Potassium Silicate

for use in crop production

Executive Summary

The following petition is under consideration with respect to the USDA NOP Final Rule, Subpart G, the National List of Allowed and Prohibited Substances:

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

The petition requests the use of potassium silicate in organic agriculture for plant disease control and as a plant or soil amendment. The Petition as submitted makes no distinction when petitioning for these two separate uses, and they are henceforth handled jointly in this TAP review.

Potassium silicate is a source of highly soluble potassium and silicon. It is used in agricultural production systems primarily as a silica amendment, and has the added benefit of supplying small amounts of potassium. The NOP has no prior ruling on the use of this substance. The National List allows the use of some synthetic silica-based fertilizers, but they are allowed only as micronutrient amendments as a means to deliver trace metals and are not intended as silica fertilizers per se. The List also allows the use of silicon dioxide in food processing.

Silicon is an essential micronutrient, and deficiencies significantly affect plant health. However, such deficiencies are rare except in cases of silica-accumulating crops (sugarcane, rice) and/or highly weathered soils typical of tropical regions. There are numerous studies on the use of silica amendments to control disease mechanically (when applied as a foliar spray) and physiologically (when used a fertilizer). There is also substantial anecdotal evidence citing the benefits of siliceous substances in organic agriculture. Numerous silica- and non-silica-based alternatives exist, although they may be less effective than potassium silicate. Where needed, the generic mineral glauconite can be used to supply additional silica in significant quantities.

All TAP reviewers agreed that the petitioned substance should be considered synthetic. Two reviewers felt it should be prohibited. One of these reviewers cited the nature of potassium silicate as a highly soluble synthetic fertilizer, and also questioned its effectiveness as a fungicide. The other dissenting reviewer raised similar concerns, questioning the need for silica amendments in organic systems and the legitimacy of supporting evidence. Both of these reviewers indicated that use of the substance in organics should be revisited if and when the need, effectiveness, and mode of action are better demonstrated. The third reviewer was in favor of adding the substance to the List, with annotations. The reviewer viewed the potential benefits as significant, and felt that the substance ultimately is compatible with a system of organic agriculture.

Summary of TAP Reviewer Analyses

Synthetic/ Nonsynthetic	
Synthetic (3) *Nonsynthetic (0)*	*Reviewer 1: synthetic* *Reviewer 2: synthetic* *Reviewer 3: synthetic*

Allowed or Prohibited for use as a plant disease control § 205.601(i)	**Notes/suggested annotations:**
Allowed (1) *Prohibited (2)*	*Reviewer 1: Allowed with annotations: not to be derived from industrial byproducts; use limited to foliar spray applications to correct silicon deficiencies* *Reveiwer 2: Prohibited* *Reviewer 3: Prohibited*

Allowed or Prohibited for use as a plant or soil amendment § 205.601(j)	**Notes/suggested annotations:**
Allowed (1) *Prohibited (2)*	*Reviewer 1: Allowed with annotation: not to be derived from industrial byproducts; use limited to foliar spray applications to correct silicon deficiencies* *Reveiwer 2: Prohibited* *Reviewer 3: Prohibited*

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 silicate	**CAS Number:**	1312-76-1
Trade name:	AgSil, KASIL	**Other Codes:**	None found
Other names:	silicic acid potassium salt, soluble potash glass		

Characterization

Composition (variable):
$K_2Si_2O_5 – K_2Si_2O_2$

Physical Properties:

Molecular weight:	variable
Appearance:	Fine powder, may be dissolved in aqueous solution.
Color:	Solid is colorless to yellowish; solution
pH	≈11.3
Solubility:	120mg SiO_2 as $Si(OH)_4$ per liter. Very slowly soluble in cold water, increasingly soluble in water with increasing temperature. Agricultural preparations are soluble in all proportions. Insoluble in alcohol.
Stability:	Stable under all conditions of use and storage.
Hazardous Polymerization:	Will not occur.

Specific Uses
The petition requests the use of potassium silicate in organic agriculture for plant disease control (§205.601(i)) and as a plant or soil amendment (§205.601(j)). The Petition as submitted to the NOP makes no distinction when petitioning for these two separate uses, and they are henceforth handled jointly in this TAP review. Primarily, the beneficial effects of potassium silicate amendments are derived from additions of soluble silica species (predominately SiO_2) rather than potassium; the intended uses as stated in the petition support the assumption that the substance is used primarily as a silicate fertilizer. Potassium silicate is approved by the USDA as a fertilizer for conventional agriculture, and is used on variety of crops including rice, wheat, barley, sugar cane, melons, grapes, cucurbits, sugar cane, and ornamentals. Potassium silicate is also used to control certain fungal diseases on high value crops.

How Made:
Potassium silicates are manufactured using a calcination process that combines silica sand (SiO_2) and potassium carbonate (K_2CO_3) at 1100-2300°F for up to 15 minutes (NOP Petition; Rawlyk and McDonald 2001). The two substances fuse into glass, which can be dissolved with high-pressure steam to form a clear, slightly viscous fluid, or cooled and ground into a powder. Carbon dioxide is evolved from this reaction. The solution can be dried to form hydrous powder crystals of potassium silicate.

Functionality

Applications of potassium silicate are primarily intended to provide supplemental silica. Most soils contain significant quantities of silica, but continuous cropping, particularly with crops that accumulate significant quantities of silica, can reduce plant-available levels of Si to the point that supplemental Si fertilization is required. There appears to be a need for Si amendments in temperate as well as tropical crop production systems, and Si fertilizers are applied to crops in several countries for increased productivity and sustainable production (Ma et al. 2001, Korndorfer and Lepsch 2001).

