Magnesium Sulfate

Crops

Identification of Petitioned Substance

Chemical Names:
Magnesium sulfate

Other Name:
Epsom salt
Bitter salts
Magnesium sulfate anhydrous
Sulfuric acid, magnesium salt

Trade Names:
None

CAS Numbers:
7487-88-9 (magnesium sulfate anhydrous)
18939-43-0 (sulfuric acid magnesium salt)
14168-73-1 (monohydrate)
10034-99-8 (heptahydrate)

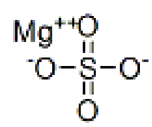
Other Codes:
050503 (USEPA PC Code [U.S. EPA 2010a])
231-298-2 (EINECS)

Characterization of Petitioned Substance

Composition of the Substance:

The compound magnesium sulfate (anhydrous) contains magnesium, sulfur, and oxygen, $MgSO_4$. Magnesium sulfate also occurs in hydrated forms ($MgSO_4 x H_2O$), including monohydrate and heptahydrate. The monohydrate and heptahydrate forms contain one and seven H_2O molecules, respectively (ChemIDplus Lite, 2011; Kawamura and Rao, 2007). Magnesium sulfate is considered ionic because a metal (magnesium) and a non-metal (sulfate) are bonded. Within the sulfate molecule, there is a covalent bond between the sulfur and oxygen atoms. The molecular structure of magnesium sulfate is shown in Figure 1.

Figure 1. Molecular Structure of Magnesium Sulfate



Properties of the Substance:

Magnesium sulfate is an odorless solid that is generally found as needle-like colorless crystals or as a white crystalline powder (Kawamura and Rao, 2007). The substance is considered very soluble in boiling water. Different forms of magnesium sulfate have different molecular weights and differ in their solubility in water. The physical and chemical properties of magnesium sulfate are presented in Table 1.

Specific Uses of the Substance:

Magnesium sulfate has a wide variety of uses in agriculture, food processing, personal care products, and medicine. In agriculture, magnesium sulfate is added to soil to correct for magnesium deficiency (Kawamura and Rao, 2007). Crops that heavily depend on magnesium-rich soil include potatoes, peppers, tomatoes, and roses. Magnesium sulfate is also commonly added to potted plants. The high solubility of magnesium sulfate makes it an ideal compound for adding magnesium to the soil. Adding magnesium sulfate to the soil improves the uptake of nitrogen and phosphorous by crops (Epsom Salt Council, 2009).

Table 1. Physicochemical Properties of Magnesium Sulfate

Physical or Chemical Property	Value
Physical State	Solid
Appearance	White crystalline powder or needle-like colorless crystals
Odor	Odorless
Taste	Bitter, salty, cooling
Molecular Weight	120.36 (anhydrous); 138.38 (monohydrate); 246.47 (heptahydrate)
Boiling Point	NA
Melting Point	2,055 °F or 1124 °C
Solubility in Water	anhydrous: 269 g/L (0 °C), 255 g/L (20 °C) heptahydrate: 710 g/L (20 °C)
Vapor Pressure	< .01 mm Hg at 20 °C
Density	2.66 g/cm^3 (anhydrous); 2.445 g/cm3 (monohydrate); 1.68 g/cm^3 (heptahydrate)

Source: Chemical Book, 2010

Magnesium sulfate is added to livestock feed as a magnesium supplement when necessary. If livestock are feeding on pastures with high potassium levels, which interfere with the uptake of magnesium by grasses, supplemental magnesium sulfate may be needed (Epsom Salt Council, 2009).

In food processing, magnesium sulfate is used as a flavor enhancer in bottled water and as a firming agent in soybean curd. Magnesium sulfate also is used as a nutrient, primarily in salt-replacer products, dietary supplements, carbonated diet soft drink beverages, sports drinks, and enhanced (fortified) water beverages. It is used as in fermentation and malting aid in beer, ale, and other malt beverages (Kawamura and Rao, 2007).

Magnesium sulfate has many human medicinal uses. Injections of magnesium sulfate can be used as an anticonvulsant to control and prevent seizures in children suffering from acute nephritis. Magnesium sulfate injections can help lower the blood pressure of pregnant females suffering from preeclampsia and prevent pre-term labor. Asthma attacks can be treated with magnesium sulfate. When taken intravenously, it reduces the resistance within the airways and facilitates normal airflow. Magnesium sulfate can act as a laxative when taken orally and is used to relieve constipation (Adnani, 2010).

