Potassium Sulfate

for use in crop production

Executive Summary[1]

The following petition is under consideration with respect to NOP regulations subpart G, governing the inclusion of substances on the National List of Allowed and Prohibited Substances:

Petitioned: **Addition of potassium sulfate to section 205.601(j), "Synthetic substances allowed for use in organic crop production as plant or soil amendments."**

Potassium sulfate is a source of highly soluble potassium, and has the additional benefit of supplying sulfur. It is used in agricultural production systems where potassium is a limiting nutrient and also as a substitute for potassium chloride on chloride-sensitive crops. The NOP has no prior ruling on the use of the substance.

The nature of the petitioned substance is highly debatable. Naturally occurring potassium sulfate is not subject to the TAP review process because "naturally-occurring" substances are implicitly allowed for use in organics. The intended sourcing of the petitioned form of potassium sulfate, however, brings into question the interpretive distinctions between a "synthetic" and a "non-synthetic" under organic law. According to the petitioner, the product "should not be treated differently than product produced from natural brines" since it is produced from naturally occurring minerals. The crux of the decision to grant the petition rests on how one chooses to interpret this equivalency claim.

All TAP reviewers agreed that the petitioned substance should be considered synthetic. In general, the reviewers also agreed that it should be restricted as a soil adjuvant. Two reviewers felt that the substance should not be added to the National List, while one reviewer felt that it should be added to the List with an annotation that restricts it use. The two reviewers who recommended that it not be added to the List felt that the substance was acceptable from a purely agrobiochemical standpoint, but that such an addition would run contrary to the principles of organic production practices.

Summary of TAP Reviewer Analyses

Synthetic/ Nonsynthetic	Allowed or Prohibited	Notes/suggested annotations:
Synthetic (3) *Nonsynthetic (0)*	*Allowed (1)* *Prohibited (2)*	***Reviewer 1:*** *Prohibition of the petitioned form of potassium sulfate as a soil adjuvant in organic production, no annotation.* ***Reeviewer 2:*** *Addition of the petitioned form of potassium sulfate as an allowed synthetic, with an annotation that it be restricted to use on crops that are sensitive to chloride found in potassium chloride or in other potassium fertilizers containing excessive salts.* ***Reviewer 3:*** *Prohibition of the petitioned form of potassium sulfate as a soil adjuvant in organic production, no annotation.*

[1]*This Technical Advisory Panel (TAP) review is based on the information available as of the date of this review. This review addresses the requirements of the Organic Foods Production Act to the best of the contractor's ability, and has been reviewed by experts on the TAP. The substance is evaluated against the criteria found in section 2119(m) of the OFPA [7 USC 6517(m)]. The information and evaluation presented to the NOSB is based on the technical evaluation against those criteria, and does not incorporate commercial availability, socio-economic impact or others factors that the NOSB and the USDA may consider in making decisions.*

Identification

Chemical name:	potassium sulfate	**CAS Number:**	7778-80-5
Trade name:	SOP,	**Other Codes:**	
Other names:	sulfate of potash, sulfuric acid dipotassium salt	**EEC No.(EINECS/ELINCS)**	231-915-5

Characterization

Composition:
K_2SO_4

Physical Data (Merck 2002):

Molecular weight:	174.26 g/mol
Melting point:	1069°C
Boiling point:	1689°C
pH	≈7
Density:	2.332 g/cm^3
Solubility:	1g dissolves in 8.3mL water, 4mL boiling water, 75 mL glycerol Solubility in water is decreased by KCl or $(NH_4)_2SO_4$ Insoluble in alcohol, most organic solvents
Stability:	Stable under normal temperatures and pressures. If heated above decomposition temperatures (>700°C) toxic gases/vapors may be released (SO_x, K_2O).
Hazardous Polymerization:	Will not occur.

Physical Properties:
Colorless or white, odorless, hard, bitter crystals, or white granules or powder. The aqueous solution is neutral (Merck 2002).

How Made:
Potassium sulfate is refined from naturally occurring mineral salt deposits or by chemical synthesis. Naturally occurring potassium deposits, referred to indiscriminately as “potash”, are usually the source of one or more ingredients of synthetic production. The deposits are found as a conglomeration of potassium chloride (muriate of potash, KCl, or MOP), potassium sulfate (sulfate of potash, or SOP), and potassium nitrate (nitrate of potash, KNO_3, or NOP). Deposits are predominantly mined, while some are obtained through solar evaporation of natural brines from saline lake beds. Potassium chloride is the most abundant mineral found in deposits. Individual potassium salts and any impurities are separated through physical dissolution processes.

According to documents contained in the petition, industrial synthesis of potassium sulfate is a two-step process: first, ionic separation of mined potassium chloride and another sulfate-bearing salt (in this case, magnesium sulfate) via electrolysis, followed by the joining of potassium and sulfate ions in controlled lab settings at temperatures up to 120°C (Konigsberger and Eriksson 1999). As noted by the petitioner, the potassium chloride and magnesium sulfate used in production are obtained from natural sources (Andres 2001). Specific manufacturing processes employed by the petitioner are considered confidential and thus are not disclosed in detail.