Silicon is the second most abundant element in the earth's crust, and hence is plentiful in most soils. Soluble silica concentrations in soil generally range from 30-40 mg SiO_2 per liter and are dominated by monosilicic acid, $Si(OH)_4$. Generally speaking, silicon has not been considered an essential plant nutrient in the past, despite proven beneficial effects of silicon in plant growth and disease prevention (Epstein 1994, 1999, 2000). High silica uptake has been shown to improve drought resistance, increase resistance to fungi and other pathogens, and increase plant growth rate and yield (Marschner 1995, Piorr 1986, Belanger et al. 1995). However, its essentiality as a micronutrient for higher plants is difficult to prove, partly due to the fact that many positive effects of Si are most apparent in cases of abiotic stresses. Silica amendments have also been shown to correct soil toxicities resulting from high levels of soluble Mn^{2+}, Fe^{2+}, and Al^{3+} (Tisdale et al. 1999).

Crop plants differ greatly in their ability to take up silicon. Silica is absorbed by plants as silicic acid, with cereals and grasses containing the highest concentrations (0.2-2.0%). Marschner (1986) divided plants into three major groups, depending on their SiO_2 content: wetland *Gramineae* such as wetland rice, 10-15% (shoot dry weight), dryland *Gramineae*, such as sugar cane and most cereal crops, 1-3%, and legumes and most dicotyledons, <0.5%.

Status

OFPA, USDA Final Rule

Potassium silicate is not listed in the Final Rule. Synthetic silicates of zinc, copper, iron, manganese, molybdenum, selenium, and cobalt are allowed as micronutrient plant or soil amendments in cases of documented soil deficiency (§205.601(j)(6)(ii)). In processing applications, silicon dioxide (SiO_2) is an allowed synthetic.

Certification

Domestic certifiers

California Certified Organic Farmers (CCOF) Certification Handbook – Not listed (CCOF 2000).
Idaho Department of Agriculture (ISDA) Organic Food Products Rules – Not listed (Section 02.06.33, 2000).
Texas Department of Agriculture (TDA) Organic Certification and Standards Materials List – Not listed. For processing, allows silicon dioxide as a floating agent (2000).
Washington Department of Agriculture (WSDA) Organic Crop Production Standards – Not listed (WAC 16-154-070, 2000).
Organic Materials Review Institute (OMRI) Generic Materials List – Not listed (2002).

International certifiers

CODEX – Substances Allowed for Use in Soil Fertilizing and Conditioning: - basic slag, in cases of recognized need
Substances Allowed for Plant Pest and Disease Control: - mineral powders (stone meal, silicates)
- sodium silicate
- clay silicate (bentonite)

IFOAM – Appendix 1 (Fertilizers and Soil Conditioners) - basic slag of mineral origin
Appendix 2 (Crop Protectants and Growth Regulators) - silicates (e.g. sodium silicate, quartz) of mineral origin.

Canada – Not listed (CGSB 2002).
Japan – Not listed (JAS 2001).

Regulatory

EPA – Potassium silicate is registered as a pesticide under the Toxic Substance Control Act, and is considered List 3 (Inerts of unknown toxicity) under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).
FDA – Potassium silicate is considered interchangeable with sodium silicate, a GRAS substance.
IARC – Not listed.
OSHA – Not listed.
NIEHS National Toxicity Program (NTP) – Not listed.

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.***

Additions of potassium silicate have a very low potential for adverse reactions with other materials used organic farming systems. The substance may react in storage with ammonium salts to form hydrogen gas, and care should be taken to avoid contact with raw manure in closed storage. Potassium silicate solutions have a high pH, and applications may have adverse effects if used on alkali sensitive crops. According to the Petition, mixtures incorporating compost tea or citric acid have been used successfully in the past to lower the pH of potassium silicate solutions.

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.***

Potassium silicate has no known chronic hazards, and neither silica nor potassium appreciably bioconcentrate in the food chain (except with silica in the case of aquatic siliceous species). Potassium silicate contains no volatile organic compounds, and applications will not result in the release of any hazardous or environmentally persistent byproducts (Blumberg 2001).

The breakdown products of the material are potassium and silicon dioxide, both naturally occurring in practically all animal species and ecosystems (King et al. 1938). Diluted potassium silicate solution readily depolymerizes into various silica-based species loosely associated with potassium ions. Concentrations used in foliar sprays and nutrient solutions are dominated by silicic acid, which is readily absorbed by plants. Dissolved potassium and silica species are indistinguishable from their naturally occurring analogs.

The mode of action of potassium silicate is not fully understood. There appears to be both a mechanical mode of action (when applied as a foliar spray), and a physiological mode of action (when translocated within plant tissues) with current research mostly supporting the latter hypothesis. Silicon impregnates along epidermal cell walls (Parry and Smithson 1964). These layers become effective barriers against water loss and fungal infection (Sangster 1970, Takeoka et al 1984). Silicon is also deposited in xylem vessel cell walls, preventing constriction of xylem under high transpiration stress (Raven 1983), and in endodermal root cells, where it acts as a barrier against infection of the stele by parasites and pathogens (Bennett 1982). Although there appears to be a relationship between silicate treatments, resistance to fungal attack, and expression of plant defense mechanisms (Cherif et al 1992), a concurrent study (Cherif et al 1992a) showed that accumulation and polymerization of silica at fungal infection sites has no role in providing a physical barrier against fungal attack. Further evidence points to the accumulation of silica in the trichomes of fruit as a possible barrier (Samuels et al 1993).