Epsom salt, a common form of magnesium sulfate, is easily dissolved in water and is used to relieve muscle aches and pains as well as to reduce itching and inflammation. It is commonly added to bath water and used by individuals suffering from joint pain (Epsom Salt Council, 2009).

Magnesium sulfate also has a number of veterinary uses. It acts as an anticonvulsant, laxative, bronchodilator, electrolyte replacement aid with hypomagnesaemia, and may be used to treat cardiac arrhythmias. Specifically in swine, magnesium sulfate is administered to treat malignant hypothermia (Dodman, 2010).

<u>Approved Legal Uses of the Substance:</u>

Magnesium sulfate is currently included on the National List as a synthetic substance allowed for use in organic crop production as a soil amendment if a magnesium deficiency is documented (7 CFR 205.601). Magnesium sulfate is also included on the National List as a synthetic substance allowed for use in livestock production when used as a disinfectant, sanitizer, or in medical treatments as applicable (7 CFR 205.603). In addition, the National List states that magnesium sulfate is allowed for use as a nonsynthetic ingredient "in or on processed products labeled as 'organic' or 'made with organic (specified ingredients or food group[s])' (7 CFR 205.605).

Magnesium sulfate is considered by the Food and Drug Administration (FDA) as generally recognized as safe (GRAS) when used as a nutrient or dietary supplement (21 CFR 184.1443). The Food and Nutrition Board, an organization established by the Institute of Medicine that provides guidance to the public and policy makers on nutrition and food sciences, has recommended that cereal grain products be fortified with magnesium in response to the potential risk of deficiency among significant segments of the population (FAQS, 2010).

Multiple products containing magnesium sulfate are approved by the FDA for medicinal use in humans. Magnesium sulfate can be administered via injection or can be orally ingested (U.S. FDA, 2010). In 2010, the FDA approved a product containing magnesium sulfate, which acts a colon cleanser in preparation for a colonoscopy (Braintree Laboratories, 2010).

The FDA allows magnesium sulfate to be prescribed legally by veterinarians as an extra-label drug. An extra-label drug is defined as the veterinary use of a drug in a manner for which it was not approved.[1] No specific veterinary formulations of magnesium sulfate are available. The National Lists allows the addition of magnesium sulfate to animal feed according to 7 CFR 205.603. Intravenous injection is used when treatment is required immediately; however, adding magnesium sulfate to animal feed offers an alternative in less urgent situations.

Under the authority of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the EPA exempts residues of magnesium sulfate—used as a solid diluent, carrier, or safener—from the requirement of a tolerance when used in accordance with good agricultural practices as inert (or occasionally active) ingredients in pesticide formulations applied to pre- and post-harvest agricultural crops (40 CFR 180.1001[c]). No pesticide products containing magnesium sulfate are currently registered with the EPA.

Action of the Substance:

Magnesium is vital in maintaining crop growth and yield. Specifically, magnesium is critical in biochemical and physiological plant processes, including photosynthetic carbon dioxide fixation, protein synthesis, chlorophyll formation, partitioning and utilization of photoassimilates, photophosphorylation (including ATP formation in chloroplasts), loading of sucrose in the phloem, photo-oxidation in leaf tissues, and the generation of reactive oxygen species (Cakmak and Yazici, 2010).

As discussed by Cakmak and Yazici (2010), magnesium is stored in plant cells that conduct photosynthesis in leaves. Within the plant cell, light energy is converted to chemical energy by means of photosynthesis. In areas of high light intensity, plants need a higher amount of magnesium in order to prevent deficiency, which presents itself through leaf damage (i.e., reddish spots, interveinal chlorosis). High light intensity increases the generation of highly-reactive oxygen species in chloroplasts, which causes damage by inhibiting photosynthetic carbon dioxide fixation (Cakmak and Yazici, 2010).

Magnesium plays a role in a biochemical mechanism that some plant species use to reduce aluminum toxicity in acidic soils. A sufficient level of magnesium is needed for the release of organic acid anions from roots to modify an aluminum-toxic root-zone soil. Organic acid ions released from roots chelate toxic aluminum ions, forming aluminum-organic acid complexes that are no longer toxic to the plant (Cakmak and Yazici, 2010).