Specific Uses
Potassium sulfate is commonly used as a specialty fertilizer on crops that are sensitive to soil chloride levels, such as potatoes, lettuce, tobacco, avocados, peaches, and legumes. It is also used in cases where chloride buildup may be problematic. Mined and synthesized potassium sulfate are identical, and thus are functionally interchangeable. Worldwide, almost all technical grade potassium sulfate production (>99%) is used in agriculture. The remaining SOP is used in a wide range of industrial uses and for manufacturing potassium alum, potassium carbonate, and glass (Horn 2000).

Status

History of Use:
The term “potash” comes from the colonial practice of collecting wood ashes from large pots and using it for fertilizer, soap, gunpowder, and glass (Thompson, no date). Worldwide, sulfate of potash (SOP) production since the mid-eighties has been characterized by an up and down cycle. The latest upward trend ended in 1998 due to development of new SOP sources that outpaced demand, and a massive reduction of tobacco cropping acreage in the US (–21%) and China (-32%). According to industry representatives, the SOP market is characterized by major over-capacities in production, with further increases expected (Horn 2000). This fact, coupled with predicted decreases in demand, has necessitated the development of new markets. In the US, SOP accounts for four to six percent of total agricultural potassium sales (Thompson, no date).

Functionality:

The primary function of potassium sulfate is as a readily available source of potassium (K), a primary nutrient taken up by plants in lager amounts than any other nutrient except N. The most important function of K is the activation of more than 80 plant enzymes (Tisdale et al 1999). It is also integral to a number of other plant processes including water relations and maintenance of plant turgor, ATP production, translocation of carbohydrates, and protein synthesis. As a result, K deficiencies cause numerous problems, from decreasing rates of photosynthesis (Smid and Peaslee 1976) to the weakening of straw in grain crops (Schulte 1975). K stress can also increase the incidence of crop damage due to bacterial and fungal diseases, insect and mite infestation, and nematode and virus infection (Tisdale et al 1999). In addition, potassium has important effects on quality factors such as size, shape, color, taste, shelf life, and fiber quality.

In conventional agriculture, potassium sulfate is used mostly on potatoes, fruit, and tobacco, which are sensitive to high applications of chloride (Tisdale et al 1999). It offers several advantages as a specialty fertilizer: it is virtually free of chloride, it has a low salt index, its high solubility allows a great deal of flexibility in fertigation systems and for foliar application, and it also provides a trace source of sulfur.

Regardless of farming practices, nutrients will be removed in produce and must be replaced to sustain production and fertility of the soil. In organic systems, soil solution K^+ is replenished by inputs of plant and animal residues. The effectiveness of these inputs will vary according to soil type. Annual K additions to apple trees grown on an oxisol (highly weathered soil) maintained soil K levels higher than recommended without reducing fruit quality or storage life (Ernani et al 2002).

The complete "Petition Justification Statement" is as follows: "The product has been regarded as a synthetic substance by OMRI despite of the fact that it is only produced from naturally occurring mined minerals and therefore should not be treated differently than product produced from natural brines" (Andres 2001). The petitioner also states that "the substance is chemically neutral and due to its low chlorine content is more favorable for the fertilization of chloride sensitive crops. Moreover it is the preferred potash source for soils prone to salinity and environmentally advantageous compared to other potash sources."

Potassium comprises 2.4 percent of the earth's crust, and it is present in large quantities in most soils, ranging between 0.5 and 2.5 percent. Like all mineral nutrients, the amount of plant-available potassium present is dependent on biochemical reactions in the soil. Plant available soil K is derived from additions of soluble K, and from weathering of soil parent material. Soils vary widely in their ability to replenish solution K^+ depending on the age of the soil, fixation of K^+ by soil particles, and the degree of leaching. The rate of weathering of potassium-bearing soil minerals is driven by K removal through crop uptake and leaching. K bound to the parent material is referred to as nonexchangeable or mineral K, and release of this K is generally too slow to meet crop requirements, hence the need for K adjuvants. Soil texture also exerts a strong influence on K^+ availability. The potential for replenishment of solution K^+ is extremely small in sandy soils where the cation exchange capacity (CEC) is due mainly to organic matter. Crops grown on sandy or highly weathered soils may experience K deficiency symptoms after a few years of cropping.

USDA Final Rule:

The Final Rule states that "mined substances of high solubility are prohibited unless used in accordance with the annotation recommended by the NOSB and added by the Secretary to the National List." The National List does not explicitly refer to synthetic potassium sulfate.

Several synthetic mineral compounds are allowed for use as plant or soil amendments:

Magnesium sulfate – allowed with a documented soil deficiency ((§205.601(j)(5)).