Potassium silicate has not been tested for ecotoxicity. It is not persistent in aquatic systems, but is highly alkaline in solution form and can be harmful to aquatic life if not diluted and disposed of properly. The following information is based on results from tests using chemically similar sodium silicate on a 100% solids basis (Blumberg 2001):

Fish (*Gambusia affnis*) LD_{50} (96h)	= 2320ppm
Water fleas (*Daphnia magna*) LD_{50} (96h)	= 247 ppm
Snail eggs (*Lymnea*) LD_{50} (96h)	= 632 ppm
Amphipoda LD_{50} (96h)	= 160 ppm

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

As outlined in the "How Made" section, potassium silicate is made via calcination, or thermal conversion into an ashlike powder. The substance is produced by reacting high-silica sand and mined potassium carbonate, yielding potassium silicate and CO_2 gas. The manufacturing process does not appear to pose a substantial risk of environmental contamination, outside of the upstream combustion of fossil fuels to power the reaction. There is no mention in the petition or in other literature of impurities resulting from the reaction, or the use of catalysts other than heat.

While the petitioner intends to use naturally occurring sand as a primary raw ingredient, silica-laden compounds used as silicon fertilizers for conventional agriculture are commonly sourced from industrial byproducts. These byproducts, referred to ubiquitously as slag, are impurities precipitated from the refining of mined materials and smelting of metal ores. Depending on the source, slags may also contain heavy metals associated with their origin or processing (e.g., uranium in phosphate ore, nickel, and zinc). Nonetheless, the use of silica slag fertilizers in agriculture is widespread, particularly in sugarcane fields and paddy rice systems. In conventional agriculture, calcium silicate slag ($CaAl_2Si_2O_8$ or $CaSiO_3$) is commonly used as a silica fertilizer (Tisdale et al 1999). Silicate slag applied at a rate of 1.5-3.0 t/ha is common practice in degraded paddy fields in Japan (Kono 1969, Takahashi and Miyake 1977). Additionally, slag has been used in foreign organic operations in the past. One organic agriculture research farm in Taiwan that used silica slag mixed with manure and soybean meal reported a 25% yield increase of high-quality sponge gourd (Hsieh and Hsieh 1989). If potassium silicate is allowed for organic crop production without specific annotation, it is possible that some silicate fertilizers will be sourced from silica slag.

Solid and aqueous potassium silicate application techniques are unremarkable, and proper use of the material is unlikely to pose a significant risk to the environment. The substance is stable under all conditions of agricultural use and storage (Blumberg 2001). There is no CERCLA Reportable Quantity established for this material, indicating a relatively benign nature. However, as mentioned in Criterion 2, the strongly alkaline solution is potentially toxic to aquatic species. Proper disposal of the bulk material would require neutralization and landfilling or dilution and discharging to sewers in accordance with legal regulations.

4. The effects of the substance on human health.

The effects of potassium silicate applications on human health are likely to be minimal. 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). An evaluation of the heath aspects of certain silicates as food ingredients determined that potassium silicate is not hazardous when used at levels established for food ingredients (FDA 1978). Sodium silicate, a GRAS substance considered by the FDA to be interchangeable with potassium silicate, has an acute LD_{50} (oral, rat) ranging from 1500mg/kg – 3200mg/kg, similar to common table salt (LD_{50} = 3000 mg/kg (oral, rat)) (Chao 1978). Potassium silicate is registered for use as a used a corrosion preventative in water at concentrations not greater than 100 ppm (Chao 1978). Silicon dioxide (SiO_2) is regulated for use as an anticaking agent, and as a stabilizer in beer production [21 CFR 172.480].

When handled and applied in an agricultural setting, the likely routes of entry are absorption through the skin and inhalation. Acute overexposure may cause skin and respiratory tract irritation. The substance has not been tested for primary eye irritation, but is regarded as an eye irritant on the basis of its high alkalinity and its similarity to sodium silicate (Blumberg 2001).

Applications of potassium silicate pose a risk primarily from inhalation or ingestion of silica-rich compounds. Respiratory problems in the agricultural sector due to inhaled dust are a proven concern (Schenker 2000). Decades ago, it was shown that dust arising from storage and handling of wheat grains contained particles that were believed to cause respiratory ailments (Baker 1961). Burning of high-silica crops, such as rice and sugarcane, have been problematic for worker health in the past (Boeniger et al. 1988). There is also significant indirect evidence linking ingested plant silica and human cancer (Sangster et al. 1983, Bhatt et al. 1984, Hodson et al. 1994), but there currently is no connection between plant silica and inorganic silica sources. Mitigation of health risks associated with respiration of silica-laden dust can be achieved though proper use of personal protective equipment including a NIOSH-approved dust respirator where dust occurs.

No carcinogenicity, mutagenicity, or developmental toxicity data are available for potassium silicate.

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

The agricultural benefits of silicon amendments on a soil ecosystem are well established. Si has been shown to mitigate adverse effects of climate (Ohyama 1985), water and mineral deficiency (Ma 1988, Ma et al. 2001), salinity (Matoh et al. 1986), and some metal toxicities (Vlamis and Williams 1967, Cocker et al. 1998, Iwasaki and Matsumura 1999).

Silica amendments are proven highly effective at reducing aluminum toxicity (Haak and Siman 1992, Myhr and Erstad 1996) through a variety of mechanisms. Monosilicic acids – the primary soluble form of soil solution silica – can increase soil pH (Lindsay 1979), adsorb to aluminum hydroxides and decrease their mobility (Panov et al. 1982), and form somewhat insoluble substances with Al ions (Lumsdon and Farmer 1995). Soluble silicon compounds can also increase plant tolerance to Al (Rahman et al. 1998). Successive silicate fertilizer applications have been shown to increase soil pH to levels that adversely affect plant growth (Miayke and Takahashi 1983), but soils with high organic matter content tend to buffer this effect, and additions of organic material were effective in correcting soil pH.