Combinations of the Substance:

Fertilizers composed of synthetic or non-synthetic materials that contain synthetic magnesium sulfate may be used as plant or soil amendments in organic crop production as long as the soil deficiency has been properly documented (7 CFR 205.601). Magnesium sulfate is generally listed as the primary active ingredient in products used as a foliar feed or as a soil amendment, but is not usually the only ingredient in

[1]Veterinarians have the ability to use drugs in an extra-label manner as a result of the Animal Medicinal Drug Use Clarification Act, which became effective in December 1996.

the product formulation. Magnesium sulfate may be combined with amino acid chelates (e.g., citric acid and glycine) in products used for soil and foliar application (JH Biotech Inc., 2010). Amino acid chelates are very useful in correcting nutrient deficiencies and are generally not phytotoxic (Lester, 2010).

Manufactured products that contain synthetic magnesium sulfate often contain other agricultural nutrients, such as nitrogen. Nitrogen, which is generally derived from glycine, is an important soil nutrient. When magnesium sulfate is applied to soil in its crystal form, the crystals can also be composed of chlorides, sodium salts, potassium salts, and lead salts (Giles Chemical, 2008). Magnesium sulfate is commonly combined with other key soil nutrients in soil amendment products.

Status

<u>Historic Use</u>:

Historically, magnesium sulfate has had a wide variety of uses in construction, manufacturing/processing, personal care products, food processing, medicine, and agriculture, and many of these uses are summarized by Giles Chemical (2008). As a building material, magnesium sulfate has been used as a setting agent and an extender in various adhesive products, as a component of cement for roofing panels and wallboard, and as an ingredient in flame retardant coatings and brick.

In pulp and paper manufacturing, magnesium sulfate acts as a stabilizing agent for oxygen and peroxide bleaching as well as for dyes. Magnesium sulfate precipitates heavy metals out of water during plating processes and acts as a coagulating agent in latex and rubber processing and a weighting agent in leather processing. In water treatment, magnesium sulfate removes heavy metals and acts as a water hardener (Giles Chemical, 2008).

In cosmetic hair products, magnesium sulfate acts as a hair wave neutralizer and as a product to increase hair density. In laundry detergents, magnesium sulfate is used as an anti-caking agent, foam stabilizer, viscosity control agent, and as a source for synthetic magnesium water hardness (Giles Chemical, 2008).

Fermentation processes are aided by magnesium sulfate, which is a source of magnesium ion in yeast and antibiotic production. Magnesium sulfate is an enzyme stabilizer in breweries and in cheese and high-fructose corn production (Giles Chemical, 2008).

Magnesium sulfate has many human medicinal uses (also discussed in **Specific Uses of the Substance**). Injections of magnesium sulfate can be used as an anticonvulsant to control and prevent seizures in children suffering from acute nephritis. Magnesium sulfate injections can also lower the blood pressure of pregnant females suffering from preeclampsia and prevent pre-term labor. Asthma attacks can be treated with magnesium sulfate. When taken intravenously, magnesium sulfate reduces the resistance within the airways and facilitates normal airflow. Magnesium sulfate can act as a laxative when taken orally and is used to relieve constipation (Adnani, 2010).

Epsom salt, a common form of magnesium sulfate, is an analgesic soaking agent (Giles Chemical, 2008). It is easily dissolved in water and is used to relieve muscle aches and pains as well as reduce itching and inflammation. It is commonly added to bath water and used by individuals suffering from joint pain (Epsom Salt Council, 2009).

In veterinary medicine, magnesium sulfate acts as an anticonvulsant, laxative, bronchodilator, electrolyte replacement aid with hypomagnesaemia, and has been used for the treatment of cardiac arrhythmias. Specifically in swine, magnesium sulfate is administered to treat malignant hypothermia (Dodman, 2010).

In accordance with 7 CFR 205.601, magnesium sulfate may be used in combination with synthetic or non-synthetic crop fertilizers to act as a plant or soil amendment. Epsom salts, a nonsynthetic or synthetic source of magnesium sulfate, are also used in this way as fertilizers (OMRI, 2010a). For plants, magnesium sulfate improves nitrogen and phosphorous uptake, helps seeds to germinate, increases chlorophyll production, and aids in the production of flowering (Epsom Salt Council, 2009).