Sulfates, carbonates, oxides, or silicates of zinc, copper, iron, manganese, molybdenum, selenium, and cobalt – allowed as micronutrient adjuvants, not to be used as a defoliant, herbicide, or desiccant. Those made from nitrates or chlorides are not allowed. Soil deficiency must be documented by testing ((§205.601(j)(6)(ii)).

Potassium chloride, a commonly used source of soluble potassium, is prohibited by the National List unless it is derived from a mined source and applied in a manner that minimizes chloride accumulation in the soil ((§205.602(g)).

Regulatory

U.S. certifiers

The **Virginia Dept. of Agriculture, Kentucky Dept. of Agriculture, NOFA-NJ,** and **NOFA-VT** explicitly allow the use of "natural" potassium sulfate. The **Washington State Dept. of Agriculture** allows the use of greensand (glauconite). **NOFA-MA** allows the use of "mined [potassium] sources only, and without chemical processing." Synthetic sources are prohibited, as is the use of any form of potassium chloride. **RI Certified Organic** allows mined potassium sulfate, prohibits potassium chloride due to excessive solubility, high salt index, and chloride content, and prohibits "all synthetic potassium sources." **Oregon Tilth** defers the to National List in terms of allowed synthetics and prohibited non-synthetics.

International certifiers

The UN FAO **Codex Alimentarius** guidelines allow the use of "rock potash" and "mined potassium salts" which are "less than 60% chlorine." The substance also must be "obtained by physical procedures but not enriched by chemical processes to increase solubility." Under these guidelines, mined potassium fertilizers including muriate of potash (MOP) and potassium magnesium sulfate are acceptable. **European Union** organic standards allow potassium sulfate "obtained from crude potassium salt by a physical extraction process, and containing possibly also magnesium salts" (EEC No 1073/2000). The **Canadian Standard for Organic Agriculture** (CSOA) Permitted Materials List (PML) for Crop Production allows mined potassium sulfate (CGSB 1999). **Italian Association for Biological Agriculture** Standard for Organic Crop Production allows the use of potassium sulfate in organic production, "after authorization of the inspection body" determines sufficient need (AIAB 2001). The **Austrian Ministry of Agriculture** (BMLF) allows potash sources in organic agriculture, "possibly containing epsom salts; produced from an unrefined epsom salt using physical extraction methods."

OMRI performed a brand name review of the petition substance at the request of the petitioner, and concluded that the substance should be considered synthetic under the OFPA of 1990.

EPA regulates sulfuric acid dipotassium salt under the Toxic Substances Control Act**.** It is also regulated as a List 4B Inert under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

FDA classifies potassium sulfate under 21CFR73.85, (Listing of Color Additives Exempted from Certification), and 21CFR184.1643 (GRAS).

The following agencies do not list potassium sulfate:

NIOSH (National Institute of Occupational Safety and Health), **OARC** (International Agency for Research on Cancer, **NIEHS NTP** (National Toxicity Program), **ACGIH** (American Conference of Governmental Industrial Hygienists), **OSHA** (Occupational Safety and Health Organization), **DOT** (Department of Transportation).

Section 2119 OFPA U.S.C. 6518(m)(1-7) Criteria

1. The potential of the substance for detrimental chemical interactions with other materials used in organic farming systems.

Potassium sulfate has no known adverse reactions with normal agricultural compounds (WFS 2001). Potassium (K^+) and sulfate (SO_4^-) ions are ubiquitous in nature, and K^+ is particularly essential in a soil agroecosystem. The availability of soil solution K^+ is closely dependent on the soil cation exchange capacity (CEC), the amount of exchangeable K, and the soil's capacity to fix clay and render it unavailable to plants. In addition, plant K^+ uptake is directly affected by the presence of other cations, particularly Ca^{2+} and Mg^{2+}; in general, K^+ uptake is reduced as Ca^{2+} and Mg^{2+} are increased. Applications of high rates of limestone to a soil with low plant-available K^+ may induce potassium deficiency in crops grown on these soils. In general, factors affecting K^+ availability are not affected by additions of organic inputs, and the likelihood for detrimental chemical interactions with other materials is slim.

2. The toxicity and mode of action of the substance and its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.

Ecotoxicological Effects

LC_{50} =	510 – 990 mg/1 (Pimephales promelas)
LC_{50} =	<620 – 780 mg/l (Ceriodaphnia dubia)
EC_{50} =	890 mg/l (Daphnia magna, 48h)
EC_{50} =	2900 mg/l (Scenedesmus suspicatus, 72h)

Breakdown products/contaminants

The substance readily ionizes into potassium (K^+) and sulfate (SO_4^{2-}) in water. Neither chemical is listed as a Hazardous Substance, Priority Pollutant, or Toxic Pollutant under the Clean Water Act (ISU 2000). The substance has a low (0.11mg/L) Aquatic Hazard Concern Concentration (ECOTOX 1995). Contamination of waterways in large quantities could possibly cause fish kills, but in general the substance is not toxic to aquatic organisms. Potassium sulfate has a salt index of 46 (Rader et al 1943). This relatively low salt index may reduce potential foliage injury compared to other K salts (Follett et al. 1981). By comparison, potassium chloride (muriate of potash) has a benchmark salt index of 116, higher than both sodium nitrate (100) and ammonium nitrate (105).