Applications of potassium silicate can increase the quantity of mobile phosphates in the soil (Gladkova 1982, Singh and Sarkar 1992, O'Reilly and Sims 1995). In addition to stimulating desorption of phosphate anions from soluble phosphates of calcium, aluminum, iron and magnesium, silica fertilizers also have good adsorption capacity. Application of Si-rich material has the potential to decrease P leaching by 40-70%, while retaining P in a plant-available form (Matichenkov and Bocharnikova 2001).

In addition to altering soil biochemical interactions, numerous studies have demonstrated a connection between potassium silicate fertilization and increased disease and pest resistance. There is significant evidence that silica fertilization may positively affect both silicon-accumulator plants and non-accumulator plants (Korndorfer and Lepsch 2001):

Foliar applications of potassium silicate have been shown to reduce the severity of powdery mildew and increase chlorophyll content and plant growth in strawberries (Wang and Galletta 1998). Potassium silicate did not reduce isolation frequency of *Phytopthora nicotianae* and *Pythium ultimum* or root rot, however it did reduce levels of *T. semipenetrans* (nematode) in soil (Walker and Morey 1999). Potassium silicate has been used in nutrient solutions to control *Pythium* diseases on tomatoes and cucumbers (Adiatia and Besford 1986). An industry-sponsored study showed a foliar potassium silicate spray provided "good to excellent control" of powdery mildew on winegrapes throughout pre-harvest at 630 ppm SiO_2 and 1260 ppm SiO_2 solutions, applied at 500L/ha (McFadden-Smith 2001).

On cucumber plants, silicate fertilizer applied at a rate of 700 or 1400 kg SiO_2/ha/yr for three years increased plant growth, and reduced damage caused by wilt disease (Miyake and Takahashi 1983). A study demonstrating the uptake of silicate by hydroponic cucumbers showed pronounced resistance to powdery mildew (*Sphaerotheca fuliginea*) when applied at 110 mg/L SiO_2 (Adapt and Bedford 1986). In a greenhouse study, dissolved silicate amendments via drip line reduced damage to cucumbers caused by *Didymelia byronise* (O'Neil 1991).

Crops that accumulate Si such as rice and sugarcane are particularly vulnerable to Si deficiency, and additions of silica fertilizers to soils low in plant-available Si result in marked productivity improvements. Following silicate fertilization in low-Si soil, rice yield increases of ten percent are common and may exceed thirty percent at times of severe leaf blast infection (Yoshida 1981). In one study, applications of sodium silicate (400 kg/ha) on upland rice reduced neck blast (*Pyricularia oryzac*) and improved overall crop quality (Yamauchi and Winslow 1987). Silica applied to lowland rice soils in Japan since 1955 have resulted in a significant increase in yield (Takahashi et al. 1990). In the US, applications of calcium silicate to rice at up to 6.0 Mg/ha (2.7 t/ac) have been shown to be beneficial (Anderson et al. 1987). Silica slag amendments used on rice systems in Louisiana had a positive effect on the incidence of blast (*Pyricularia grisea*), sheath blight (*Rhizoctonia solani*) and brown spot (*Bipolaris oryzae*) (Bollich et al. 1996). In another study, silicon amendments appear to be effective at very low concentrations; soluble SiO_2 applications of 100 mg/L increased wetland rice yields significantly (Okuda and Takahashi 1965, Takahashi and Miyake 1977).

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

<u>Soil fertility</u>
Silica is endemic in large quantities in most agroecosystems, and thus there are few organically approved commercial sources of silica fertilizer. Where Si amendments are needed, a number of agricultural products high in silica may be used to supplement soil reserves. These range from field trash, such as rice hulls and sugarcane bagasse, to shells from aquatic

animals. Where agricultural solutions are not available or practical, the use of glauconite is a viable alternative. Glauconite is a composite mineral of hydrated iron-potassium silicates (7% K_2O, 54% SiO_2). The mineral is mined from naturally occurring sedimentary deposits known as greensand, and has an established history of use as a natural soil conditioner. The substance is commercially available and OMRI-listed.

Plant disease control

A number of foliar treatments to control fungal disease are currently used in organic agriculture, with research ongoing; some of these are agricultural products. In one study, an aqueous solution of burnt rice husks (400 q/ha) was shown to be as effective and economically viable as a 1% commercial sodium silicate solution for treatment of rice blast (*Pyricularia oryzae*) (Hsieh and Hsieh 1989). Sulfur is by far the most widespread treatment for powdery mildew and botrytis bunch rot on grapes, and there is a strong agricultural drive for effective organically acceptable controls of fungal disease as copper sulfate falls out of favor due to environmental concerns (Willer et al. 2002, Kauer et al. 2002). Control of grapevine powdery mildew (*Uncinula necator*) in a greenhouse was achieved with applications of *Bacillus subtilis* (94% disease reduction), Synertrol Hort-oil[1] (92%), milk (70%), whey (64%), and Ecocarb[2] (57%) (Crisp et al. 2002). Further reductions were achieved by combining vegetable oils and Ecocarb or whey. Disease suppression by canola oil on grapes (Azam et al. 1998), and by potassium carbonate on sweet peppers (Fallik et al. 1997) and potatoes (Olivier et al. 1998) has also been demonstrated. Another study gave positive results on control of cucurbit powdery mildew with JMS Stylet oil, a biocompatible fungicide (McGrath and Shishkoff 1999). The use of plant extracts such as giant knotweed (Milsana™) and neem tree (Agroneem™, Trilogy™, Triact™) are being investigated for use as fungicides, as well.