Magnesium sulfate is added as a source of magnesium to livestock feed, particularly for cattle and sheep. Supplemental magnesium is necessary when livestock are feeding on pastures with high potassium levels; high potassium interferes with the uptake of magnesium by grasses (Epsom Salt Council, 2009). It also may be added to livestock feed for its laxative properties.

OFPA, USDA National Organic Program Final Rule:

Magnesium sulfate is currently included on the National List as a synthetic substance allowed for use in organic crop production (25 CFR 205.601). Specifically, magnesium sulfate is approved for use as a plant or soil amendment when soil deficiency has been documented. The National List also includes magnesium sulfate as a synthetic substance allowed for use in organic livestock production as a disinfectant, sanitizer, or in medical treatments as applicable (25 CFR 205.603). Non-synthetic sources of magnesium sulfate are allowed as ingredients labeled as "organic" or "made with organic (specified ingredients or food group[s])" (25 CFR 205.605).

International:

The Canada Food Inspection Agency, Food and Drug Regulations (last modified in 2009), permit the use of magnesium sulfate as a soil amendment and crop nutrient when a soil deficiency has been documented. Acceptable forms of magnesium sulfate include mined kieserite and natural or synthetic Epsom salt. Mined sources of magnesium sulfate are permitted for use in healthcare products and production aids. Non-synthetic sources of magnesium sulfate are classified as a food additive. Sulfates produced using sulfuric acid are prohibited (Canadian General Standards Board, 2009).

The European Economic Community (EEC) Council Regulation permits the use of non-synthetic magnesium sulfate (kieserite) as a fertilizer and soil conditioner (Annex I, EC No. 889/2008). Non-synthetic magnesium sulfate is also permitted as a feed material of mineral origin (Annex V, EC No. 889/2008). Magnesium sulfate is not listed as an approved organic processing agent.

International Federation of Organic Agriculture Movements (IFOAM) lists magnesium sulfate as a permissible mineral for use as a fertilizer and soil amendment agent (KRAV, 2001). Approved mineral fertilizers can only be applied in their natural form (i.e., without any further processing to increase solubility, with the exception of grinding).

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

Evaluation Question #1: What category in OFPA does this substance fall 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?

(A). Magnesium sulfate is considered a mineral.

(B). Some forms of magnesium sulfate can be considered as synthetic and as inert ingredients that are exempt from a requirement of tolerance (40 CFR 180.1001[c]).

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)).

Magnesium sulfate can be produced by recovery of the mineral kieserite (magnesium sulfate monohydrate) or epsomite (magnesium sulfate heptahydrate) from natural sources. Open-pit mines are used to recover mineral forms of magnesium sulfate. These products then undergo a process of dehydration to form anhydrous $MgSO_4$ and subsequent purification (HSDB, 2003). The substance is characterized as synthetic.

The synthetic form of magnesium sulfate is produced by a chemical reaction in which magnesite ore (consisting of $MgCO_3$) or magnesium hydroxide (obtained from seawater) is ignited to produce magnesium oxide. Magnesium oxide is then reacted with sulfuric acid, producing magnesium sulfate. To produce a high grade of purity, the magnesium sulfate is re-crystallized and separated from the parent solution (Kawamura and Rao, 2007).

Evaluation Question #3: 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).

Magnesium sulfate can be obtained from naturally-occurring sources or manufactured by a chemical process.

Several mineral forms of magnesium sulfate are recovered from the ground. The magnesium sulfate generally found in nature is in the hydrated form (i.e., contains water). Specifically, magnesium sulfate monohydrate and magnesium sulfate heptahydrate occur in nature as the minerals kieserite and epsomite, respectively (Kawamura and Rao, 2007).

As discussed in the response to Evaluation Question #2, the synthetic form of magnesium sulfate is produced by a chemical reaction in which magnesite ore (containing $MgCO_3$) or magnesium hydroxide ($Mg[OH]_2$) is ignited to produce magnesium oxide. Magnesium oxide is then reacted with sulfuric acid, producing magnesium sulfate. To produce a high grade of purity, the magnesium sulfate is re-crystallized and separated from the parent solution (Kawamura and Rao, 2007).

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)).