Areas of concentration

Potassium is absorbed by plants in larger amounts than any other nutrient besides N. The dry weight concentration in plant tissues ranges from 0.5-6 percent. Unlike most other plant nutrients, K forms no coordinated compounds in the plant; it exists solely in its ionic form, K^+, and strongly influences functions related to the ionic strength of solutions in plant cells. Excess K^+ not absorbed by plants or soil fauna is typically adsorbed onto soil organic matter and clay minerals. Soil K fixation may also increase during wetting-drying cycles in soils with a high proportion of 2:1 clays, thereby decreasing soil K availability (Olk et al 1995). On cleared land following fertilizer application in a conventional system, p to 35% of the K may be leaching during cropping, with coarse textured soils and soils subject to high rainfall being the most prone to leaching. In most soils, however, K leaching losses are small (Tisdale et al 1999).

3. The probability of environmental contamination during manufacture, use, misuse, or disposal of the substance.

The petition as supplied to UC SAREP does not include confidential information relating to the manufacturing processes. Non-specific information contained in the petition describes the synthesis of potassium sulfate as a two step process involving the disassociation of potassium chloride and magnesium sulfate "by means of electrolysis," followed by "the joining of potassium and sulfate ions in a reaction vessel" (Petition). The first step of this process does not appear to pose a significant risk of environmental contamination. No further information is provided about the process, including the nature of the second step and the possible use of catalysts.

Potassium sulfate is an inorganic, water soluble fertilizer that may increase soil salinity. Nitrogen and potassium fertilizer salts generally have much higher salt indexes compared to phosphorus fertilizers. As mentioned above, potassium chloride has a salt index of 46 on a scale of 116 (Rader et al 1943). Table 1 gives the salt indices of several soluble potassium fertilizers relative to their nutrient compositions. Fertilizers with a higher percentage of P_2O_5 generally have a lower salt index per unit of plant nutrient. Salt toxicity is likely to be more serious in coarse textured soils or soils with low moisture content. Organically cropped soils tend to buffer salinity effects more than conventional systems due to their higher soil organic matter content.

Potassium sulfate ionizes into K^+ and SO_4^-, two low toxicity ions. The substance is not strongly acidic or basic, and no neutralization is necessary before disposal into a drain. When applied in a manner consistent with good management practices, no detrimental effects of potassium sulfate with regard to the environment are known (PPI 2002). Large spills could damage vegetation and cause localized leaching of K^+.

TABLE 1 Salt Index of some inorganic potassium fertilizers

Material	$\%P_2O_5$	Salt Index per Unit of Plant Nutrients
Manure salts, 20%	20.0	5.636
Potassium chloride	60.0	1.936
Potassium nitrate	46.6	1.580
Potassium sulfate	54.0	0.853
Potassium magnesium sulfate	21.9	1.971

Adapted from Rader et al. 1943

4. The effects of the substance on human health.

Potassium is an essential element for humans as a key electrolyte for maintaining basic cardiovascular functions. The use of potassium supplements is commonplace (ANL 2001). Potassium sulfate is used in homeopathic medicine to treat eye, ear, nose, and throat discharge (Pinador 1998).

Acute Toxicity
LD_{50} = 6600 mg/kg (oral, rat) (GISAAA 1985)
LD_{Lo} = 750 mg/kg (oral, rat) (WFS 2001)

Airborne Exposure Limits
OSHA Permissible Exposure Limit (PEL): 15 mg/m^3 total dust, 5 mg/m^3 respirable fraction for nuisance dusts (RTECS 1995).
ACGIH Threshold Limit Value (TLV): 10 mg/m3 total dust containing no asbestos and < 1% crystalline silica for Particulates Not Otherwise Classified (PNOC).

Potassium sulfate is much less toxic than common table salt (LD_{50} = 3000 mg/kg (oral, rat)) when ingested. Applied as a fertilizer, the primary routes of entry are absorption through skin and inhalation. Acute overexposure may cause eye, skin, and respiratory tract irritation. Health risks due to dermal or inhalation absorption are considered low, and no significant adverse effects are expected (EPA SAT, no date). No carcinogenicity, mutagenicity, or developmental toxicity data were found for potassium sulfate.

5. *The effects of the substance on biological and chemical interactions.*

Potassium is abundant in nature. As a primary nutrient fertilizer, potassium sulfate will typically have a positive effect on plant growth. The substance quickly dissociates to K^+ and SO_4^- in the soil. Most of the nutrients are immediately absorbed by plant roots and soil microfauna or adsorbed by soil particles; a small percentage may leach from the soil profile under certain conditions. In its ionic form, potassium is held on cation exchange positions of clay and has a unique relationship with other nutrients. Because K^+ competes for soil bonding sites with other cations present in soil solution, particularly Ca^{2+} and Mg^{2+}, there is some potential for potassium sulfate to affect the availability of other soil nutrients. As noted in Criteria 1, high potassium fertilization may cause magnesium deficiencies in soils already low in magnesium. In addition, sodium (Na^+) is similar to potassium in its chemical properties, and has been shown to substitute partially for potassium in some crops (Thompson, no date).