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

From a purely agronomic perspective, potassium silicate appears to be compatible with sustainable agriculture. Si in the soil is continuously removed via crop uptake and by leaching due to desilication processes. There is significant evidence to support the claim that silicon amendments are highly beneficial in some agroecosystems. In addition, the substance contains no persistent or environmentally toxic metabolites, and it appears to pose little risk based on its historical use as a food additive and its chemical similarity to sodium silicate, a GRAS substance.

However, organic law generally does not tolerate the listing of soil amendments that are not naturally occurring in the form that they are used. While the National List allows the use of some synthetic silica-based fertilizers (§205.601(j)(6)(ii)), they are allowed only as micronutrient amendments as a means to deliver trace metals and are not intended as silica fertilizers per se. A strong argument can be made that the substance is ultimately not compatible with organic agriculture based on the fact that it is a fertilizer of high solubility and is not naturally occurring. Furthermore, silica fertilization is largely unnecessary in most soils due to the continuous replenishment by natural soil reserves. Where silica amendments are needed, the availability of a naturally occurring generic substitute (glauconite) makes its inclusion on the National List difficult to justify.

[1] Canola-based product
[2] Potassium bicarbonate-based surfactant

Tap Reviewer Discussion

Reviewer 1 *[Trained crops agronomist, working as a specialist in organic farmer for a non-profit information provider; 15 years experience in organic education and extension; Central]*

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.*

   There is very little information provided in this section. However, based on an overall reading of the TAP document, I feel satisfied that there is **little or no concern** that harmful interactions might result. The specific concern cited as regards alkali-sensitive crops strikes me as a hazard due to the improper or ill-advised use of the material; not the sort of hazard that criterion #1 was intended to address.

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.*

   The only suggestion that there may be an environmental issue with this substance is in the area of disposal. In this instance the concern revolves around the alkaline nature of the substance rather than any innate toxicity. It is hard for me to imagine that farm use is unlikely to result in disposal of enough material to affect an aquatic system—except, perhaps, for a very small pond. In any instance, the use of any amendment in a manner that causes pollution of surface- or ground-waters is a violation of § 205.203 (d), which addresses the mishandling of natural fertilizer materials.

   Therefore, I feel that there is **no significant cause for concern** over the use of potassium silicate, with regard to toxicity or contamination of the environment.

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

   Three issues are highlighted under this criterion: gas emissions, disposal of bulk material, and the possible use of slag.

   Fossil fuels are used to drive the chemical reaction that creates potassium silicate, thereby releasing a certain amount of polluting gasses. Also, the chemical reaction, itself, releases CO_2. However, there is no indication in the information provided that these releases are exorbitant or that they amount to a recognizable hazard.

   The disposal of bulk material again appears to be a hazard chiefly from the standpoint of alkalization of the water in aquatic systems. (There is no suggestion of any persistent or insidious pollutants.) I trust that EPA or related regulations are in place to control such “point” pollution.

   Much is made in the TAP document of the use of silica-rich slag in international organic production. Slags are prohibited in US organic production, due in large part to the presence of heavy-metal contaminants in many sources. The TAP document suggests that, **if approved for organic use, potassium silicate be approved with an annotation** that it be manufactured only from naturally occurring sand.

   Generally, I believe that that **the probability of environmental contamination during manufacture, use, misuse, or disposal, is low and does not present a barrier to use of this substance in organic crop production.**

4. *The effects of the substance on human health.*

   The point of concern on this issue revolves around silicate dusts as an inhalation hazard. I concur with the last statement of this section, which suggests that health risks can be adequately mitigated through the proper use of personal protective equipment such as dust respirators. With proper use and common-sense precautions, I feel that potassium silicates **do not present a significant human health danger**.

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

   I agree that, from an agronomic perspective, the effects are largely, and even highly, positive. **Based on evaluation of this criterion, there are good reasons to support use of potassium silicate in organic production.**

6. *The alternatives to using the substance in terms of practices or other available materials.*

   <u>Soil fertility:</u> The <u>Functionality</u> section suggests that Si deficiencies may appear under a wide range of US climates and cropping systems. This raises the question of whether the agronomic alternatives cited under #6 are adequate to rectify deficit conditions. The TAP specifically mentions, rice hulls, sugarcane bagasse, and the shells of aquatic animals. I’m

under the impression that these by-products are economically available only in certain regions of the country. Much is said about glauconite, which I concur, is a good material. However, it is mined on the East Coast and the cost-plus-shipping is generally considered too high for agronomic use in most areas of the United States. Alternatively, it is reasonable to suppose that other mineral deposits might provide significant amounts of silicon. I checked the label on Azomite®—a rock mineral product that is more available in the West and Midwest; it purports to be 65.85% silica oxide (SiO_2).

It is important in organic agriculture to remember that the strategy is not to feed the plant directly with readily soluble nutrients, but to enrich the soil and enhance the biological processes that provide crop nutrition in a metered fashion. Theoretically, organic systems utilizing rotations and green manures would replenish the supply of soluble silica from native soil supplies, it being such an abundant element. However, there is no research cited to support or refute this, or to suggest a possible timeframe; we would be taking that on faith as an organic principle.

I am inclined to believe that **there are organic alternatives to potassium silicate as a soil amendment/fertilizer**, though the material might be allowed for use as a micronutrient to correct deficiencies.

<u>Plant disease control:</u> The TAP document does a good job of listing several of the current fungicidal alternatives. Though there are existing options for pest management, the use of silicates is consistent with organic management. **I would be inclined to accept its use as a pest control agent**, especially in light of the fact that copper materials are falling into disfavor and sulfur is phototoxic when temperatures increase.