Magnesium sulfate is discharged into water from various industrial sources, including mills, smelters, and mines. Weathering reactions (i.e., leaching) can also introduce magnesium sulfate to aquatic environments. Magnesium sulfate is highly soluble in water and is not expected to volatize or to undergo hydrolysis. In freshwater and saltwater, the magnesium sulfate complex acts as the primary source of total magnesium. An important removal process for magnesium sulfate in water is the ion exchange that occurs with calcium present in sediments. The uptake of magnesium by water is significant and results in sulfate reduction, meaning that aquatic contamination is unlikely (Bodek et al., 1988). One estimated dissociation constant (K_d) for magnesium sorption in river sediments is 1.3 m^3/kg, which indicates that magnesium ions are weakly sorbed on sediments. In seawater, high temperature areas act as sinks for magnesium (Pettine et al., 1994). Magnesium sulfate is not expected to be persistent in aquatic systems or bioconcentrate in the food chain (Pestell, 2007). Magnesium sulfate is considered as highly soluble and is not likely to be harmful to the aquatic environment because it is highly mobile.

In soil, weathering removes magnesium sulfate by increasing its mobility through the soil. Weathering increases the solubility of magnesium sulfate. In acidic soils, high solubility prevents the persistence of magnesium minerals. In moist soils, volatilization of magnesium sulfate is not of concern because the compound is considered ionic and will not volatilize (Bodek et al., 1988).

In the atmosphere, magnesium sulfate will exist in the particulate phase. Removal from the ambient atmosphere is predicted to occur by wet and dry deposition (Bodek et al., 1988).

<u>Evaluation Question #5:</u> 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)).

If applied as a foliar feed in recommended doses (assuming also that a magnesium deficiency has been documented), magnesium sulfate would not be expected to produce toxic effects. However, if too much magnesium sulfate is added to the soil, or if the substance is added when a magnesium deficiency has not been determined, the uptake of other important nutrients will be affected. In the soil, magnesium and specifically calcium are in competition for absorption by the plant. When too much magnesium sulfate is applied to the soil or if it is applied when unnecessary, the uptake of calcium and potassium will be affected. Plants require potassium for food transport, regulation of water balance, and protein and chlorophyll production. Calcium is required for root hair growth, cell division, production of normal cell walls, and maintaining the plant's resistance to disease. The balance of soil nutrients is critical to the life of the plant, and too much of one nutrient can disturb that balance. Excess magnesium in the soil will also increase the hardness of the soil and make it less desirable for crop growth (NSRL, 2011).

Magnesium sulfate contains magnesium, which in mammals is required for many neurochemical transmissions, enzymatic reactions, and muscular excitability. The substance has a depressant effect on the central nervous system. Convulsions are controlled by administering magnesium sulfate, which blocks neuromuscular transmission and also decreases the amount of acetylcholine released by the motor nerve impulse (HOSPIRA, 2004).

When the level of magnesium in the blood plasma rises above threshold levels (i.e., 4 mEq/liter) and approaches 10 mEq/liter, the deep tendon reflexes are decreased and eventually disappear. Heart block can occur as well as respiratory paralysis (HOSPIRA, 2004).

Vasodilatation is produced when magnesium levels approach 10 mEq/liter. Sweating and flushing are symptoms of a lower dose of magnesium, and larger doses can cause the blood pressure to lower (HOSPIRA, 2004).

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

Both natural and synthetic forms of magnesium sulfate are used in crop production. If used as a foliar feed as directed by the manufacturer, environmental contamination is unlikely. Mining and additional manufacturing operations can produce runoff materials containing magnesium sulfate. However, magnesium sulfate is considered highly soluble and will not volatilize (Bodek et al., 1988). In the presence of water molecules, magnesium sulfate does not undergo hydrolysis, a process in which water molecules split apart existing molecules into two parts (Bodek et al., 1988). This means that magnesium sulfate will remain in the water in its original form.

In magnesia plants, based on seawater, the water used in the plant is returned to the ocean after the magnesia is removed. Due to recent technological innovations, the turbidity of the effluent has been decreased, which will result in minimal changes to the ocean environment. None of the discharges from either natural or synthetic magnesia plants has a noxious quality, and their appearance can be made acceptable with modern treatment methods (Kramer, 2002).

<u>Evaluation Question #7:</u> 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)).

Magnesium sulfate can only be used as a foliar feed and soil amendment in organic crop production when a magnesium deficiency in the soil has been documented (7 CFR 205.601). This helps to minimize the risks of applying excessive amounts of magnesium sulfate to the soil. It also reduces the likelihood of harmful effects from the interaction of magnesium sulfate with other soil nutrients.

