., 1979. Wine: An Introduction. University of California Press, Berkely, CA.

Canadian General Standards Board, 2011. Retrieved August 16, 2011 from http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/internet/bio-org/documents/032-0311-2008-eng.pdf

Cleveland Clinic, 2010. Sulfite Sensitivity. Retrieved August 25, 2011 from http://my.clevelandclinic.org/disorders/sulfite_sensitivity/hic_sulfite_sensitivity.aspx

CODEX Alimentarius Commission, 2010. Guidelines for the Production, Processing, Labelling, and Marketing of Organically Produced Foods. GL-32-1999. Retrieved September 22, 2011 from http://www.codexalimentarius.net/web/more_info.jsp?id_sta=360

Delfini, C. and Formica, J.V., 2001. Wine microbiology: Science and technology. Marcel Dekker Inc., Italy.

Eureka, 2010. Eureka Project 4506 WineSulFree. Retrieved August 29, 2011 from http://www.eurekanetwork.org/project/-/id/4506

European Commission, 2008. European researchers seek alternatives to sulphur dioxide in wine. Retrieved August 29, 2011 from http://ec.europa.eu/research/headlines/news/article_08_11_04_en.html

European Economic Community, 2008. Commission Regulation No 889/2008. Retrieved June 28, 2011 from http://www.organic-world.net/news-eu-regulation.html

FAO, 1995. Agricultural Services Bulletin No.119. Retrieved September 22, 2011 from http://www.fao.org/docrep/V5030E/V5030E0d.htm

Gawel, R., 2011. The Use of Sulfur Dioxide in Wine. Retrieved August 25, 2011 from http://www.aromadictionary.com/articles/sulfurdioxide_article.html

Grotheer, P., Marshall,M., and Simonne, A., 2009. Sulfites: Separating Fact from Fiction, University of Florida. Retrieved September 22, 2011 from http://edis.ifas.ufl.edu/fy731

Henderson, P., 2008. Sulfur dioxide: Science behind this anti-microbial, anti-oxidant, wine additive. Retrieved July 6, 2011 from http://www.practicalwinery.com/janfeb09/page1.htm

Hazardous Substances Database (HSDB), 2010. Sulfur dioxide. Retrieved June 28, 2011 from http://toxnet.nlm.nih.gov/cgi-bin/sis/search/r?dbs+hsdb:@term+@rn+@rel+7446-09-5

International Agency for Research on Cancer (IARC), 1992. IARC monographs on the evaluation of the carcinogenic risk of chemicals to man: Occupational exposures to mists and vapours from strong inorganic acids, and other industrial chemicals. Vol. 54. Lyon, France: World Health Organization, International Agency for Research on Cancer.

OMRI, 2011. Generic Materials Search: metabisulfite. Retrieved September 22, 2011 from http://www.omri.org/simple-gml-search/results/metabisulfite

Pambianchi, D., 2000. Solving the Sulfite Puzzle. WineMaker Magazine, Winter 2000. Retrieved September 22, 2011 from http://www.winemakermag.com/stories/article/indices/34-sulfite/634-solving-the-sulfite-puzzle

Phillips, C., 2006. The Chemistry and Measurement of SO_2. Wine Business Monthly. Retrieved June 28, 2011 from http://www.winebusiness.com/wbm/?go=getArticle&dataId=44897

U.S. Department of Agriculture, 1995. TAP Report: Sulfur Dioxide. Retrieved June 28, 2011 from http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5068082&acct=nopgeninfo

NOSB, 2011. Formal Recommendation by the National Organic Standards Board (NOSB) to the National Organic Program (NOP): 2012 Sunset Review of Sulfur Dioxide listed on §205.601 Synthetic substances allowed for use in organic crop production: (g) As rodenticides (1) Sulfur dioxide—underground rodent control only (smoke bombs); April 29. Retrieved September 14, 2011 from http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5091715

TTB, undated. Laboratory Analysis for Small Wines. Retrieved October 13, 2011 from http://pathowe.net/Documents/W%2013%20Laboratory%20Techniques%20for%20Small%20Wineries.pdf

U.S. Department of Agriculture, 2010. Policy Memorandum: Sulfur dioxide in wine made with organic fruit. Issued September 20, 2010.

U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological Profile for Sulfur Dioxide. Dec. 1998. Retrieved June 28, 2011 from http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=253&tid=46

U.S. Environmental Protection Agency (U.S. EPA), 2007a. Reregistration Eligibility Decision – Inorganic Sulfites. Retrieved June 28, 2011 from http://www.epa.gov/pesticides/reregistration/REDs/inorganicsulfites.pdf

U.S. Environmental Protection Agency, 2007b. Effects of Acid Rain. Retrieved June 28, 2011 from http://www.epa.gov/acidrain/effects/

U.S. Environmental Protection Agency (U.S. EPA), 2010. Sulfur Dioxide (Six Common Pollutants). Retrieved June 28, 2011 from http://www.epa.gov/airquality/sulfurdioxide/index.html

Whitney, E., Whitney, E.N., and Rolfes, S.R., 2008. Understanding Nutrition. Wadsworth Cengage Learning, 12th Edition, Belmont, CA.