7. *Its compatibility with a system of organic agriculture.*

The TAP document outlines the compelling arguments under this criterion exceptionally well. Potassium silicate is a benign and generally beneficial material that can easily find a place in organic production systems. However, this argument can be made for a number of synthetic materials such as ammonium sulfate, calcium nitrate, calcium oxide and calcium hydroxide. Organic agriculture does not "short cut" crop nutrition by using soluble fertilizers; the few exceptions involve those materials like sodium nitrate, which are naturally found in a soluble form. And even sodium nitrate has restrictions on its use.

Finally, however, the wording on this criterion is "compatibility with a system of "sustainable" agriculture. **I do feel it is compatible with a sustainable agricultural system.**

Do you have any additional references?

I have no additional references.

How does the need to apply this substance compare to the ability of organic cropping systems to replenish silica from soil reserves?

I have raised this question above. I will state again that, in theory, a combination of sound cropping practices that includes crop rotations and green manures (that include grasses) should increase the availability of silicon. Where silica has been sorely depleted, I believe there are rock-powder-amendments and organic by-products, which should be available for soil application.

In spite of this, I do believe that potassium silicate should be allowed for use as a micronutrient via foliar fertilization. The contribution to pest resistance is enormous; it is highly consistent with organic principles that maintain nutritional underlies insect pest and disease resistance.

Recommendations to the NOSB:

a) The substance should be considered **synthetic** on the National List

a) The substance should be **allowed with restrictions** for use in organic crop production as a plant disease control and a plant soil amendment.

I believe that potassium silicate should be allowed as a synthetic for pest control under § 205.601 (i) with the annotation that it not be derived from industrial by-products and that it be used only as a foliar spray; it should be allowed as a micronutrient under § 205.601 (j) (6) with the annotation that it not be derived from industrial by-products and that it be used only as a foliar spray to correct or counterbalance silicon deficiencies.

I feel these would be consistent with the decisions made regarding calcium oxide and calcium hydroxide at the May 2002 NOSB meeting in Austin.

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

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.*

   The substance should have minimal interactions with materials commonly used in organic agriculture when applied to soil or as a foliar application. During storage of the compound, care must be taken to avoid wetting the material. The resulting solution forms a mild alkaline mixture, which may become reactive. When applying it as a solution it may corrode application equipment and harm sensitive plants if not buffered to a neutral pH. Spills are slippery. Reacts with acids, ammonium salts, reactive metals and some organics.

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.*

   Toxicity of potassium silicate is not well documented but thought to be minimal. When applied as an amendment to soil or foliar application in accordance to application requirements, potassium silicate will have little to no potential to contaminate or persist in the environment. Potassium silicate affects on metabolic interactions are not well characterized if at all. Silicon is inserted mainly in plant cell wall structures. Other metabolic reactions requiring silicon, such as enzymatic, are poorly characterized. Little toxicity information, such as Lethal Dose (LD_{50}), is available.

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

   Solutions can have high pH (alkalinity). Undiluted or un-neutralized solutions are harmful to aquatic life.

   The production of potassium silicate is energy intensive requiring temperatures in excess of 1000˚F. for synthesis. Potentially large amounts of carbon dioxide can be released during the manufacture of potassium silicate. Additional energy is required to convert solids or liquids into a form suitable for storage and application.

   Disposal of potassium silicate will require neutralization.

4. *The effects of the substance on human health.*

   Spray mist or dust may irritate the respiratory tract and cause skin itching and redness. Ingestion of dust or spray causes irritation to esophagus and stomach. Aggravates existing lung and skin medical conditions. Proper guidelines will need to be developed for application if they do not already exist.

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

   Silica is absorbed by plants as silicic acid. Cereals and grasses tend to accumulate the most silicon. Accumulation of silica in these plants can be as high as 20% of the dry weight. Dicotyledons accumulate much less silica. Silica impregnates epidermal and vascular tissue. Reduced lodging, water loss and fungal infections are attributed to adequate silica in these tissues. No biochemical role for silica has been determined.

   The application of potassium silicate to soil has been shown to be beneficial. Beneficial effects include reducing the toxic effects of manganese, iron and aluminum. Increased phosphorus availability occurs under beneficial levels of silica. Silica has been shown to be beneficial in impoverished rice soils.

   In general, soils contain 20 to 40% silica, which is often adequate for plant demands. Most normal soils have adequate soil solution concentrations of silica in the range of 3 to 40 ppm silica. Rice soils often require in excess of 100 ppm silica. Tropical soils that are highly weathered contain less than 10% silica and may require amendments to correct silica deficiency. Silica deficient soils are often found in high rainfall regions where soils become intensively weathered. These types of soils usually exhibit aluminum toxicity, low base saturation and low pH. Organic management techniques to build soil organic matter often eliminate these poor soil qualities.

6. *The alternatives to using the substance in terms of practices or other available materials.*

   Organic management for soil quality can often eliminate many undesirable soil characteristics that potassium silicate can alleviate. Organic management often results in neutral soil pH reducing toxic effects manganese, iron and aluminum. The increase in soil organic matter results in increased phosphorus availability. The purported beneficial affects of silica on the reduction of disease has only been demonstrated in a few studies. Generally, the conclusion that one can derive from these studies is that silicon has a beneficial effect on reducing some fungal diseases in soils where silicon is low (Schuerger and Hammer 2003; Rodrigues et al 2003; Kim et al. 2002). Many of these studies show beneficial effects in rice and sugarcane but not in other commercial crops. More studies are required to definitively state that silica is useful to prevent fungal infections in other crops. In the United States, low silicon soils are rare. Low silicon soils are general associated with oxisols or highly weathered soils. Highly weathered soils are often found in tropical environments. These soils have lost their primary minerals containing silicon and have weathered to oxides of iron and aluminum. Hawaii may have highly weathered soils and there are reports of beneficial effects of silicon fertilization on sugarcane crops grown on these highly weathered soils. Organic management can often reduce disease through crop diversity and nutrient management. The necessity of potassium silicate for organic production has not been demonstrated.