<u>Evaluation Question #8:</u> 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)).

Various nutrients react in the soil and balancing these nutrients is important in maintaining the proper environment for plant growth. Nutrient balance is very important, because a very high concentration of one cation in the soil can adversely affect the uptake of other cations. For example, excess calcium (Ca) can induce a magnesium deficiency and can reduce phosphorus availability. Excess potassium in the soil can also suppress magnesium uptake by plants (NSRL, 2011).

Soil microorganisms are greatly affected by soil acidity, so it is critical that soil amendments be used considering the potential pH effects. Because magnesium sulfate is a magnesium salt of sulfuric acid, it is a neutral salt. Aqueous solutions of magnesium sulfate are considered neutral or only very slightly acidic. Therefore, application of magnesium sulfate to crops at recommended levels is expected to have little or no effect on soil pH (Brennan, 2010).

<u>Evaluation Question #9:</u> Discuss and summarize findings on whether 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)).

If used in accordance with 7 CFR 205.601, it is unlikely that magnesium sulfate will cause harm to the environment.

Magnesium sulfate exists in the atmosphere as a particulate as is not likely to be released following most manufacturing processes. The substance is removed from the atmosphere by wet and dry deposition.

The physicochemical properties of magnesium sulfate make it an unlikely cause of contamination to the aquatic environment. Magnesium sulfate is considered highly soluble in water and also very mobile.

Magnesium is not likely to volatize in soil due to its ionic properties. Magnesium sulfate also undergoes ion exchange with calcium, which allows for its removal in sediments. The uptake of magnesium by rivers is significant and results in sulfate reduction, and its estimated K_d value for magnesium sorption in river sediments (1.3 m^3/kg) indicates that magnesium ions are weakly sorbed on sediments.

<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)).

Magnesium sulfate has many human medicinal uses (see Specific Uses of the Substance). It is has exhibited laxative properties when ingested orally and is an effective anticonvulsant when administered via injection. Before using magnesium sulfate, it is important to check that an individual's renal function is adequate as an accumulation of magnesium ions in body fluids can cause toxic effects, including heart changes, cyanosis, and flaccid paralysis (Gilman and Goodman, 1980).

Toxic effects have been observed in the neonates of women that have been administered an incorrect dose of magnesium sulfate for conditions such as preeclampsia. Effects include depression of cardiac function and of reflexes, flushing, sweating, hypotension, flaccid paralysis, hypothermia, and circulatory collapse. These symptoms can proceed to fatal respiratory paralysis (McEvoy, 2002). There is also an increased risk in blood loss in mothers administered magnesium sulfate injections (Kynczl-Leisure and Cibilis, 1996). Magnesium is known to cause vasodilation, which causes the symptoms of flushing and sweating in low doses and circulatory collapse in higher toxic doses (Micromedex, 2010).

Evaluation Question #11: 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)).

Dolomite limestone is a non-synthetic substance that can be used to treat magnesium deficiency in soils. The substance contains both calcium and magnesium and is produced by quarrying and crushing the material to a fine consistency. Products containing dolomite are generally more expensive and are not as effective as magnesium sulfate in treating soils that have been documented as magnesium deficient (Organic Livestock Research Group, 2000). The addition of dolomite limestone will also stabilize pH in acidic soils. Pastures are commonly dusted with dolomite limestone at times when hypomagnesaemia, the result of an insufficient intake of magnesium, in livestock is feared (Organic Livestock Research Group, 2000). Dolomite, a type of limestone, is considered a nonsynthetic mined mineral and approved for use in organic crop production, since it is not listed as prohibited at 7 CFR 205.602.

Several products included in on the Organic Materials Research Institute (OMRI) Products List have mined (non-synthetic) dolomite limestone as the active ingredient (OMRI, 2010b):

- Agricultural Dolomite: Blue Mountain Minerals, 24599 Marble Quarry Rd., Columbia, CA 95310
- EarthBox® All Natural Dolomite: Laminations, Inc., 1350 Van Storch Ave., Scranton, PA 18509
- Ground Dolomite: Ash Grove Cement Co., 13939 N Rivergate Blvd., Portland, OR 97203
- Nature's Intent DOLOPRIL: Pacific Calcium, Inc., 32117 Highway 97, Tonasket, WA 98855
- Oxyfertil® Drip: Chemical Lime, P.O. Box 1938, Salinas, CA 93902
- PEL-LIME® Pelletized Dolomitic Limestone: Bridgewell Resources, LLC, 12420 SE Carpenter Dr., Clackamas, OR 97015
- Pro-Pell-It! Pelletized Dolomite: Marion Ag Services, Inc., 20160 NE Main St., St Paul, OR 97137

No other substances currently on the National List will have a similar impact as a foliar feed because they do not contain magnesium. Magnesium sulfate products cannot be used as a soil amendment or as a foliar feed unless a documented deficiency of magnesium has been provided. The purpose of using magnesium sulfate products is to supply a source of magnesium to the soil or to the surface of crops.