6. Alternatives to using the substance in terms of practices or other available materials.

Most organic cropping systems receive significant inputs of K via additions of green manures and composting. K in green manure and compost occurs predominantly as soluble inorganic K^+. In animal waste, concentrations range from 4-40 lbs K/t of dry matter (Sutton et al 1985). Stevens and Priest (1992) reported that one ton of dairy manure contained 10-15lbs K, but unprocessed manures may contain high salt concentrations. Sullivan and colleagues (2000) report that manures contain 0.6% salts on a dry weight basis, and that 20 tons of fresh manure would add 90lbs salt/acre. In contrast, composts generally have low salt indices (approx. 4 mmhos/cm) that vary depending on their composition (Smith 1997). Both composts and manures vary widely in their composition, and may not be as reliable as mineral fertilizers.

Currently, the National List allows the use of naturally derived inorganic potassium salts in cropping systems. These may consist of K^+ in combination with Cl^-, SO_4^{2-}, NO^{3-}, PO_4^{3-}, and $P_2O_4^-$. Sylvite, sylvinite, and langbeinite are the most common mineral K sources (Thompson, no date). These substances are highly soluble, and may be used in addition to green manures and composts when the latter are considered inadequate in terms of timing, form, or nutrient concentration. Sylvite is a mineral salt composed primarily of muriate of potash (KCl), and the refined substance contains 60-62 percent K_2O. Unrefined sylvinite (KCl•NaCl) contains 20-30 percent K_2O.

Potassium sulfate and potassium chloride have different effects in an agroecological system. In sandy soil, Sanogo and Yang (2001) reported a higher incidence of sudden death syndrome of soybean fertilized with potassium sulfate than in plants fertilized with potassium chloride. However, potassium sulfate has several advantages over potassium chloride. Sulfate ions from K_2SO_4 exhibit stronger adsorption to soil particles than KCl, making K_2SO_4 relatively less likely to leach (Tisdale 1999). On podzolic soils it was shown that, compared to potassium chloride, potassium sulfate had a stronger effect on the mineralization of organic compounds and on the migration of nitrogen beyond the root zone (Yanishevskiy et al 1990). Panique and colleagues (1997) found that applications of K_2SO_4 increased potato tuber yield more than KCl at rates up to 280 kg $K•ha^{-1}$. Lastly, the use of K_2SO_4 instead of KC1 appears to offer considerable promise as a means of decreasing tuber cadmium uptake (Sparrow et al 1994).

There are several mineral sources of K that do not contain chloride. The mineral langbeinite ($K_2SO_4•2MgSO_4$, 22% K_2O + 18% MgO + 22% S; also known as potassium magnesium sulfate or double sulfate of potassium and magnesium, and commercially as K-Mag® or Sul-Po-Mag®) is commonly used in organic agriculture as a source of potassium sulfate. Along with KNO_3 (13% N + 44% K_2O), langbeinite is often included in various mixtures, blends and compound fertilizers. Like pure potassium sulfate, these products are water-soluble and virtually chloride-free, hence they are favored by producers of chloride-sensitive crops (e.g. potato, tobacco, fruit and vegetables) with high market value that require other essential nutrients such as S, N and Mg. They are also typically more costly than KCl fertilizers due to their complex manufacturing requirements (Thompsom, no date). Other allowed mineral K sources are geared towards slow release. An example is glauconite (3% K), also known as greensand, which is mined from a 70-80 million year old marine deposit and consists of iron-potash-silicates and marine trace minerals. Slow release fertilizers provide a source of nutrients that is useful for building soil potassium reserves, but not appropriate for quick remedy of a potassium deficiency.

7. The compatibility of the substance with a system of sustainable agriculture

As a soil adjuvant, the petitioned substance appears to be compatible with a system of organic agriculture. It is used as an elemental potassium fertilizer, and it has the added benefit of being a source of sulfur. The composition and mode of action of the substance are identical to the naturally occurring form, which is allowed in organic agriculture. It appears that the primary concern regarding this petition is the intended *sourcing* of potassium sulfate: the petition requests the approval of a chemical that has been derived from industrial laboratory processes, as opposed to a naturally-occurring substance. As noted in the "How Made" section, the substance is made by means of "electrolysis" and includes the use of a "reaction vessel"; specific manufacturing information considered "confidential" was excluded from the petition received by SAREP. Prior to initiation of the TAP review process, a third party review of all proprietary information concluded that the petitioned substance is synthetic, based on the manufacturing processes (OMRI 2002). There have been no other reviews of the substance vis-à-vis organic standards. In terms of other mineral nutrients, The National List currently allows the use of synthetically derived elemental sulfur and magnesium sulfate[2] under "Synthetic substances allowed for use in organic crop production as plant or soil amendments" (§205.601(j)).