7. *Its compatibility with a system of organic agriculture.*

   Since potassium silicate has not been demonstrated to be beneficial in organic or conventional cropping systems there is no reason to recommend its use. Certain soils and crops may benefit from silica amendments. Often organic management can alleviate soil problems related to fertility. Addition of composts and green manure are a source of silicon and the addition of organic matter in soil may help to retain silicon. Rice and sugarcane may be obvious exceptions that require silica amendments, especially on impoverished or highly weathered soils.

Do you have any additional references?

Rodrigues FA, Vale FXR, Korndorfer GH, Prabhu AS, Datnoff LE, Oliveira AMA, Zambolim L 2003. Influence of silicon on sheath blight of rice in Brazil. CROP PROTECTION 22 (1): 23-29

Kim SG, Kim KW, Park EW, Choi D 2002. Silicon-induced cell wall fortification of rice leaves: A possible cellular mechanism of enhanced host resistance to blast. PHYTOPATHOLOGY 92 (10): 1095-1103

Schuerger AC, Hammer W. 2003. Suppression of powdery mildew on greenhouse-grown cucumber by addition of silicon to hydroponic nutrient solution is inhibited at high temperature. PLANT DISEASE 87 (2): 177-185

The literature on silica is generally small and often conflicting. Generally, only rice and sugarcane crops have shown benefit from silicon additions. Many anecdotal accounts purport the benefits of silica. More research is required to determine the positive biochemical and soil fertility benefits of silica.

How does the need to apply this substance compare to the ability of organic cropping systems to replenish silica from soil reserves?

Organic systems are designed to recycle nutrients where possible. Addition of nutrients is often achieved through the use of compost. Application of compost derived from lawn clippings and tree pruning would likely add silica to soil. Recycling of crop residues and animal manure will maintain soil silica levels. In general, soil solution silica levels are generally adequate for most crops in organic production.

Recommendations to the NOSB:

a) The substance should be considered **synthetic** on the National List

   The substance is manufactured and requires considerable energy during production. The compound is synthesized.

b) The substance should be **prohibited** for use in organic crop production as a plant disease control and a plant soil amendment.

The use of potassium silicate is not required for general organic agricultural done in the United States. Organic management approaches such as cover cropping and use of manure and compost should efficiently recycle silica. Special cases may be considered where high demanding silica crops such as rice and sugarcane are grown on impoverished or highly weathered soils. However, as stated earlier, the use of composts and manure would help to alleviate problems with low silicon in soils. The petition for potassium silicate use in organic agriculture should be revisited if widespread soils of low silicon content for use in organic agriculture can be demonstrated or if scientific studies show in the future the benefits of silicon to soils and disease suppression.

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Reviewer 3 *[*Ph.D., plant pathology; 13 years organic industry years experience in certification, farm manager, assistant farm advisor, and produce brokerage; agriculture consultant providing on-site technical advice, field monitoring and research for fresh produce growers and shippers; Pacific*]*

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 silicate has the potential for minor adverse chemical interactions with other materials when used under best management guidelines in agricultural systems. The most important effect would be on alkali sensitive crops due to the high

pH of potassium silicate solutions. However, mitigation is easily achieved. If high pH is of concern, the pH can be lowered before or after application by adding acidifying materials from the Allowed Substance List.

Potassium (K^+) ion is a natural constituent of soil. K^+ comprises a significant amount of the exchangeable soil solution ions and is an essential macronutrient for plant growth. 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. High levels of K^+ may displace NH_4^+ in clays, especially illite and cause leaching of NH_4^+, but this effect would usually be small under normal fertilization procedures.

Silicon, although very common in soil, is largely unavailable for use by plants, occurring for the most part as an insoluble component of rock and clay. Silicon is an essential micronutrient for some plants such as rice, but much less deficient than potassium: silicon deficient soils are generally highly weathered, tropical soils with high levels of iron oxide and low levels of siliceous minerals. Silicate from potassium silicate at recommended levels would not be expected to change the behaviour of other ions in soil solution detrimentally. Possible benefits include an increase in phosphate desorption from Mg, Ca, Fe and Al to make phosphate available to plants and increased absorption of phosphate to decrease phosphate leaching. Phosphate leaching can be a serious environmental problem. Silicates may reduce the toxicity of high levels of manganese, iron and aluminum.

Potassium silicate has little to none adverse reactions when used under best management guidelines for the application as a fungicide. The high pH of the solution, if uncorrected, would affect tank mixes of materials sensitive to high pH. The reported negative effects potassium silicate has on plant-infecting fungi might also negatively affect naturally or added beneficial fungi in tank mixes or on plant leaves.

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 silicate is nontoxic if used with some precautions. In undiluted form, an alkaline solution it is toxic to aquatic species. Contamination of water must be avoided.
The dissolution of potassium silicate in soil solution results in potassium and silicon dioxide ions, which are common in animal species and ecosystems. The potassium ion will react with the cation exchange complex, reaching equilibrium with solution within days of application. Diluting potassium silicate solutions with water results in depolymerization to various silica-based ions, loosely associated with K^+. Foliar sprays are mostly silicic acid and absorbed by plants.
The mode of action as a fungicide is unclear. Most importantly, potassium silicate does not seem toxic to fungi, and therefore has fewer dangers to non-target species than toxic materials.
Potassium silicate has no chronic hazards, does not bio-concentrate in the food chain, nor makes volatile or toxic organic compounds when used as recommended. Use will not result in hazardous of environmentally persistent byproducts.