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

It is important that soil be tested before crops are planted. A soil test will determine how much magnesium is present in the soil. Generally, the amount of magnesium sufficient for healthy crop yield is 10–15 percent and should be twice the amount of potassium in the soil. Nutrient balance is critical in soils. If too much calcium is present, magnesium deficiency will be induced and phosphorous availability becomes decreased. If an excess of potassium is present, magnesium uptake is reduced. Adequate soil testing can ensure that crops are grown in a suitable soil environment with the appropriate balance of nutrients.

Additional Questions Specific to Magnesium Sulfate

The following additional questions were posed by the NOSB Crops Committee to aid the National List review for magnesium sulfate use in organic crop production (USDA, 2011).

Additional Question #1). What is the availability of mined Epsom salts and what is the process by which this material is prepared for commercial agricultural use? Do those processes render the mined sources synthetic?

Magnesium sulfate can be found as a naturally occurring mineral or it can be produced synthetically. The two most commonly occurring, nonsynthetic magnesium sulfate minerals are epsomite ($MgSO_47H_2O$) and kieserite ($MgSO_4H_2O$). Although these minerals occur in the United States, they are not mined domestically. In the year 2000, 27,000 metric tons of kieserite and 85 metric tons of Epsom salts were imported to the U.S., almost exclusively from Germany. Between 1990 and 2000, magnesium sulfate mineral imports changed from primarily Epsom salts to primarily kieserite (Kramer, 2002).

Table 2 summarizes the primary forms of synthetic and nonsynthetic magnesium sulfate, along with preparation methods, and synthetic/nonsynthetic classification.

Table 2. Summary of the Available Forms of Magnesium Sulfate

Form of Magnesium Sulfate	**Raw materials**	**Production Process**	**Synthetic or nonsynthetic**
Magnesium Sulfate Minerals	Mined epsomite ($MgSO_47H_2O$) or kieserite ($MgSO_4H_2O$)	No processing	Nonsynthetic
Processed Epsom Salts ($MgSO_47H_2O$)	Magnesium hydroxide or magnesite ore	Magnesium oxide is prepared by igniting magnesium hydroxide (obtained from sea water) or ignition of magnesite ore (consists of $MgCO_3$). The magnesium oxide formed is then reacted with sulfuric acid to produce magnesium sulfate (Kawamura and Rao, 2007).	Synthetic
	Mined minerals, primarily kieserite	Magnesium sulfate heptahydrate is manufactured by dissolution of kieserite in water and subsequent crystallization of the heptahydrate. The material is separated from the mother liquor by centrifugation, dried and sieved (Kawamura and Rao, 2007).	Nonsynthetic
Anhydrous Magnesium Sulfate	Any hydrated form of magnesium sulfate	Dehydration (e.g., by heating)	Nonsynthetic

Mined, raw mineral forms of magnesium sulfate are considered nonsynthetic. The process of dehydration that may accompany processing these raw minerals does not result in a chemical change in the parent compound. However, there are no commercially available products containing mined, raw mineral magnesium sulfate in bulk quantities suitable for agricultural use. The OMRI Products List does not include nonsynthetic magnesium sulfate products, and all products listed for use in soil and foliar applications are classified as synthetic substances. These products contain either solid crystalline or liquid forms of synthetic magnesium sulfate and products containing either form are classified as synthetic (OMRI, 2011). The availability raw mineral product is low as few operations are currently mining raw magnesium sulfate. No mining operations have been identified in the United States (Kramer, 2002).

Specifically for anhydrous magnesium sulfate, the process of dehydration by heating does not produce the chemical change required for classification of the substance as synthetic. Although this form of magnesium sulfate is processed, it is not considered synthetic. The OMRI Products List includes no products that contain nonsynthetic forms of magnesium sulfate (OMRI, 2011).