By creating a National List of Approved Substances, it appears that the USDA recognizes the ambiguity inherent in allowing/restricting certain substances in organic production systems: the National List implicitly acknowledges that not all naturally occurring compounds may be fit for use in organics, while the utility and ubiquity of some "synthetic" substances may fit the functional definition of "organic." A decision to include the petitioned form of potassium sulfate represents just such a dilemma. A strong argument can be made that since there are several alternatives to the substance – including the naturally occurring chemical analog – it is unnecessary to add a functional equivalent to the National List. In addition, the substance has been previously identified as "synthetic" by an established industry entity, and organic standards in general tend to preclude the use of synthetics (see Regulatory Status, above).

There appear to be two counterarguments to this. First, the substance is essentially natural because it is derived from two naturally occurring mineral salts, and hence it may be considered equivalent to the primary extracted substance. By comparison, two other manufacturing methods for potassium sulfate use substrates that are not naturally occurring (Konigsberger and Eriksson 1999; Palmer, personal communication). One of these was abandoned as too expensive to

[2] §205.601(j)(5) Magnesium sulfate –allowed with a documented soil deficiency

compete against mined sources. Second, the substance is functionally and economically superior to most (if not all) allowed alternatives, and it is ubiquitous when used appropriately. Along these lines, the substance may be considered “synthetic” and still merit approval on the National List; the crux of the matter is whether the advantages of allowing a synthetic outweigh the disadvantages of growers having to defer to other less suitable forms of potassium fertilizer due to economic constraints. However, economic concerns have not been considered critical criteria in and of themselves in the past. In addition, a decision to allow the use of “synthetic” potassium sulfate may set the stage for future decisions of the same kind. Cumulatively, such decisions may serve to undermine the integrity of organic standards over the long term.

Tap Reviewer Discussion

Reviewer 1 *[Western US, Ph.D. in Horticulture, 19 years experience as Extension Vegetable Specialist in Texas and California, specialization in nutrient and irrigation management]*

Evaluation of the Petition against the Organic Farming Production Act Section 2119 U.S.C. 6518(m)(1-7) Criteria:

1. *The potential of the substance for detrimental chemical interactions with other materials used in organic farming systems.*
   Potassium sulfate is indistinguishable from other potassium salts permitted in organic production, save for the fact that it contains fewer impurities.

2. *The toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.*
   This product is essentially non-toxic. Upon application to moist soil, the product dissociates into its constituent ions, both of which are common in soil. K^+ is held on cation exchange sites, and is not leached in significant quantities except in very sandy soil. If leached, K^+ has essentially no detrimental environmental impact. Of the possible accompanying anions in potassium fertilizers, SO_4^- is the least problematic in soils or the environment.

3. *The probability of environmental contamination during manufacture, use, misuse, or disposal of the substance.*
   According to the information contained in the packet provided, the product is manufactured from naturally occurring salts that are combined in an industrial process that essentially exchanges anions; the only byproduct of the process is $MgCl_2$, another naturally occurring compound. Probability of environmental contamination would appear to be minimal. There is no indication that the mining process for this product is more problematic than that of competing mineral products.

4. *The effects of the substance on human health..*
   This product presents no undue human health hazard in its mining, manufacturing, or soil application.

5. *The effects of the substance on biological interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including salt index and solubility in the soil (crops, and livestock).*
   As previously stated, application of this product to soil simply increases the soil concentration of two common and biologically benign ions. Application at appropriate agronomic rates (typically less than 200 kg K ha^{-1}) would result in soil concentrations of K^+ and SO_4^- no higher than is naturally present in many highly fertile Western soils, in which exchangeable K often exceeds 300 mg kg^{-1}, and SO_4^- is the predominate anion. The only potentially harmful effect of this product on crops or the soil biota would be through increases in soil salinity. In this regard this product is preferable to the use of manure-based composts, which have higher salt content (including chloride) per unit of K content. Use at reasonable agronomic rates has minimal consequences on soil salinity.

6. *The alternatives to using the substance in terms of practices or other available materials.*
   Alternative sources of K are available, but most have serious drawbacks. Manure composts can contain substantial K, but repeated use of these products can result in a build-up of soil P to environmentally undesirable levels. Furthermore, manure composts can contain high salt concentration, which requires leaching to maintain soil productivity. Also, there is may be an insufficient supply of manure compost to provide the amount of potassium required in areas of the country severely deficient in soil K. Cover crops typically contain significant amounts of K, but in soils of severe K deficiency growth of the cover crop itself may be limited by K availability; cover cropping in severely K-deficient soil is not a solution to K availability. Potassium magnesium sulfate behaves similarly to potassium sulfate in soil, but delivers less K per unit of material applied. Mineral K forms that require weathering to make K plant available may fit the organic philosophy of long-term soil building, but provide limited K supply in the shorter term.