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 silicate. Production from high silica sand and mined potassium carbonate produces potassium silicate and CO2, with insignificant direct effects on the environment. However, the significant energy requirement (likely using fossil fuels) for the process can have a range of negative effects. No impurities seem likely.

Use of silica slag instead of sand, which may contain toxic heavy metals, may result in environmental contamination due to errors in properly handling these metals during manufacture and disposal. No information on whether significant amounts of such metals may be present after manufacture of potassium silicate from slags was provided, so I cannot comment on its use.

4. *The effects of the substance on human health.*
When used as an agricultural fertilizer or fungicide there should be no adverse effects on human health, provided standard precautions are followed to protect applicators from skin and eye exposure, and inhalation or ingestion. The danger from inorganic silicates is circumstantial, but can be avoided with proper procedures. Crops will not excessively bio-accumulate potassium or silicon and therefore normal consumption of crop or associated products will not introduce toxic levels of potassium in humans. Potassium is an essential element for humans, and silicon dioxide is used in food processing.

5. *The effects of the substance on biological interactions in the agro ecosystem, including the physiological effects of the substance on soil organisms (including salt index and solubility in the soil (crops, and livestock).*
Potassium silicate when used at recommended application rates will show little to no adverse effects in agro ecosystems. Normal application will not lead to any salinity problems. Adverse pH effects are possible (especially in already alkaline soils), which would alter the makeup of soil organisms, but the pH can be lowered in a variety of ways. Leaching of potassium or ammonium could occur in light textured soils or soils prone to flooding. Normally only minimal leaching loss occurs. Potassium, if applied in excess could interfere with the uptake of other cations especially ammonium. However, these effects should be short-term and not affect yield potential. Soil organisms are not known to be sensitive to potassium and silicon in soil and likely would be only slightly affected. Excess silicate in soil is extremely unlikely, and applications show a neutral or beneficial effect.

6. *The alternatives to using the substance in terms of practices or other available materials.*
   No other source of potassium silicate is available, however many sources of potassium and silicate in separate materials are available. Such sources are only valuable as fertilizer, not as fungicides.

   Soil Fertility. Alternate sources of potassium range from mined deposits to organic wastes to allowable synthetics. The advantage of pure potassium silicate over mined or organic waste sources is that it reduces the possible excess application of associated nutrients. This could be especially true in the case of organic materials (such as composts and manures) 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 materials. However, the amount of excess potassium in organic materials managed for N would not lead to significant adverse consequences in agro ecosystems. A naturally occurring source of silica (glauconite) has an established history and is available at reasonable cost.

   Fungicide. Several foliar fungicides are available. However, all currently listed organically acceptable materials have serious limitations in effectiveness. Two of the most effective allowable synthetics, sulfur and copper, have environmental concerns, and also have limitations. All of the other available materials are frequently ineffective for the diseases that potassium silicate is claimed to control. A different source of potassium silicate (burnt rice husks) has shown similar fungicidal activity as sodium silicate.

7. *Its compatibility with a system of organic agriculture.*
   As a fertilizer, potassium sulfate is not compatible with organic agriculture. As a fungicide, potassium silicate is in-between a prohibited, processed, highly soluble material (generally incompatible with organic agriculture) and an allowed synthetic material that is could be deemed compatible under specific circumstances. Manufacture of potassium silicate from slag could not be successfully evaluated due to lack of information about the process.

Concluding remarks

Clearly, potassium silicate is a synthetic because, although the potassium carbonate and sand are mined, they require very high temperature treatment to form potassium silicate, and therefore a significant contribution of fossil fuel or fossil fuel replacement energy.

As a fertilizer, potassium silicate is highly soluble (generally a trait that puts a material in the prohibited grouping) and 'jolts' the soil with a rapid release of nutrients, even though the effects of a rapid availability of potassium and silica is not believed to have nearly as profound an impact as other materials such as sodium nitrate (an allowed non-synthetic material, with restrictions). As a source of potassium or silicate for soil fertility, there are several effective non-synthetic, low soluble alternatives (lack of alternatives can mitigate other prohibited traits). Although synthetic silicates of metallic micronutrients have been allowed, they are not allowed as a source of silica, and probably should remain so: the reason for allowing these synthetic metallic silicates is the lack of acceptable materials, not that they are compatible with organic philosophy. The weight of the above evidence puts potassium silicate as a fertilizer in the prohibited column.

As a fungicide, the same concerns about synthetics are present. However the amounts used are much smaller, there is no 'jolt' to the soil and, most importantly, effective alternatives are not available. Unfortunately, there is not convincing evidence that potassium silicate will be even as effective as the alternatives, and its mode of action is not understood. These are important considerations. Sulfur and copper are allowed synthetics because, although they have some non-target toxicity and environmental troubles, they have a well-understood mode of action and breakdown products, have been used by organic farmers for a long time, and are proven effective. Potassium silicate does not have significant non-target toxicities, environmental risks or breakdown products, but does have a poorly understood mode of action, a short history of use, and has not been proven widely effective.

Recommendations to the NOSB:

The substance should be listed as a **prohibited synthetic** on the National List.

However, I encourage the NOSB to reassess the material, perhaps as a restricted synthetic fungicide if, in the future, the mode of action becomes better understood, and much more significant and widespread effectiveness as a fungicide is proved.

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