Additional Question #2). What is the availability of purely natural forms (mined) of magnesium sulfate, and can these forms be adapted for both soil and foliar applications?

As described under Additional Question #1 above, natural magnesium sulfate is not actively mined in the U.S. and must be imported. In 2000, 85 tons of Epsom salts and 27,000 tons of kieserite were imported from Germany (Kramer, 2002). There are three U.S. producers of magnesium sulfate and their facilities produce a magnesium sulfate solution (25 percent solids) and epsomite crystal (Kramer, 2002).

Animal feed supplements and fertilizers represent about 22 percent of the U.S. market for magnesium sulfate. The U.S. Geological Survey (USGS) reports that more 'natural' forms of magnesium sulfate (i.e., the natural minerals epsomite and kieserite) are used for livestock and crop applications because a high level of purity is not usually required for products used for these applications (Kramer, 2002). Although "natural" as used by USGS is not necessarily equivalent to "nonsynthetic," the source does identify these materials used in these applications as "mainly natural minerals, which are imported into the United States." Magnesium sulfate in its solid form can be applied to soil or used as a feed supplement. Foliar application would require a liquid form. Because magnesium sulfate minerals are soluble in water, foliar application would be feasible.

Commercially available products containing nonsynthetic forms of magnesium sulfate in either a liquid or solid form are not listed with OMRI. No products containing the mined, raw minerals kieserite or epsomite are listed with OMRI, and no such products have been identified through internet searches. Products specifically containing Epsom salts are classified on the OMRI Products List as synthetic (OMRI, 2011).

Additional Question #3). How much synthetic magnesium sulfate is used in organic crop production, and how common is the usage? To what crops is magnesium sulfate most commonly applied as a soil amendment and which as a foliar amendment?

Data have not been identified to characterize the forms or quantities of magnesium sulfate used in organic crop production and specific patterns of use. However, Kramer (2002) reported that approximately 22 percent of the magnesium sulfate produced in the U.S. is used for livestock feed and crop application. The forms of magnesium sulfate and patterns of use were not identified.

As of 2002, U.S. producers of magnesium sulfate and their facilities produce a magnesium sulfate solution (25 percent solids) and epsomite crystal. These products can be used for soil and foliar applications (Kramer, 2002). Generally, magnesium sulfate containing crystals are inserted into the holes where crops will soon be planted. They can also be spread around the base of the plant for absorption into the soil and will subsequently enter the root system. Products that are distributed in a liquid form are typically sprayed onto crops (foliar spray) using a special nozzle and spray system. Liquid products are generally used for foliar application (PQ Corporation, 2004; Savoy, 2005).

According to Savoy (2005), a soil test is typically required to determine whether or not magnesium sulfate should be added as a soil amendment. Soils with less than 40 pounds of magnesium per acre may need magnesium fertilization. Crops for which magnesium is recommended when the soil tests below 40 pounds per acre include: grapes, tomatoes, potatoes, tobacco, nut trees, cabbage and ornamentals. However, other crops may require the use of magnesium sulfate as a fertilizer when soil conditions are not favorable (Savoy, 2005).

Soil applications of magnesium commonly take multiple years to correct magnesium-deficiency symptoms, whereas foliar sprays are effective within a few days after application and according to PQ Corporation (2004), a producer of synthetic magnesium sulfate, foliar application is advantageous because it produces benefits more quickly than soil application. Magnesium sulfate is a desirable foliar applicant because it speeds the ripening process of certain fruits and vegetables. Magnesium sulfate is commonly applied as a spray to perennials, such as apple trees, and also to orange trees, tomatoes, peppers and roses. Magnesium sulfate products are commonly applied as a spray to lawns and shrubs (PQ Corporation, 2004).

Additional Question #4). Is there sufficient natural magnesium sulfate available in useful forms to eliminate usage of the synthetic forms?

Data on the exact quantity of the available mineral forms of magnesium sulfate has not been identified. Based on information presented by USGS, nonsynthetic magnesium sulfate minerals are not mined in the U.S. (Kramer, 2002). No commercially available products containing nonsynthetic magnesium sulfate have been listed with OMRI (OMRI, 2011). Therefore the production of synthetic magnesium sulfate is likely needed to generate a sufficient quantity of magnesium sulfate to fulfill current needs.

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