7. *Its compatibility with a system of organic agriculture.*
   There is no scientifically valid reason to conclude that potassium sulfate is incompatible with organic agriculture. The material is highly effective for its intended use, environmentally benign when used at agronomically appropriate rates, and has minimal impact on soil physical or biological properties. Its mining and manufacturing is no more deleterious than that of competing products that are deemed acceptable.

Concluding remarks:

As suggested by the preceding discussion, there is no scientifically valid to ban the use of potassium sulfate as a fertilizer in organic agriculture. It is a more desirable fertilizer material than most of the present alternatives, in several ways: low salt index, high analysis (which limits fossil fuel consumption in transport), and high solubility with a low level of impurities (which makes it ideal for injection into drip irrigation systems, which are increasingly being used by organic growers). The only justification for banning its use is that its manufacturing process violates the intent of the Organic Foods and Production Act; whether it violates the letter of the law is a matter for lawyers to decide. My opinion as a scientist is that this product should be allowed to be used in organic production. However, my understanding of the intent of the law is that the electrolysis reaction used in the manufacture of the product does indeed constitute a 'synthetic' reaction, and the product must therefore be banned from use in organic agriculture solely on that basis.

Recommendations to the NOSB:

a) The substance should be listed as a **synthetic** on the National List.
b) The substance should be **prohibited** for use as a soil adjuvant in organic agriculture.

Reviewer 2 *[West coast, Ph.D. .in Crop and Soil Science, specializing in soil fertility and sustainability of managed and natural ecosystems; carbon and nitrogen cycling processes]*

Evaluation of the Petition against the Organic Farming Production Act Section 2119 U.S.C. 6518(m)(1-7) Criteria:

1. *The potential of the substance for detrimental chemical interactions with other materials used in organic farming systems.*
Potassium sulfate has little to none adverse reactions when used under best management guidelines for the application of potassium fertilizers in agricultural systems. Potassium (K^+) and sulfate (SO_4^-) ions comprise a significant amount of the exchangeable soil solution ions. In general, potassium ions occupies up to 2 meq/100g soil on charge depending on soil mineralogy. The amount of potassium found in soil solution ranges from 1 to 10 ppm and is controlled by clay mineralogy. Soils dominated by kaolinitic clays have more potassium in equilibrium with soil solution that illitic or other 2 to 1 expanding clays. Fertilization of potassium at recommended levels would not be expected to change the behavior of other ions in soil solution substantially. Application of fertilizer, such as lime and certain organic wastes, containing large amounts of calcium and magnesium may interfere with potassium uptake by plants.

2. *The toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.*
Potassium sulfate is nontoxic if used according to normal fertilizer practices. The dissolution of potassium sulfate in soil solution results in potassium and sulfate ions. The potassium ion will react with the cation exchange complex immediately reaching equilibrium with solution within days of application. The sulfate ions will react with calcium, magnesium and organic matter to form inert substances. The displacement of hydrogen ions by potassium ions from the cation exchange complex may result in the formation of sulfuric acid ($H_2 SO_4$). The effect of the highly dissociable sulfuric acid should be very short lived but could harm germinating seedlings depending of time of application, soil pH buffer capacity and soil moisture.

3. *The probability of environmental contamination during manufacture, use, misuse, or disposal of the substance.*
Large scale environmental contamination is unlikely from the manufacture, use, misuse or disposal of potassium sulfate. However, details of the manufacturing process were not provided, so therefore, I cannot comment on the manufacturing of potassium sulfate as outlined in the petition. The synthesis of potassium sulfate using electrolysis suggests a purifying process with no mention of the energy requirement or the fate of the byproducts following the synthesis of the potassium sulfate.

4. *The effects of the substance on human health.*
When used as an agricultural fertilizer there should be no adverse effects on human health. Crops will not bio-accumulate potassium and therefore normal consumption of crop or associated products will not introduce toxic levels of potassium in humans. On the other hand, the application of the potassium sulfate fertilizer by people could cause minor irritations to the respiratory tract, eyes and skin from handling and application, but should not contribute to any long-term health effects.

5. *The effects of the substance on biological interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including salt index and solubility in the soil (crops, and livestock).*
Potassium sulfate when used at recommended fertilizer application rates will show little to none adverse effects in agroecosystems. Normal application will not lead to any salinity problems. Leaching of potassium could occur in light textured soils or soils prone to flooding, but normally only minimal leaching loss occurs. Potassium if applied in access could interfere with the uptake of other cations especially ammonium. However, these affects should be short-term and not affect yield potential.

6. *The alternatives to using the substance in terms of practices or other available materials.*
Many sources of potassium sulfate are available. They range from mined deposits to organic wastes. The advantage of pure potassium sulfate over mined or organic waste sources is that it reduces the possible over application of associated

nutrients. This could be especially true in the case of organic wastes that are managed for their N content. In many cases, excess potassium (excess defined as over recommended application rate) could be applied when managing for specific amounts of N in organic waste. However, the amount of excess potassium in organic waste managed for N would not leads to any adverse consequences in agroecosystems.

7. *Its compatibility with a system of organic agriculture.*
The issue of compatibility of processed potassium sulfate is a highly debated subject. Purists would judge anything processed as not suitable for organic production. Others would be happy knowing that the processed potassium sulfate has little or no health or environmental risk associated with its use. However, the concept of organic goes beyond the factors associated with only its use and consumption. For example, the synthesis of the potassium sulfate from natural sources requires energy input and the production of waste. If these costs, both monetary and environmental, are included a more realistic evaluation of the use of synthetic potassium sulfate in organic systems can be made.

Concluding remarks:
The substance is synthesized from naturally occurring substances. The synthesis requires energy input and may also produce waste. Without knowing the true energy and environmental cost of producing synthetic potassium sulfate, it is difficult to assess whether it should be allowed in organic agriculture. One of the hallmarks of organic production beside production of good clean healthy food is the production of food in an environmentally clean fashion. Since information on the manufacturing process was omitted this evaluation is not possible.

If the synthetic potassium sulfate is produced in an environmentally friendly manner I would encourage its use as an organic amendment. If the production of synthetic potassium sulfate requires more energy and produces more byproducts to produce than an equivalent mined source I hesitate to recommend it. I hesitate to recommend the mined source as well because of environmental problems associated with the mining process, but since potassium is required for maximum yield potential, growers must have a source of potassium. Unlike N, which can be biologically synthesized through N fixation, sources of potassium in soils are limited.

Recommendations to the NOSB:
a) The substance should be listed as a **synthetic** on the National List
b) The substance should be **allowed with annotation** that it be restricted to use on crops that are sensitive to chloride found in potassium chloride or in other potassium fertilizers containing excessive salts.

Reviewer 3 *[West coast organic vegetable grower, 20 years experience. Doctoral Candidate and Lecturer in the Environmental Studies, specializing in history and philosophy of agroecology and alternative agriculture.]*

Evaluation of the Petition against the Organic Farming Production Act Section 2119 U.S.C. 6518(m)(1-7) Criteria:

Criteria 1-5 are not relevant to this case. But this does not in itself qualify a substance for inclusion. It is not necessary for something to be grossly or subtly toxic or ecologically damaging for it to be inappropriate to organic agriculture. We could name several synthetically derived nitrogen fertilizer sources, for example, which if used in moderation, might not be harmful, and might in fact stimulate biological activity in the soil, yet these are clearly and unquestionably disqualified for inclusion on the National List.

6. *The alternatives to using the substance in terms of practices or other available materials.*
Composting and cover-cropping/green manuring are foundational elements of any organic cropping system. The conscientious recycling/return of nutrients and organic matter to the soil resource is crucial to the ecological integrity and long-term viability (i.e. sustainability) of any organic farming operation. This cannot be overemphasized as it is at the core of traditional understandings of organic practice, and is indeed one of its defining characteristics. Organic farming practices are meant to be in harmony with ecological processes, always and especially beginning with the soil itself.

However, even with an adequate composting and cover-cropping soil fertility/husbandry program in place, it is sometimes still necessary or desirable to add potassium as a soil amendment. If this is the case, sufficient alternatives exist. The petitioners do not offer any compelling reasons as to why their particular product should be made available. On the contrary, the petition makes only a cursory attempt to justify inclusion, especially considering OMRI's aforementioned assessment of the product. If there were specific applications of this particular form of potassium, where existing alternatives would not be as effective, then the petitioners certainly should have included these in their documentation.

7. *Its compatibility with a system of organic agriculture.*
It may be that synthetically derived fertilizers such as the one under consideration here are only deemed incompatible with organic/sustainable agricultural systems on the basis of narrowly defined technical criteria. Some may see this as overly nitpicking. Nevertheless, this is clearly mandated by the Organic Foods Production Act of 1990, and the National Organic Program's Final Rule. In practice, there may occasionally exist situations and circumstances where

such substances might be appropriately applied. But lacking any specific examples in this case, there does not appear to be any basis for making an exception.

[The reviewer did not provide any additional references]

Concluding remarks:

Considering the conclusions drawn by the Organic Materials Review Institute with regard to Sulphate of Potash Crystalline, it is not at all clear to me why this petition is being reviewed in the first place. During my preliminary reading of the documents in question, I thought that there must be something missing. It seemed obvious, given the absence of any persuasive arguments or examples of special situations in which this product might be especially useful, and without the need for any complicated deliberations, that the proposed substance is clearly inappropriate for inclusion on the National List. Is the NOSB required to consider ALL petitions put before it, regardless of their merit? Other than that, I have no further comments.

Recommendations to the NOSB:

a) The substance should be listed as a **synthetic** on the National List.
b) The substance should be **prohibited** for use as a soil adjuvant in organic agriculture.

* * *

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